YANGON UNIVERSITY OF ECONOMICS

DEPARTMENT OF STATISTICS

MASTER OF APPLIED STATISTICS PROGRAMME

A STUDY ON PRODUCTION OF RICE IN MYANMAR

(2000-2001 to 2019-2020)

PHYO PAING AUNG

MAS – 20

MAS 1st BATCH

SEPTEMBER, 2023

YANGON UNIVERSITY OF ECONOMICS

DEPARTMENT OF STATISTICS

MASTER OF APPLIED STATISTICS PROGRAMME

A STUDY ON PRODUCTION OF RICE IN MYANMAR (2000-2001 to 2019-2020)

This thesis is submitted to the Board of Examination as partial fulfillment of the requirements for the Degree of Master of Applied Statistics

Supervised by:	**Submitted by:**
Daw Thida Win	Phyo Paing Aung
Associated Professor	MAS - 20
Department of Statistics	MAS 1st Btach
Yangon University of Economics	Yangon University of Economics

September, 2023

ACCEPTANCE

Accepted by the Board of Examiners of the Department of Statistics, Yangon University of Economics in partial fulfillment for the requirement of the Master Degree, Master of Applied Statistics.

……………………..

(Chairperson)

Prof. Dr. Mya Thandar

Pro-Rector

Yangon University of Economics

……………………..

(External Examiner)

Daw Khin Moh Moh

Lecturer (Retd.)

Department of Statistics

Yangon University of Economics

……………………..

(Examiner)

Professor Dr. Aye Thida

Professor/Head

Department of Statistics

Yangon University of Economics

……………………..

(Examiner)

Dr. Sanda Thein

Professor

Department of Statistics

Yangon University of Economics

……………………..

(Supervisor)

Daw Thida Win

Associated Professor

Department of Statistics

Yangon University of Economics

September, 2023

ABSTRACT

Rice is a dominate crop in Myanmar and it is making important contributions to the country's GDP, employment and income generation. Myanmar is the world's seventh-largest rice-producing country in 2017-18 and still has a great potential for higher production. In this study, the secondary time series data for twenty years' period from 2000-2001 to 2019-2020 were used in data analysis. The main objective is to find the trend and forecasts of rice production and to determine the best fitted regression model for the volume of rice production in Myanmar. According to the results of time series analysis, the cubic trend model was the best fitted trend model for rice production. Multiple linear regression model and Cobb-Douglas production function model (log-log model) were used to determine the best fitted regression model for the rice production in Myanmar. As a result, the Cobb-Douglas production function model was the more appropriate model and it was used for the prediction of rice production. The predictor variables; harvested area, agricultural implements and average annual rainfall were found as the influencing factors on volume of rice production. It was also found that the sum of three rice production elasticity is the increasing return to scale.

.

ACKNOWLEDGEMENTS

First and foremost, I would like to pay my special regards to Dr. Tin Tin Htwe, Rector of Yangon University of Economics, for her kind permission to conduct this study for the Master of Applied Statistics course.

I am extremely grateful to Professor Dr. Mya Thandar, Pro-rector of Yangon University of Economics, I pay my deep sense of gratitude to her for providing me the opportunity to prepare the thesis and her valuable suggestions and recommendation to develop this thesis.

I would like to offer sincere thanks to respectful teachers Daw Khin Moh Moh, Lecturer (Retd), Department of Statistics, Yangon University of Economics, for the intensive teaching, support and guidance for research knowledge.

Also, I wish to show my gratitude to Professor Dr. Aye Thida, Head of the Department of Statistics and Programme Director of Master of Applied Statistics, for her precious advice and her kindness to complete my research paper.

I would like to express my sincere thanks to Professor Dr. Sandar Thein, Department of Statistics, Yangon University of Economics, for her valuable suggestions, helpful advices and recommendations to improve my thesis.

I would like to express my special thank and high indebtedness to my supervisor, Daw Thidar Win, Associated Professor, Department of Statistics, Yangon University of Economics for her continuous supervision, valuable suggestion, guidance, comments, support and encouragement throughout this thesis.

I would like to offer sincere thanks to respectful all teachers from Department of Statistics, Yangon University of Economics, for their intensive teaching, support and guidance for research knowledge.

Finally, I would like to express my gratitude to all classmates and colleagues of MAS Programme for the opportunity to learn from their rich experiences and thoughts that was shared during the course.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
CAP	Capital
CSO	Central Statistical Organization
CRS	Constant Return to Scale
DAR	Department of Agricultural Research
DMH	Department of Meteorology and Hydrology
DOA	Department of Agriculture
DRS	Decrease Return to Scale
DW	Durbin-Watson
FAO	Food and Agriculture Organization
FDI	Foreign Direct Investment
GAP	Good Agricultural Practices
GDP	Gross Domestic Product
HYV	High Yielding Varieties
ILO	International Labour Organization
IRRI	International Rice Research Institute
LAND	Land
LIFT	Livelihoods and Food Security Fund
MADB	Myanmar Agricultural Development Bank
MOALI	Ministry of Agriculture, Livestock and Irrigation
MOEE	Ministry of Electricity and Energy
MRIA	Myanmar Rice Industry Association
MRSDS	Myanmar Rice Sector Development Strategy
MRF	Myanmar Rice Federation
MRPTA	Myanmar Rice and Paddy Traders Association
MSE	Mean Square of Error
MSR	Mean Square due to Regression
PROD	Volume of Rice Production
RAIN	Average Annual Rainfall

RSCs	Rice Specialization Companies
SHYP	Special High-Yielding Program
SPSS	Statistical Package for the Social Science
SSE	Sum of Squares of Errors
SSR	Sum of Squares due to Regression
SST	Sum of Squares of Total
UNESCO	United Nations Educational, Scientific and Cultural Organization
VIF	Variance Inflation Factor

CHAPTER I
INTRODUCTION

Myanmar is one of the agriculture nation, heavily relies on agriculture as a cornerstone of the country's economy. Approximately 80% of the country's agricultural output is attributed to rice cultivation, making it a vital agricultural product. The significance of rice in the lives of the populace cannot be overstated; nearly the entire population of the country primarily depends on rice as a staple food, illustrating its central role in the daily diet and nutrition of the people.

1.1 Rationale of the Study

Rice is the most important food crop of Myanmar and it remains a strategic sector. It is making important contributions to the country's Gross Domestic Product (GDP), income and employment generation in Myanmar. In 2019-20, about 70.5% of the country's populations (54.58 million) live in rural areas and their livelihood drives the agriculture sector as an important growth engine of rural development. Vokes and Goletti (2013) stated that rice is a vital crop of Myanmar, 80 percent of all Myanmar farmers are growing rice and dominated the agriculture sector, accounting for around 60 percent of the net sown area and around 80 percent of the total value of sector production. Since rice is labor intensive, the labor absorption rate is highest in the rice industry and nearly three-fourths of farm household income is derived from rice farming and related activities, especially in the major rice grown areas in Myanmar (Department of Planning, 2016).

Rice is the major staple food for Myanmar people as it contributes about 73 and 80 percent of the total daily dietary energy requirement in urban and rural households, respectively (CSO, 2012). In Myanmar, rice also carries the largest weight in the Consumer Price Index, accounting for 17% on average and 27% for low-income groups (CSO, 2012). In July 2016, the Government of Myanmar officially announced a 12-point economic plan targeted at developing a market-oriented economy. The government focuses on strengthening farming production, enhancing food security, increasing exports and improving living standards of the rural population, which depends on farming as their first and key source of income.

Myanmar is the world's seventh-largest rice-producing country in 2020 and exported about 0.7 million metric tons. The target of rice production that fulfills both domestic and export requirements was set by the Myanmar Agricultural Sector. The target is the paddy production must reach at least 19.40 million metric tons, about 60% of which is for local food consumption and 40% for international trade by 2030. The target has been achieved by 7.70 million hectares (ha) of rice harvested area with an annual average yield of at least 4.20 MT/ha per cropping season (Ministry of Agriculture, Livestock and Irrigation, 2015).

Since the rice is very crucial to be sustainable growth and development, rice production is essential for the economic growth. Therefore, this study intends to emphasize on the rice production of Myanmar.

1.2 Objectives of the Study

The objectives of the study are:

(i) To study the situation of rice production in Myanmar.

(ii) To find the trend and forecast values of rice production in Myanmar.

(iii) To determine the best fitted regression model for the volume of rice production in Myanmar.

1.3 Method of Study

To reach the objectives of the study, descriptive statistics was used to present the situation of rice production, time series analysis was used to find the trend and forecast values of rice production and regression analysis was used to find out the influencing factors on rice production in Myanmar.

1.4 Scope and limitations of the Study

This study based on the secondary data and the related information obtained from Statistical Year Book (CSO), Department of Agriculture (Myanmar), General Administrative Department (Myanmar), the World Bank, International Rice Research

Institute (IRRI), International Labor Organization (ILO) and Food and Agriculture Organization (FAO). The study period is 20 years from 2000-2001 to 2019-20.

1.5 Organization of the Study

This study was divided into five chapters. As the introduction part, the rationale of the study, the objectives of the study, method of study, scope and limitations of the study and organization of the study are presented in Chapter I. Literature review is described in Chapter II. The research methodology is presented in Chapter III. Chapter IV deals with the analysis of the rice production and forecasting. Chapter V is the conclusion.

CHAPTER II
LITERATURE REVIEW

This chapter delves into the rich historical background of rice cultivation, reviews the current state of rice production in Myanmar, explores the major rice-growing areas within the country, analyzes Myanmar's rice sector development strategy, and reviews pertinent studies related to rice production. Additionally, it establishes the analytical framework essential for a comprehensive understanding of the subject matter.

2.1 Historical Background

Rice has fed more people over a longer period of time than any other crop. As far back as 2500 B.C. rice has been documented in the history books as a source of food and for tradition as well. Beginning in China and the surrounding areas, its cultivation spread throughout Sri Lanka, and India. It was then passed onto Greece and areas of the Mediterranean. Rice spread throughout Southern Europe and to some of North Africa. From Europe rice was brought to the New World. From Portugal it was brought into Brazil and from Spain to Central and South America.

Rice could be taken to many parts of the world due to its versatility. It is able to grow in the desert conditions of Saudi Arabia, in the wetland deltas of Southeast Asia in the flooded rice plains which we are most familiar with**.**

Two species have emerged as the most popular cultivated rice. Oryza sativa and Oryza glaberrima, of these two species the more widely produced is O. sativa. From an early history in the Asian areas rice has spread and is now grown on all continents except Antarctica**.** Being able to grow in this wide spectrum of climates is the reason rice is one of the most widely eaten foods of the world.

Today, the majority of all rice produced comes from China, India, Indonesia, Bangladesh, Vietnam, Thailand, Myanmar, Pakistan, Philippines, Korea and Japan. Asian farmers still account for 87% of the world's total rice production.

2.2 Reviews on the Rice Production of Myanmar

The Republic of the Union of Myanmar is the largest country in Southeast Asia with 676,552 square kilometers. Due to its geographic size, Myanmar varies considerably both topographically and meteorologically. Annual precipitation and monthly mean maximum/minimum temperatures also show considerable variation over time and space, and are particularly affected by the summer monsoons. In general, the climate is cooler in the mountainous north and warmer in the southern Delta areas of the Ayeyarwady River, with monthly mean maximum temperatures from 24.1°C to 38.2°C in May, and monthly mean minimum temperatures from 2.3°C to 20.8°C in December. Most major rice growing areas, such as the Ayeyarwady, Yangon and Bago Divisions, are naturally provided with fertile deltaic alluvial soil and abundant monsoon rainfall.

Throughout of Myanmar's history, successive governments had set their policies to support the rice sector because of its critical role in food security, and its social and political importance in the country. Traditionally, rice production occurred only as a monsoon crop in the rainy season (from the end of May through November). In the late 1970s, the first Green Revolution in Myanmar was launched through the Special High-Yielding Program (SHYP) to boost rice production, leading the path from self-reliance to rice exportation. The cultivation of high-yielding varieties was combined with appropriate agricultural practices and high inputs of agrochemicals with state subsidies. Rice marketing and trade were solely under state management, with a quota delivery system in procuring paddy from farmers and in exporting rice to the international market.

In the early 1990s, the program expanded the cropping area of paddy, used high-yielding varieties, and introduced summer paddy technology in areas where water resources were available. Private sector involvement also advanced and became significant after the liberalization of rice export in 2003. Since then, various reform measures, such as lessening control on economic activities, relaxing price controls, deregulating export and import restrictions, opening border trade, reducing government subsidies, and establishing industrial zones and private banks, were taken to promote the active participation of the private sector in the national economy.

Through the Rice Specialization Companies (RSCs), private sector involvement through contract farming arrangements with rice farmers was encouraged. As a temporary solution to limited access to affordable seeds and other inputs, credit, and extension, the RSCs provided these support to farmers. Other private sector groups, such as the Myanmar Rice and Paddy Traders Association (MRPTA), were also actively engaged in paddy trading and milling. In 2012, the Myanmar Rice Federation (MRF) was formed by restructuring and upgrading the Myanmar Rice Industry Association (MRIA). MRF is the umbrella organization representing the six private sector group of millers, traders, farmers/paddy producers, fertilizer, seed, and pesticide entrepreneurs, and the RSCs.

In 2011, the country opened its doors to democratic and economic transformation. One of the development goals set by the present government is to increase rice exports while maintaining domestic food security. It is envisaged that increasing rice exports will generate the needed income to fuel agricultural development, revive the economy, and alleviate poverty pervading in rural areas (MRF, 2014).

2.3 Major Rice-growing Areas

Myanmar's rice-growing areas can be categorized into two agro-ecosystems namely, favorable lowlands, which accounts for 68% of the 7.59 M ha sown area in 2012-2013, and unfavorable rainfed, which comprises 32% of the rice area (DoA 2013). These two agro-ecosystems are further divided into seven rice sub-ecosystems. The favorable lowland is comprised of the rainfed lowlands (48%) and irrigated lowlands (20%). The unfavorable rainfed area is subdivided as drought prone, deep-water, submerged, salt affected and uplands. In 2012-2013, the total harvested rice area was 7.24 M ha (DoA, 2013).

The Ayeyarwaddy delta, the rice bowl of Myanmar, covers 35,032 km2 (Driel and Nauta, 2013; MoALI, 2013). Three regions occupy the delta — Ayeyarwaddy, Yangon, and Bago. Most areas are favorable for rice cultivation while some are prone to flooding in the monsoon and salinity intrusion toward the end of monsoon and during the summer season. Of the total 2.89 M ha of rice area in the delta, 371,880 ha are classified as flood-prone, 22,416 ha are salt-affected, and 64,941 ha are drought-prone (Department of Agricultural Research unpublished data). The delta has a monsoonal climate which delivers an average annual rainfall of 1,500 mm–2,000 mm in the north, increasing to 2,500 mm in the southeast and 3,500 in the southwest.

More than 90% of the rain falls between mid-May and mid-November (Driel and Nauta, 2013; MoALI, 2013). Seeding for the monsoon cropping commences in late May to June, followed by transplanting in July to August. In deepwater areas, cropping begins in September when the water begins to recede, making it possible for farmers to prepare the land. The harvest season is from October to November for the regular monsoon crop and January for late monsoon crop.

There is limited fresh water available in most parts of the lower delta during summer. Rice is mostly grown in the middle and upper part of the delta, near rivers and small dams. Summer cropping usually starts in late October until January and harvest period is from February to April.

Rice production in the delta increased significantly from 1976 to 1988 with the implementation of the Paddy Land Development Projects 1 and 2 by the World Bank and the Asian Development Bank. The construction of polders provided with embankments, sluice gates, and drainage systems protected the rice farms from salt water intrusion (Driel and Nauta 2013). However, the polders degraded and cyclone Nargis damaged many of the polders, resulting in the uncontrolled entry of salt water and, thus, reducing rice yield. Many of the damaged rice areas remain prone to salt water intrusion even in the monsoon season.

The Ayeyarwaddy delta is home to 21 million people, with the majority depending on rice production for livelihood. The average farm size per household is about 4.5 ha, which is the largest in the country. However, the delta is also the place of many landless people with low levels of income (Driel and Nauta 2013, Denning et al. 2013).

The central dry zone covers approximately 54,390 square kilometers or 10% of the country's total land area. It is considered a vulnerable region with poor natural resources. It stretches across the southern part of Sagaing Division, the middle and western part of Mandalay Division, and most parts of Magway Division (Ministry of Environmental Conservation and Forestry, 2011).

Drought is a major problem of farmers in the zone. Inland salinity is also present in some areas. Of the 1.17 M ha rice area, 149,081 ha are drought-prone and 4,900 ha are saline-affected (DAR unpublished data). Soil erosion is also a huge problem. Finally, the land, mostly sandy loam, has low fertility and thus, thin vegetation.

The dry zone has a bimodal rainfall pattern. Most of its rainfall comes with the southwest monsoon, ranging from 508 mm to 1016mm per annum with high variability and uneven distribution. The monsoon season is from mid-May to October, but the onset is erratic with prolonged dry spells (Aung, 1997). Farmers begin planting in July until October, depending on the availability of irrigation water from dams and reservoirs and on rainfall. Harvesting period is from November to January for monsoon paddy. Summer cropping begins in January and lasts until April. Harvest season is from April to June.

