# Analysis of the effectiveness of chemical fertilizer use in rice production: Çanakkale province-Türkiye sample

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## Abstract

According to FAO data for the year 2021, world paddy production areas have been calculated as 165 million ha and the production amount as 787 million tons. According to TSI data for 2022, the paddy production area in Türkiye has been determined as 120,511 ha and the production amount as 950,000 tons. Türkiye's self-sufficiency rate in rice is around 80%. Türkiye has a share of 5.71% in world paddy imports. Çanakkale province ranks 4$^{th}$ with 10% of paddy cultivation areas and 10.21% of production throughout the country. The average paddy yield in the province is 805.50 kg da$^{-1}$, which is above the country's yield value (788.31 kg da$^{-1}$). In the examined enterprises, it has been found out that 25.13 kg da$^{-1}$ of pure nitrogen, 7.52 kg da$^{-1}$ of pure phosphorus and 5.37 kg da$^{-1}$ of pure potassium fertilizer are used per unit area in paddy production. In the study, the effect of chemical fertilizer factor on the amount of paddy production has been examined with the help of the production function. Coefficients of elasticity in the rice production estimation function have been determined as; pure nitrogen ($X_1$) 0.639, pure phosphorus ($X_2$) 0.140 and pure potassium ($X_3$) 0.220. Pure nitrogen ($X_1$) and pure potassium ($X_3$) have been found to be statistically significant at the level of 1% and 5% respectively. It has been concluded that the sum of the coefficients of the production elasticity of the estimation equation ($\sum\beta_i$ 0,999) expresses the constant return to the scale. Among the factors included in the equation, the variable with the highest marginal efficiency coefficient has been found to be pure potassium ($X_3$). In the study, it has been determined that pure nitrogen, pure phosphorus and pure potassium fertilizers are being used below the economic optimum level in paddy production. In other words, the results of the research revealed that the fertilizer factor is not used rationally in paddy production and in this case, it causes a loss of yield and therefore loss of income for the producer.

**Keywords:** Paddy. Chemical fertilizer. Functional analysis. Elasticity. Efficiency. Cobb-Douglas. Türkiye.

## 1. Introduction

Paddy is one of the most crucial crops throughout the world since more than half of the world's population uses it as the main food source. Although it contains 5-10% protein in its composition, it is the most used product after wheat in human nutrition because it is rich in amino acids which are essential for nutrition. Approximately 3 billion people in the world meet their daily calorie needs from paddy. In particular, Asian countries provide an average of

30% of their daily calorie needs from rice, while this rate reaches 70% in some countries (CGIAR, 2017).

The most significant cereal crop in the world is rice (*Oryza sativa L.*), which is the main source of nutrition for about half of the world's population, especially in Asia, where around 90% of the world's rice is grown and consumed (Abbas et al., 2024). In terms of acreage cultivated, rice is the second-largest crop in the world, accounting for around 11% of all agricultural land and is the most significant grain crop in the world and an annual semi-aquatic plant (Amanullah, 2016).

Rice cultivation, which is the main source of income of 100 million farmer families in the world (90% Asia) and approximately 25 thousand farmer families in Türkiye, has different characteristics from other agricultural products that are subject to trade. In particular, the highest production in the world is in the countries in the Asian continent (90%), and only 5-6% of the paddy produced in the world is traded and the rest is consumed in the countries where it is produced intensively. Therefore, in many countries, paddy production is regularly financially supported in terms of self-sufficiency (Sezer, 2017).

In 2021, paddy was harvested on a total area of 165.25 million hectares in the world. In the same year, the world average paddy yield was 476.4 kg $da^{-1}$ and the total production amount was 787.3 million tons. Türkiye's share in the total paddy production area harvested in the world is 0,08% and 0,13% in the production amount. Türkiye has a value well above the world average with 772.3 kg $da^{-1}$ paddy yield (FAO, 2022).

In 2021, the most harvested area in paddy production worldwide was reported in India with 28.07%, and it was followed by China with 18.11% and Bangladesh with 7.08%. In the same year, paddy was harvested on an area of 129,475 hectares in Türkiye, ranking 52nd in the world with a share of 0.08%. In 2021, China had the highest share of production with 27.03%, and it was followed by India with 24.83% and Bangladesh with 7.23% (FAO, 2022).

Leading countries in the world in terms of paddy production are China, India, Indonesia, Bangladesh and Vietnam, respectively. In the mentioned countries, paddy, also known as rice in its processed form, has a significant place particularly in the diets and economies of Asian and Far Eastern countries (Cramb, 2020).

If the worldwide population growth rate continues at the current rate, it is indispensable to increase paddy production to meet demand by 2030. For this reason, in order to meet the nutritional needs of the increasing world population, it is necessary to increase the yield value obtained from the production areas.

Due to the increase in the yield value obtained from the unit area in agricultural production, particularly the use of chemical fertilizers is gradually increasing. In parallel with this, excessive use of chemical fertilizers leads to deterioration of surface and groundwater quality and physical-chemical structures of agricultural soils (Kashem and Singh, 2002). Excessive chemical fertilization application is one of the most vital factors causing environmental pollution in agricultural processes. Nitrate pollution in groundwater, toxicity caused by phosphorus compounds, and destruction of ammonia in the atmosphere can be counted as an example of environmental problems caused by excessive fertilization applications (Onho and Erich, 1990; Wang et al., 2013).

Fertilizers are natural or artificial substances that are added to the soil in order to ensure better nourishment of the plants and to make the soil fertile in terms of physical, chemical and biological characteristics. Artificial fertilizers, in addition to their different chemical structures, have high production costs and put pressure on the purchasing power of producers (Kaya, 2010).

The use of chemical fertilizers contributes significantly to increasing the yield of the product. The factors affecting crop productivity in field crops in India have been analyzed with the help of production function. In a study conducted in the area, the elasticity coefficient of the fertilizer factor in field crops production has been determined as 0.521 and has been found to be statistically significant at the level of 1% (Sinha, 2023).

Having examined the studies on the same issue, it is understood that there is a limited number of studies based on functional analysis that aim to reveal the importance of the fertilizer factor only in paddy production.

Effective use of resources in agricultural production is extremely significant. Forasmuch as, the efficient use of resources not only reduces the cost of the product, but also increases the product income and increases the competitiveness of the enterprises. In crop production, the effective use of the fertilizer used is as significant as the amount of fertilizer used per unit area. In other words, the ratio of the price of the last unit of fertilizer used in production (factor price or marginal cost) to the monetary value of the increase in total production of the fertilizer used gives the efficiency level of the fertilizer used.

In this study, the efficiency of fertilizer use in the production of paddy, which is among the hot climate cereals, has been examined economically. For this purpose, the relationship between the amount of paddy production and the amount of pure nitrogen, pure phosphorus and pure potassium fertilizer used in production has been analyzed functionally. Within the scope of the study, marginal efficiency coefficients have been calculated for fertilizer groups with the help of marginal product value and factor price, and the research findings have been analyzed in comparison with other research findings on the same issue.

## 2. Literature Review

There are limited studies analyzing the economic aspects of fertilizer use in paddy production (Ajani et al., 2014; Abiola et al., 2016, Addison et al. 2016; Nodin et al., 2022; Fattah et al., 2023; Laksono et al., 2023). In this section, some of these researches carried on the subject are summarized below.

Bhujel and Ghimire (2006) examined the levels of input use in paddy production in their study conducted with 35 farmers in Nepal. In the study, the elasticity coefficients of 9 variables in paddy production were calculated and interpreted.

On the other hand, in the study conducted by Nimoh et al. (2012) in Ghana with 70 producers, there were 5 independent variable factors in the paddy production function. In the study, the elasticity coefficient and marginal efficacy coefficient of the chemical fertilizer variable were determined. Shantha et al. (2012) carried out a detailed cost analysis of paddy production in their research which was conducted with 158 farmers in Sri Lanka. In this study, the relationships between 6 production factors used in paddy production and the amount of paddy production were functionally examined.

In a study conducted with 200 producers in Vietnam, Long et al. et al. (2013) examined the cost of paddy production. Within the scope of the study, the elasticity coefficients of 6 variables in the paddy production estimation function were calculated and their importance levels were determined. In the study, the data were evaluated in 2 groups as winter-spring and summer-autumn according to the paddy production season.

In the study conducted by Reddy and Reddy (2013) in India, the marginal efficiency coefficients of the inputs used in paddy production for 3 different enterprise sizes (small, medium and large) in 4 different settlements were calculated and examined. Shende and Bagde (2013) investigated the level of input use and product cost in paddy production in a study conducted with 60 farmers in India. In the study, the elasticity coefficients and marginal efficiency coefficients of the production factors were calculated and interpreted.

Kadiri et al. (2014) investigated the cost factors in paddy production in detail in a study conducted in Nigeria with 300 farmers. In the study, the relationships between the amount of paddy production and the size of the enterprise, seed costs, family and foreign labor costs, chemical fertilizer costs and agricultural control costs were analyzed using 4 different production functions. In the study conducted in Indonesia by Riyan et al. (2014), the effect of the amount of seeds, chemical fertilizers, pesticides and labor factors used per unit area on the amount of paddy production was examined with the help of the production function.

Hile et al. (2015, 2016) made an impact assessment of the use of technology in paddy production in India. Adedoyin et al (2016) conducted a study with 396 farmers in Malaysia and they found that 5 independent variable factors were involved in the paddy production function. In the study, the elasticity coefficient and marginal efficacy coefficient of the chemical fertilizer factor were calculated.

In the survey conducted with 2019 farmers in Nigeria by Ajoma et al. et al. (2016), the effects of the factors involved in paddy production on the amount of paddy production were analyzed with the help of the production function. In the study, the elasticity coefficients and significance levels of the inputs used in production and the marginal efficiency coefficients were calculated and interpreted.

Gözener (2016) conducted a study in Türkiye and found out that there were 6 independent variables in the paddy production function. The elasticity coefficient of the chemical fertilizer factor in the paddy production function has been determined and interpreted. Kaka et al. (2016) carried out a study in Malaysia with 397 producers and came up with the finding that there were 5 independent variables in the paddy production function. The elasticity coefficient of the chemical fertilizer variable in the paddy production function was calculated.

In the study conducted in Sri Lanka by Kanthilanka and Weerahewa (2016), the factors affecting paddy production were examined in terms of functionality. In the study, 9 independent variable factors were included in the estimation equation. In the equation, the elasticity coefficients of urea, triple super phosphate (TSP) and potash fertilizers were determined. Yumnam et al. (2016) investigated the efficiency of factors used in paddy production in two different regions in terms of econometrics. The elasticity coefficient of the chemical fertilizer variable in the paddy production function was calculated and interpreted.

In the research conducted with 100 farmers in India by Kannaki and Louis (2017), the amount of inputs used in paddy production was examined, and the factors affecting paddy production were analyzed with the help of production function. In the research conducted with 217 farmers in Nigeria by Ogbc et al. (2017), seed, fertilizer, agrochemical, land and labor production factors used in paddy production were evaluated in 2 groups according to "Rice Production Ecologies”. In a study carried out by Sonawane et al. (2017) in India with

62 producers, 9 independent variables were included. In the study, the fertilizers used per unit area were evaluated in 3 groups as nitrogen, phosphorus and potash fertilizers, and their elasticity coefficients were calculated and analyzed.

