Global Journal of Engineering and Technology [GJET].
ISSN: 2583-3359 (Online)
Frequency: Monthly
Published By GSAR Publishers
Journal Homepage Link- https://gsarpublishers.com/journal-gjet-home/

The implementation of climate change analysis on food crop production

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Article History

Received: 03/01/2025
Accepted: 14/01/2025
Published: 16/01/2025

Vol – 3 Issue – 12

PP: - 04-09

Abstract

The objective of this research is to develop a system for analysing actual rainfall data and potential data on agricultural land area, harvest area and production using the Oldeman classification on prediction/estimation. This will be achieved by integrating multiple regression methods and building an application implementation programme as an instrument of information on the effect of climate change on food production (rice) that can be used to predict. The study employs multiple regression analysis and correlation of predictors to estimate and predict the statistical analysis aimed at ascertaining the extent of the influence of climate change on food production (rice) and the accuracy of the data using RMSE (Root Mean Square Error).The research is intended for use in an information system, where data that has been classified or processed is interpreted to provide accurate information to maintain local and national food security and the welfare of farmers. The information processing system is designed to transform data into useful information, or to convert data from a form that is not readily usable into a form that is beneficial to the intended recipients

Keywords- *Instrument of information, oldeman climate classification, regression analysis, RMSE*

INTRODUCTION

The influence Of climate change on the agricultural sector is multidimensional, ranging from resources, agricultural infrastructure, agricultural production systems, food security to the welfare of farmers. This situation, directly and indirectly, will affect most of the agricultural sector in Indonesia, including the world of vocational education in the agricultural sector which has a very complex future challenge in preparing graduates as part of the regeneration of skilled workers in agriculture who play an active role as one of the solutions to the problems faced by the farming community today and in the future to welcome the Golden Indonesia 2045 as the 'world food barn' (Rahman et al., 2023). Indonesia, an archipelagic and agrarian country, is a geographical gift. Its territorial characteristics play an important role in the global climate system. However, this geographical condition also has vulnerabilities to climate change, both past and future. Climate change triggers and spurs climate anomaly and variability and results in the acceleration of the frequency of various extreme climate events including an increase in the intensity of El Nino and La Nina and a high increase in rainfall which has an impact on almost every sector of activity, including agriculture, conditions that can be seen from the impact of climate change is the decline in agricultural / food production including vegetables and fruits both in quantity and quality which has an impact on the social and economic dimensions of society. The aforementioned conditions are poised to exert a direct or indirect influence on agricultural activities within the province of South Sulawesi. The Maros Regency, in particular, is noteworthy due to its location in the western part of South Sulawesi, between 40°45' and 50°07' South latitude and 109°205' and 129°12' East longitude. It is bordered by Pangkep Regency to the north, Makassar City and Gowa Regency to the south, and Bone Regency to the west. The total area of Maros Regency is 1,619.12 km2, with paddy fields covering 25,917 ha and non-field land comprising 60,877 ha of dry land and 78,903 ha of other land. Based on the records of the Meteorological Station Agency, the minimum air temperature ranges from 22.80°C (occurs in July and August) and the maximum temperature ranges from 33.70°C (occurs in October) (Kompasiana,. 2015). As is known, agricultural activities are efforts to utilize natural resources that are closely related to climate and weather conditions. Soil processing activities and rice seedbeds, for example, will only be carried out when rainfall is sufficient so