In areas near irrigation systems, rice is grown during the monsoon and summer season. In areas far from irrigation systems, annual crops such as pulses, sesame, sunflower, and groundnut are cultivated in summer. Other farmers support their living by rearing livestock and collecting products such as fuel wood, posts, and fodder.

There are 14.5 million people living in the dry zone, giving the region a population density of 123 people per square kilometer (Ministry of Environmental Conservation and Forestry, 2011). According to the LIFT Baseline Survey Results (2012), the average farm size is 1.82 ha, 60% smaller compared to the 4.5 ha in the Ayeyarwaddy Delta, and the average household size is 5–7. Chronic poverty is found in the dry zone and this level of poverty is directly correlated with the effects of drought and dry spells. About 39% of the population is landless, working as seasonal laborers in farms (Integrated Household Living Conditions Assessment Project, 2005 and 2010).

2.4 Myanmar Rice Sector Development Strategy (MRSDS)

The Ministry of Agriculture, Labour and Irrigation (MoALI) of Myanmar, together with the International Rice Research Institute (IRRI), the Food and Agriculture Organization Regional Office in Asia-Pacific (FAO-RAP), and The World Bank carried out the major and noble task of formulating the Myanmar Rice Sector Development Strategy (MRSDS). The strategy will be an invaluable complement to Myanmar's food and agricultural development policy under a new government and during this transformation period for the country.

2.5 Vision, Goals, and Targets

By 2030, Myanmar envisions food-secure farmers and consumers enjoying the economic benefits provided by a transformed, dynamic, environmentally sustainable, and internationally competitive rice sector.

The ultimate goal of the rice sector strategy is a food-secure nation where smallholder farming households have tripled their household incomes, including income derived from rice and rice-based farming, thereby enjoying a decent standard of living comparable to that of urban dwellers. The sustainable intensification of rice production, using efficient and effective natural resource management methodologies for higher rice productivity and profitability is the cornerstone for achieving this goal by 2030.

It is envisioned that Myanmar's future rice system will be characterized by market-oriented rice production where the farmers and the private sector are actively engaged in a transparent and vertically integrated rice value chain. It is also envisaged that the government of Myanmar will establish a level playing field in the industry through well-coordinated programs and sound policies that offer incentives and protection to local and foreign private investors in the rice sector. Development in the rice sector will contribute to "building a progressive agriculture sector that will propel economic development in other sectors and eventually transform Myanmar into a modern, industrialized nation."

The MoALI targets production growth that satisfies both domestic and export requirements1. By 2030, production must reach at least 19.40 million metric tons, about 60% of which is for local food consumption and 40% for international trade. The target will be achieved by maintaining 7.70 million hectares (ha) of rice area harvested with an annual average yield of at least 4.20 MT/ha per cropping season. Rice of varying quality and form will be produced to meet both domestic and foreign market demand.

2.6 Strategic Objectives of the MRSDS

Five strategic objectives guide the key themes and actions to achieve Myanmar's vision of its rice sector by 2030:

1. **Increase rice productivity and improve rice quality and nutritional value**

The competitiveness of Myanmar's rice in both domestic and international markets will be improved through increased productivity. This will be done through cropping intensification, the use of high-yielding and stress-tolerant varieties, and the promotion of sustainable resource management practices and systems, including cropping systems suitable to varying production conditions by agro-ecological zones.

2. **Adapt to, and mitigate the effects of, climate change and reduce risks, while protecting rice ecosystems and the environment**

   The adaptation of rice farming to the effects of climate change will be improved and farmers' capacity to cope with associated risks will be enhanced. Moreover, the environmental impacts of rice farming will be minimized while conserving the diversity and richness of rice ecosystems and preserving rice heritage and culture.

3. **Promote Myanmar rice as a quality brand to enhance its competitiveness in international trade**

   Rice food quality and safety will be improved and competitiveness and fairness in domestic and international markets will be promoted. Moreover, equitable access to rice will be provided for all consumers.

4. **Improve the well-being and capacity of smallholder farmers**

   The well-being and capacity of smallholder farmers, including women and children, will be improved in the context of long-term changes in demography, farm size, and labor supply.

5. **Enhance efficiency in the rice value chain and reduce postharvest losses**

   Weaknesses along the rice value chain will be reduced, thus improving efficiency and minimizing postharvest losses, all to increase the market value of rice production and improve rice food quality.

2.7 Related Studies

Shah, M.A.A., et.al (2019) studied that a statistical study of the determinants of rice crop production in Pakistan. The study conducted in district Lodhran and 31 villages selected as samples randomly. Time series data collected from Crop Reporting Service (CRS) for the period of last 10 years (2005-2014) containing 516 cases and 14,964 observations. Two different multiple linear regression models are applied to study the relationship between the yield of rice and the various factors which are affecting the rice crop production. The model is based on monthly average temperature and humidity during crop period and model II is based on average temperature and humidity during crop period. Durbin-Watson test is applied to measure the serial correlation on the residuals and variation inflation factor (VIF) is also applied to test the multicollinearity. The VIF values of independent variables in model I indicate the presence of multicollinearity and Durbin-Watson test shows autocorrelation in model I where as model II is recommended due to the better value of R^2 and Durbin-Watson test and found no pattern of multicollinearity. The three most important factors that affect the yield per acre in mounds (1 mound = 40 kg) are DAP and Urea Fertilizer and Disease attack respectively. Thus model II is acceptable for the estimation of rice yield not only for district Lodhran but also for the case of Pakistan.

IFPRI (2022), indicated that rice productivity in Myanmar; Assessment of the 2021 monsoon and outlook for 2022 from the Myanmar Agriculture Performance Survey (MAPS). The survey covers plots of 2672 rice producers, spread over 259 townships in all state and regions of the country. This study found that rice productivity at the national level during the monsoon of 2021 decreased on average by 2.1 percent compared to the monsoon of 2020. This study also found that prices for most inputs used in rice cultivation increased significantly between these two seasons. Prices of urea, the most important chemical fertilizer used by rice farmer, increased by 56 percent on average and mechanization cost increased by 19 percent.

Muhammad Islam and Rabia Siddiqui (2021), stated that statistical modeling and significance of Inputs Studies for the Rice Crop Productivity in Pakistan. The Multiple Linear Regression (MLR) model is applied to investigate the significant factor for rice crop yield enhancement. The inputs variable such as owned land, seed rate, DAP, urea, no. of wasters, no. of ploughs, no. of levels, crop life periods days, other fertilizer, variety super yes or no, seed type yes or no, spray no or yes and disease attack yes or no are studied in MLR model for rice productivity. Adj k^2 is found to be 0.422 and it is good fit for cross sectional data.

Lasini Wickramasinghe, et.al (2021), described that modeling the relationship between rice yield and climate variables using statistical and machine learning techniques. The relationship between the rice yield and climate variables of two geographically adjacent districts in Sri Lanka was modeled by applying three statistical methods and three machine learning techniques. Based on the significance of weightages and exponents associated with the climatic parameters in the yield functions of the statistical models, the rainfall, temperature, and average wind speed were found to be the most influential climatic factors.

2.8 Analytical Framework

The analytical framework for volume of rice production is shown in Figure (2.1).

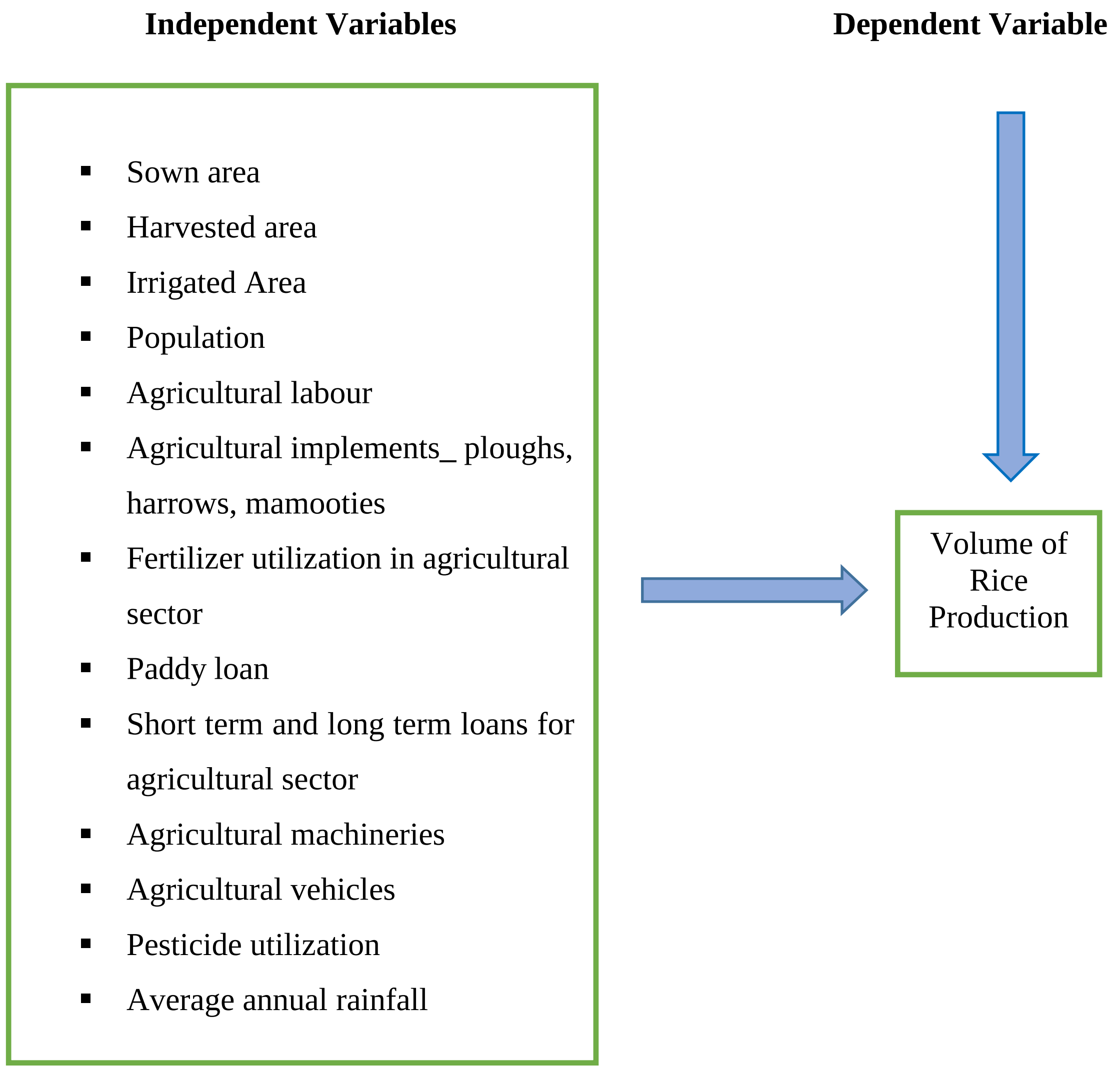


Figure (2.1) Analytical Framework

In Figure (2.1), the dependent variable is volume of rice production. The independent variables consist of sown area (Thousand Acres), harvested area (Thousand Acres), agricultural implements_ ploughs, harrows, mamooties (Million), fertilizer utilization in agricultural sector (Metric Ton), paddy loan (Million Kyats), short term and long term loans for agricultural sector (Million Kyats). agricultural machineries (Thousand Number), agricultural vehicles (Thousand Number), pesticide utilization (Gallon), agricultural labour (In Million), Irrigated Area (Thousand Acres) and average annual rainfall (Millimeter).

CHAPTER III
RESEARCH METHODOLOGY

In this chapter, explored three key concepts: time series analysis, multiple linear regression, and the Cobb-Douglas production function. Firstly, dive into understanding time series analysis, then introduce the multiple linear regression model along with its assumptions, significance testing, and how to handle multicollinearity. Finally, discussed about the Cobb-Douglas production function, a vital tool for the study.

3.1 Components of Time Series

The series are observations made sequentially over time. The objective of time series analysis is to produce accurate forecasted values of time series. A time series can be divided into four components. They are trend (T_t), seasonal variation (S_t), cyclical variation (C_t) and irregular variation or residual variation (R_t).

Trend – The secular trend (T_t) also known as the long term is a time series component that describes the long-term general movement of the time series.

Seasonal variation – The seasonal variation (S_t) describes fluctuation in the time series that recur during specific time periods.

Cyclical variation – The cyclical variation (C_t) generally describes fluctuation of a time series about the secular trend that is attributable to a pattern off variable.

Residual variation – The residual variation (R_t) is what remains after the secular, cyclical and seasonal components have been removed. Part of the residual variation may be attributable to unpredictable rare event and part to the randomness of human actions. In any case, the presence of the residual component makes it impossible to forecasts the future values of a time series without error.

3.2 The Proposed Trend Model

The proposed trend models for the value of time series in period t, y_t which are developed to fit the set of time series data are as follows:

a. Linear Trend Model

$$y_t = \beta_0 + \beta_1 t + \varepsilon_i \tag{3.1}$$

b. Quadratic Trend Model

$$y_t = \beta_0 + \beta_1 t + \beta_2 t^2 + \varepsilon_i \tag{3.2}$$

c. Cubic Trend Model

$$y_t = \beta_0 + \beta_1 t + \beta_2 t^2 + \beta_3 t^3 + \varepsilon_i \tag{3.3}$$

d. Exponential Curve Trend Model

$$y_t = \beta_0\, exp(\beta_0\, t + \varepsilon_i) \tag{3.4}$$

3.3 Economic Models Involving Regression Analysis

The first basic idea to which the students of economics is introduced to is that of relationships between economic variables. The nature and strength of the relationships between variables such as these may be examined by regression and correlation analysis-two statistical techniques that although related, serve different purpose. Regression analysis is helpful in ascertaining the probable form of the relationship between variables, and the ultimate objective. When this method of analysis is employed, usually it is to predict or estimate the value of one variable corresponding to a given of another variable. The idea of regression was first elucidated by the English Scientist Sir Francis Galton (1821-1911) in report of this research on heredity-first in sweet peas and later in human stature. Correlation analysis on the other hand, is concerned with measuring the strength of the relationship between variables.

Historically, regression analysis was first applied to random sample from approximately normal distributions. Paired values of two variables each of which is normally distributed, from what is known as bivariate normal (frequency) distribution. As statistical methods were adopted by workers in other disciplines, the emphasis on correlation coefficients was taken over quite uncritically in many instances. On the 1920, most economists who were measuring relationships between variables would have said they were doing correlation problems or correlation analysis. Only a few of the more erudite economists paid much attention to related measures that emerged from the same conclusions the standard error of estimate, the regression coefficients, and the standard errors of the regression coefficients.

As of 1928 the distinction between “correlation models” and “regression models” was clearly understood by a very limited number of statisticians, among who, R.A. Fisher was the most prominent. These statisticians were engaged primarily in the design of controlled experiments. Since many problems of interest to economists were slows in recognizing these distinctions and adapting them to get a third situation, characteristic of economic time series, in which the values of the variables were neither normally distributed nor derived from controlled experiments. Only in the very late 1920s and early 1940s formal models were advanced which appeared to cover the special problems of regression analysis when applied to economic time series.

3.4 Multiple Linear Regression Model

Multiple regression analysis is a method of taking into account simultaneously the relationship between all the variables when two or more independent variables are to be used in making estimates of the dependent variable. The use of two or more independent variable regression analysis is an extension of the basic principles used in two-variable regression analysis. It is necessary to determine the equation for the average relationship between the variable.

In the linear equation that represents the multiple regressions model is

$$Y_i = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \cdots \beta_k X_{ik} + \varepsilon_i$$

(3.5)

where

Y_i = value of the dependent variable in the i^{th} trial, of observation

β_0 = constant in the regression equation, which indicates the value of y when all $X_{ij} = 0$

$\beta_1 \dots, \beta_k$ = regression coefficients associated with each of the x_k independent variable

X_{ij} = value of the j^th independent variable in the i^th trial, or observation, associated with the process of sampling

ε_i = the random error in the i^th trial or observation, associated with the process of sampling

3.5 Assumptions of the Multiple Linear Regression Model

The following are the necessary assumptions underlying the multiple linear regression models when inference is an objective of the analysis:

1. The x_i may be either random or non-random (fixed) variables. Because of their role in explaining the variability in the dependent variable *y*, they are sometimes referred to as explanatory variables. The x_i is also some time referred to as predictor variables, because of their role in predicting y.
2. The independent variables, the x_i values, are measured without error.
3. For each combination of x_i values, there is a normally distributed subpopulation of *y* values.
4. The variances of the subpopulation of *y* values are all equal.
5. The *y* values are independent. This means that the value of *y* observed for one value of *x* does not depend on the value observed for another value of *x*.
6. The ε_i is normally and independently distributed with mean 0 and variance σ^2.
7. There is no perfect multicollinearity. That is, there are no perfect linear relationships among the explanatory variables. Multicollinearity may cause the algebraic signs of the coefficients to be the opposite of what logic may dictate, while greatly increasing the standard error of the coefficients.