In the study conducted with 100 farmers in India byMaurya et al. (2018), 5 inputs used in paddy production were analyzed using the production function. In the analysis, the enterprises were evaluated in 3 groups according to their size: marginal farms (< 1 ha), small farms (1-2 ha), medium farms (> 2 ha). In the study, in addition to the elasticity coefficients of the factors in the paddy production estimation equation, marginal yield values were also calculated and interpreted.

In the study of Pudaka et al. (2018), which was carried out with 100 producers in Indonesia, there were 5 independent variables in the paddy production function. In the estimation equation obtained in the research, the elasticity coefficients of other factors were determined along with the fertilizer factor. In the study, the marginal efficiency coefficient of the fertilizer factor was calculated. In a study conducted with 159 producers in Indonesia by Ida and Azhar (2018), 6 independent variables were included in the paddy production function. Together with the coefficient of determination ($R^2$) of the rice production function, the elasticity coefficient and marginal efficiency coefficient of the fertilizer factor in the estimation equation were calculated.

In a study conducted with 240 farmers in Iraq by Al-Mashadani et al. (2019), the amount of inputs used in paddy production was examined. In the study, the elasticity coefficients and significance levels of the factors affecting paddy production were determined. Together with this, in the same study, the marginal efficiency coefficients of the factors used in paddy production were calculated and interpreted. In the study conducted with 125 farmers in India by Kumar and Singh (2019), the cost of paddy crop, including fertilizer and fertilization costs in paddy production, was examined in detail. In the study, the $R^2$ value of the production function prepared for paddy production, the elasticity coefficient and significance level of the fertilizer factor were determined. In the study, the marginal efficiency coefficient of the fertilizer factor was also determined.

In the study conducted with 30 producers in Indonesia by Sahara et al. et al. (2019), the efficiency of fertilizer use in paddy production was analyzed using the production function. In another study conducted with 123 farmers in Indonesia by Siagian et al. (2019), 16 independent variable factors were involved in the paddy production function. The coefficient of determination ($R^2$) of the paddy production function was calculated, and the marginal efficiency coefficient of the fertilizer variable was determined and interpreted.

Purba et al. (2020), in their study conducted with 93 producers in Indonesia, carried out a technical efficiency analysis of paddy production. In the study, 9 factors that affect paddy production were analyzed in detail. Rashid (2020) analyzed the elasticity coefficient and marginal efficiency coefficient of the fertilizer factor in the estimation equation for paddy production in a study conducted with 256 producers in Tanzania. In the study conducted with 240 producers in Cambodia by Sary et al. (2020), the amount of input use in paddy production was examined in detail, the determination coefficient of the estimation equation was calculated, and the effects of factors on the production amount were examined by using elasticity coefficients.

In the study conducted in Thailand by Somjai et al. (2020), the factors of labor, capital use, paddy price and average amount of chemical fertilizer use, which are effective in paddy production, were analyzed with the help of production function. Yusuf et al. (2020) carried out a cost analysis in paddy production in 4 settlements in the research conducted with 203 producers in Indonesia. In the study, the share of the total cost of chemical and organic fertilizers and fertilization labor costs used in the settlements in the cost of paddy production is given in detail at the monetary and proportional level.

In the study conducted with 30 producers in Indonesia by Bakri et al. (2021), 7 independent variable factors were involved in the paddy production function. In the study, fertilizers used in paddy production were evaluated in 4 groups as urea fertilizer, NPK fertilizer, tabas fertilizer and DMA fertilizer. In addition to the elasticity coefficients of the fertilizers specified in the study, the marginal efficiency coefficients were also calculated and interpreted. In the research conducted with 88 producers in Indonesia by Ginting and Andari (2021), the relationship between the amount of paddy production and the seeds, chemical fertilizers, pesticides and labor factors used in production was analyzed with the help of production function. In the study conducted in Indonesia by Juliatmaja et al. et al. (2021), the effect of production area, workforce, urea fertilizer, NPK fertilizer, pesticide and seed inputs on the amount of paddy production was examined with the help of production function.

In the equation prepared in the study conducted with 200 farmers in Bangladesh by Billah (2022), the elasticity coefficients and importance levels regarding the costs of the inputs used in paddy production were determined. In the research conducted in Bangladesh by Hoque et al. (2022), the fertilizer factor used in paddy production was statistically examined.

In the research conducted in India by Lamani and Thimmaiah (2022), the inputs used in paddy production were revealed in terms of both quantity and monetary size. In the study, the cost of the inputs used in production in paddy production is given in detail. In the research, seed, chemical fertilizer, pesticide and labor factors that are effective in paddy production were analyzed with the help of production function. In the study, the marginal efficiency coefficients of the factors involved in production were calculated, and the results obtained were analyzed and interpreted with other research findings.

In the research conducted with 337 producers in Nigeria by Adewumi et al. (2023), the effectiveness of the fertilizer factor in the enterprises using and not using UDP Technology in paddy production was examined. In the research conducted with 202 farmers in Indonesia by Djafar et al. (2023), 5 factors that are effective in paddy production were analyzed with the help of production function. Within the scope of the study, the elasticity coefficient and marginal efficiency coefficient were calculated and interpreted for each factor in the estimation equation created regarding the factors used in paddy production.

In the study conducted with 60 producers in India by Jayaprada et al. (2023), the cost of paddy production, including chemical fertilizer, was examined in detail, and the values of the factors were given as monetary value and proportional. In the research conducted with 100 producers in India by Kumar et al. (2023), the shares of inputs used in paddy production in product cost are given in detail on the basis of small, medium and large enterprise groups.

In the study conducted with 45 farmers in Indonesia by Laksono et al. (2023), the effect of land area, workforce, seeds, fertilizer and pesticides factors on paddy production was analyzed. In the study conducted with 50 producers in India by Raj et al. (2023), the factors used in paddy production were analyzed functionally. Elasticity coefficients and importance levels were determined for the 6 factors determined in the study, and the marginal efficacy coefficients of the factors were calculated and interpreted.

In the study conducted in India by Singh et al. (2023), the effect of input costs on paddy production value in paddy production was analyzed with the help of production function. In the research conducted with 43 producers in Indonesia by Susvadi et al. (2023), the efficiency of input use in paddy production was analyzed using the production function. Yüzbaşıoğlu and Abacı (2023) conducted a study with 164 producers in Türkiye and examined the inputs used in paddy production functionally.

In the study conducted in Pakistan by Abbas et al. (2024), the product cost in paddy, including fertilizer cost and fertilization cost factors for conventional rice varieties and hybrid varieties, was calculated, and the differences for both groups were analyzed. In their research conducted with 120 farmers in Nepal, Bhatt et al. (2024) discussed the cost factors in paddy production in two different periods in detail. In the study, the factors affecting paddy production were analyzed with the help of production function.

In the study conducted with 315 producers in Nigeria by Obiekwe et al. (2024), the cost factors in paddy production were examined in detail. In the research, the effect of socio-economic factors on the amount of paddy production was functionally examined.

## 3. Materials and Methods

### 3.1. Materials

The primary data of the study consists of the data compiled from the agricultural enterprises producing paddy in the province of Çanakkale in the Marmara Region of Türkiye. Within the scope of the research, face-to-face surveys were conducted in January-February 2019 for the paddy product produced in 2018. The secondary data of the research include; Data published by the Food and Agriculture Organization of the United Nations (FAO), the Ministry of Agriculture and Forestry and the Turkish Statistical Institute (TSI). In the study, publications of various national and international institutions and organizations related to paddy, researches, theses and commission reports were referred to.

### 3.2. Methods

#### 3.2.1. Method used in sampling

The formula proposed by Neyman was used to determine the number of surveys applied in the study (Yamane, 1967).

$$n = \frac{\Sigma(NhSh)^2}{N^2D^2 + \Sigma Nh(Sh)^2}$$

In the formula:

n = Sample Volume

Nh=number of enterprises in the h layer

Sh=standard deviation of the h layer

N= Total number of enterprises belonging to the sampling frame

D = Acceptable margin of error (d/z)

d=Deviation from the mean at a certain level z=t The degree of freedom in the distribution chart (N-1) and the "t" value of a certain confidence limit (Erkan and Çiçek, 1996).

Çanakkale Provincial Directorate of Agriculture and Forestry 2018 Farmer Registration System (FRS) data were used to determine the number of paddy production enterprises to be included in the sampling framework. According to the data of the same year, it is understood that paddy production is carried out in an area of 65,000 da in 865 agricultural enterprises throughout the province. Within the scope of the research, a questionnaire was applied to 74 agricultural enterprises with a 99% confidence interval and a 5% deviation from the average.

In the study, "Cobb-Douglas Type Function" was used to determine the relationships between the amount of paddy production and the inputs used in production (Zoral, 1984; Miller, 2008).

In marginal analyses, the price formed in the free market in the average paddy sales price of the enterprises and the rate (1.13) found by adding the interest rate applied by Ziraat Bank to crop production in 2018 on top of 1 TL were taken into account as factor cost (Yılmaz and Yurdakul, 2000). In the research conducted, the USD/TL parity was taken into account as 1 US$ = 5.51 TL (CBRT, 2024). The sales price of paddy in 2018 was calculated as 2.92 TL $kg^{-1}$ = 0.53 USD. Within the scope of the study, for paddy production; Geometric Mean Values (GOD), Marginal Product (MP), Marginal Income (MI), Marginal Cost (MC) and Marginal Efficiency Coefficients (MEC) were calculated and interpreted.

### 3.2.2. Method applied in econometric analysis

In the study, the Cobb-Douglas type function was used to determine the relationships between the amount obtained from paddy production and the pure nitrogen, pure phosphorus and pure potassium fertilizers used in production (Doll and Orazem 1984; Beattie and Taylor 1987, Neill, 2002). Literature reviews indicate that this type of function is suitable for functional analyses of agricultural production activities (Heady and Dillon, 1966; Özcelik, 1989; Mazid et al., 2015; Zhang et al., 2017). The equation belonging to the main mass for the Cobb-Douglas type function like this (Gujarati and Porter, 2014).

$$Y = aX1^{b1}X2^{b2}\,X3^{b3}\ldots Xn^{bn}$$

When the logarithm of both sides is taken, the equation happens to be like that (Anagnostopoulos and Kotsikas, 2010).

$$\log Y = \log \alpha + \beta 1 logx1 + \beta 2 logx2 + \ldots + \beta k logxk + e^u$$

The $\beta_i$ symbols in the equation indicate the production elasticity of the production factors ($\beta_i$ = 1, 2,.. n).The significance levels of the coefficients ($\beta_i$) of production elasticity are tested with the help of the formula.

$$t\,\beta i = \beta i / se(\beta i)$$

The determined $t\beta_i$ value is compared with the value at the junction of the row showing the degree of freedom in the "t-table" (n-k-1) and the column indicating the desired level of significance.

Multiple regression (R) and coefficient of determination ($R^2$), elasticity coefficients ($\beta i$), standard errors ($se\beta i$) and significance levels ($t\beta i$), geometric means of the variables ($X_i$G, ROI), simple correlation coefficients ($ri_j$) and standard deviation (S) and significance level (F value) of the equation which belong to the regression equation of paddy production were determined as a result of regression analysis performed with the help of an appropriate statistical package program. Regarding the estimation equation in the study; Coefficient of Determination ($R^2$), Significance Test of Partial Correlation Coefficients ($b_i$), Autocorrelation and Multicollinearity tests were also performed.