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that the land can be processed with the expected production results, of course, so that the occurrence of natural factors that have an impact on the preparation of planting areas, harvest areas, and production is a factor that needs to be predicted. This is necessary to ascertain the potential rice production in an area, as previously discussed in studies on the subject. For instance, policy analyses of climate change impacts have not thoroughly addressed data processing of production potential, focusing instead on climate data (rainfall), planting area, harvest area, production, and productivity (Research and Development of Pati Regency, Central Java Province, 2011; (Rahman, 2013). However, the utilization of information system applications for processing potential production data remains underdeveloped. The processing of rainfall data is predominantly manual, lacking the application of systematic retrieval methods as one of the input data sources. The objectives of this study are threefold: first, to implement the analysis of actual rainfall data and agricultural potential data on planting area, harvest area, and production using Oldeman classification in the prediction/estimation process by integrating multiple regression methods; second, to build the implementation of program applications as information instruments on the effect of climate change on food production (rice) that can be used to predict; and third, to assess the impact of climate change on food production (rice) using the aforementioned instruments. The data set under consideration encompasses the agricultural potential of Maros Regency, as reported by the Agriculture, Food Crops and Horticulture Office of the region, in conjunction with BMKG Class I Maros.

Research Elaborations

Location and Research Design

The present study was conducted at the Department of Agriculture, Food Crops and Horticulture, located in Maros Regency, as well as at the Maros Climatology Station of the BMKG. The data collected for this study included climate data (rainfall) and data on the potential of agriculture in Kab. The data collection period for the study spanned from March 2013 to May 2013 (Rahman, 2013). The research design employed regression statistical functions as a methodological framework, integrating information system applications to facilitate analysis.

Population and Sample

Data on the condition of the agricultural area of Maros Regency, the data used in this study is an excerpt of rainfall data and agricultural potential data which includes planting area, harvest area and production during the last 4 years, from 2009 to 2012 and reports from related agencies (Maros Food Crops and Horticulture Agriculture Office, and Maros BMKG Climatology Station Climate Information Products) which are applicable as simulation data analyzed for future interests with the same treatment analysis standards on the latest data samples if needed, as a simulation material of the method used.

Data Collection Methods

In this study, a quantitative descriptive analysis method was used, that is, research based on solving factual problems that exist at the present time. The data used in this research is a quotation of rainfall data and agricultural potential data, which includes planting area, harvesting area and production from related agencies (Maros Food Crops and Horticulture Agriculture Office, and Maros BMKG Climatology Station Climate Information Products) for 4 years. The supporting data needed in the estimation and modeling process come from literature studies (Bulletins and Journals) for the production center area according to its commodities in the production center of Maros Regency.

Data Analysis

The collected data are tabulated and analyzed descriptively and quantitatively using multiple regression and correlation methods in a stepwise fashion, first classifying rainfall data based on Oldeman calcification using the number of base and dry months and then using agricultural potential data for 4 years. The data will be divided into two parts, the first part will be used as a training set and the second part will be used for the prediction function, which will finally be tested for the accuracy of the method used.

To determine the possible form of relationship/influence between two or more independent variables (X) and the dependent variable (Y). The main purpose of determining this method is to predict or estimate the value of one variable (Y) in relation to another variable (X). Meanwhile, correlation analysis is used to find the direction and strength of the relationship between two or more variables, both symmetrical, causal and reciprocal relationships (Rahman, Jafar Alamsyah, et al., 2024; Rahman, Sumardin, et al., 2024).

Functionally, Y = f (X1, X2, X3, ..., Xn) or in a mathematical equation is written as: $Y = a + b_1X_1 + b_2X_2 + b_3X_3 + ... + b_nX_n$ (1)

Y= Bound Variables
X= Independent Variable
a = Price Y when Price X = 0 (Constant price)
b = The direction number or regression coefficient, regression coefficient, which shows the number of increases or decreases in the dependent variable based on changes in the independent variable, and for the regression equation and the relationship between the number of wet months (X1), the number of dry months (X2), the area planted (X3) and the area harvested (X4). (Rahman, 2013)

Furthermore, one thing that is very important to do is to know the level of data accuracy, namely how accurate the calculated data is with the actual data, so in knowing the level of data accuracy, an index that is commonly used to determine the level of quality of a system is the Root Mean Square Error (RMSE). The error value can be expressed as follows (Rahman, 2013):

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(X_{orginal\,data} - X_{count\,result})^2}{n}} \quad (2)$$

$X_{orginal\ data}$ = Orginal Data
$X_{count\ result\ data}$= Count Result
n = Amount of Data.