3.6 Estimated Equation

The least squares method is used to develop the estimate regression model (Aldrich, 1998). The estimated ordinary least squares equation is written in a form to the multiple regression case:

$$\hat{Y} = \hat{\beta}_0 + \hat{\beta}_1 X_1 + \hat{\beta}_2 X_2 + \cdots + \hat{\beta}_k X_k \quad (3.6)$$

The method of ordinary least squares chooses the estimates to minimize the sum of squared residuals.

$$\sum_{i=1}^{n}(y_i - \hat{\beta}_0 - \hat{\beta}_1 x_1 - \hat{\beta}_2 x_2 - -\hat{\beta}_k\, x_k)^2 \tag{3.7}$$

The minimization problem can be solved using multivariable calculus. This lead to k + 1 linear equation in k + 1 unknowns $\hat{\beta}_0, \hat{\beta}_1, \ldots, \hat{\beta}_k$:

$$\sum_{i=1}^{n}(Y_i - \hat{\beta}_0 - \hat{\beta}_1 X_1 - \hat{\beta}_2 X_2 - \cdots - \hat{\beta}_k\, X_k)^2 = 0$$

$$\sum_{i=1}^{n} x_{i1}(Y_i - \hat{\beta}_0 - \hat{\beta}_1 X_1 - \hat{\beta}_2 X_2 - \cdots - \hat{\beta}_k\, X_k)^2 = 0$$

$$\sum_{i=1}^{n} x_{i2}(Y_i - \hat{\beta}_0 - \hat{\beta}_1 X_1 - \hat{\beta}_2 X_2 - \cdots - \hat{\beta}_k\, X_k)^2 = 0$$

.

.

.

$$\sum_{i=1}^{n} x_{ik}\left(Y_i - \hat{\beta}_0 - \hat{\beta}_1 X_1 - \hat{\beta}_2 X_2 - \cdots - \hat{\beta}_k\, X_k\right)^2 = 0 \tag{3.8}$$

These are often called the ordinary least squares first order conditions. The ordinary least squares first order conditions can be obtained by the method of moment, under assumption: *E(ε)=0 and* $E(X_j\varepsilon)=0$*, where j=1,2, …, k* . The equation in (3.4) is the sample counterparts of these population moments, although the equation has omitted the division by the sample size n. Nevertheless, the modern computers running standard statistics and economics software can solve these equations with large n and k very quickly.

3.7 Testing for Significance

The significance tests of the simple regression model were the *t* test and the *F test.* (Bellhouse, 2001). In the simple regression model, these tests always generated the same conclusion. If the null hypothesis was rejected, concluded that $\beta_0 \neq 0$. In multiple regression, the *t* test and the *F* test have different purposes.

The *F* test is used to determine whether there exists a significant relationship between the dependent variable and the entire set of independent variables in the model; thus the *F* test is a test of the overall significance of the regression.

If the *F* test shows that the regression has overall significance, the *t* test is then use to determine whether each of the individual independent variables is significant. A separate *t* test is used for each of the independent variables, thus the *t* test is a test for individual significance.

3.7.1 Test for the Significance of Overall Multiple Regression Model

The overall *F*-test is used to test for the significance of overall multiple regression model. The ANOVA procedure tests the null hypothesis that all the β-value are zero against the alternative that at least one β is not zero.

The hypothesis for *F* test takes the following form

Null Hypothesis : $\beta_0 = \beta_1 = \beta_2 = ... = \beta_k = 0$

(No linear relationship between the dependent variable and the independent variables)

Alternative Hypothesis : At least one $\beta_j \neq 0$

(Linear relationship between the dependent variable and at least one of the independent variables)

If the null hypothesis is rejected, we conclude that one or more of the parameters in the model is not equal to zero. Thus, the overall relationship between the dependent variable y and the independent variables $x_1, x_2, \ldots, x_k$ significant. However, if the null hypothesis is not rejected, we conclude that there is an overall significant relationship and our regression does not significantly to explain the variation in the dependent variable.

This ration of mean square regression to mean square error follows the *F*-distribution when the assumption that the residents are normally distributed is valid and the null hypothesis is true. The ratio of *F*- statistic;

$$F = \frac{MSR}{MSE}$$

where; the MSR is the mean square due to the regression which is equal to

$$MSR = \frac{SSR}{k}$$

where; the MSE is the mean square of error which is equal to

$$MSE = \frac{SSE}{n-k-1}$$

where; $n - k - 1$ is the degrees of freedom and k is the number of independent variables. The decision rule for the F-test takes the following form;

Reject the null hypothesis if : $F > F_{\propto,k,n-k-1}$

Do not reject the null hypothesis if : $F \leq F_{\propto,k,n-k-1}$

where; $F_{\propto,k,n-k-1}$ is based on F the distribution with k degrees of freedom in the numerator, $n - k - 1$ degrees of freedom in the denominator, and a probability of α in the upper-tail of the probability distribution.

3.7.2 Test for Individual Partial Regression Coefficient, $\boldsymbol{\beta_j}$

An individual partial regression coefficient, β_j in the multiple regression model is tested to determine the significance of the relationship between x_i's and y. For any parameter β_j the hypotheses take the form.

Null Hypothesis : $\beta_j = 0$

Alternative Hypothesis : $\beta_j \neq 0$

The t statistics for $\hat{\beta}_j$ is simple to compute given $\hat{\beta}_j$ and its standard error:

$$t = \frac{\hat{\beta}_j}{se\ (\hat{\beta}_j)}$$

The decision rule for this test takes the following form:

Reject the null hypothesis if : $t < -t_{\propto/2,n-k-1}$

(or)

$t > -t_{\propto/2,n-k-1}$

3.7.3 Standard Error of Estimate

It shows how to choose an unbiased estimator of σ^2, which can obtain unbiased estimators of $Var\ (\hat{\beta}_j)$. Because an unbiased estimator of σ^2 is the sample average of the square errors: $n^{-1} - \sum_{i=1}^{n} {\varepsilon_i}^2$.

Nevertheless, the error can be written as $\varepsilon_i = y_i - \hat{\beta}_0 - \hat{\beta}_1 x_{i1} - \cdots - \hat{\beta}_k x_{ik}$. It replace each β_j with its OLS estimator, the $\varepsilon_i = y_i - \hat{\beta}_0 - \hat{\beta}_1 x_{i1} - \cdots - \hat{\beta}_k x_{ik}$. It seems natural to estimate σ^2 by replacing in the general ε_i with the $\hat{\varepsilon}_i$. The unbiased estimator of σ^2 in the general multiple regression case is

$$\hat{\sigma}^2 = (\sum_{i=1}^{n} \varepsilon_i{}^2)/(n-k-1) = \frac{SSR}{(n-k-1)} \quad (3.9)$$

The positive square root of $\hat{\sigma}^2$, denoted $\hat{\sigma}$, is call the standard error of the regression. The standard error of the regression is an estimator of the standard deviation of the error term. This estimate is usually reported by regression packages, although it is called different things by different packages. The σ^2 is also called the standard error of the estimate and the root mean squared error.

3.7.4 The Coefficient of Multiple Determination R^2

The coefficient of multiple determinations is defined as:

$$R^2 = \frac{\sum(\hat{y}_i - \bar{y})^2}{\sum(y_i - \bar{y})^2} = 1 - \frac{\sum(y_i - \hat{y})^2}{\sum(y_i - \bar{y})^2} \quad (3.10)$$

The numerator of the middle term is the explained sum of squares, or the sum of squares due to regression, SSR, as it is sometimes called. The denominator is the total sum of squares SST. The subscription on R^2 indicates the y is the dependable variable and $x_1, x_2, \ldots, x_k$ one independent variable.

Therefore, it can be written as:

$$R^2 = \frac{SSR}{SST} \quad (3.11)$$

The coefficient of multiple determination what proportion of the total variability in *y*, the dependent variables is explained by the independent variables. That is the percentages of the total variation of the dependent variable that can be explain by the explanatory variables. The value of R^2 will be between zero and one, where R^2= 0, the regression model cannot explain anything about the variation in the department variable or the estimated model of the data. The case of $R^2 = 1$ represents a perfect fit of the estimated model of the data. A high value of R^2 shows good fit and a low value of R^2 shows a poor fit.

3.7.5 The Adjusted Coefficient of Multiple Determination $\bar{R}^2$

A measure that recognized the number of independent variables in the regression model is called the adjusted coefficient of multiple determination and is denoted by $\bar{R}^2$.

$$\bar{R}^2 = \frac{\sum(Y_i - \hat{Y})^2}{(n-k-1)} \bigg/ \frac{\sum(Y_i - \bar{Y})^2}{(n-1)} \qquad (3.12)$$

Reporting the adjusted R^2 is extremely important in comparing two or more regression models that predict the same dependent variable but have a different number of independent variables.

3.8 Multicollinearity

The term multicollinearity is due to Ragnar Frisch (1934). Originally it meant the existence of a perfect, or exact, linear relationship among some or all explanatory variables of a regression model. There are several sources of multicollinearity. As Montgomery and Peck (1982) note, multicollinearity may be due to these factors. (1) The data collection method employed, for example, sampling over a limited range of the values taken by the regressors in the population. (2) Constraints on the model or in the population being sampled. (3) Model specification, for example, adding polynomial terms to a regression model, especially when the range of the *x* variable is small. (4) An over determined model.

Multicollinearity problem arises when one of the independent variables is linearly related to one or more of the other independent variables. Such a situation violates one of the conditions for multiple regression. Specially, multicollinearity occurs if there is a high correlation between two independent variables, x_i and x_j if the correlation coefficient r_{ij} between X_i and X_j in the multiple linear regression model is high, multicollinearity exist. Multicollinearity is a problem of degree. Any time two or more independent variables are linearly related, some degree of multicollinearlity exists. If its presence becomes too pronounced, the model is adversely affected. The presence of multicollinearity creates many problems in use of multiple linear regression model.

The most direct way of testing for multicollinearity is to produce a correlation matrix for all variables in the model. If a correlation is greater than 0.7 or less than -0.7, the independent variables are highly correlated. If a correlation is less than 0.5, it can be concluded that multicollinearity is not problem. Another way to detect multicollinearity is use to value of Tolerance. If the value of Tolerance is not less than 0.1, it can be said that there is no multicollinearity problem in this study. The third way to detect multicollinearity is to use the variance inflation factor (*VIF*). The *VIF* associated with any X-variable is found by regression it on all the other X-variables. The resulting R^2 is then used to calculate that variable's *VIF*. The *VIF* for any X_i represents that variable's influence on multicollinearity.

The *VIF* for any independent variable is a measure of the degree of the multicollinearity contributed by that variable.

The *VIF* for any given independent variable X_i is

$$VIF(X_i) = \frac{1}{1-R^2} \tag{3.13}$$

Where, ${R_i}^2$ is the coefficient of determination obtained by regression x_i on all other independent variables. Multicollinearity produces an increase in the variation, or standard error, of the regression coefficient. *VIF* measures the increase in the variance regression coefficient over that which would occur if multicollinearity were not present. In general, multicollinearity is not considered a significant problem unless the *VIF* of a single X_i measure at least 10 or the sum of the *VIF*'s for all X_i is at least 10.

3.9 Residual Analysis

Residual analysis refers to a set of diagnostic methods for investigating the appropriateness of a regression model utilizing the residual. If a regression model is appropriate, the residuals $\varepsilon_i = Y_i - \hat{Y}_i$ should reflect the properties ascribed to the model error terms ε_i. Since regression model assumes that the ε_i is normal random variables with constant variance, the residual should show a pattern consistent with these properties.

There are two graphical residual analysis methods. The first involves residual plots, where the residuals are plotted as a scatter plot against the corresponding fitted value. The second involves normal probability plots of the residual, where the ranked residuals are plotted against their expected values under normality.

3.9.1 Check for Linearity Assumption

The use of the residual plots and normal probability plots for investigating the following departures from regression model are:

a. The regression function is not linear
b. The error terms ε_i not independent.
c. The distribution of Y are not normal; or, equivalently, the ε_i is not normally distributed.
d. The distribution of *Y* does not have constant variances at all level of *X*; or, equivalently, the ε_i does not have constant variance.

A plot of the residual against the fitted values also provides information as to whether or not the error terms ε_i have constant variance. If the error term variance is constant, the residual plot should show the residuals falling within a horizontal band around the central line. To check whether the linearity assumption, residual plot is can be drawn. If the residual plot has in straight line structure, the regression model is linear. If the residual plot has in curve nature, the regression model is nonlinear which is shown in Figure (3.1).

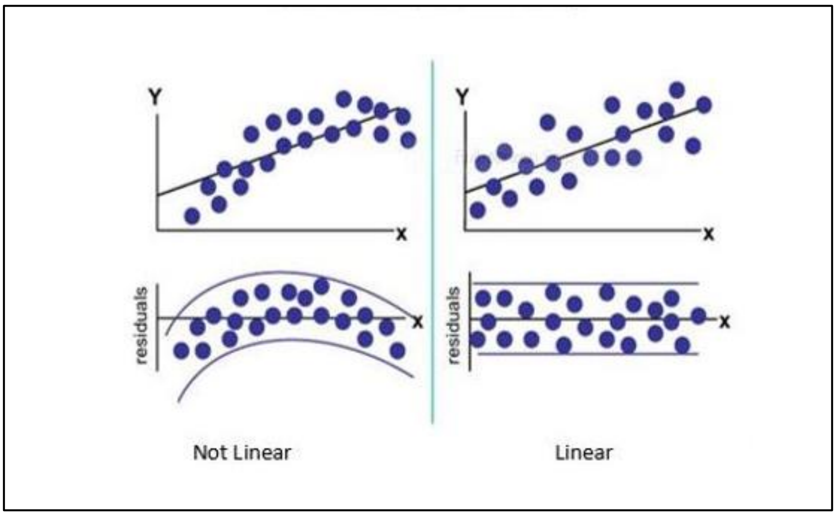


Figure (3.1) Residual Analysis for Linearity

In Figure (3.1), the two plots of the left side of figure are not in linear pattern. The residuals are display in curved pattern and they are not in straight line structure. The two plots of the right side are linear pattern. The residuals are scattered in randomly and not in curved pattern.

3.9.2 Residual Analysis for Independence

It is assumed that the residual terms are independent of each other, i.e. their pair-wise co-variance is zero. This means that there is no correlation between the residuals and the predicted values, or among the residuals themselves. If some correlation is present, it implies that there is some relation that the regression model is not able to identify. If the independent variables are not linearly independent of each other, the uniqueness of the least square's solution (or normal equation solution) is lost.

The residual analysis for independence is shown in Figure (3.2)

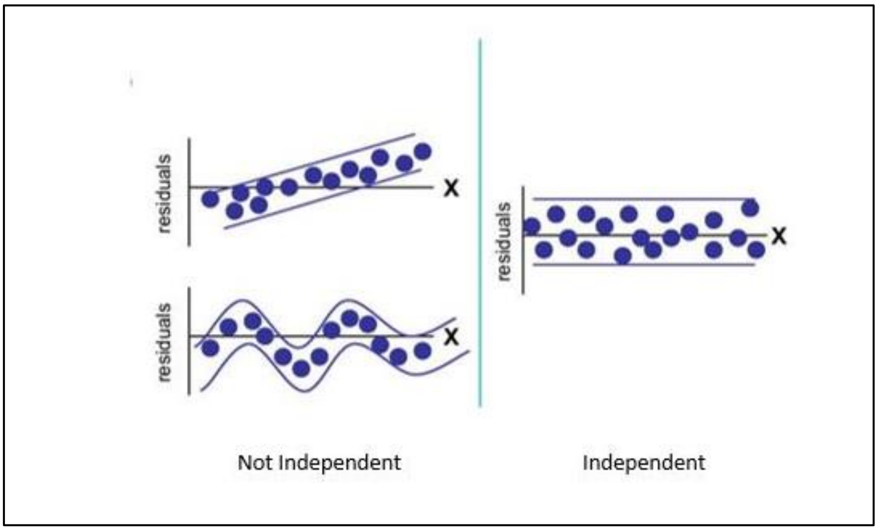


Figure (3.2) Residual Analysis for Independent

In Figure (3.2), the two plots of the left side are not independent residual. The residuals are distributed in pattern and not randomly displayed. The right one plot is independent residual. The residuals are randomly displayed and they are not in pattern.

3.9.3 Residual Analysis for Normality

To check for normality, several methods are used in statistics. They are

1. the stem-and-leaf display of the residuals.
2. the box plot of the residual
3. the histogram of the residual
4. a normal probability plot of the residual

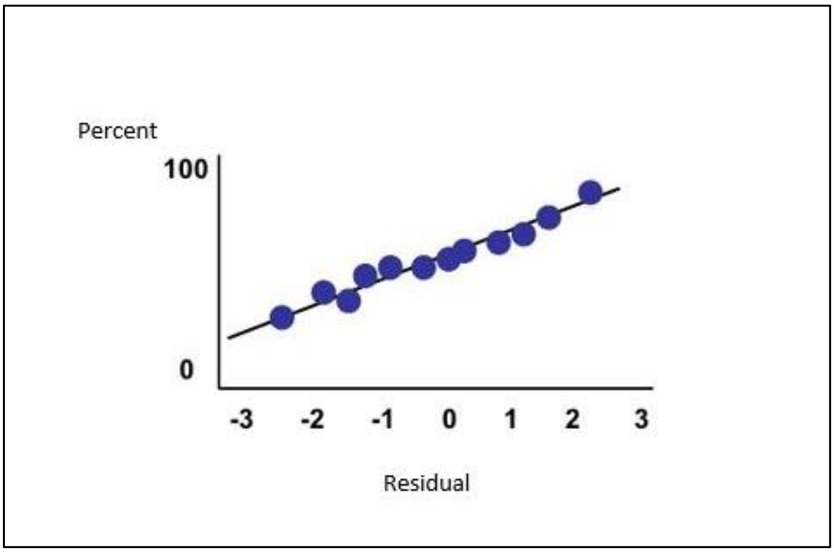


Figure (3.3) Residual Analysis for Normality

In this study, examine the histogram of the residual and construct normal probability plot of the residuals are used for checking the normality assumption. When using a normal probability plot, normal errors will approximately display in straight line which is shown in Figure (3.3).