The following formula was used to calculate the marginal physical productivity (MPP) of any Xi input used in paddy production (Singh et al., 2004; Mobtaker et al., 2010; Rafiee et al., 2010).

$$MPPxij = \beta ij \frac{GM(Y)}{GM\ (Xi)}$$

In the equation; MPPxj is the marginal physical output of the input, αj is the regression coefficient of the input, GM(Y) is the geometric mean value of the dependent variable, and GM(Xj) is the geometric mean of the inputs.

Geometric means are used in the Cobb-Douglas type model. The equation used in the calculation of marginal revenue (MR-) for any production input (Xi) is given below (Karagölge, 1973; Singh et al., 2004; Mobtaker et al., 2010; Rafiee et al., 2010).

$$MjRxj = \beta j \frac{GM(Y)}{GM(Xij)} * Py$$

Multiplying the marginal yield by the product price gives the Marginal Income. In this case, the jth factor of production is used in such a way as to maximize profit or in the most economical way.

Marginal Efficiency Coefficients (MEC-), which are found by dividing marginal revenues by factor prices, express which factor is used more or less effectively, and which factor is used more or less economically. The equation used to calculate the marginal efficiency coefficient is shown below (Singh et al., 2004; Mobtaker et al., 2010; Rafiee et al., 2010).

$$MEC = \frac{\text{Marginal Factor Revenue}}{\text{Marginal Factor Cost (Factor Price or Opportunity Cost)}}$$

The following rules have been taken into account in the interpretation of the calculated marginal activity coefficients for production factors (Hopper, 2008; Timmer, 2012,2013; Taru et al., 2008; Semerci, 2013):

If MEC = 1 (MR=MC), the factor is used effectively.

If MEC > 1, factor is used less and should be increased (MR>MC),

If MEC < 1, the factor is overused and should be reduced (MR<MC).

It has been found that pure nitrogen was used in all 74 paddy production enterprises identified with the help of the sampling formula. However, it was determined that the use of pure phosphorus was in 64 enterprises (9,335 da) and pure potassium fertilizer was found in 41 enterprises (5,553 da). For this reason, within the scope of the research, with the help of the data obtained from 41 enterprises (5,553 da) using pure nitrogen, pure phosphorus and pure potassium fertilizer in Çanakkale province, with the amount of paddy production; the relationships between the amount of pure nitrogen, pure phosphorus and pure potassium use were analyzed using the Cobb-Douglas production function (Neill, 2002). The variables that take place in the paddy production function in the study are as given below.

Y = Paddy production amount (kg enterprise$^{-1}$): Total amount of paddy production per enterprise.

The independent variables in the function are given below.

$X_1$ = Amount of Pure Nitrogen (kg enterprise$^{-1}$).

$X_2$ = Amount of Pure Phosphorus (kg enterprise $^{-1}$).

$X_3$ = Amount of Pure Potassium (kg enterprise $^{-1}$).

# 4. Research Findings

## 4.1. The level of chemical fertilizer uses in paddy production in the examined enterprises

In order to obtain higher yields in paddy production, it is necessary to fertilize on time and in appropriate amounts. For this reason, first of all, fertilizer should be used after taking soil samples from the paddy pans where paddy will be planted and having them analyzed. The rice plant needs 16 nutrients, particularly such as nitrogen, phosphorus, potassium and zinc. In determining the amount of fertilizer to be given to the paddy plant, the decision should be made according to the soil analysis.

Murayama (1979) stated that the plants should take 19-21 $da^{-1}$ kg of nitrogen to obtain one ton of paddy crop. Naturally, with the increase in yield, the intake of N also increases. As a result of the N fertilizer trials carried out at the Thrace Agricultural Research Institute, it was seen that the species grown in the country reached optimum yield with 17-18 kg of $da^{-1}$ nitrogen (Sürek et al., 1998). For this, the most suitable nitrogen fertilizers recommended in paddy production are ammonium sulfate and urea (Hill, 1992).

In general, although it varies according to soil characteristics, the amount of phosphorus to be applied is between 6-8 kg $da^{-1}$ in paddy agriculture. As phosphorus fertilizers, 25-30 kg $da^{-1}$, 20-20-0, or 15-15-15 compound fertilizers between 30-35 kg $da^{-1}$ or compound fertilizers specially developed by some companies for paddy crops and containing three main nutrients could be used (Sürek, 2015).

The soils of Türkiye are rich in potassium. For this reason, there is no need to use potassium fertilizer in paddy fertilization. However, potassium deficiency could sometimes be noted in fields where paddy is sown on top of each other or where heavy land is leveled. In this case, for the purpose of high and quality yield, it is recommended to use some potassium fertilizer at intervals of 2 or 3 years, depending on the need. In cases of potassium deficiency, the quality of the product and the effective utilization of nitrogen fertilizers decrease. As a source of potassium, 15-15-15 compound fertilizer between 30-35 kg or compound fertilizers specially developed by some companies for paddy products and containing three main nutrients could be used (Sürek, 2015).

The total amount of physical chemical fertilizer in paddy production for the enterprises examined in the study was 1.149.256,425 kg and the amount of pure fertilizer was 387,668.390 kg. Pure nitrogen was applied in the entire production area of 74 enterprises surveyed in a total paddy production area of 10,461 da. In addition to this, pure fertilizer was used in 9,335 fields and pure potassium fertilizer was used in an area of 5,553 da in the enterprises examined (Table 1).

**Table 1: Chemical fertilizer use status in general (74 enterprises)**

| Chemical Fertilizer Type | Total Amount of Fertilizer Used (kg) | Enterprises Using Fertilizer | | | Enterprises Not Using Fertilizer | |
|---|---|---|---|---|---|---|
| | | (Pieces) | Area (da) | Quantity (kg $da^{-1}$) | (Pieces) | Area (da) |
| Pure Nitrogen (N) | 282,230.290 | 74 | 10,461 | 26.979 | - | - |
| Pure Phosphorus (P) | 75,625.250 | 64 | 9,335 | 8.101 | 10 | 1,126 |
| Pure Potassium (P) | 29,812.850 | 41 | 5,553 | 5.369 | 33 | 4,908 |
| Pure Total | 387,668.390 | - | - | 40.358 | - | - |
| Total Physical Fertilizer | 1,149,256.425 | - | - | 109.861 | - | - |

An average of 40,358 kg $da^{-1}$ of pure fertilizer was used per decare in the examined enterprises, and 26,979 kg $da^{-1}$ of this amount consists of pure nitrogen, 8,101 kg $da^{-1}$ of pure phosphorus and 5,369 kg $da^{-1}$ of pure potassium fertilizer. In other words, 66.85% of the pure fertilizer used in paddy production is pure nitrogen fertilizer.

Within the scope of this research, the effects of chemical fertilizer use on the amount of paddy production have been examined. In this context, there are 41 enterprises that use all pure nitrogen, pure phosphorus and pure potassium fertilizers. The total amount of chemical fertilizers used in paddy production in these enterprises was calculated as 624,457.300 kg and the total amount of pure fertilizer was calculated as 211,130.710 kg (Table 2).

**Table 2: Chemical fertilizer use status in the analyzed enterprises (41 enterprises)**

| Chemical Fertilizer Type | Total Quantity Used (kg) | Quantity Used in Unit Area (kg $da^{-1}$) |
|---|---|---|
| Pure Nitrogen (N) | 139,541.010 | 25.129 |
| Pure Phosphorus (P) | 41,776.850 | 7.523 |
| Pure Potassium (P) | 29,812.850 | 5.369 |
| Pure Total Chemical Fertilizer | 211,130.710 | 38.021 |
| Total Physical Chemical Fertilizer | 624,457.300 | 112.454 |

The number of enterprises using all the chemical fertilizer types mentioned in Table 2 is 35 and paddy production has been carried out in an area of 5,553 da. The total amount of physical fertilizer use per decare in these enterprises is 112,454 kg. The amount of pure fertilizer used per unit area in these enterprises is 38.021 kg $da^{-1}$, and the highest share in the amount of pure fertilizer belongs to pure nitrogen with a share of 66.09%.

In the research conducted, it was determined that the producers used chemical fertilizers a total of 5 times during the production season in paddy production. In the study, the total cost of fertilizer cost and fertilization labor was calculated as 30.94 USD $da^{-1}$, with the labor cost of 5.96 USD $da^{-1}$, the chemical fertilizer cost of 24.98 USD $da^{-1}$. The total variable costs in paddy production is 208.86 $da^{-1}$ and the share of fertilizer costs and fertilization labor costs among the paddy crop changing costs has been determined as 14.81%. The product cost in paddy production is 290.62 USD $da^{-1}$ and the share of fertilizer cost and fertilization labor cost in total product cost is 10.65%. The findings of other studies on the same issue are given below.

In their study, Long et al. (2013), calculated the share of chemical fertilizer cost in paddy production cost as 24.66% in winter-spring period and 26.90% in summer-autumn period. In the research conducted by Shende and Bagde (2013), the share of chemical fertilizer cost in paddy production cost was determined as 9.29%. According to the study conducted by Kumar and Singh (2019) in India, fertilizer and fertilization costs in paddy production accounted for 16.52% of the cost of paddy crop.

In the research conducted by Yusuf et al. (2020), the cost of chemical and organic fertilizers in paddy production and the share of fertilization labor in product cost according to settlements was calculated as 26.11% in Bunga Raya, 18.78% in Sabak Auh, 17.79% in Sungai Apit, and 15.46% in Sungai Mandau. In the study conducted byMishra et al. (2020) in India, the share of farm manure and chemical fertilizer costs in paddy production in paddy production cost was determined as 13.35%. In the study conducted by Subedi et al. (2020), the share of chemical fertilizer costs in paddy production in product changing costs was determined as 13.41%.

In the study conducted by Lamani and Thimmaiah (2022), the share of chemical fertilizer cost in the cost of paddy product was found to be 16.52%. In the study conducted in India byJayaprada et al. (2023), the share of chemical fertilizer cost in paddy production cost was found as 13.38%. In the research conducted by Kumar et al. (2023), the share of chemical fertilizer and animal manure costs used in paddy production in product cost was calculated as 11.44% in small enterprises, 11.46% in medium-sized enterprises, 11.05% in large enterprises, and 11.38% as the average of enterprises.

In the study conducted by Bhatt et al. (2024), the share of chemical fertilizer cost in paddy production in product cost was determined as 11.35% for main season rice and 12.88% for spring rice. In the research conducted by Obiekwe et al. (2024), the share of chemical fertilizer cost used in paddy production in the product cost was determined as 13.54%.

In the study conducted with 164 farmers in Türkiye, Yüzbaşıoğlu and Abacı (2023) determined that fertilizer costs in paddy production constitute 22.29% of the variable costs of the product and 18.67% of the product cost. In the study conducted byAbbas et al. (2024) in Pakistan, the share of fertilizer and fertilization costs in the cost of paddy production was determined as 22.84% for conventional rice varieties and 21.14% for hybrid varieties.

In this study, the share of fertilizer and fertilization costs in paddy production in paddy product cost was determined at a lower level than the shares calculated by Long et al. (2013), Kumar and Singh (2019), Yusuf et al. (2020), Lamani and Thimmaiah (2022), Yüzbaşıoğlu and Abacı (2023), Kumar et al. (2023), Abbas et al. (2024) and Obiekwe et al. (2024).

In other researches on the same subject, the amount of chemical fertilizers used per unit area in paddy production is summarized below.