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Accuracy is done to determine the accuracy of the prediction results compared to the actual data which includes rainfall data and agricultural potential data, henceforth the accuracy is intended to determine how much difference and suitability of the data obtained with the regression statistical function.

After analyzing the existing problems and solving the problems that will be carried out, then from the concept, the selection of methods and tools that allow the program to manipulate information proportionally is carried out.

Software Engineering

Socialization and testing of information system applications developed after implementation is carried out to analyze the model created, which is the design process and simulation of the use of media generated from the previous design and development stage. (Abd Rahman, 2023). The application is a tool that will be used to input rainfall data and potential data (planting area, harvest area and production) in months per year for the last 4 (four) years 2009 - 2012 which are available in the data provided by related agencies (BMKG Maros Class 1 Climatology Station and Maros Food Crops and Horticulture Agriculture Office) as simulation material and of course also applies to each of the latest year data inputted. However, previously the data was divided into 2 (two) parts to be used as input data, for the first data in 2009 - 2011 is data that will be processed by the system using regression statistical functions, while for the second data in 2012 is data that is a prediction year..

Result

Method of Approach

The method used in this research, is an experimental method by processing rainfall variables that affect agricultural potential data from secondary quotation data from the Maros Food Crops and Horticulture Agriculture Office, and climate information products from Maros Climatology Station BMKG Maros Kab. Secondary data obtained.

Table 1 BMKG Rainfall Data

Moon	Rainfall (mm/bln)			
	2009	2010	2011	2012
January	1226	1033	864	611
February	719	532	502	443
March	186	274	576	574
April	146	218	395	230
May	219	430	206	164
June	83	197	9	69
July	46	229	1	44
August	-	88	0	0
September	17	330	0	2
October	16	201	188	115
November	112	455	470	198
December	486	752	772	395

Table 2 Potential Data of the Agriculture, Food Crops and Horticulture Office of Maros Regency

Potential	2009	2010	2011	2012
Planting Area (ha)	18.741	21.125	19.644	46.384
Harvest Area (ha)	44.097	33.862	32.077	48.333
Production (ton)	262.641	250.995	297.327	322.429

Tables 1 and 2 are processed by statistical mathematical functions using multiple regression and correlation to produce an outpProductionut estimation of the size of the effect of climate change on the production function which includes planting area, harvest area and rice production tons/year.

Table 3 Testing of Estimation Accuracy of Root Mean Square Error (RMSE) Two Predictors

Year	Original Data	Result Data	RMSE	RMSE²
	Planting Area (X_3)	Planting Area (Y_1)	(e)	$(e)^2$
2009	18.741	30.958,200	-0,652	0,425
2010	21.125	25.197,400	-0,037	0,037
2011	19.644	15.572,600	0,207	0,043
2012	46.384	34.167,800	0,263	0,069
$RMSE=\sqrt{((\Sigma e^2)/n)}*(100\%)$				0,379

The output obtained was tested using RMSE (*Root Mean Square Error) /* absolute percentage error value to test the accuracy of the results of the multiple regression estimation of 2 predictors.

Table 4 Testing of Estimation Accuracy of Root Mean Square Error (RMSE) Three Predictors

Year	Original Data	Result Data	RMSE	RMSE²
	Planting Area (X3)	Planting Area (Y1)	(e)	$(e)^2$
2009	44.097	44.096, 99999	$2,310.10^{15}$	$5,33603.10^{30}$
2010	33.864	33.862, 99999	$3,008.10^{15}$	$9,04922.10^{30}$
2011	32.077	32.076, 99999	$3,062.10^{15}$	$9,37692.10^{30}$
2012	48.333	48.332, 99999	$2,108.10^{15}$	$4,44170.10^{30}$