3.9.4 Residual Analysis for Homoscedasticity

Linear regression makes the assume that the residuals have constant variance at every level of the predictor variable(s). This is known as homoscedasticity. When this is not the case, the residuals are said to suffer from heteroscedasticity and the results of the regression analysis become unreliable. To check whether the constant variance, one can examine the residual plot. The Figure (3.4) is shown the residual analysis for equal variance.

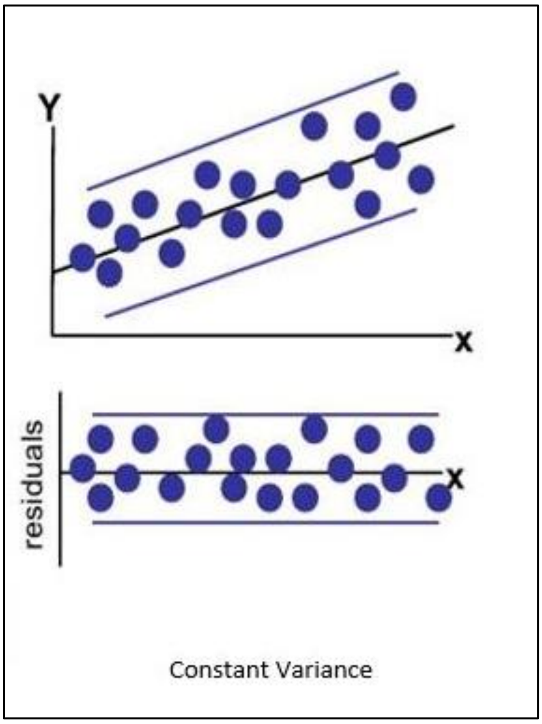


Figure (3.4) Residual Analysis for Equal Variance

`In Figure (3.4), the residuals of each plot are spread equal at each level of the fitted values. So, we can say that the constant variance assumption is met.

3.9.5 Test for Serial Correlation

Durbin-Watson test will now be considered as a test of the null hypothesis that no serial correlation is present $(\rho = 0)$. The alternative hypothesis can be that ρ is nonzero or in the one-tailed case, that ρ is positive or negative.

The Durbin-Watson test involves the calculation of a test statistic based on the residuals from the ordinary lest squares regression procedure. The statistic is defined as

$$\text{Durbin-Watson} = d = \frac{\sum_{t=1}^{n}(\hat{\varepsilon}_t - \hat{\varepsilon}_{t-1})^2}{\sum_{t=2}^{n}\hat{\varepsilon}_t^{\ 2}} \qquad (3.14)$$

Table (3.1) Range of the Durbin-Watson Statistic

Value of DW	Result
4 - $d_L < DW < 4$	Reject null hypothesis ; negative serial correlation present
4 - $d_U < DW < 4 - d_L$	Result indeterminate
$2 < DW < 4 - d_U$	Accept null hypothesis
$d_U < DW < 2$	Accept null hypothesis
$d_L < DW < d_U$	Result indeterminate
$0 < DW < d_L$	Reject null hypothesis ; positive serial correlation present

Source: Gujarati, Damodar N (2009), Basic Econometrics

A great advantage of the *d* statistics is that it is based on the estimated residuals, which are routinely computed in regression analysis. Because of this advantage, it is now a common practice to report the Durbin-Watson *d* along with summary statistics such as R^2, adjusted R^2, *t*-ration, etc. Although, it is now used routinely, it is important to note the assumption underlying the *d* statistics:

a. The regression model includes an intercept term. If such term is not present, as in the case of the regression through the origin, it is essential to return the regression including the intercept term to obtain the *RSS*.
b. The explanatory variables, the *X*'s, are nonstochastic, or fixed in repeated sampling.
c. The disturbance ε_i are generated by the first-order autoregressive scheme: $\varepsilon_i = \rho\, \varepsilon_{t-1} + u_t$.
d. The regression model does not include lagged value(s) of the dependent variable as one of the explanatory variables. Thus, the test is inapplicable to models of the following type:

$$Y_t = \beta_1 + \beta_2 X_{2t} + \beta_3 X_{3t} + \cdots + \beta_k X_{kt} + \gamma Y_{t-1} + \varepsilon_t \qquad (3.15)$$

where Y_{t-1} is the one-period lagged value of *Y*. Such models are known as autoregression models.

e. There are no missing observations in the data.

3.10 Cobb-Douglas Production Function (Log-Log Model or Double Log Model)

If some of the assumptions are not satisfied, then there are several ways to processed. One option is to use least squares and to derive the properties of this estimator under more general conditions. Another option is to adjust the specification of the model – for instance, by changing the included variables, the functional form, or the probability distribution of the disturbance terms. In this section, one of the various functional forms of the linear regression model which is used in this thesis is discussed Cobb-Douglas Production Function.

The progressive refinement during the recent years in the measurement of the volume of physical production in manufacturing suggests the possibility of attempting (i) to measure the changes in the amount of labour and capital which have been used to learn out this volume of goods, and (ii) to determine what relationships existed between the three factors of labour, capital and product.

In the 1920s the economist Paul Douglas was working on the problem of relating inputs and output at the national aggregate level. A survey by the National Bureau of Economic Research found that during the decade 1909-1918, the share of output payed to labour was fairly constant at about 74%, despite the fact the capital labour ration was not constant. He enquired of his friend Charles Cobb, a mathematician, if any particular production function might account for this. This gave birth to the original Cobb-Douglas production which they propounded in their 1928 paper; “A theory of Production”.

A various transformations discussed there in the context of the two-variable case can be easily extended to multiple regression models. Consider an agriculture sector which produces output using a technology described by a Cobb-Douglas production function:

$$Y_i = \beta_0 X_{1_i}^{\beta_1} X_{2_i}^{\beta_2} e^{\varepsilon_i} \tag{3.16}$$

where Y = output

X_1 = labour input

X_2 = capital input

ε = stochastic disturbance term

e = base of natural logarithm

From Equation (3.15), it is clear that the relationship between output and the two inputs is nonlinear. The log-transform this model is

$$\ln Y_i = \beta_0 + \beta_1 \ln X_{1i} + \cdots + \beta_2 \ln X_{2i} + \varepsilon_i \qquad (3.17)$$

The model is linear in the parameters β_0, β_1 and β_2 and therefore a linear regression model. It is nonlinear in the variables *Y* and *X* but linear in the logs of these variables. Equation (3.16) is a log-log or double-log model, the multiple regression counterpart of the two-variable log-linear model.

The properties of the Cobb-Douglas production function are quite well known:

a. To the labour input, that is, it measures the percentages change in output for, say, a one percent change in the labour input, holding the capital input constant.
b. Likewise, β_2 is the partial elasticity of output with respect to the capital input, holding the labour input constant.
c. The sum (β_1+β_2) gives information about the returns to scale, that is, the response of output to a proportionate change in the inputs. If this sum is 1, then there are constant returns to scale, that is, doubling the inputs will double the output, tripling the inputs will triple the output, and so on. If the sum is less than 1, there are decreasing returns to scale-doubling the inputs will be less than double the output.

Before proceeding further, a log-linear regression model involving any number of variables the coefficient of each of the *x* variables measures the partial elasticity of the dependent variable *y* with respect to that variable.

Thus, if we have a k-variable log-linear model:

$$\ln Y_i = \beta_0 + \beta_1 \ln X_{1i} + \beta_2 \ln X_{2i} + \cdots + \beta_k \ln X_{ki} + \varepsilon_i \qquad (3.18)$$

each of the partial regression coefficients, β_2 through β_k, is the partial elasticity of *y* with respect to variable to variables X_k.

Return to Scale

The Cobb-Douglas production function is based not only in the short run production but also in the long run production. It can easily be found in the return to scale of the production by adding elasticities of inputs.

a. Constant return to scale (CRS); if $\beta_1 + \beta_2 = 1$
b. Increasing return to scale (IRS); if $\beta_1 + \beta_2 > 1$
c. Decreasing return to scale (DRS); if $\beta_1 + \beta_2 < 1$

Return to scale are concerned with how output varies with the use of inputs. Constant return to scale imply that the production function is homogeneous of degree one; scaling the inputs of production by a constant lead to the same proportional change in output. Elasticities are convenient because they are measure as proportion or percentage rather than with unit measure. A scale elasticity equal to one implies constant return to scale; increasing and decreasing return to scale are indicated by scale elasticities greater than or less than one.

CHAPTER IV
ANALYSIS OF RICE PRODUCTION

In this chapter, rice productions of Myanmar were presented by descriptive analysis, time series analysis and multiple regression analysis. First study is the descriptive analysis of related variables on rice production in Myanmar. Second study is finding the trend and forecasts of rice production in Myanmar. The third study is determining the best fitted regression model for the volume of rice production in Myanmar.

4.1 Volume of Rice Production

Rice production is central to the economy and food security of Myanmar and has a long tradition. In the years immediately prior to World War II it was the largest rice-producing nation in the world, and it continues to be one of the ten largest rice-producing countries in terms of total yield (IRRI, 2002). Between 1900 and 1940, Myanmar exported 2 to 3 million MT rice annually, up to 70% of national production (Win 1991). In the early 1960s, annual exports were in the range 1.3 to 1.7 million MT (USDA data from World Rice Statistics).

The volume of rice production in Myanmar from (2000-2001 to 2019-20) is shown in Table (4.1) and Figure (4.1).

Table (4.1) Volume of Rice Production in Myanmar (2000-2001 to 2019-2020)

Year	Rice Production (Thousand Tons)
2000-2001	20986.9
2001-2002	21569.2
2002-2003	21460.7
2003-2004	22770.2
2004-2005	24360.9
2005-2006	27245.8
2006-2007	30435.0
2007-2008	30954.1
2008-2009	32058.5
2009-2010	32165.8
2010-2011	32065.1
2011-2012	28552.1
2012-2013	26216.6
2013-2014	26372.1
2014-2015	26423.3
2015-2016	26210.3
2016-2017	25672.8
2017-2018	25624.5
2018-2019	27573.6
2019-2020	26268.8

Source: Myanmar Statistical Year Book (2005, 2010, 2015 and 2020)

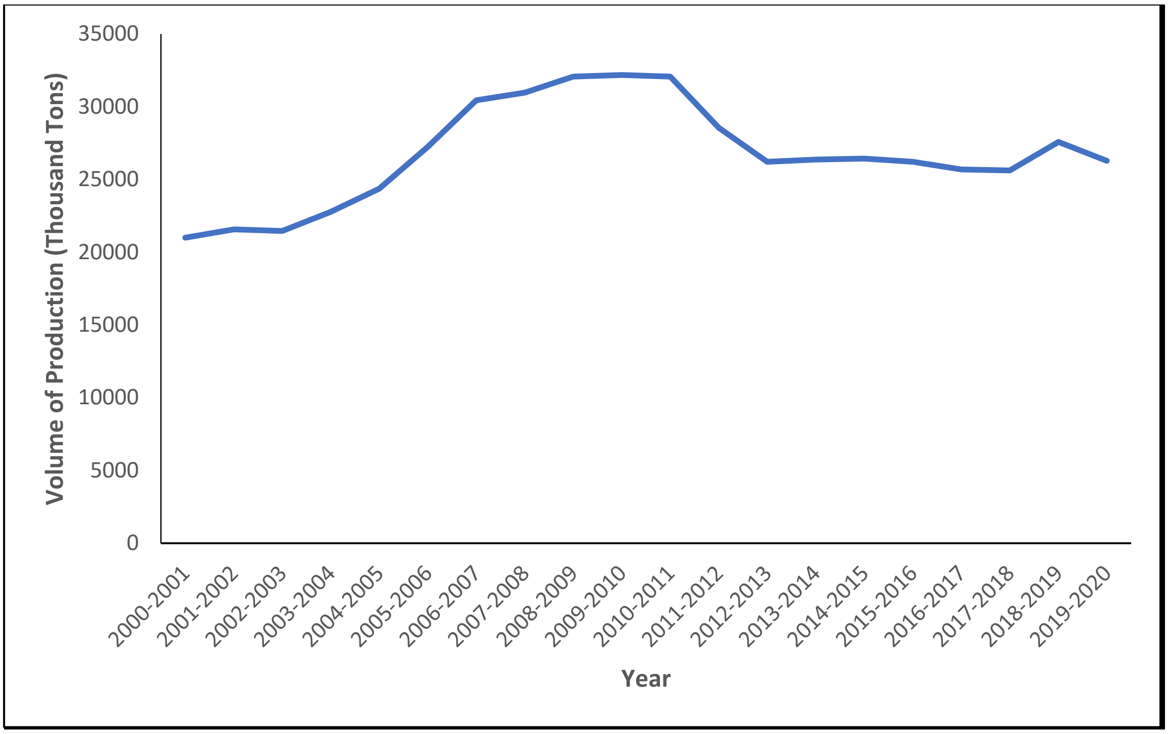


Figure (4.1) Volume of Rice Production in Myanmar (2000-2001 to 2019-2020)
Source: Table (4.1)

According to the Table (4.1) and Figure (4.1), the volume of rice production yield was 20986.9 thousand tons in 2000-2001. The volume of rice production slightly increases from fiscal year 2000-2001 to 2004-2005 and it yield was 24360.90 thousand tons in 2004-2005. The volume of rice production in 2005-2006 and 2006-2007 significantly fold up the production of 2000-2001. Due to the promoting summer paddy production, investment in irrigation was indispensable not only in the Dry Zone in Upper Myanmar but also in Lower Myanmar. The volume of rice production was regularly raised up between 2007-2008 and 2010-2011. The volume of rice production slightly decreases from fiscal year 2011-2012 to 2017-2018. In 2011, Myanmar opened its doors to democratic and economic transformation. Foreign Direct Investment (FDI) increased under the new democracy government and made a lot of job creations in urban area. Consequently, rural to urban migration increased and agricultural sector faced labour shortage problem. This problem effected on rice production sector and related with the decrease trend of 2011-12 to 2017-18. The production was slightly increased in 2018-19 and it yield was 27573.6 thousand tons.

4.2 Agricultural Labour and Total Population

The total population of Myanmar is estimated to be 65 million by 2050. The projection is based on steadily declining population growth rate over the projection period: from 0.9 per cent in 2015 to 0.3 per cent in 2050. Decreasing crude birth rates is the main reason for the decline. The population ages steadily and substantially over the projection period (Census Report). Out of this total about 70.5% are living in rural area where farming is the main occupation. Myanmar is an agricultural country, it is estimated that the agriculture sector represents between 35 to 40 percent of gross domestic product (GDP) and that up to 70 percent of the labor force (of 32.5 million) is directly or indirectly engaged in agricultural activities or depend on agriculture for their income.

Agricultural labour and total population during 2000-2001 to 2019-2020 are stated in Table (4.2) and Figure (4.2).