In the research conducted with 294 producers in Türkiye, Gaytancioğlu and Sürek (2001) determined the use of nitrogen in paddy production as 29.1 kg $da^{-1}$ (recommended 16 kg $da^{-1}$ - 18 kg $da^{-1}$), phosphorus use as 12.5 kg $da^{-1}$ (6 kg $da^{-1}$ - 10 kg $da^{-1}$) and potassium use as 3.9 kg $da^{-1}$. In the study, no recommendation was made since the country's soils are rich enough in terms of potassium fertilizer.

In the research conducted with 127 producers in Iran, Alipour et al. (2012) reported that 13.74 kg da-1 of nitrogen fertilizer, 7.71 kg $da^{-1}$ of phosphorus and 4.08 kg $da^{-1}$ of potassium were used in paddy production.

In their study Long et al. (2013) determined that in winter-spring period nitrogen was used in the amount of 10.05 kg $da^{-1}$, phosphorus 6.49 kg $da^{-1}$, potassium 4.19 kg $da^{-1}$ in paddy production and n itrogen 10.47 kg $da^{-1}$, phosphorus 7.55 kg $da^{-1}$, potassium 4.78 kg $da^{-1}$.

In the research conducted by Shende and Bagde (2013), chemical fertilizer use levels in paddy production was as follows; nitrogen 17.048 kg $da^{-1}$, phosphorus 4.651 $da^{-1}$, potassium was 0.459 kg $da^{-1}$, zinc fertilizer 0.25 kg $da^{-1}$. In the study conducted in Ghana by Ragasa et al. (2013), the level of chemical fertilizer uses in paddy producing enterprises was determined as 37.5 kg $da^{-1}$. In another study conducted with 150 producers in Ghana by Addison et al. (2016), the use of fertilizer in paddy production was determined as 47.99 kg $da^{-1}$. In the study conducted by Kannaki and Louis (2017), it was reported that phosporus 11.35 kg $da^{-1}$, nitrogen 15.57 kg $da^{-1}$, potash 11.12 kg $da^{-1}$ were used in the research area.

In the study conducted in China in 2015 byYuan and Peng (2017), the use of nitrogen in paddy production in Huanghuazhan and Yangliangyou settlements was determined as 18 kg $da^{-1}$, phosporus use as 9.16 kg $da^{-1}$, potash use as 12.05 kg $da^{-1}$ and zinc fertilizer use as 0.5 kg $da^{-1}$.

In the research conducted by Rao et al. (2018) in India, it was determined that farmers used 32.55 kg $da^{-1}$ of nitrogen, 18.32 kg $da^{-1}$ of phosphate, 7.20 kg $da^{-1}$ of potassium, 0.23 kg $da^{-1}$ zinc, 1,524.55 kg $da^{-1}$ of farmyard manure in paddy production.

In the study conducted by Al-Mashadani et al. (2019), it was reported that 147 kg of $da^{-1}$ chemical fertilizer was used in paddy production. In the study conducted with 30 producers in Indonesia bySahara et al. (2019), it was determined that 17.5 kg $da^{-1}$ of urea fertilizer, 25.00 kg $da^{-1}$ of phonska fertilizer, 10.00 kg $da^{-1}$ of ZA fertilizer, manure 26.250 kg $da^{-1}$ were used in paddy production.

In the study conducted by Purba et al. (2020), it was determined that 32.96 kg of $da^{-1}$ nitrogen fertilizer, 22.37 kg of $da^{-1}$ phosphate fertilizer, 19.52 kg of $da^{-1}$ potassium fertilizer were used in paddy production. In the research conducted with 256 producers in Tanzania byRashid (2020), the level of chemical fertilizer use in paddy production was determined as 23,092 kg $da^{-1}$. In the study conducted Sary et al. (2020), it was reported that an average of 26.9 kg da-1 of fertilizer was used in paddy production, although it varied between 10 kg $da^{-1}$ and 50 kg $da^{-1}$.

In the study conducted by Lamani and Thimmaiah (2022), the amount of chemical fertilizer use in paddy production was calculated as follows: nitrogen fertilizer 29.25 kg $da^{-1}$, phosphate fertilizer 21.50 kg $da^{-1}$, potassium fertilizer 3.75 kg $da^{-1}$, zinc fertilizer 2.50 kg $da^{-1}$. In the research conducted with 96 paddy farmers in Indonesia bySaepudin and Amelia (2022), the use of chemical fertilizers varied between 40 kg $da^{-1}$ and 95 kg $da^{-1}$, but was determined as an average of 64,635 kg $da^{-1}$.

In the study conducted with 200 producers in Ghana by Adams et al. (2023), the level of chemical use in paddy production was determined as 4.59 kg $da^{-1}$. In the research conducted with 337 manufacturers in Nigeria by Adewumi et al. (2023), the differences between enterprises using and not using UDP technology and the efficiency of the use of inputs were examined with the help of the production function. The use of Urea Deep Placement (UDP) technology to boost nitrogen availability, a key ingredient in rice production, was introduced to rice farmers in selected Northern Nigerian states. In the study, the use of Fertilizerwas determined as 18.20 kg $da^{-1}$ (urea briquettes users) in enterprises using UDP technology and the use of chemical fertilizers in enterprises not using this technology was determined as 38.45 kg $da^{-1}$.

In the study conducted in India by Dey et al. (2023), the use of fertilizer in paddy production was found as follows: nitrogen fertilizer 12.72 kg $da^{-1}$, phosphorus fertilizer 5.37

kg $da^{-1}$, potassium fertilizer 4.99 kg $da^{-1}$. In the study conducted by Laksono et al. (2023), although the use of Urea, SP-36 and KCl fertilizers in paddy production varies between 4.5 kg $da^{-1}$ -7.5 kg $da^{-1}$, it was reported that an average of 6.14 kg $da^{-1}$ was used.

Considering the results of the study conducted on the subject, it is understood that the amount of chemical fertilizer use in paddy production is different. The main thing in paddy production is the extent to which the recommended suggestions are followed according to the results of soil analysis. According to the results obtained in this research, chemical fertilizers are used above the recommended amounts. For this reason, considering the values calculated as a result of the research, it is similar to the amount of fertilizer recommended to be used per unit area in paddy production in Türkiye (Gaytancioğlu and Sürek, 2001).

The amount of chemical fertilizers used in paddy production should be evaluated in each country's own way. Yet, although there is support for the use of chemical fertilizers in paddy production in some countries such as Türkiye, in other countries there is no support for the use of chemical fertilizers in paddy production by the state. Similarly, while some countries such as Türkiye make difference support or support payments under other names in paddy product purchases, other countries do not have similar practices. In this way, both chemical fertilizer support and support applied in product procurement affect the use of inputs in paddy production between countries. This situation could positively or negatively affect the amount of fertilizer to be used by paddy producers in paddy production.

### 4.2. Functional analysis of chemical fertilizer use in paddy production

The relationship between the amount of pure nitrogen, pure phosphorus and pure potassium fertilizer use and the amount of paddy production in the enterprises examined in the study was analyzed with the help of the Cobb-Douglas type production function (Debertin, 2012). As a result of the econometric analysis carried out using the data obtained from 41 paddy production enterprises that used pure nitrogen, pure phosphorus and pure potassium fertilizers together and determined according to the sampling method in Çanakkale province, the functional relationship between the variables in production is as follows;

$$Y = 1.765 * X_1^{0.639} * X_2^{0.140} * X_3^{0.220}$$

It has been formed in the form *(S=0.102; R=0.977; $R^{0.955}$=264.59; F=158.65)*

Multiple correlation and determination coefficients of equation ($F_{calc.} > F_{table}$) has been found to be significant at 1% probability level. The calculated coefficient of determination for the obtained function shows that approximately 95% of the changes in the amount of paddy production could be expressed by the independent variables in the model and that the chosen model is appropriate. The existence of autocorrelation in the equation created in the study was tested by applying the "Durbin Watson (DW) Test", and the positive autocorrelation test was applied because the $DW_{calculation}$ of the equation was calculated as 1.562 (Özçelik, 1994). As a result of the test, it was understood that there was no positive correlation for function ($DW_h$ 1.562> $DW_{U\ (0.01)}$ 1.474) (Tables 3 and 4).

**Table 3: Basic statistics of the forecast equation**

| R | R Square | Adjusted R Square | Std. Error of the Estimate | R Square Change | F Change | Sig. F Change | Durbin-Watson |
|---|---|---|---|---|---|---|---|
| 0.977 | 0.955 | 0.952 | 0.102 | 0.955 | 264.59 | .000 | 1.562 |

**Table 4: Paddy production function variance analysis table**

| | *Degree of freedom* | *Sum of Squares* | Average of Squares | F- Value | "P Value" |
|---|---|---|---|---|---|
| *Regression* | 3 | 8.189 | 2.730 | 264.59 | 0.000 |
| *Remainder* | 37 | 0.382 | 0.010 | | |
| *Total* | 40 | 8.571 | | | |

When the production elasticity of the independent variables is examined, it is seen that the production elasticity coefficients of all the factors have a positive character (Table 5).

**Table 5: Production elasticity of production factors in paddy production**

| | $X_1$ (Pure N) | $X_2$ (Pure P) | $X_3$ (Pure K) | ($\Sigma\beta_i$) |
|---|---|---|---|---|
| Production elasticity (βi) | 0.639 | 0.140 | 0.220 | 0.999 |
| Standard error (seβi) | 0.123 | 0.097 | 0.096 | - |
| tβi | 4.965* | 1.423 | 2.476** | - |

*(**): Significant at 1% probability level*
*(**): Significant at 5% probability level*

The sum of the production elasticities of the factors involved in the estimation function ($\sum\beta_i$) is 0.999. This means a fixed return in paddy production. In short, it reveals that when the pure nitrogen, pure phosphorus and pure potassium used in paddy production are increased by 1%, the production amount could increase by 1%.

In the study, pure nitrogen ($X_1$) was found to be statistically significant at the level of 1% whereas pure potassium ($X_3$) at the level of 5%. From a theoretical point of view, it could be stated that a 1% increase in the amount of pure nitrogen used in paddy production will increase production by 0.639%, a 1% increase in the amount of pure phosphorus will increase paddy production by 0.14%, and a 1% increase in the amount of pure potassium will increase production by 0.22%.

In the study, marginal product quantities, marginal product values and marginal efficiency coefficients related to the use of pure nitrogen, pure phosphorus and pure potassium, which are effective in the amount of paddy production, are given in Table 6.

**Table 6: Marginal efficiency coefficients of the factors included in the estimation equation**

| | $X_1$ (Pure N) | $X_2$ (Pure P) | $X_3$ (Pure K) | Y |
|---|---|---|---|---|
| Geometric mean (log) | 3.27604 | 2.75725 | 2.64157 | 4.78857 |
| Geometric mean (kg) | 1,888.16 | 571.80 | 438.10 | 61,456.29 |
| Marginal Yield (kg) | 20.80 | 15.05 | 30.86 | |
| Marginal product value (TL) | 60.73 | 43.94 | 90.12 | - |
| Factor prices ($) | 1.13 | 1.13 | 1.13 | - |
| Marginal efficacy coefficient | 53.74 | 38.88 | 79.75 | - |
| Marginal efficacy coefficient (US$) | 9.75 | 7.06 | 14.47 | - |

As could be seen from the examination of Table 6, the highest marginal efficiency coefficient among the fertilizers used in paddy production belongs to pure potassium ($X_3$). This variable is followed by pure nitrogen ($X_1$) and pure phosphorus ($X_2$), respectively. In determining the marginal product values, factor prices which are 1 TL more than the normal interest rate have been taken into account (Rehber and Erkuş, 1984; Çelik and Bayramoğlu, 2007; Vural and Turhan, 2011). According to marginal efficiency coefficients; Pure phosphorus, pure nitrogen and pure potassium factors are used below the economic optimum level ($x_j$>1). Therefore, increasing the use of pure phosphorus, pure nitrogen and pure potassium factors, which have a high coefficient of marginal efficiency, in other words, the use of fertilizer should be regulated according to the amounts recommended after having carried out the soil analysis and without causing environmental pollution.