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RMSE=√((Σe²)/n)*(100%)	$2,65537.10^{13}$

Table 5 Testing of Estimation Accuracy of Root Mean Square Error (RMSE) Four Predictors

Year	Original Data	Result Data	RMSE	RMSE²
	Planting Area (X3)	Planting Area (Y1)	(e)	(e)²
2009	262.641	262.641,0	0,000	0,000
2010	250.995	250.995,0	0,000	0,000
2011	297.327	297.327,0	0,000	0,000
2012	322.429	322.429,0	0,000	0,000
RMSE=√((Σe²)/n)*(100%)				0,000

Table 4 multiples 3 predictors and in Table 5 multiples 4 predictors each on the second training and testing data with the.

Research Stages

In the implementation stage, system development is executed in accordance with the plan from the preceding stage. This system development is predicated on the design of system requirements, which is represented by a use case diagram. The use case diagram describes the expected functionality of a system, emphasizing the "what" rather than the "how." In essence, it delineates the pattern of system behavior and the sequence of related transactions executed by a single actor. Activity diagrams, on the other hand, meticulously detail the sequence and stage of activities in a process within the analysis application. Class diagrams offer a comprehensive depiction of the structure and description of classes, packages, and objects, along with their interrelationships, such as encoding, association, and others. (Nugroho, A., 2005).

System *Planning*

The application's design commences with the input of two types of data: rainfall data and agricultural potential data, which are subsequently stored in the database. The subsequent analysis of the database's stored data involves the implementation of mathematical functions, including multiple regression and correlation statistics. The results of this data analysis are then stored in the database and form the basis of an output report. This report serves to predict or estimate the results of the analysis.

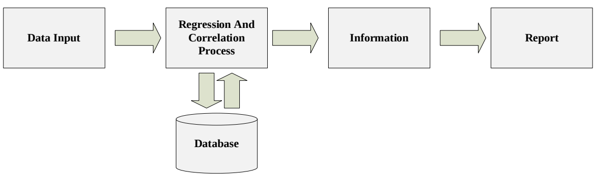

Figure 1. Application Design Process Diagram

All data concerning rainfall and potential, including planting area, harvest area, and production, are entered into the system, which has been designed for this purpose. The system then stores the entered data in a database. The database can then be queried by the system to retrieve data for analysis using multiple regression and correlation. Multiple regression is a statistical method that involves the estimation of parameters, the generation of populations, and the evaluation of the final value. It does so by determining the possible form of relationship or influence between two or more independent variables (X) and the dependent variable (Y). Multiple regression also seeks to identify the direction and strength of the relationship between two or more variables. The formation of a data set results in each data set having a final value according to the level of the formulated predictor. (Sugiyono, 2012.)

In the context of engineering and modeling information systems, the present study employs regression analysis to translate the conceptual model into the database model.

The following presentation offers a visual representation of the data structure of rainfall files and potential data.

Table 6 Database of Climate Influences on Food Crop Production

Nama Field	Type	Long	Key	Information
year	int	4	Primary	Year going on
moon	int	11	-	The month lasts (January - Desember)
Plantin g Area	int	11	-	Planting Area
Harvest area	int	11	-	Harvest Area
product ion	int	11	-	Rice Production

From the table above, it consists of 5 *fields*, namely year, month, planting area, harvest area, and production. The *primary key* is *the* year field.

Order of Application Operation Activities

The sequence of the process of an activity carried out, from the *activity diagram* of the system is divided into three activities:

1. **Operator**

Login is done for system access, input rainfall data and potential data into the system.

2. **Program Implementation System**

The input rainfall data is entered into the system and subsequently undergoes a classification process based on the Oldeman climate classification, which refers to the number of wet and dry months. Subsequent data input into the system is processed by the system using multiple regression analysis with "n" predictors and root mean square error (RMSE) in programming languages to produce model training data. This data is then employed to determine predictions at the beginning of the year by entering rainfall data as input.