Table (4.2) Agricultural Labour and Total Population (2000-2001 to 2019-2020)

Year	Agricultural Labour (In Million)	Total Population (In Million)	Percentage of Agricultural Labour
2000-2001	29.98	48.89	61.33
2001-2002	29.94	49.26	60.78
2002-2003	29.77	49.58	60.04
2003-2004	29.41	49.88	58.97
2004-2005	29.20	50.18	58.19
2005-2006	29.00	50.50	57.42
2006-2007	28.76	50.83	56.57
2007-2008	28.63	51.17	55.96
2008-2009	28.48	51.54	55.26
2009-2010	27.85	51.00	54.60
2010-2011	28.33	52.35	54.12
2011-2012	28.42	52.80	53.83
2012-2013	28.39	53.26	53.31
2013-2014	27.10	51.42	52.70
2014-2015	27.16	51.99	52.23
2015-2016	27.11	52.45	51.69
2016-2017	27.04	52.92	51.10
2017-2018	27.02	53.39	50.61
2018-2019	26.79	53.86	43.35
2019-2020	25.35	54.58	46.45

Source: Myanmar Statistical Year Book, (2005, 2010, 2015 and 2020),

World Bank, (2020)

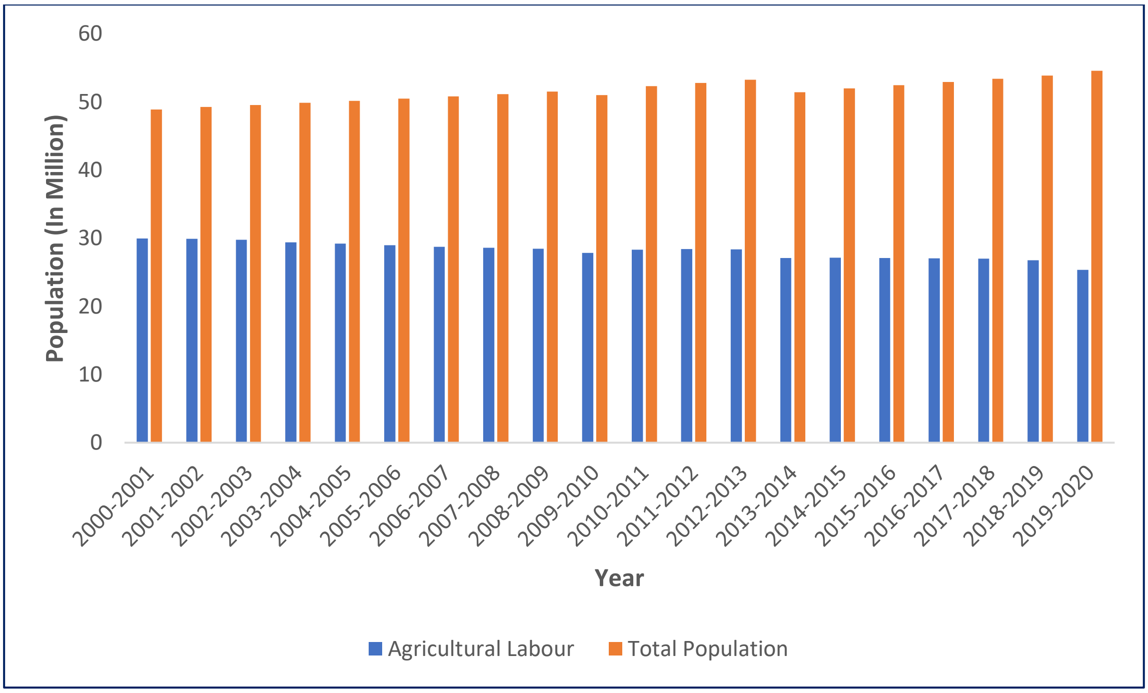


Figure (4.2) Agricultural Labour and Total Population (2000-2001 to 2019-2020)

Source: Table (4.2)

Agriculture labour data is from world development indicators database of World Bank. According to the Table (4.2) and Figure (4.2), the percentage of agricultural labour was over 60% during the period of 2000-2001 to 2002-2003. The percentage of agricultural labour was decreased to 58.97% in 2003-04 fiscal year. The agricultural labour in Myanmar had decreased gradually year by year reaching about 46.45% in 2019-2020.

The reasons for decline of agricultural labour are increased agricultural mechanization, rural to urban migration and external migration.

4.3 Sown Area, Irrigated Area and Harvested Area

The rice-growing soils of Myanmar were classified by Soviet soil scientists into 18 main soil types and 7 soil groups. These soil types approximated the FAO/UNESCO nomenclature (Ye Goung et al, 1978). The main rice-growing soil groups fall under Gleysols, Fluvisols, Planosols, and Vertisols**.** The classification system of the Food and Agriculture Organization (FAO) Gleysols are formed under waterlogged conditions produced by rising groundwater. In the tropics and subtropics, they are cultivated for rice or, after drainage, for field crops and trees. Fluvisols are found typically on level topography that is flooded periodically by surface waters or rising groundwater, as in river floodplains and deltas and in coastal lowlands. Planosols are characterized by a subsurface layer of clay accumulation. They occur typically in wet low-lying areas that can support either grass or open forest vegetation. They are poor in plant nutrients, however, and their clay content leads to both seasonal waterlogging and drought stress. Vertisols are characterized by a clay-size-particle content of 30 percent or more by mass in all horizons (layers) of the upper half-meter of the soil profile, by cracks at least 1 cm (0.4 inch) wide extending downward from the land surface, and by evidence of strong vertical mixing of the soil particles over many periods of wetting and drying. They are found typically on level or mildly sloping topography in climatic zones that have distinct wet and dry seasons.

Constriction of irrigation work for crop cultivation historically started since the days of Myanmar Kings. After 1988, the government put forward continuous efforts in the construction of dams and reservoirs throughout the country by utilizing large capital investment, man power and machineries and with the available domestic resource and expertise.

Myanmar has abundant land, water resources, and a good climate for rice. The majority of Myanmar’s sown area is planted to monsoon rice, whereas summer rice is planted between November and February in the country’s lower part and from January to March in the central dry zone regions. Rice growing takes about 5-6 months. Monsoon rice are harvested in November-December, including the Ayeyarwady, Bago, and Yangon region of Lower Myanmar. In some regions, farmers grow a second crop because irrigation allows using another variety of rice. The harvest period of summer rice is from February to April.

Sown Area, Irrigated Area and Harvested Area are shown in the following Table (4.3) and Figure (4.3).

Table (4.3) Sown Area, Irrigated Area and Harvested Area (2000-2001 to 2019- 2020)

(Thousand Acres)

Year	Sown Area	Irrigated Area	Harvested Area
2000-2001	15713.00	4608.61	15573.00
2001-2002	15940.00	4577.65	15845.00
2002-2003	16032.00	4558.69	15757.00
2003-2004	16168.00	4675.31	16130.00
2004-2005	16946.00	4643.52	16822.00
2005-2006	18259.00	5188.05	18246.00
2006-2007	20076.00	5424.72	19952.00
2007-2008	19990.00	5453.48	19796.00
2008-2009	20001.00	5323.18	19960.00
2009-2010	19933.00	5545.69	19912.00
2010-2011	19885.00	5402.00	19796.00
2011-2012	18762.00	4927.12	18698.00
2012-2013	17893.00	4618.81	17270.00
2013-2014	17999.00	4805.25	17181.00
2014-2015	17722.00	4632.88	16975.00
2015-2016	17821.00	4640.13	16728.00
2016-2017	17695.00	4636.13	16615.00
2017-2018	17930.00	4939.33	16668.00
2018-2019	17867.00	5027.12	17666.00
2019-2020	17306.00	4596.24	17101.00

Source: Myanmar Statistical Year Book, (2005, 2010, 2015 and 2020)

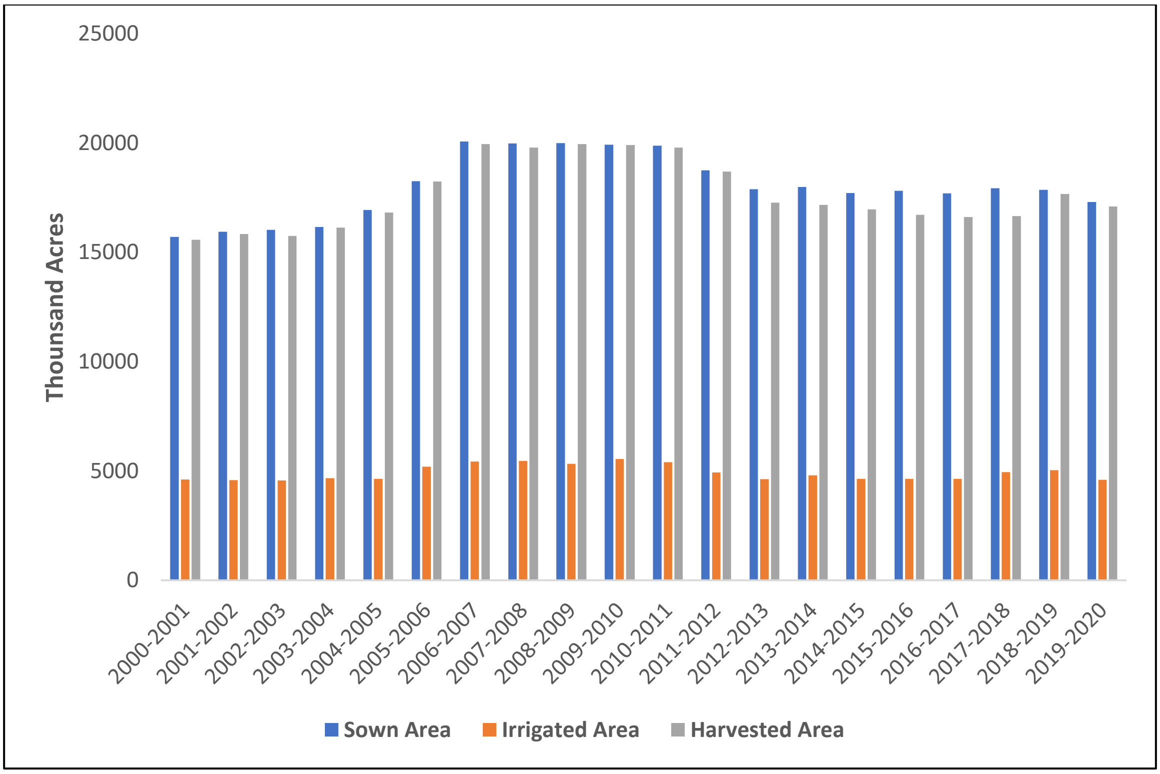


Figure (4.3) Sown Area, Irrigated Area and Harvested Area (2000-2001 to 2019-2020)

Source: Table (4.3)

Table (4.3) and Figure (4.3) showed that the sown area, harvested area and irrigated area had increased from 2000-2001 to 2010-2011 continuously. The sown area increased from 15713 (thousand acres) to 18259 (thousand acres) from the fiscal year of 2001-2001 to 2005-06. The years between 2006-07 and 2016-17 shows positively incline in sown area. The irrigated area raised to 5424 (thousand acres) in 2006-07 from 4608.61 (thousand acres) of 2000-2001. The irrigated areas continuously raised to 5402 (thousand acres) in 2010-11. The year after of 2010-11, the irrigated area slightly declines to the year of 2016-17. The impact of increase in irrigated area was due to the construction of new reservoirs and dams and renovation of existing reservoirs for the purpose of raising strong capacity and efficient delivery of irrigation. The harvested area increased from 15573 (thousand acres) in 2000-2001 to 19952 (thousand acres) in 2006-07. The years between 2007-08 and 2010-11 shows positively incline but it was again slightly decreased from 2011-12 to 2017-18. The harvested area slightly increased from 2018-2019 to 2019-2020.

4.4 Agricultural Equipment

There are three components – implements, machineries and vehicles. Implements contain ploughs, harrows and spades. The machineries are seed drills (plough), rotary harrows, water pumps and tractors. Vehicles include carts. The major objectives of the mechanization program are to increase income and reduce the drudgery of the small farmers and to foster the development of the farm equipment industry in the rural areas.

Prior to 1990s in Myanmar, animal power had played vital role farm operation like ploughing, harrowing and threshing. Beginning from 1991, government initiated the large scale private farming in agriculture and has encouraged the agricultural mechanization, especially to develop small scale agricultural machineries by local production, importing from abroad and marketing to domestic private sector. Despite these efforts, growth of farm mechanization is still low and slow.

Agricultural Equipment in Myanmar (2000-2001 to 2019-2020) is shown in the following Table (4.4).

Table (4.4) Agricultural Equipment in Myanmar (2000-2001 to 2019-2020)

(Thousand Number)

Year	Implements	Machineries	Vehicles
2000-2001	9952	771	1759
2001-2002	10069	801	1772
2002-2003	10150	816	1769
2003-2004	10357	843	1785
2004-2005	10472	858	1789
2005-2006	10573	875	1795
2006-2007	10713	895	1798
2007-2008	10843	907	1807
2008-2009	10859	904	1798
2009-2010	10942	959	1768
2010-2011	10962	967	1769
2011-2012	10998	947	1780
2012-2013	11036	992	1776
2013-2014	11063	1002	1769
2014-2015	11108	1022	1763
2015-2016	11131	1029	1758
2016-2017	11095	1041	1742
2017-2018	11145	1062	1732
2018-2019	11145	1068	1712
2019-2020	11123	1083	1720

Source: Myanmar Statistical Year Book, (2005, 2010, 2015 and 2020)

Table (4.4) shows agricultural equipment in Myanmar from 2000-2001 to 2019-2020. In 2000-2001, implements are 9952 (thousand number), machineries are 771 (thousand number) and vehicles are 1759 (thousand number) respectively. The developing of agricultural equipment is increased to 11123 (thousand number) implements, 1083 (thousand number) machineries and 1720 (thousand number) vehicles in 2019-2020. Agricultural equipment is increased year by year. Industrial revolution in agricultural sector raises demand in use of implements machines and vehicles. State and Regional government set agricultural development policy and encourage and supply innovative agricultural equipment.

4.5 Paddy Loans and Short Term and Long Term Loans

Paddy loans and short term and long term loans are implemented and launched by Myanmar Agricultural Development Bank (MADB). MADB is one of the government-affiliated financial institution and subordinate organization of Ministry of Agriculture, Livestock and Irrigation (MOALI). MADB has two types of program including Seasonal Loan and Term Loan. The Seasonal Loan targets crop production and paddy loan include in this loan type. Paddy loan aims to production inputs such as cultivation cost, fertilizer cost, pesticide cost and labour cost. Short term and long term loan is under the Term Loan category and aims to procurement of farming tool and equipment such as working animal and agricultural machinery.

Paddy Loans and Short Term and Long Term Loans data are shown in the following Table (4.5).

Table (4.5) Paddy Loans and Short Term and Long Term Loans (2000-2001 to 2019-2020)

(Million Kyats)

Year	Paddy Loans	Short Term and Long Term Loans
2000-2001	9524.87	62.60
2001-2002	9819.21	277.48
2002-2003	9607.24	1088.34
2003-2004	16856.55	1502.71
2004-2005	22986.56	5711.83
2005-2006	29292.06	3261.21
2006-2007	38555.19	7945.18
2007-2008	50092.96	9057.08
2008-2009	57917.72	3010.25
2009-2010	76124.72	3779.52
2010-2011	156494.46	8897.26
2011-2012	311530.22	7104.98
2012-2013	507130.31	13206.72
2013-2014	1035840.60	3991.88
2014-2015	1047681.70	18707.30
2015-2016	993009.80	10897.86
2016-2017	1535351.10	10521.92
2017-2018	1457545.65	16865.55
2018-2019	1278750.90	97752.38
2019-2020	1282966.50	97110.75

Source: Myanmar Statistical Year Book, (2005, 2010, 2015 and 2020)

Table (4.5) shows the paddy loans and short term and long terms loans from 2000-2001 to 2019-2020. It is found that the paddy loans are 9524.87 (Million Kyats) in 2000-2001 and 1282966 (Million Kyats) in 2019-2020. Short term and long term loan have increased fixedly from 62.60 (Million Kyats) in 2000-2001 to 97110.75 (Million Kyats) in 2019-2020. The amount of paddy loan engagement increase multiple by year after year with increasing demand in need of fertilizer, pesticides and labour cost. After the 2010 general election, loans engagement in 2010-11 increase in and most of sanctions are lifted and renewed from international.

4.6 Fertilizer Utilization in Agricultural Sector (2000-2001 to 2019-2020)

Chemical fertilizers were first introduced to Myanmar in 1956, but widespread use did not occur until 1978 when the government encouraged fertilizer use by subsidizing fertilizer prices. The domestic fertilizer industry in Myanmar is concentrated around the production of urea fertilizer from the abundant sources of natural gas in the country. Fertilizer plants in Myanmar are scattered in Salay, Kyunchaung and Kyaw Swa, and another production of urea fertilizer from two new fertilizer plants, Myaung Daga in Hmawbi Township and another in Kan Gyi Dauk of Pathein Township, will support domestic requirements in the future (Tin Maung Shwe 2011). As requirement for plant nutrients, phosphate and potash fertilizers are imported. The Ministry of Electricity and Energy (MOEE) prefers to export natural gas in order to obtain foreign exchange, and thus supplies of gas to the urea plant have been decreasing. Although imports of fertilizers are liberalized to the private sectors, most of farmers are unable to acquire sufficient amount of fertilizer due to financial constraints.

Fertilizer Utilization in Agricultural Sector (2000-2001 to 2019-2020) are shown in the following Table (4.6).

Table (4.6) Fertilizer Utilization in Agricultural Sector (2000-2001 to 2019-2020)

Year	Fertilizer (Metric Ton)
2000-2001	264171
2001-2002	119047
2002-2003	82269
2003-2004	19624
2004-2005	11215
2005-2006	11762
2006-2007	13612
2007-2008	7687
2008-2009	10570
2009-2010	6866
2010-2011	5707
2011-2012	1753
2012-2013	93455
2013-2014	74968
2014-2015	28442
2015-2016	2427473
2016-2017	3167342
2017-2018	3483797
2018-2019	2139589
2019-2020	1681424

Source: Myanmar Statistical Year Book, (2005, 2010, 2015 and 2020)

Table (4.6) shows the fertilizer utilization in agriculture sector from 2000-2001 to 2019-2020. It is found that 264171 (metric ton) in 2000-2001 and 1681424 (metric ton) in 2019-2020. The utilization of fertilizer continuously declines within the period of 2002-03 to 2011-12 fiscal years. The period between 2012-13 and 2014-15 shows the amount of use in fertilizer increased significantly compare to previous years. The utilization of fertilizer increased outstandingly to 2427473 (metric ton) in 2015-16, 3167342 (metric ton) in 2016-17 and 3483797 (metric ton) in 2017-18. The fertilizer utilization was decreased 1681424 (metric ton) in 2019-2020.