In some studies, on paddy production, the relationships between production amount and inputs have been examined with the help of the Cobb-Douglas production function both in Türkiye and in Far East Asian countries. In this section, the findings obtained in the other studies on the same subject are given in general terms and these research findings are compared.

In a study involving 97 producers in Edirne, the effect of seeds, fertilizers, pesticides, number of parcels, educational status and tractor power factors on the production amount was analyzed using the Cobb-Douglas production function. In the study, the elasticity coefficient of the chemical fertilizer variable in the function was 0.15 and was found to be statistically significant at the level of 1% (Semerci, 1998).

In the study conducted by Bhujel and Ghimire (2006), the elasticity coefficients and significance levels of fertilizers in the paddy production estimation equation are: Nitrogen - 0.33 (sign. 1%), Phosphorous 0.01 (sign. 1%), while potash fertilizer is determined as 0.02 (sign. 10%).

In a study conducted with the participation of 71 producers in the Indian state of Kerala, the effect of 8 different variables on the income of paddy production was aimed to be determined by using the Cobb-Douglas production function. In the study, the elasticity coefficient of the fertilizer input, which is one of the variables in the function, was calculated as 0.17 and was found to be statistically significant at the level of 1%. The marginal efficiency coefficient of the fertilizer factor was determined as 2.83 (Suresh and Keshava Reddy, 2006).

In the study of Sikdar et al. (2008), elasticity coefficient of chemical fertilizer variable in the paddy production function was 0.1572 and it was found significant at a level of 1%. In the study conducted with 60 farmers in Nigeria by Sani et al. (2010), 4 production factors were included in the paddy production estimation equation, and the elasticity coefficient of the chemical fertilizer input was 0.05 and was found to be statistically significant at the level of 5%. The marginal efficiency coefficient of the fertilizer factor is 7, which indicates that the use of fertilizer in paddy production is low and should be increased.

In the study involving 70 paddy producers in Ghana, researches tried to determine the effect of 5 different variables on the amount of paddy production. In the study, the elasticity coefficient of the chemical fertilizer variable was 0.1804 and it was found to be statistically significant at the level of 17%. In the study, the marginal efficiency coefficient of the fertilizer variable was calculated as 1.76 (Nimoh et al., 2012). In the estimation equation prepared in the study of Shantha et al. (2012), the elasticity coefficient of the chemical fertilizer used in paddy production was calculated as 0.231 and was found to be statistically significant at the level of 1%.

In the study of Long et al. (2013), the elasticity coefficients and significance levels in the production function in paddy production were found as follows: In the winter-spring period, urea was calculated as 0.156 (sign. 5%), phosphorus fertilizer was 0.024 (non sign.) and potassium fertilizer was 0.036 (non sign.). Same data in the summer-autumn period were obtained as follows; urea was determined as 0.039 (non sign.), phosphorus fertilizer was 0.039 (non sign.), potassium fertilizer was 0.025 (non sign.). In the research, the elasticity coefficients and significance levels in the cost function were found as follows: In winter-spring period urea was determined as 0.059 (non sign.), phosphorus fertilizer as 0.422 (sign. 10%), potassium fertilizer as 0.568 (sign. 5%). Same data in the summer-autumn period were on the other hand, urea was 0.317 (non sign.), phosphorus fertilizer was0.147 (sign. 5%), potassium fertilizer was 0.108 (non sign.).

In the study conducted by Reddy and Reddy (2013), the marginal elasticity coefficient of the chemical fertilizer factor used in paddy production was determined as -1.28, 3.61, -1.80 in small, medium and large enterprises in Kaligiri Mandal settlement, while 3.51, 33.30, 0.32 in Muttukur Mandal settlement, and 4.45, -1.55, 1.73 in Pellakur Mandal settlement, respectively. In the study conducted by Shende and Bagde (2013), the elasticity coefficient of the fertilizer factor was calculated as -0.028 in the estimation equation of paddy production, yet it was not found to be statistically significant. The determined value shows that the fertilizer factor is used excessively in paddy production.

In the study conducted by Kadiri et al. (2014), the elasticity coefficient of the chemical fertilizer factor in the estimation equation for paddy production was calculated as -0.25 and was found to be statistically significant at the level of 5%. In the study conducted by Riyan et al. (2014), the elasticity coefficient of the chemical fertilizer factor in the function of paddy production was calculated as 0.001 and was found to be statistically significant at the level of 10%.

In their study conducted with 396 producers in Malaysia, Abiola et al. et al. (2016) examined the efficiency of input use in paddy production with the help of production function. In the study, the elasticity coefficient of the chemical fertilizer factor in the estimation equation was 0.503 and it was found to be statistically significant at the level of 1%. The marginal efficiency coefficient of the fertilizer factor is 0.06, indicating that the input is overused in paddy production. In a study conducted with 150 producers in GhanaAddison et al. (2016), the elasticity coefficient of the fertilizer variable in the paddy production function was 0.15 and was found to be statistically insignificant.

In the study conducted by Ajoma et al. (2016), the elasticity coefficient of the chemical fertilizer factor in the paddy production estimation equation was 0.016 and was not found to be statistically significant. In the study, the marginal efficiency coefficient of the chemical fertilizer factor was calculated as 0.50, indicating that the level of use of the specified value in paddy production is excessive and should be reduced. In the research conducted by Gözener (2016), the elasticity coefficient of the chemical fertilizer factor in the paddy production function was 0.0451 and was found to be significant at the level of 5%.

In the study involving 288 paddy producers in India in the 2012-13 period, the effect of 7 different variables on the amount of paddy production was aimed to be determined. In the study, the variables of labor, animal bollard pull, animal manure and potash fertilizer were found to be statistically significant at the level of 5% in the production factors included in the production function (Hile et al., 2016).

In their study Kaka et al. (2016) found that the elasticity coefficient of chemical fertilizer variable in paddy production function was 0.896 and this value was considered as statistically significant with a level of 10%. In the study by Kanthilanka and Weerahewa (2016), the elasticity coefficient of urea fertilizer in estimation equation was determined as 0.229 and it was found to be statistically significant at the level of 5%. In the same study, however, Triple Super Phosphate (-0.075) and Potash fertilizers (0.030) were not found to be statistically significant.

In the study conducted in Himachal Pradesh State by Yumnam et al. (2016), the elasticity coefficient of the fertilizer factor in the paddy production estimation equation in small scale enterprises was 0.134, and this value was found to be statistically significant at the level of 5%. In large enterprises in the same state, the elasticity coefficient of the fertilizer factor in the paddy production estimation equation was determined as 0.144 and the calculated value was not found to be statistically significant. In the study conducted in Manipur State, in small businesses, the elasticity coefficient of the fertilizer factor in the paddy production estimation equation was determined as 0.149 and this value was not found to be statistically significant. In large enterprises in the same state, the elasticity coefficient of the fertilizer factor in the paddy production estimation equation was 0.362 and was found to be statistically significant at the level of 1%.

Kannaki and Louis (2017) found that the efficiency coefficients of chemical fertilizers were for Phosporus -0.63, for nitrogen 0.43, and forpotash 0.56. In the study, the elasticity coefficients of nitrogen and potash fertilizers were found to be statistically significant at the level of 5%. In the study conducted by Ogbc et al. (2017), the elasticity coefficient of fertilizer in the "Deep water" group was calculated as 0.197 and was found to be statistically significant at the level of 10%. In the study, the elasticity coefficient of the fertilizer factor in the "Upland Pooled" group was found to be statistically insignificant.

In the study conducted by Sonawane et al. (2017), fertilizers used per unit area were evaluated in 3 different groups as nitrogen, phosphorus and potash. In the research, the elasticity coefficients of chemical fertilizer variables were 0.030 for nitrogen, -0.045 for phosporus and 0.020 for potash, and the calculated values were not statistically significant.

However, in the study, the elasticity coefficient of farm fertilizer (manure) was 0.025 and it was found to be statistically significant at the level of 10%. In the study conducted in India, animal manure and chemical fertilizer variables, which are among the variables in the estimation equation, were found to be statistically significant at the level of 5% (Yumnam et al., 2017).

In the study conducted by Maurya et al. (2018), animal manure and chemical fertilizer were evaluated as a single variable. In the study, the elasticity coefficient of the factor specified in paddy production was calculated as 0.326 in marginal enterprises, 0.302 in small enterprises and 0.372 in medium-sized enterprises. All of the determined coefficients were found to be statistically significant at the level of 1%. In the study conducted by Pudaka et al. (2018), the marginal efficiency coefficient of the chemical fertilizer factor was determined as 9.54. This calculated value shows that the fertilizer factor is used less in paddy production in the enterprises and should be increased.

In the research conducted by Ida and Azhar (2018), the elasticity coefficient of the chemical fertilizer factor in the estimation equation for the paddy production function was -0.288 and it was found to be significant at the level of 1%. In the study, the marginal efficiency coefficient of the fertilizer factor was determined as 17.17. This calculated value revealed that the fertilizer factor is used excessively in paddy production in the enterprises and has to be reduced.

In the study conducted by Al-Mashadani et al. (2019), the elasticity coefficient of the chemical fertilizer factor used in paddy production was calculated as 0.141 and was found to be statistically significant at the level of 1%. In the study, the marginal efficiency coefficient of the chemical fertilizer factor was determined as 0.538, and the calculated value shows that excessive fertilizer is used in paddy production and the amount of pesticide used per unit area should be reduced in order to reach the economic optimum level.

In the study conducted by Kumar and Singh (2019), the elasticity coefficient of the fertilizer factor was determined as -0.092 in the estimation equation prepared for paddy production, and it was found to be statistically insignificant. In the study, the marginal efficiency coefficient of the fertilizer factor was calculated as -1.030, which indicates that the use of fertilizer in paddy production is excessive. In the study conducted with 30 producers in Indonesia by Sahara et al. (2019), the elasticity coefficients of chemical fertilizers in the estimation equation of paddy production were: for urea fertilizer 0.306 (sign. 5%), for phonska fertilizer -0.273 (non sign.), for ZA fertilizer -0.021 (sign. 10%), and for manure 0.073 (non sign.).

In the study conducted by Siagian et al. (2019), none of the 7 different fertilizer types in the paddy production function was found to be statistically significant. In the study, the marginal efficiency coefficient of the chemical fertilizer variable was calculated as 2.83. This value shows that the use of fertilizers in the enterprises examined in the research area is not sufficient and should be increased.