3. **Leadership Elements**

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Observing existing data as initial information to make decisions.

User Interface

This is an inherent aspect of the program's design, which is part of the software requirements analysis. This analysis encompasses the information domain, performance, and interface. The interface of this application is as follows:

1) Main menu display

Figure 2. Main menu interface

This functionality enables user interaction with the application. To input data, users should select the "insert data" button. Subsequent to data analysis, users select the "process" button and then the "result" button to view the results of the process. To access reports, users should select the "history" button. Finally, the "chart" button enables the visualization of the desired graph.

2) Form Input Data

Allows for input of data that has been prepared.

Figure 3. Data input menu

Explaining the application data input form which functions to make it easier for users to interact with the application in entering rainfall data and agricultural potential data sourced from related agencies (BMKG Class 1 Maros Climatology Station and Maros Food Crops and Horticulture Agriculture Office) by pressing / clicking the insert button for the next year's data up to the year of data that has been prepared, if there is a possible data input error then the user (user) can press the clear or Backspace button on the computer key board.

Displaying data that has previously been inputted and adjusted to the input year that the user displays, for example 2020 to 2024 is the processing data that will be carried out by the system and makes 2025 a prediction year..

3) Report data view

Regression 4 (four) Predictors

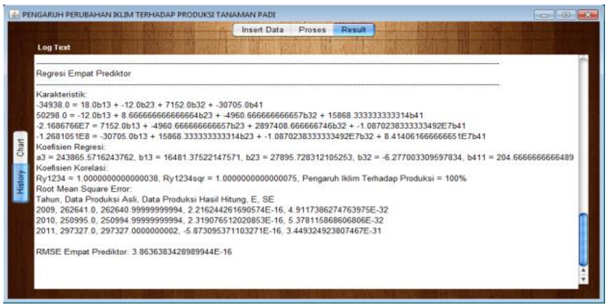

Figure 4. Four predictor regression report data form menu

The regression application report form menu 4 (four) predictors in the application simulation example above elucidates the outcomes of the acquisition of rice production in 2009 of 262,640,99999999994 tons, in 2010 of 25 0,994,99999999994 tons and in 2011 of 297,327,0000000002 tons, at the level of accuracy / validation of RMSE analysis of 3,864. 1016%, as illustrated in the figure. This figure demonstrates the magnitude of the correlation and the trigger influence factor of climate influence on production by 100%, with the level of regression coefficients b13 of 16,481.38, b23 of 27,895.79, b32 of -6. .277 and b41 of 2,04.67 at the constant price. The obtained a3 = 243,865.57 demonstrates the strong direction of the decrease and increase in the length of wet and dry months (climate), planting area, and harvest area on production, which is used as a prediction in that year.

Conclusion

The utilization of multiple regression and correlation function methods for the analysis and implementation of information systems based on the results of estimating the chances of the influence of climate change is quite possible, given the example of simulated data from the total agricultural area (Tables 1 and 2) of Maros District from 2009 to 2012. A planting area of 93.36% (ha/year) with a correlation coefficient of 0.933629 at an accuracy level of 0.379, and a harvest area of 100% (ha/year) with a correlation coefficient of 1.0 at an accuracy level of 2.65537. The correlation coefficient for rice production was determined to be 0.94367, with an accuracy level of 0.000, indicating a strong and significant relationship between rainfall and rice production. This suggests that rainfall exerts a substantial influence on food commodities, particularly rice, and consequently, indirectly impacts the social and economic dimensions of the community.

The employment of multiple regression and correlation function methods facilitates the quantification of the influence of rainfall on the function of rice production based on land area and harvest area in contributing value. In the future, it is imperative for the government to regulate good cropping patterns so as to maintain Indonesia's national food security towards Golden Indonesia in 2045.

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