4.7 Pesticides Utilization (2000-2001 to 2019-2020)

There are three pesticide formulation plants in Myanmar. Two are neem formulation plants in Paleik and Pakokku and another one is pilot pesticide formulation plant in Hmawbi established in 1990. Registered Technical Grades are imported and formulated in that plant. Data of pesticide consumption in Myanmar points out that the pesticide consumption is very low compared to many neighboring countries.

Table (4.7) shows the pesticides utilization from 2000-2001 to 2019-2020. It is found that 8388 (gallon) in 2000-2001.

Table (4.7) Pesticides Utilization (2000-2001 to 2019-2020)

Year	Pesticides (Gallon)
2000-2001	8388
2001-2002	17758
2002-2003	16221
2003-2004	6445
2004-2005	15688
2005-2006	3653
2006-2007	15532
2007-2008	366830
2008-2009	413781
2009-2010	438680
2010-2011	595716
2011-2012	732086
2012-2013	129514
2013-2014	133429
2014-2015	292979
2015-2016	450467
2016-2017	654582
2017-2018	1185207
2018-2019	9761999
2019-2020	1298460

Source: Myanmar Statistical Year Book, (2005, 2010, 2015 and 2020)

The pesticide utilization continuously declines within the period of 2002-03 to 2006-07 fiscal years. The period between 2007-08 and 2011-12 shows the amount of use in pesticides increased significantly compare to previous years. The pesticides utilization declined again in 2012-13, 2013-14 and 2014-15. The years between 2015-16 and 2019-20 shows positively incline in pesticides utilization. The widely use of pesticides increase can be visible after the Cyclone Nargis (2008-09) due to the direct import from abroad. After year 2000, pesticide production is stopped due to lack of mechanical failure. This is the one reason of decline trend from 1999-00 to 2006-07.

4.8 Average Annual Rainfall (2000-2001 to 2019-2020)

Myanmar's climate pattern is highly influenced by the monsoon – about 95% of its annual national average rainfall is received from the Southwest Monsoon, from May to October, with spatial and temporal variability. The Central Dry Zone has the least benefit from the Southwest Monsoon, due to high mountains surrounding the area (rain shadow effect).

Actual rainfall data are collected from 32 stations by the Department of Meteorology and Hydrology (DMH). The stations are Myitkyina, Mohnyin, Loikaw, Hpa-an, Falam, Hakha, Katha, Mawlaik, Monywa, Shwe Bo, Hkamti, Dawei, Myeik, Bago, Pyay, Magway, Gangaw, Mandalay, Pyin Oo Lwin, Nyaung Oo, Mawlamyine, Yay, Sittway, Thantwe, Yangon, Lashio, Taunggyi, Keng Tung, Pathein, Yezin, Tatkone and Pyinmana. The actual rainfall is recorded throughout the country at 9:30 am of Myanmar standard time. The average annual rainfall is the average value of actual rainfall data from these 32 stations.

Table (4.8) shows the average annual rainfall from 2000-2001 to 2019-2020.

Table (4.8) Average Annual Rainfall (2000-2001 to 2019-2020)

Year	Rainfall (Millimeter)
2000-2001	2375
2001-2002	2598
2002-2003	2638
2003-2004	2280
2004-2005	2484
2005-2006	2381
2006-2007	2713
2007-2008	2599
2008-2009	2563
2009-2010	2371
2010-2011	2188
2011-2012	2895
2012-2013	2442
2013-2014	2571
2014-2015	2245
2015-2016	2511
2016-2017	2309
2017-2018	2376
2018-2019	2312
2019-2020	2286

Source: Myanmar Statistical Year Book, (2005, 2010, 2015 and 2020)

The average annual rainfall is 2375 (millimeter) in 2000-2001 and 2286 (millimeter) in 2019-2020. The minimum value of average annual rainfall is 2188 (millimeter) in 2010-11 and the maximum value of average annual rainfall is 2895 (millimeter) in 2011-12. Rice requires more water than any other crops. Rice cultivation is done only in those areas where minimum rainfall is 1150 (millimeter). Although the regions are having average annual rainfall between 1750 (millimeter) and 3000 (millimeter) are most suitable. The average annual rainfall had fallen in the most suitable range of 1750 (millimeter) to 3000 (millimeter) during the twenty-year period.

4.9 Fitting and Selection of Trend Model for Volume of Rice Production

The study is conducted using secondary time series data of rice production from 1998-99 to 2017-18. The required annual time series data are obtained from the Central Statistical Organization (CSO) of Myanmar.

Using yearly data of volume of rice production from 2000-2001 to 2019-20, four different model of trend are estimated, namely linear, quadratic, cubic and exponential equation. Each equation is estimated with ordinary least squares method. First of all, overall significance of each model is judged based on the value of *F*-statistic and its *P*-values. The null hypothesis of *F*-test is all coefficients in the model are equal to zero, implying that all coefficients in the model are not statistically significant simultaneously. The second evaluation measure of the performance of models is *R*-square, often called the coefficient of determination. It indicates that how much percentage of variation out of total variation of the dependent variable can be explained by the model. The value of *R*-square ranges between zero and one. In general, the higher value of *R*-square, the better model can explain about the dependent variable. However, it should be noted that there is a tendency of increase in *R*-square value as number of independent variable increases in the model, regardless of whether the increase independent variables are theoretically relevant or not.

4.9.1 Best Fitted Trend Model for Volume of Rice Production

The outputs for four estimated trend models, namely, linear, quadratic, cubic and exponential curve are shown in Table (4.9).

Table (4.9) The Estimate of Fitted Trend Models

Variables	Linear	Quadratic	Cubic	Exponential
Constant	24753.308 (15.593)***	18370.104 (10.757)***	14514.308 (6.526)***	24320.562 (16.970)***
t	190.101 (1.434)	1930.974 (5.156)***	3898.425 (4.356)***	0.008 (1.682)
t^2		-82.899 (-4.758)***	-311.503 (-3.186)**	
t^3			7.257 (2.368)*	
F-ratio	2.058	13.730***	13.503***	2.830
R^2	0.103	0.618	0.717	0.136
Adjusted R^2	0.053	0.573	0.664	0.088
Std. Error	3417.399	2295.350	2036.007	0.127

Note *=10% Significant, **=5% Significant, ***=1% Significant

Source; SPSS output

According to Table (4.9), the cubic model is best fitted trend model. It is found that the regression model as a whole is statistically significant at 1 percent level, which is indicated by F-statistic = 13.503 and its p-value = 0.000. Moreover, the coefficient of determination (R^2 = 0.717) indicated that 71.7 percent of the variation of the dependent variable is explained by the independent variable.

The coefficients of linear trend (t) is significant at 1% level, quadratic trend (t^2) at 5% and cubic trend (t^3) are statistically significant at 10 percent level, which are indicated by their t-statistic, 4.356 for linear, -3.186 for quadratic and 2.368 for cubic, and their p-value, p = 0.000, p = 0.006 and p = 0.031 respectively. Based on the finding of overall significance and explanatory power, the cubic model seems to be the best model of other estimated models. However, to make the final decision, it is important to look at the observed line graph and estimated line graphs which could provide a visual insight of how much a particular model, fit the observed time series. The scatter plot of observed time series and fitted line graph of cubic model are shown in Figure (4.4). Thus, it is decided to choose the cubic model to use as a forecasting model for this study. The estimated cubic model can be described below in detail.

$$\hat{Y}_t = 14514.308 + 3898.425\ (t) - 311.503\ (t^2) + 7.257\ (t^3)$$

$$R^2 = 0.717,\ F\text{-value} = 13.503$$

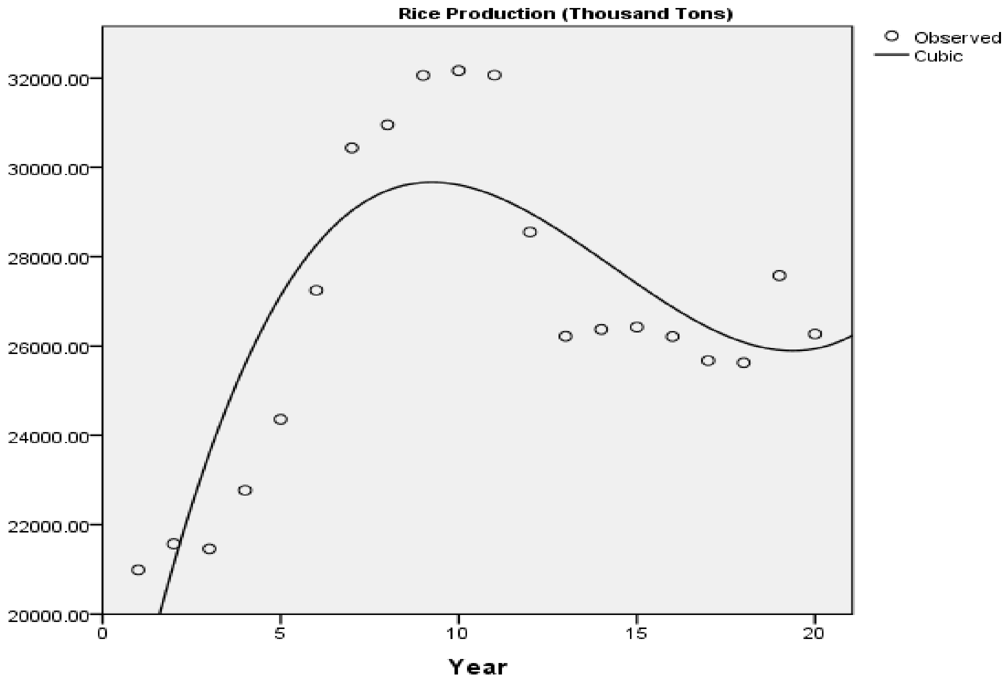


Figure (4.4) Plot of Actual and Estimate Values for Volume of Rice Production

4.9.2 Forecasting

The forecasting values for volume of rice production 2020-2021 to 2022-2023 by using best fitted cubic trend model are described in Table (4.10).

Table (4.10) Forecasting Values for Volume of Rice Production

Year	Forecast Value (Thousand Tons)
2020-21	26215.49
2021-22	26784.74
2022-23	27688.92

Source; SPSS output

According to the forecasting result, the volume of rice production had shown tendency to decrease pattern of movement from year to year.

4.10 Estimated Model for Volume of Rice Production

In this section, multiple linear regression model and Cobb-Douglas production model for volume of rice production are presented. The volume of rice production is used as dependent variable (*Y*). It is conducted by using volume of rice production from 2000-2001 to 2019-2020.

The following symbols are dependent variable and predictor variables.

Y = volume of rice production
X_1 = population (In Million)
X_2 = sown area (Thousand Acres)
X_3 = harvested area (Thousand Acres)
X_4 = agricultural implements_ ploughs, harrows, mamooties (Million)
X_5 = fertilizer utilization in agricultural sector (Metric Ton)
X_6 = paddy loan (Million Kyats)
X_7 = short term and long term loans for agricultural sector (Million Kyats)
X_8 = agricultural machineries (Thousand Number)
X_9 = agricultural vehicles (Thousand Number)
X_{10} = pesticide utilization (Gallon)
X_{11} = agricultural labour (In Million)
X_{12} = Irrigated Area (Thousand Acres)
X_{13} = average annual rainfall (Millimeter)

The regression models of volume of rice production are as follows:

(I) $$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ ...+ \beta_{13} X_{13} + \varepsilon \quad (4.1)$$

(II) $$lnY = \beta_0 + \beta_1 lnX_1 + \beta_2 lnX_2 + \beta_3 lnX_3 + \ ...+ \beta_{13} lnX_{13} + \varepsilon \quad (4.2)$$

where ε is disturbance term and the unknown parameters $\beta_0, \beta_1, \beta_2, \beta_3 ... \beta_{13}$ in the multiple linear regression model and Cob-Douglas production function model (log-log model) are estimated.

4.10.1 Multiple Linear Regression Model for Volume of Rice Production

The following Table (4.11) represents the significant parameter estimates and summary statistics for multiple linear egression model for volume of rice production.

Table (4.11) Significant Parameter Estimates and Summary Statistics for Multiple Linear Regression Model

Independent Variables	***B***	***t***	**Sig.**	**Std. Error**
Constant	-13947.546***	-6.311	0.000	2209.879
X_2	2.452***	28.587	0.000	0.086
X_7	-0.010**	-2.248	0.039	0.005
X_{13}	-1.463**	-2.006	0.062	0.729
F-ratio	275.239***		0.000	
R^2	0.981			
Adjusted R^2	0.977			
Durbin-Watson	1.332			

Note *=10% Significant, **=5% Significant, ***=1% Significant

Source; SPSS output

The estimated multiple linear regression model can be described as follows:

Y = – 13947.546 + 2.452 X_2 – 0.010 X_7 – 1.463 X_{13}

Se = (2209.879) (0.086) (0.005) (0.729)

P.value = (0.000) (0.000) (0.039) (0.062)

R^2 = 0.981 ; F = 274.239

According to the results of Table (4.11), Sown area is significant at 1%, Short term and long term loans and Average annual rainfall are significant at 5% level. The coefficient of Sown area is 2.452, Short term and long term loans is -0.010 and Average annual rainfall is -1.463. The model is significant at 1% level.

4.10.2 Cobb-Douglas Production Function for Volume of Rice Production (Log-Log Model)

The significant parameter estimates and summary statistics of log-log model for volume of rice production are presented in Table (4.14).

Table (4.12) Significant Parameter Estimates and Summary Statistics for Log-Log Model

Independent Variables	***B***	***t***	**Sig.**	**Std. Error**
Constant	-11.173***	-15.013	0.000	0.744
$ln\ X_3$	1.319***	39.661	0.000	0.033
$ln\ X_4$	1.006***	12.956	0.000	0.078
$ln\ X_{13}$	-0.112***	-3.051	0.008	0.037
F-ratio	960.076***		0.000	
R^2	0.994			
Adjusted R^2	0.993			
Durbin-Watson	1.727			

Note *=10% Significant, **=5% Significant, ***=1% Significant

Source; SPSS output

A regression analysis is conducted to evaluate how well the linear combination of (logs) of harvested area, agricultural implements and average annual rainfall are significantly related to the volume of rice production F = 960.076, at 1% level. The R^2 value of 0.994 means that about 99% of the variation in the log of rice production is explained by the (logs) of harvested area, agricultural implements and average annual rainfall. The regression equation for volume of rice production is;

ln Y = – 11.173 + 1.319 lnX_3 + 1.066 lnX_4 – 0.112 lnX_{13}

Se = (0.744) (0.033) (0.078) (0.037)

P.value = (0.000) (0.000) (0.000) (0.008)

R^2 = 0.994 ; F = 960.076

According to the *P*-value it can be said that the variables (logs) of harvested area, implements and average annual rainfall are significant at 1% level. The volume of rice production elasticities of harvested area, agricultural implements and average annual rainfall are 1.319, 1.066 and -0.112 respectively. If the agricultural implements and average annual rainfall remain unchanged, one percent increases in the harvested area led on the average to about a 1.319 percent increase in the rice production. Similarly, if the harvested area and average annual rainfall remain unchanged, one percent increases in the agricultural implements led on the average to about a 1.066 percent increase in the rice production. And then, if the harvested area and agricultural implements remain unchanged, one percent increases in the average annual rainfall led on the average to about a 0.112 percent decrease in the rice production. Sum of three rice production elasticities achieved 2.231, which gives the value of the returns to scale parameter. It is found that the rice production is increasing by return to scale in this study.

4.11 Comparison of Two Different Models

The significant parameter estimates and summary statistics for two models are presented in Table (4.13).

Table (4.13) Comparison of the Estimates of Fitted Regression Models

Variables	Multiple Regression Model	Log-Log Model
Constant	-13947.546 (-6.311***)	-11.173 (-15.013***)
Sown Area	2.452 (28.587***)	
Harvested area		1.319 (39.661***)
Agricultural implements		1.006 (12.956***)
Short term and long term loans	-0.010 (-2.248**)	
Annual rainfall	-1.463 (-2.006**)	-0.112 (-3.051***)
F-ratio	275.239***	960.076***
R^2	0.981	0.994
Adjusted-R^2	0.977	0.993
Std. Error	527.538	0.010
Durbin-Watson	1.332	1.727

Note *=10% Significant, **=5% Significant, ***=1% Significant

Source; SPSS output

Among the fitted regression models, log-log model (Cobb-Douglas Production Model) is chosen as the best fitted or most suitable estimated regression models of the volume of rice production based on the t statistic, F statistic, R^2, Standard Error and d-statistic. In this model, t statistic and F statistic are significant and R^2 indicates that 99.4% of the variable in the log of volume of rice production is explained by the (logs) of harvested area, agricultural implements and average annual rainfall. Moreover, *d* statistic (Durbin-Watson) indicates that there is no positive and negative correlation between disturbances. So it can be concluded that the log-log model (Cobb-Douglas Production Model) fits the data quite well from a statistical point of view.

4.12 Testing for the Assumptions about Multiple Regression in Cobb-Douglas Production Function

To determine the violation of required assumptions from multiple linear regression model for the volume of rice production, the following procedures have been used.

4.12.1 Testing for Normality of Disturbances

One of the basic assumption is that disturbances are normally distributed with zero mean and constant variance. The Histogram of disturbances and the Normal plot of disturbances for the volume of rice production are shown in Figure (4.5).