In the study conducted by Purba et al. (2020), the elasticity coefficients and significance levels of chemical fertilizers used in paddy production were found as follows: for nitrogen fertilizer 0.049 – (sign. 10%), for phosporus fertilizer 0.072 – (sign. 5%), and forpotash fertilizer 0.057 – (sign. 10%). In the research conducted with 256 producers in Tanzania by Rashid (2020), the elasticity coefficient of the fertilizer factor was determined as 6 in the estimation equation for paddy production, and it was found to be statistically significant at the level of 10%. The marginal efficiency coefficient of the chemical fertilizer factor used in paddy production was calculated as 6.86, which indicates that the fertilizer factor is used less in paddy production and should be increased.

In the study conducted by Sary et al. (2020), the elasticity coefficient of the chemical fertilizer factor was determined as 0.259 (sign. 1%) for “wet season” and 0.175 for "dry season" (sign. 5%). In the study conducted by Somjai et al. (2020), the elasticity coefficient regarding the amount of chemical fertilizer use in the paddy production estimation equation was calculated as 0.142 and the factor was found to be statistically significant at the level of 5%.

In the study conducted by Subedi et al. (2020), the elasticity coefficient of the chemical fertilizer factor in the estimation equation for paddy production was calculated as 0.30 and was found to be statistically significant at the level of 1%. In the study, the marginal efficiency coefficient of the chemical fertilizer factor was determined as 4.64, which indicates that the level of chemical fertilizer use in paddy production is low and should be increased.

(2021) In the study carried out by Bakri et al., fertilizers used in paddy production and their elasticity coefficients were determined as; for urea fertilizer (0.210), for NPK fertilizer (0.154), for tabas fertilizer (0.303) and for DMA fertilizer (0.089), respectively. The study showed that none of these fertilizer types was statistically significant. The marginal efficiency coefficients of the fertilizers were found as follows: for urea fertilizer (7.67), for NPK fertilizer (6.41), for tabas fertilizer (8.80) and for DMA fertilizer (7.18). The values calculated in the research revealed that the amount of chemical fertilizers used in the unit area in paddy production is used less and the level of use should be increased.

In the study conducted by Ginting and Andari (2021), the chemical fertilizer factor in the estimation equation for paddy production was found to be statistically significant at the level of 10%. In the study conducted by Juliatmaja et al. (2021), the elasticity coefficient and significance level of chemical fertilizers used in paddy production were determined as follows: for urea fertilizer 5.319 – (sign. 1%), for NPK fertilizer 5.480 – (sign. 1%).

In the study conducted by Billah (2022), the elasticity coefficient of the chemical fertilizer cost variable in the paddy production estimation equation was -0.51 and was found to be statistically significant at the level of 10%. In the study conducted with 106 producers in Nigeria by Bulus et al. (2022), the elasticity coefficient of the fertilizer factor in the paddy production estimation equation was -0.875 and was found to be statistically significant at the level of 1%.

In the study conducted in Bangladesh by Hoque et al. (2022), the elasticity coefficient of the fertilizer factor used in paddy production was calculated as 0.260 and was found to be statistically significant at the level of 5%. In the study conducted by Lamani and Thimmaiah (2022), the elasticity coefficient for chemical fertilizer cost in the paddy production estimation equation was calculated as -0.092 and was found to be statistically insignificant. In the study, the marginal efficiency coefficient regarding the cost of chemical fertilizers in paddy production was calculated as -1.03, and this value reveals that there is an excessive use of fertilizers in paddy production and that the amount of chemical fertilizers used per unit area should be reduced in order to reach the economic optimum point.

In the study conducted with 200 producers in Ghana by Adams et al. (2023), the elasticity coefficient of the fertilizer factor was determined as 0.4008 in the estimation equation prepared to determine the efficiency of input use in ~~paddy~~production, and it was found to be statistically significant at the level of 5%. In the research conducted with 337 producers in Nigeria by Adewumi et al. (2023), the elasticity coefficient of the fertilizer factor in the estimation equation for paddy production in enterprises using UDP Technology was 0.099 and was found to be statistically significant at the level of 1%. The elasticity coefficient for the fertilizer factor in the estimation equation for paddy production in enterprises that do not use UDP Technology was 0.196 and was found to be statistically significant at the level of 1%.

In the research conducted by Djafar et al. (2023), the elasticity coefficient of urea fertilizer factor was calculated as 0.042 and the elasticity coefficient of NPK fertilizer was calculated as -0.021. The marginal efficiency coefficient was calculated as 0.05 in urea fertilizer and 0.01 in NPK fertilizer, and both fertilizers are used excessively in paddy production, and the amount of use of both fertilizers needs to be reduced in order to reach the economic optimum. In the study conducted by Elvina et al. (2023) in Indonesia, the elasticity coefficient of the fertilizer factor in paddy production was determined as 0.365 and was found to be statistically significant at the level of 1%.

In the study conducted by Laksono et al. (2023), it was determined that the elasticity coefficient (-0.284) of the fertilizer factor negatively affected paddy production. In the study conducted by Raj et al. (2023), the elasticity coefficient of the fertilizer factor in the paddy production estimation equation was determined as 0.271 and was found to be statistically significant at the level of 1%. In the study, the marginal efficiency coefficient of the fertilizer factor was determined as 0.61 for salt water unaffected farmers and 0.90 for only water affected farmers, and both values indicate that the fertilizer factor is overused in paddy production and should be reduced.

In the study conducted in India by Singh et al. (2023), the effect of input costs on paddy production value in paddy production was analyzed with the help of production function. In the study, the elasticity coefficient of the fertilizer factor was calculated as 0.096 (for tribal) and -0.051 for non-tribal), and both coefficients were not found to be significant at the level of statistical significance. In the research conducted with 43 producers in Indonesia by Susvadi et al. (2023), the efficiency of input use in paddy production was analyzed using the production function. The elasticity coefficient of organic fertilizer in the estimation equation was determined as 0.011, for urea fertilizer 0.008 and for SP36 fertilizer 0.019, and all of the coefficients of the factors were not found to be statistically significant. In the study conducted by Yüzbaşıoğlu and Abacı (2023), the elasticity coefficient of the fertilizer factor was 0.233 and was found to be statistically significant at the level of 5%.

In the study conducted by Bhatt et al. (2024), the elasticity coefficient and significance level of the chemical fertilizer factor in paddy production were calculated as 0.141 for main season rice and were found to be statistically significant at the level of 1%. The coefficient of the same factor is for Spring Rice was 0.081 and was found to be statistically insignificant.

When the results of the research on the subject are examined in the literature, it is revealed that the amount of chemical fertilizer used in paddy production varies between countries as well as within the country in terms of both pure and physical amount. Because the amount of chemical fertilizer needed by agricultural enterprises in paddy production may vary according to the results of soil analysis and the capital allocated by the enterprises for chemical fertilizer. For this reason, when the results of each research are examined and the results obtained are compared, the elasticity coefficient of the chemical fertilizer in the production function and the significance level of this coefficient may differ. Accordingly, the marginal efficiency coefficient of the chemical fertilizer factor may be below "1" in some research results and above "1" in others. The main reason for this is that in parallel with the elasticity coefficients, the sales price of paddy and the factor price of chemical fertilizers differ from country to country.

In the study, the marginal efficiency coefficient of pure nitrogen used in paddy production was calculated as 53.74 TL (9.75 USD), 38.88 TL (7.06 USD) for pure phosphorus and 79.75 TL (14.47 USD) for pure potassium. All calculated values are above the value of 1. When the determined coefficients are taken into account in USD, it shows that the marginal efficiency coefficients of pure nitrogen and potassium fertilizers are higher than all other research findings. However, the coefficient for pure phosphorus calculated in this study (7.06 USD), Suresh and Reddy (2006) is as follows [2.83], for Nimoh et al. (2012) [1.76], Abiola et al (2016) [0.06], forSiagian et al. (2019) [2.83], for Bakri et al. (2021) NPK is higher than the coefficients calculated by fertilizer [6.41]. However, the pure phosphorus coefficient determined as a result of the research was as follows; for Pudaka et al. (2018) [9.54] and for Bakri et al. (2021) (Urea fertilizer [7.67], Tabas fertilizer [8.80], DMA fertilizer [7.18]).

It could be stated that the more the marginal efficiency coefficient for the use of fertilizers in agricultural production is close to the "1" level, the more this factor is used close to the economical optimum level. In this study, when the marginal efficiency coefficients were taken into account and analyzed comparatively with other research findings, it was concluded that none of the pure nitrogen, pure phosphorus and pure potassium fertilizers were used at the economically optimum level in paddy production.

## 5. Conclusion and Recommendations

Paddy is very essential for human nutrition in the world and is one of the most produced agricultural products. Asian countries such as India, China, Bangladesh, and Indonesia are the leading countries in paddy production and export. In Türkiye, since the beginning of the 2000s, paddy cultivation area, production amount and yield have increased continually. However, today, rice production does not meet domestic demand and the supply deficit is tried to be eliminated through imports. For this reason, Türkiye paid 78,893,000 USD for the import of 179,494 tons of paddy in 2020.

According to TSI data for 2022, Çanakkale province, which is determined as a research area, ranks 4th in the country with 12,046 ha in Türkiye's paddy production areas and 97,034 tons in production amount. In this study, research data have been obtained from 74 agricultural enterprises determined by Stratified Sampling Method. In the research, the relationship between pure nitrogen, pure phosphorus and pure potassium fertilizers used in production with the amount of paddy production has been analyzed using the Cobb-Douglas type production function.

In the research conducted, the labor cost of the producers in fertilizer applications in paddy production has been calculated as 5.96 USD $da^{-1}$, the fertilizer cost has been found as 24.98 USD $da^{-1}$, and the fertilizer and fertilization cost has been calculated as 30.94 USD $da^{-1}$. The total of variable costs in paddy production is 208.86 USD $da^{-1}$ and the share of fertilizer cost and total cost of fertilization labor has been determined as 14.81%. The product cost in paddy production is 290.62 USD $da^{-1}$ and the share of fertilizer cost and total cost of fertilization labor is 10.65%. However, the support for the use of fertilizer in paddy applied in the country does not even reach the level of 5% of the fertilizer cost. For this reason, the support for fertilizer use applied in paddy production should be determined in a more rational way by taking into account current conditions.

In the study, the use of fertilizer per unit area in paddy production has been determined as 25.129 kg $da^{-1}$ pure nitrogen, 7.523 kg $da^{-1}$ pure phosphorus and 5.369 kg $da^{-1}$ pure potassium fertilizer. According to these values, the total amount of pure fertilizer use per unit area has been determined as 38.021 kg $da^{-1}$ and the total physical fertilizer usage amount has been found as 112.454 kg $da^{-1}$. In the research, the elasticity coefficients of the fertilizers in the estimation equation created for paddy production; pure nitrogen ($X_1$) has been found to be significant at the probability level of 1% and pure potassium ($X_3$) fertilizer has been found to be significant at the probability level of 5%. It has been concluded that the sum of the production elasticity coefficients of chemical fertilizers in the estimation equation ($\sum\beta_i$ 0.999), which are effective on the amount of paddy production, expresses a constant return to the scale.

The marginal efficiency coefficient of all the variables in the estimation equation has been found to be above "1". However, it has been understood that no fertilizer group is used in an optimal level. Considering the marginal efficiency coefficients calculated as a result of the research, it is necessary to increase the amount of use of all fertilizer groups in order to reach the economically optimum level. In other words, attention should be paid to the effective and rational use of resources.