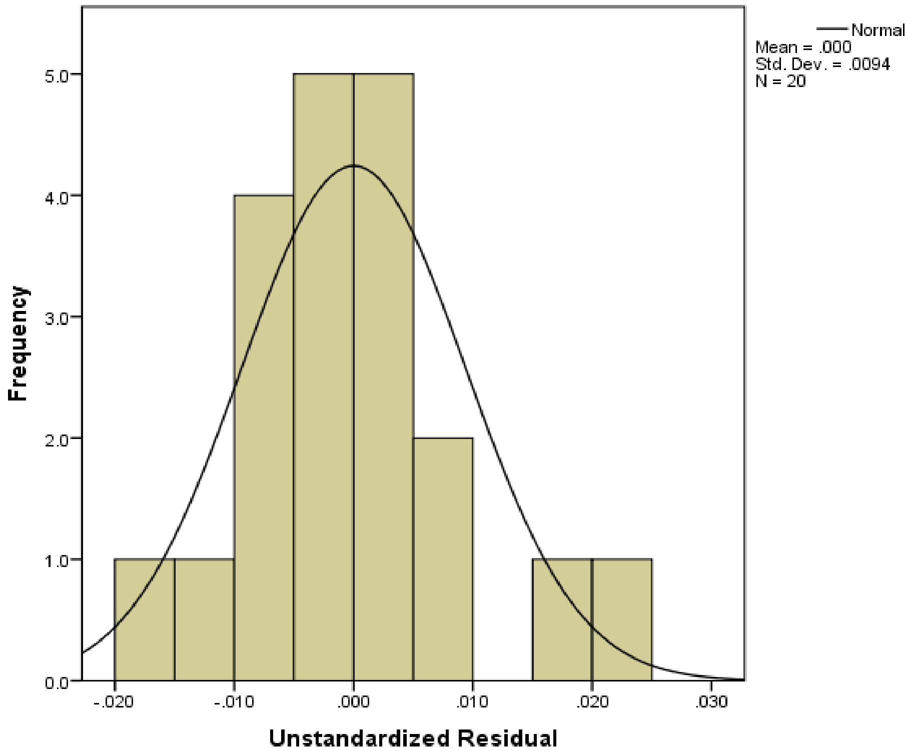


Figure (4.5) Histogram for Residuals of the Cobb-Douglas Production Function

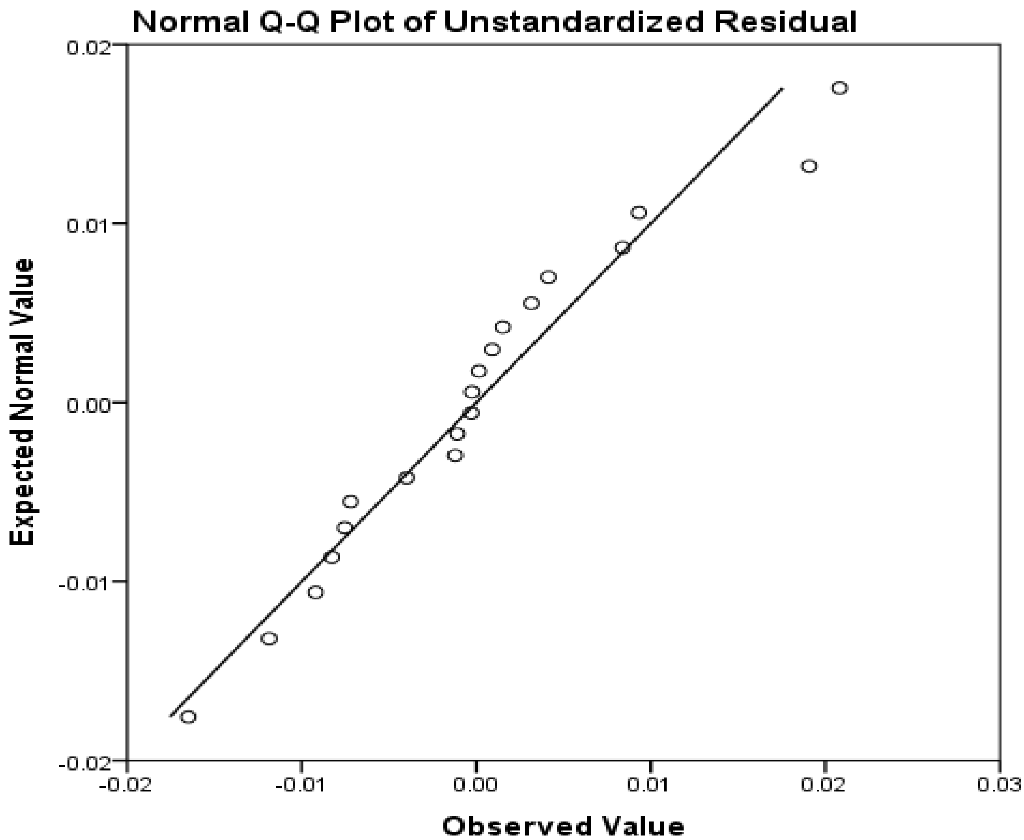


Figure (4.6) Normal Plot of Regression Residuals of the Volume of Rice Production

According to Figures (4.5) and (4.6), it can be concluded that the normality assumption appears to be generally reasonable.

4.12.2 Testing for Autocorrelation of Disturbances

Another basic assumption of the multiple linear regression model is that the disturbances are independent of each other. Figure (4.7) represents error patterns that can reveal information about the model by plotting disturbance at a time tend disturbance at time t-1.

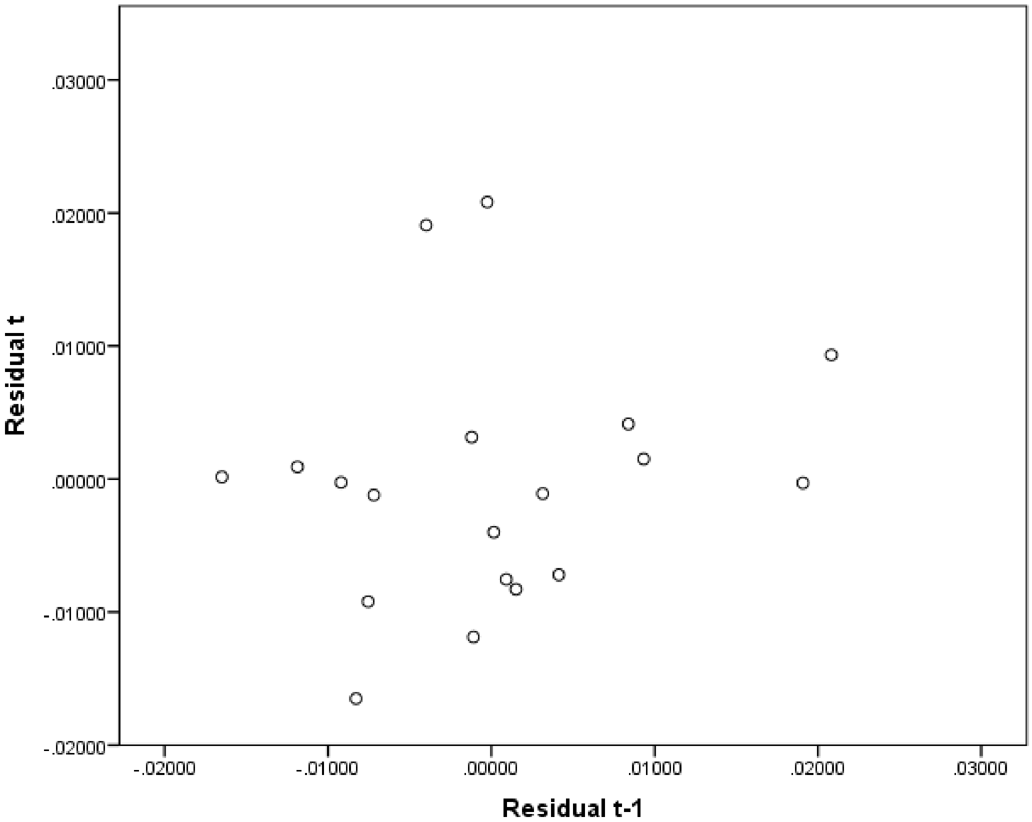


Figure (4.7) Detection of Autocorrelation of the Volume of Rice Production

This figure shows that there is no positive and negative autocorrelation because correlation between disturbances at time tend disturbance at time t-1 are not correlated.

Durbin-Watson test is used to determine whether the residuals were autocorrelated or not. The Durbin-Watson statistics is used to test the hypothesis of no autocorrelation. Figure (4.8) represents to determine if the null hypothesis of no autocorrelation is rejected or not rejected. For $\alpha = 0.01$ or 1% level of significance, critical values for the Durbin-Watson d statistic are d_L= 0.77 and $d_U = 1.41$. Since D.W=1.727, the null hypothesis is not rejected and it is concluded that there is no evidence of autocorrelation. As a general rule, if d is close to 2, assume that autocorrelation is not problem. Therefore, DW statistic satisfied that there is no positive and negative correlation between disturbance terms in the Cobb-Douglas production model for the volume of rice production.

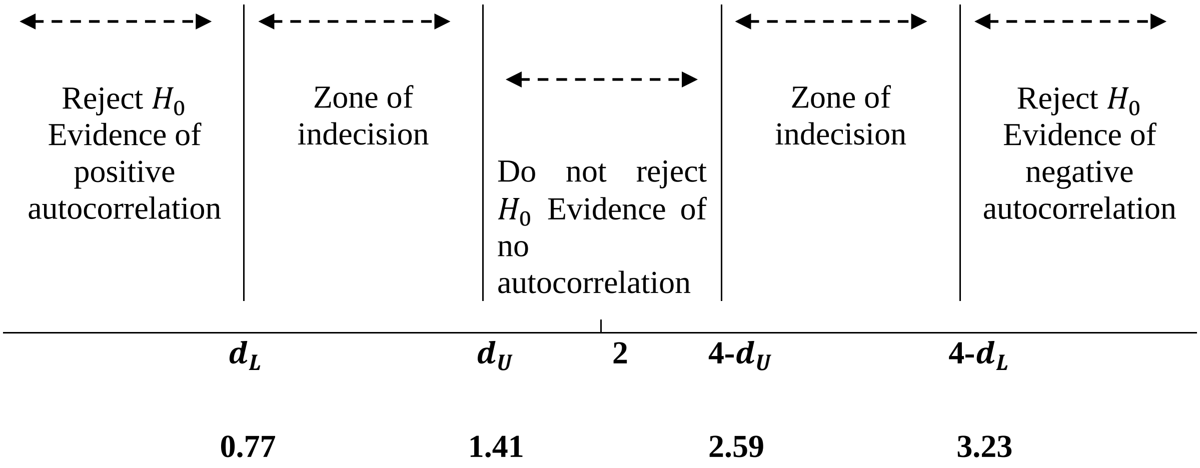


Figure (4.8) Durbin-Watson Statistic of the Volume of Rice Production

4.12.3 Testing for Homoscedasticity of Disturbances

One of the basic assumption of the multiple regression model is homoscedasticity. Heteroscedasticity can often be detected by plotting the estimated Y values against the disturbances. Figure (4.9) represents the predicted rice production on x axis and the disturbance for rice production on y axis.

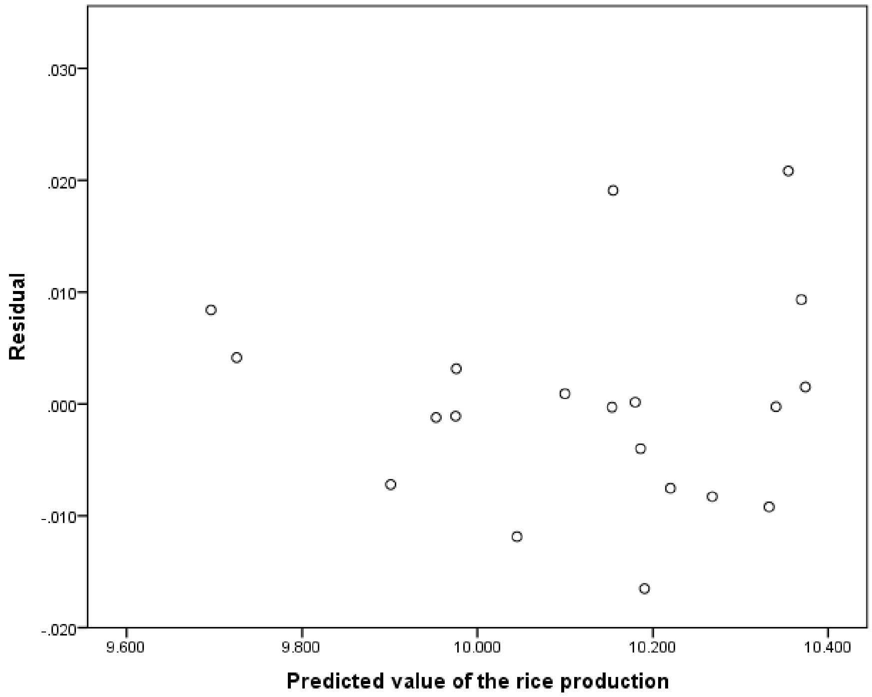


Figure (4.9) Residual Pattern for Heteroscedasticity of the Volume of Rice Production

The figure can be seen that there is no residual pattern. Therefore, it can be concluded that residuals in rice production has an equal variance or homoscedasticity.

4.12.4 Detecting Multicollinearity

The problem of multicollinearity, which is a problem of higher correlation among the independent variables in the model, is also assumed. The most detect way of testing for multicollinearity is to produce a correlation matrix for all variables in the model. The correlation matrix for all variables of the multiple regression model of the volume of rice production is as follow.

Table (4.14) Correlation Matrix

	$Ln\ x_3$	$Ln\ x_4$	$Ln\ x_{13}$
$Ln\ x_3$	1.000	0.427	0.172
$Ln\ x_4$	0.427	1.000	-0.189
$Ln\ x_{13}$	0.172	-0.189	1.000

Source; SPSS output

According to the correlation matrix, it was found that correlation between (log of) harvested area and (log of) agricultural implements is 0.427, correlation between (log of) harvested area and (log of) average annual rainfall is 0.172 and correlation between (log of) agricultural implements and (log of) average annual rainfall is -0.189, respectively. Therefore, it can be concluded that multicollinearlity is not problem according to correlation matrix.

This problem can also be deleted from the value of Tolerance and VIF (variance inflation factor). If the correlation among the independent variables is weak association and the value of the Tolerance is not less than 0.1 and the value of the VIF is not above 10, it is the indication of absence of multicollinearity problem. According to the findings from this study, Tolerance and VIF value of independent variables are shown in following Table (4.15).

Table (4.15) Tolerance and VIF of Independent Variables

No	Independent Variables	Tolerance	VIF
1	$Ln\ x_3$	0.752	1.330
2	$Ln\ x_4$	0.747	1.339
3	$Ln\ x_{13}$	0.886	1.128

Source; SPSS output

According to the Table (4.15), among the independent variables, it is found that the collinearity statistics of the value of the Tolerance is not less than 0.1. The values of the VIF are 1.330, 1.339 and 1.128 respectively. Therefore, it can be concluded that there is no seriously multicollinearity problem in this model.

4.12.5 Return to Scale of Rice Production

Return to scale in a Cobb-douglas production function depends on the sum of the exponents α and β. Return to scale are concerned with the use of inputs.

(1) Constant Returns to Scale; if a Cobb-Douglas production function exhibits constant returns to scale, doubling all inputs will result in a doubling of output.

(2) Increasing Returns to Scale; if a Cobb-Douglas production function exhibits increasing returns to scale, doubling all inputs will result in more than a doubling of output.

(3) Decreasing Returns to Scale; if a Cobb-Douglas production function exhibits decreasing returns to scale, doubling all inputs will result in less than a doubling of output.

The elasticities of Cobb-Douglas production function of the volume of rice production are harvested area = b_1= 1.319, agricultural implements = b_2= 1.006 and average annual rainfall = b_3= -0.112 respectively. The sum of the elasticities, estimate of returns to scale is 2.213 and it is greater than 1. That is showing to increasing return to scale. Therefore, it can be concluded that if the doubling inputs of harvested area, agricultural implements and average annual rainfall, the result output of rice production will be more than a double.

CHAPTER V
CONCLUSION

This chapter provides of findings about relationship between rice production and related factors, conclusion of the study, recommendations and possible future research.

5.1 Findings and Discussions

The major objective of this thesis is to determine the best fitted trend and the best fitted regression model for volume of rice production in Myanmar within the twenty years' period of 2000-2001 to 2019-20. In this study, the secondary time series data were used to achieve the objective and collected from the database of Central Statistical Organization (CSO) and the World Bank.

It was found that the cubic trend model is the best fitted trend for volume of rice production with the significant at 1% level. In this model, the coefficient for linear trend was significant at 5% level and cubic trend and quadratic trend were significant at 10% level. The forecasting values for rice production had shown tendency to decrease pattern of movement from 2018-19 to 2020-21 according to the cubic model.