## 6. References

ABBAS, S.; AHMED, W.; NOOR, R. S.; FATIMA, S.; MISAAL, M. A. The public sector's role towards sustainable agricultural economy and rural development: Techno-economic feasibility analysis of hybrid paddy production. *Journal of Agricultural Sciences, Vol.* 30, No. 1, pp. 131-144. (DOI: 10.15832/ankutbd.1298140). 2024.

ABIOLA, O. A.; SHAMSUDIN, M. N.; RADAM, A.; LATIF, I.A. Resource-use and allocative efficiency of paddy rice production in Mada, Malaysia. *Journal of Economics and Sustainable Development*, Vol.7, No.1, 49-55. 2016.

ADAMS, A.; AMANKWAA, L.A.; JUMPAH, E.T. Technical efficiency and its determinants in rice production: The case of small-scale rice growers in the Ejisu Juaben Municipality of Ghana. *Journal of Planning and Land Management*, Vol. 2, No. 2, pp. 38-49. (DOI:10.36005/jplm. v2i2.48). 2023.

ADEWUMI, M. O.; MURTALA, M.; AJEWOLE, O.C. Economics of rice/ paddy production in Kano and Niger States of Nigeria in the presence of technological heterogeneity. *African Journal of Agricultural Research* Vol. 19, No. 5, pp. 508-515, DOI: 10.5897/AJAR2021.15869. 2023.

ADDISON, M.; YANKYERA, K.O.; ANTOH, E.F. Gender role, input use and technical efficiency among rice farmers at Ahafo Ano North District in Ashanti Region of Ghana. *Journal of Food Security,* Vol. 4, No. 2, p. 27-35. (http://pubs.sciepub.com/jfs/4/2/1). 2016.

AJANI, R.; OLUWEMIMO, O.; ADESIYAN, A. T. Responsiveness of rice production to the use of inputs among smallholder upland rice farmers in Southwest Nigeria. Journal of Sustainable Development in Africa, Vol. 16, No.7, pp.105-117. (http://www.jsd-africa.com/Jsda/Vol16No7-Winter14A/PDF/Responsiveness%20of%20Rice%20Production%20to%20the%20Use%20of%20Inputs.Oluwemimo%20Oluwasola.pdf). 2014.

AJOMA, C.; EZIHE, J.A.; ODOEMENEM, I. Allocative efficiency of rice production in Cross River State, Nigeria: A production function approach. *IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS).* Vol. 9, No. 8 (Ver. II), pp. 32-38. 2016.

ALIPOUR, A.; VEISI, H.; DARIJANI, F.; MIRBAGHERI, B.; BEHBAHANI, A.G. Study and determination of energy consumption to produce conventional rice of the Guilan province. *Res. Agr. Eng.* Vol. 58, No. 3: 99–106. 2012.

AL-MASHADANI, A.K.; ABDULLAH, I.N.; MAHMOOD, Z.H. Estimation of production function of rice in Najaf province for season 2016. *Plant Archives,* Vol. 19, Suppl. 2, pp. 1457-1463. 2019.

AMANULLAH, H. Influence of organic and inorganic nitrogen on grain yield and yield components of hybrid rice in Northwestern Pakistan. *Rice Sci*, Vol. 23, pp. 326–333. 2016.

ANAGNOSTOPOULOS, K. P.; KOTSIKAS, L. Experimental evaluation of simulated annealing algorithms for the time-cost trade-off problem. *Appl. Math. Comput*., Vol. 217, No. 1, pp. 260–270. 2010.

BAKRI, R.; SALAM, M.; DARMA, R.; SAADAH, R.A.A. Efficiency analysis of using production factors in paddy rice farming in Macope Sub-District, Awangpone District, Bone Regency. IOP Conf. Series: Earth and Environmental Science 807 (2021) 032075, IC-FSSAT 2021, IOP Publishing, (doi:10.1088/1755-1315/807/3/032075). 2021.

BEATTIE B.R.; TAYLOR, C.R. The Economics of Production, John Wiley and Sons Inc., New York. USA. 1987.

BHATT, R. ; ADHIKARI, R.K. ; KARKI, R.; KHANAL, S. ; RAJBHANDARI, S. Comparative economics of main season and spring rice production in Kanchanpur district, Nepal. *Cognizance Journal of Multidisciplinary Studies*, Vol.4, No. 1, pp. 339-349. 2024.

BHUJEL, R.B.; GHIMIRE, S.P. Estimation of production function of hiunde (boro) rice. *Nepal Agric. Res. J.*, Vol. 7, pp.88-97. 2006.

BILLAH, A. Measurement of technical efficiency of paddy farms at Jhenaidah district in Bangladesh: A case study by Using Cobb Douglas production function. *J Pharm Negative Results*, Vol.13. pp.652-658. (DOI:10.47750/pnr.2022.13.04.087). 2022.

BULUS, G.; TIKON, F. U.; SANGARI, H. I. Resource use efficiency in rain-fed paddy rice production: A case study of Donga Local Government Area Of Taraba State, Nigeria. *Journal of Agripreneurship and Sustainable Development (JASD)*, Vol. 5, No. 4, pp.1-9. 2022.

CGIAR, 2017. Ricepedia, where is rice grown? (http://ricepedia.org/rice-as-a-crop/where-is-rice-grown). 2017.

CRAMB, R. White Gold: The commercialisation of rice farming in the Lower Mekong Basin. Palgrave Macmillan. Springer Nature Singapore, 2020. 456 p. (https://doi.org/10.1007/978-981-15-0998-8). 2020.

ÇELİK, Y.; BAYRAMOĞLU, Z. Şanlıurfa ili Harran Ovasında pamuk üretiminin fonksiyonel analizi. *Selçuk Üniversitesi Ziraat Fakültesi Dergisi*, Vol. 21, No: 41, pp. 42-50. 2007.

DEBERTIN, L.D. Agricultural Production Economics. (2. Baskı.). Pearson Education. Upper Saddle River, N.J., 427 s.USA. 2012.

DEY, S.; ABBHISHEK, K.; SWAIN, D.K. Resource use efficiency estimation and technology verification trial for sustainable improvement in paddy production: An action‑based research. *International Journal of Plant Production*, Vol. 17, No. 2, pp.337–352. (https://doi.org/10.1007/s42106-023-00243-6. ). 2023.

DJAFAR, C.; RAUF, A.; MUSTAFA, R. Analisis pendapatan dan optimalisasi penggunaan faktor produksi usahatani padi sawah di gapoktan tio olami desa bongoime kecamatan tilongkabila kabupaten Bone Bolango. *Jurnal Agribisnis dan Ilmu Sosial Ekonomi Pertanian,* Vol. 8, No. 6, pp. 497-506. 2023

DOLL J.P.; ORAZEM, F. Production Economics Theory with Applications, John Wiley and Sons Inc., New York. USA. 1984.

ELVINA, T.S.; SIREGAR, A.; GINTING, R. Analysis of factors influencing rice production in Labuhan Batu district. *Journal of Social Research*, Vol. 9, No. 2, pp. 3305-3316. 2023.

ERKAN, O.; ÇIÇEK, A. Tarım Ekonomisinde Araştırma ve Örnekleme Yöntemleri. GOP ün. Ziraat Fak. Yay. No:6, Tokat. Türkiye.1996.

FAO, 2022. Birleşmiş Milletler Gıda ve Tarım Örgütü. FAOSTAT. (http://www.fao.org/faostat/en/#data) .2022.

FATTAH, M. A.; ARIFIN.; MARDIYATI, S.; NATSIR, M.; MUSLIMIN. Efficiency, risk, and profitability of rainfed rice farming in South Sulawesi, Indonesia. *Journal of Socioeconomics and Development*, Vol. 6, No. 2, pp. 149-160. (https://doi.org/10.31328/jsed.v6i2.4775). 2023.

GAYTANCIOILU O., SÜREK H. Input use and production cost in rice cultivation in Turkey. In: Chataigner J. (ed.). *Research strategies for rice development in transition economies.* Montpellier: CIHEAM, pp. 95-104 (Cahiers Options Méditerranéennes; n. 50). (https://www.fao.org/3/X7164T/x7164t06.htm#TopOfPage). 2001.

GINTING, M.N.; ANDARI, G. Factors affecting rice production. WEAST 2020 IOP Publishing Journal of Physics: Conference Series 1899 (2021) 012068. (doi:10.1088/1742-6596/1899/1/012068). 2021.

GUJARATI, D.N.; PORTER, D. Temel Ekonometri. Literatür Yayıncılık. (5. Basımdan Çeviri). p. 915, Istanbul. Türkiye. 2014.

GÖZENER, B. Functional analysis of paddy farming and paddy farming cost. *Custos e @gronegócio on line, Vol.* 11, No. 4, pp.154-166. 2016.

HEADY, O.E.; DILLON, J.L. Agricultural Production Functions. Iowa State University Press, USA. 1966

HILL J.E. Rice production in California. Cooperative Extension, University of California, Division of Agriculture and Natural Resources Publication. 1992.

HILE, R.B.; DAREKAR, A.S.; DATTARKAR, S.B. Economic analysis and impact assessment of production technology of paddy of Konkan Region in Maharashtra. *International Journal of Commerce and Business Management*, Vol. 8, No. 2, pp. 143-152. 2015.

HILE, R. B.; SANAP, D. J.; YADAV, D. B. Impact assessment of production technology of paddy in Maharashtra. *Journal of Crop and Weed, Vol.* 12, No. 3, pp. 36-40. 2016.

HOQUE, F.; JOYA, T.A.; AKTER, A.; ANNY, S.A.; KHATUN, M.; RUNGSURIYAWIBOON, S. Profit efficiency and technology adoption of boro rice production in Bangladesh. *Iranian Economic Review*, Vol. 26, No. 3, pp. 511-524. 2022.

IDA, F.C.; AZHAR, M. Efficiency analysis of production factors of wetland paddy farming in West Aceh Regency. *Russian Journal of Agricultural and Socio-Economic Sciences,* Vol. 9, No. 81, pp. 424 - 428. 2018.

JAYAPRADA, Y.; PRASANNA, P.A.L.; LAVANYA, T.; RATHOD, S. A comparative economic analysis of seed and grain production of paddy in Karimnagar district of Telangana state. *International Journal of Statistics and Applied Mathematics*, Vol. SP-8, No. 6, pp.835-843. 2023.

JULIATMAJA, A.W.; NURSALAM, HELVIANI. Factors affecting paddy rice production in Tanggetada district Kolaka Regency. *Agribusiness Journal*, Vol. 4, No.2, pp. 57-63. 2021.

KADIRI, F. A.; EZE, C. C.; OREBIYI, J. S.; HENRI–UKOHA A. Economic analysis of paddy rice production in Niger Delta Region of Nigeria. *Asian Journal of Agriculture and Rural Development*. Vol. 4, No: 12, pp. 541-550. 2014.

KANNAKI, S.; LOUIS, L.M. Technical efficiency and its determinants in paddy production in Thiruvarur district, the Southernmost Tip of Tamil Nadu, using Cobb –Douglas stochastic production frontier analysis (cdspfa). *Proceedings of National Conference on Mathematical Modelling NCMM, July 14th 2017, Tamil Nadu, India.* pp. 9-16. 2017.

KANTHILANKA, H.; WEERAHEWA, J. Resource-use pattern in paddy cultivation in Sri Lanka: A production function approach, In: Proceedings of the 5th International Conference of Sri Lanka Forum of University Economists, 22-23 December 2016, Department of Economics Faculty of Social Sciences University of Kelaniya, Sri Lanka, 11-16 pp. 2016.