According to the comparison of the two different regression model, log-log model (Cobb-Douglas Production Model) was chosen as the more appropriate model based on the *t* statistic, F statistic, R^2 and Durbin-Watson statistic. In this model, R^2 indicates that 99.4% of the variation in the log of volume of rice production was explained by the (logs) of harvested area, (logs) of agricultural implements and (logs) of average annual rainfall. Furthermore, Durbin-Watson statistic satisfied that there is no positive and negative correlation between disturbance terms. The Cobb-Douglas Production function model for the volume of rice production has the error term is normal distributed. And then, there is not serious problem correlation between disturbance terms and residuals in the rice production have an equal variance or homoscedasticity. Finally, there is no multicollinearity problem in this study of the rice production. So, this model can be concluded that the estimated regression model fits the data quite well from a purely statistical point of views.

In the estimated log-log model (Cobb-Douglas Production Model), it is found that the volume of rice production elasticities of harvested area, agricultural implements and average annual rainfall were 1.319, 1.006 and -0.112 respectively. Over the period of study, if the agricultural implements and average annual rainfall remain unchanged, one percent increases in the harvested area led on the average to about a 1.319 percent increase in the rice production. Similarly, if the harvested area and average annual rainfall remain unchanged, one percent increases in the agricultural implements led on the average to about a 1.006 percent increase in the rice production. And then, if the harvested area and agricultural implements remain unchanged, one percent increases in the average annual rainfall led on the average to about a 0.112 percent decrease in the rice production. There are some reasons for rice production decrease by increasing of average annual rainfall. Over 65 percent of rice growing areas are located in delta and lower regions of Myanmar. According to the global warming problem, sea level of delta region is increase years by years. It may occur of floating areas and negative effects on rice production. The rise in rainfall can lead to the emergence of additional waterlogged areas in the delta region, posing challenges in effectively managing water levels within paddy fields. A heavy rainfall in rice flowering time is another problem of rice production. It may prevent of pollination process and yield decreased.

In addition, elasticities are convenient because they are measured as proportion or percentages rather than with unit measures. Sum of three rice production elasticities achieved 2.213, which gives the value of the returns to scale parameter. Thus, increasing return to scale are indicated by scale elasticities greater than one.

5.2 Suggestion and Recommendations

According to the findings, the forecasting value of rice production is slightly decrease from 2018-19 to 2019-20. As the rice is the most important food crop of Myanmar and main contributions of country's GDP, should be sustain and enhance of rice production. The government should prioritize providing comprehensive training programs to farmers aimed at imparting knowledge and fostering the adoption of

Good Agricultural Practices (GAP). Also, should be creating the transforming uncultivated wild land within the country into arable dedicated to rice production. According to data from the International Labour Organization (ILO), the percentage of agricultural labour in Myanmar has been consistently decreasing over the years. To address this trend, the government should consider increasing its provision of agricultural implements and resources. Another crucial aspect to consider is pest and disease control in paddy cultivation. At present, rice producers in the delta region are grappling with a concerning issue the proliferation of apple snail in monsoon paddy fields, causing an expanding extent of damage. The government should prioritize the implementation of comprehensive training programs focused on effective pest and disease management. An efficient drainage system is imperative for paddy farming. It plays a crucial role in ensuring optimal yields and regulating water levels within the paddy fields. Selecting the appropriate rice variety is a pivotal consideration in rice production, given the global challenges posed by climate change, which also impact regions like Myanmar. As the effects of climate change continue to influence agricultural conditions, careful varietal selection becomes increasingly vital for sustainable and resilient rice farming practices.

5.3 Further Studies

Agriculture has traditionally been one of the largest contributors to Myanmar's GDP. It accounted for a substantial portion of the country's economic output, employing a significant portion of the population. This study exclusively focused on rice production, which is among the primary crops in Myanmar's agriculture production. If data becomes available, future research endeavors may extend to cover additional major crops, including pulses (such as beans and lentils), maize, oilseeds, sugarcane and rubber.

REFERENCES

Aldrich, J. (1998). Doing Least Squares: Perspectives from Gauss and Yule. International Statistical Review / Revue Internationale de Statistique, 66(1), 61–81.

Bridge J.I, (1971), "*Applied Econometrics*", North-Holland, Amsterdam.

Cobb, C.W. and Douglas, P.H (1928),"*A Theory of Production*". American Economic Review, 139-65.

CSO (Central Statistical Organization), 2005. *Statistical Yearbook 2005*. Ministry of National Planning and Economic Development. Nay Pyi Taw, Myanmar.

CSO (Central Statistical Organization), 2010. "*Statistical Yearbook 2010"*, Ministry of National Planning and Economic Development. Nay Pyi Taw, Myanmar.

CSO (Central Statistical Organization), 2015. "*Statistical Yearbook 2015"*, Ministry of National Planning and Economic Development. Nay Pyi Taw, Myanmar.

CSO (Central Statistical Organization), 2020. "*Statistical Yearbook 2020"*, Ministry of National Planning and Economic Development. Nay Pyi Taw, Myanmar.

DAR. 2013. Preliminary proceedings, Myanmar Rice Sector Development Strategy and Program Conference and Workshop

Department of Agricultural Planning. 2000. 30 Years Strategic Plan for Agriculture Sector (In Myanmar). Ministry of Agriculture and Irrigation. 195-222 p.

Department of Planning, 2016, "*Myanmar Agriculture in Brief*", Ministry of Agriculture Livestock and Irrigation, The government of the Republic of the Union of Myanmar, 2016.

DOA. 2014. Annual Report of Agricultural Education Section 2013-2014, Department of Agriculture. Ministry of Agriculture and Irrigation, Union of Myanmar.

Felloni, F; Wahl, T; Wandschridar, P and Gilbert, J. (2001), "*Infrastructure and Agricultural production: Cross-Country Evidence and Implications for China*", Washington State University.

Government of the Union of Myanmar (2011), Myanmar Agriculture Statistics, Ministry of Agriculture and Irrigation.

Graybill, F.A. (1975), "*Theory and Application of the Linear Model*", North Scituate MA: Duxbury Press.

Gujarati, Damodar N (2009), "*Basic Econometrics*", fifth Edition, McGraw-Hill.

IFRRI (2022), rice productivity in Myanmar; Assessment of the 2021 monsoon and outlook for 2022, Strategy Support Program, working Paper 19 (May, 2022).

International Rice Research Institute. 2010. Rice in the Global Economy: Strategic Research and Policy Issues for Food Security.

Lasini Wickramasinghe, Rukmal Weliwatta, Piyal Ekarayake and Jeevani Jayasinghe (2021), modeling the relationship between rice yield and climate variables using statistical and machine learning techniques. Journal of Mathematics, Volume 2021, Article ID 6646126.

Ministry of National Planning and Economic Development (MNPED). 2012. National Comprehensive Development Plan: 20 Year Plan from 2010 to 2030.

MoALI. 2013. Myanmar Agricultural in Brief. Ministry of Agriculture, Livestock and Irrigation, Union of Myanmar.

Montgomery, D.C. and Peck, E.A. (1982) Introduction to Linear Regression Analysis. John Wiley and Sons, Inc., New York.

Muhammad Islam and Rabia Siddiqui (2021), Statistical Modeling and Significance of Inputs Studies for the Rice Crop Productivity in Pakistan. Journal of statistics, Computing and Interdisciplinary Research. Volume 3 (1) (2021) 39-44.

Myanmar Rice Fedration. 2014b. http://myanmarricefederation.org/ content/about-myanmar-rice-federation-mrf.

Noe, Su Myat (2014), "*A Study on Rubber Production Model of Kyaikkaw Village in Thahtone Township*", M. Econ (Stats) Thesis, Department of Statistics, Yangon University of Economics.

Oo, Ye Min (2016), "*Analysis of Some Aspects on the Agricultural Production in Myanmar,* "M. Econ (Stats) Thesis, Department of Statistics, Yangon University of Economics.

Proximity Designs (2013), "*Rice Policy in Myanmar*"

Shah. M,A.A., G.Ozel, C. Chesneau, M. Mohsin, F. Jaral and M.F. Bhath (2019). A statistical study of the determinants of rice crop production in Pakistan. Pakistan Journal of Agricultural Research. 33(1); 97-105.

Slow, R. (1957), "*Technical Change and The Aggregate Production Function", Reviews of Economic and Statistics,* 312-320.

Thet, Khin Khin (2013), "*A Study of Rice Production, Consumption and Sufficiency in Southern District Yangon Region*", EMPA Thesis, Yangon University of Economics.

Tun Saing. n.d. Myanmar Rice History. "*Myanmar Academy of Agriculture, Forestry, Fishery and Livestock Sciences*", P 165 (In Myanmar).

Vokes, Richard, and Francesco Goletti. 2013, "*Agriculture and Rural Development in Myanmar: Policy Issues and Challenges. Kensington*", MD: Agrifood Consulting International.

Webzter, A.L., (1995), "*Applied Statistics for Business and Economic., "Second Edition*. McGraw-Hill.

Wikipedia. 2014. Projections of population growth. http://en.wikipedia.org/wiki/Projections_of_population_growth.

APPENDIX

Volume of Rice Production
Linear

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.320	.103	.053	3417.399

Model Description

Model Name		MOD_3
Dependent Variable	1	Volume of Rice Production
Equation	1	Linear
	2	Quadratic
	3	Cubic
	4	Exponential[a]
Independent Variable		Case sequence
Constant		Included
Variable Whose Values Label Observations in Plots		Unspecified
Tolerance for Entering Terms in Equations		.0001

a. The model requires all non-missing values to be positive.

Case Processing Summary

	N
Total Cases	20
Excluded Cases[a]	0
Forecasted Cases	0
Newly Created Cases	0

a. Cases with a missing value in any variable are excluded from the analysis.

Variable Processing Summary

		Variables
		Dependent
		Volume of Rice Production
Number of Positive Values		20
Number of Zeros		0
Number of Negative Values		0
Number of Missing Values	User-Missing	0
	System-Missing	0

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.320	.103	.053	3417.399

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	24031947.740	1	24031947.740	2.058	.169
Residual	210215121.585	18	11678617.866		
Total	234247069.326	19			

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
Case Sequence	190.101	132.521	.320	1.434	.169
(Constant)	24753.308	1587.489		15.593	.000

Quadratic

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.786	.618	.573	2295.350

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	144680346.708	2	72340173.354	13.730	.000
Residual	89566722.618	17	5268630.742		
Total	234247069.326	19			

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
Case Sequence	1930.974	374.525	3.253	5.156	.000
Case Sequence ** 2	-82.899	17.324	-3.020	-4.785	.000
(Constant)	18370.104	1707.698		10.757	.000

Cubic

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.847	.717	.664	2036.007

NOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	167921903.132	3	55973967.711	13.503	.000
Residual	66325166.193	16	4145322.887		
Total	234247069.326	19			

Coefficients

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
Case Sequence	3898.425	894.853	6.568	4.356	.000
Case Sequence ** 2	-311.503	97.761	-11.347	-3.186	.006
Case Sequence ** 3	7.257	3.065	5.177	2.368	.031
(Constant)	14514.308	2223.995		6.526	.000

Exponential

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.369	.136	.088	.127

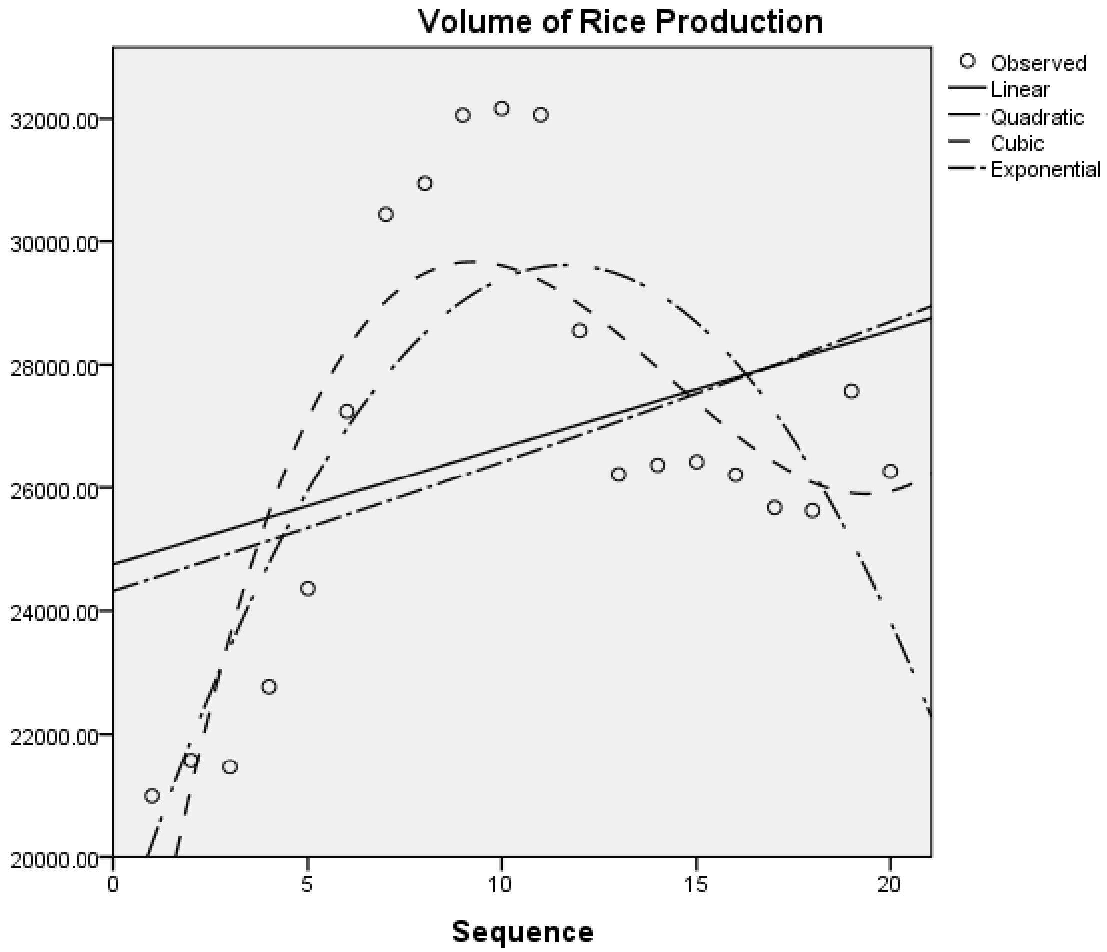
ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	.046	1	.046	2.830	.110
Residual	.290	18	.016		
Total	.335	19			

oefficients

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
Case Sequence	.008	.005	.369	1.682	.110
(Constant)	24320.562	1433.139		16.970	.000

The dependent variable is ln(Volume of Rice Production).



Regression

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	X13, X2, X7[b]	.	Enter

a. Dependent Variable: Y

b. All requested variables entered.

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	X13, X2, X7[b]	.	Enter

a. Dependent Variable: Y

b. All requested variables entered.

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.990[a]	.981	.977	527.53814	1.332

a. Predictors: (Constant), X13, X2, X7

b. Dependent Variable: Y

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	229794325.529	3	76598108.510	275.239	.000[b]
	Residual	4452743.797	16	278296.487		
	Total	234247069.325	19			

a. Dependent Variable: Y

b. Predictors: (Constant), X13, X2, X7

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-13947.546	2209.879		-6.311	.000		
	X2	2.452	.086	.997	28.587	.000	.976	1.024
	X7	.010	.005	.082	2.248	.039	.883	1.133
	X13	-1.463	.729	-.074	-2.006	.062	.864	1.158

a. Dependent Variable: Y

Collinearity Diagnostics[a]

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions			
				(Constant)	X2	X7	X13
1	1	3.310	1.000	.00	.00	.02	.00
	2	.684	2.200	.00	.00	.85	.00
	3	.005	27.115	.01	.76	.03	.37
	4	.002	41.993	.99	.23	.10	.63

a. Dependent Variable: Y

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	21106.4004	31700.0313	26749.3650	3477.70588	20
Residual	-1088.31775	682.88800	.00000	484.10220	20
Std. Predicted Value	-1.623	1.424	.000	1.000	20
Std. Residual	-2.063	1.294	.000	.918	20

a. Dependent Variable: Y

Regression

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	LnX4, LnX13, LnX3[b]	.	Enter

a. Dependent Variable: LnY

b. All requested variables entered.

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.997[a]	.994	.993	.01076	1.727

a. Predictors: (Constant), LnX4, LnX13, LnX3

b. Dependent Variable: LnY

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.333	3	.111	960.076	.000[b]
	Residual	.002	16	.000		
	Total	.335	19			

a. Dependent Variable: LnY

b. Predictors: (Constant), LnX4, LnX13, LnX3

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-11.173	.744		-15.013	.000		
	LnX13	-.112	.037	-.060	-3.051	.008	.886	1.128
	LnX3	1.319	.033	.850	39.661	.000	.752	1.330
	LnX4	1.006	.078	.279	12.956	.000	.747	1.339

a. Dependent Variable: LnY

Collinearity Diagnostics[a]

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions			
				(Constant)	LnX13	LnX3	LnX4
1	1	4.000	1.000	.00	.00	.00	.00
	2	6.901E-5	240.754	.00	.71	.16	.02
	3	4.055E-5	314.080	.06	.07	.72	.05
	4	5.591E-6	845.796	.94	.22	.12	.93

a. Dependent Variable: LnY

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	9.9498	10.3726	10.1860	.13245	20
Residual	-.01322	.02339	.00000	.00987	20
Std. Predicted Value	-1.783	1.409	.000	1.000	20
Std. Residual	-1.229	2.174	.000	.918	20