KAKA, Y.; SHAMSUDIN, M.N.; RADAM, A.; LATIF, I.A. Profit efficiency among paddy farmers: A Cobb-Douglas stochastic frontier production function analysis. *Journal of Asian Scientific Research*, Vol. 6, No. 4, pp. 66-75. 2016.

KARAGOLGE, C. Arazi tasarruf şekillerine göre erzurum ilindeki tarım işletmelerinin ekonometrik analizi. Ankara Ün. Yay. No:312. Zir. Fak. Yay. No:153, Arş. Seri No:90, Sevinç Matb., Ankara, s.8-24. 1973.

KASHEM, M.A.; SINGH, B.R. The effect of fertilizer additions on the solubility and plant-availability of Cd, Ni and Zn in soil. *Nutrient Cycling in Agroecosystems*, Vol. 62, pp. 287–296. 2002.

KAYA, M.B. Toprak gübrelemede organik madde, fosfor ve potasyum parametre kontrol sistemlerinin bulanık mantık ile tasarımı ve modellenmesi (*Designing and modelling the organic matter, phosphorus and potassium parameter control systems by fuzzy logic for fertilizing the soil*). Süleyman Demiral Üniversitesi, Fen Bilimleri Enstitüsü, Endüstri Mühendisliği Ana Bilim Dalı, Yüksek Lisans Tezi, 63 s., Isparta. Türkiye. 2010.

KUMAR, M. P. V.; SINGH, N. An Economic Analysis of Paddy Production in Raichur District, Karnataka, India. *International Journal of Current Microbiology and Applied Sciences*, Special Issue-9, pp. 183-193. 2019.

KUMAR, N.; KUSHWAHA, R.R.; MEENA, N.R.; MISHRA, H.; YADAV, A.P.S. A study on costs and returns of paddy cultivation in Ambedkar Nagar district of Uttar Pradesh. *International Journal of Statistics and Applied Mathematics*, SP-Vol. 8, No.3, pp. 107-111. 2023.

LAKSONO, B.J.; ULIYA; DEWI, R. Factor analysis of pad rice input production in Pematang Pulai Village, Sekernan Muaro District, Jambi District. *International Journal of Scientific Multidisciplinary Research,* Vol. *1, No:* 4, pp. 353–360. (https://doi.org/10.55927/ijsmr.v1i4.4367). 2023.

LAMANI, C.; THIMMAIAH, T.D. An economic analysis of paddy production: Special reference to Karnataka. *Shodha Prabha (UGC CARE Journal)*, Vol. 47, No. 2. pp. 1-11. 2022.

LONG, L. Q.; THOI, P.V.; OANH, N.K.; TUONG. D. M. Study on economic efficiency in rice production of Cuu Long Delta. *Omonrice*, Vol. 19, pp. 250-260. 2013.

MAURYA, K.; KUSHWAHA, R.R.; RAI, J.; GAUTAM, N.K.; RANJAN, A.K.; RAJBHAR, A.K. Resource use efficiency on paddy farms in Mau district of eastern Uttar Pradesh. *Journal of Pharmacognosy and Phytochemistry*, Vol. 7, No. 4, pp. 684-687. 2018

MAZID, A.; KESER, M.; AMEGBETO, K. N.; MORGOUNOV, A.; BAGCI, A.; PEKER, K.; AKIN, M.; KUCUKCONGAR, M.; KAN, M.; SEMERCI, A.; KARABAK, S.; ALTIKAT, A.; YAKTUBAY, S. Measuring the impact of agricultural research: The case of new wheat varieties in Turkey. *Experimental Agriculture*, Vol. 51, No. 2, pp. 161-178. 2015.

MILLER, E. An assessment of CES and Cobb-Douglas production functions, Working paper, 2008-05, Congressional Budget Office (CBO), Washington D.C. 32 p. 2008.

MISHRA, S.K.; SINGH, R.A.; SINGH, R.; SINGH, S.P.; SINGH, N.V.; SHARMA, M. Cost of cultivation of paddy in Pratapgarh district of Uttar Pradesh. *Journal of Pharmacognosy and Phytochemistry*, Vol. Sp 9, No. 4, pp. 42-44. 2020.

MOBTAKER, H.G.; KEYHANI, A.; MOHAMMADI, A.; RAFIEE, S.; AKRAM, A. 2010. Sensitivity analysis of energy inputs for barley production in Hamedan Province of Iran. *Agric Ecosyst Environ*, Vol. 137, No. 3-4, pp. 367- 372. 2010.

MURAYAMA, N. The importance of nitrogen for rice production. In Nitrogen and Rice. Rice Res. Inst., Los Banos, Philippines. 1979.

NEILL, R.J. Production and production functions: some ımplications of a refinement to process analysis. *Journal of Economic Behaviour & Organization*, Vol. 51, No. 4, pp. 507-521. 2002.

NIMOH, F.; THAM-AGYEKUM, E.K.; NYARKO, P.K. Resource use efficiency in rice production: The case of Kpong Irrigation Project in the Dangme West District of Ghana. *International Journal of Agriculture and Forestry*, Vol. 2, No. 1, pp. 35-40. 2012.

NODIN, M.N.; MUSTAFA, Z.; HUSSAIN, S. I. Assessing rice production efficiency for food security policy planning in Malaysia: A non-parametric bootstrap data envelopment analysis approach. *Food Policy*, 107 (2022) 102208, (https://doi.org/10.1016/j.foodpol.2021.102208). 2022.

OBIEKWE, N. ; UCHE, O.; CHIEKEZIE N. R.; OZOR M. U. Profitability and Determinants of Output of Rice Production in Anambra State, Nigeria, *Global Journal of Agricultural Research*, Vol. 12, No: 1, pp. 51-63. (https://doi.org/10.37745/gjar.2013/vol12n15163). 2024.

OGBC, A. O.; DIPCOLU, A. O.; OBAYCLU, A.E.; PORBCNI, J.B.O.; EDEWOR, S. E.; OGBC O.C.; TOLORUNJU, E.T.; OLADCJI, S.O. Technology gap and technical efficiency of rice production ecologies in South Eastern Nigeria. Conference Proceedings of The 18th Annual National Conference of The Nigerian Association of Agricultural Economists Held At Federal University of Agriculture, Abeokuta, Nigeria 16 th -19th October. 2017. pp.808-814. 2017.

ONHO, T.; ERICH, M. S. Effect of wood ash application on soil ph and soil test nutrient levels. *Agriculture, Ecosystems and Environment, Vol.* 32, No. 3-4, pp.223-239. 1990.

ÖZÇELİK, A. Ankara şeker fabrikası civarındaki şekerpancarı yetiştiren tarım işletmelerinde şekerpancarı ile buğday için fiziki üretim girdileri ve üretimin fonksiyonel analizi. A.Ü. Zir. Fak. Yay. No:1113, Ankara, Turkey.1989.

ÖZÇELİK, A. Ekonometri. A.Ü. Ziraat Fak. Yay. No:1323, Ders Kitabı No:382, s.148-156, Ankara. Türkiye. 1994.

PUDAKA, D.L.; RUSDARTI, P.; PRASETYO, E. Efficency analysis of rice production and farmers' income in Sengah Temila District Landak Regency. *Journal of Economic Education*, Vol. 7, No. 1, pp. 31 – 38. 2018.

RAFIEE, S.; MOUSAVI AVVAL, S. H.; MOHAMMADI, A. Modeling and sensitivity analysis of energy inputs for apple production in Iran. *Energy*, Vol. 35, No. 8, pp. 3301- 3306. 2010.

RAGASA, C.; DANKYI, A.; ACHEAMPONG, P.; WIREDU, A. N.; CHAPOTO, A.; ASAMOAH, M.; TRIPP, R. Adoption of improved rice technologies in Ghana. Ghana Strategy Programme, Working Paper No. 35, IFPRI. 2013.

RAJ, N. K.; LAZARUS, T.P.; VIJAYAN, A.; DURGA, A. R.; APARNA, B.; JOSEPH, B. Resource use efficiency in paddy production in the salinity affected and the unaffected areas of Alappuzha district in Kerala: An economic analysis. *Asian J. Agric. Ext. Econ. Soc.*, Vol. 41, No. 12, pp. 137-146. 2023

RASHID, F.N. Is increasing input-use for rice production a profitable proposition in Tanzania? *Review of Agricultural and Applied Economics*, Vol. 23, No. 2, pp. 54-63. (doi: 10.15414/raae.2020.23.02.54-63). 2020.

RAO, K.V.R.; GANGWAR, S.; BAJPAI, A.; CHOURASIA, L.; SONI, K. Energy assessment of rice under conventional and drip irrigation systems. In: Singh, V., Yadav, S., Yadava, R. (eds) Water Resources Management. Water Science and Technology Library, vol 78. Springer, Singapore. (https://doi.org/10.1007/978-981-10-5711-3_2). 2018.

REDDY, E. L.; REDDY, R. A Study on resource use efficiency of input factors with reference to farm size in paddy cultivation in Nellore District. *IOSR Journal Of Humanities And Social Science (IOSR-JHSS),* Vol. 17, No. 1, pp. 48-55. 2013.

REHBER, E.; ERKUŞ, A. Nevşehir'de patates üreten tarım işletmelerinin ekonomik analizi. Ankara Üniversitesi, No. TE.1, Ankara. Türkiye. 1984.

RIYAN, A. S.; MUSLICH, M. M.; SUHARTINI, S.; WEN-I, C. Analysis of inputs use in rice farm management at Sekotong, West Lombok, Indonesia. *Greener Journal of Business and Management Studies*, Vol. 4, No. 4, pp. 108-114. 2014.

SAEPUDIN, T.; AMELIA, A. Analysis of rice production approach to Cobb Douglas production function in Tambakdahan Sub-District Subang District, *Agricultural Socio-Economics Journal,* Vol. 22, No. 2, pp.121-127 (DOI:http://dx.doi.org/10.21776/ub.agrise.2022.022.2.6). 2022.

SAHARA, D.; KUSHARTANTI, E.; WINARTO, B. Profitability and efficiency of production inputs on rice farming at Karanganyar, Central Java-Indonesia. *Eurasian Journal of Agricultural Research*, Vol. 3, Issue, 1, p.24 – 35. 2019.

SANI, A.; YAKUBU, A.A.; BELLO, H.M. Resource-use efficiency in rice production under small scale ırrigation in Bunkure Local Government Area of Kano State. *Nigerian Journal of Basic and Applied Science,* Vol. 18, No: 2, pp.292-296. 2010.

SARY, S.; SHIWEI, X.; WEN, Y.; DARITH, S.; SAREN, S.; CHAND, N. V. Factors influencing the rice production of farmers in rural South-Eastern Cambodia. *Agrociencia,* Vol. 54, No. 1, pp. 78-95. 2020.

SEMERCİ, A. Trakya'da tarımsal yapı ve başlıca ürünlerde verimlilik analizleri. Trakya Üniversitesi Fen Bil. Enst. Tarım Ekonomisi Anabilim Dalı. 249 s. Edirne. Türkiye. 1998.

SEMERCİ, A. Determining the resource use efficiency in wheat (*Triticum aestivum L.*) production: A case study of Edirne province–Turkey. *Bulgarian Journal of Agricultural Science*, Vol. *19, No.* 2, pp. 314-324. 2013.

SEMERCİ, A. Productivity analysis of sunflower cultivations in Turkey. *Bulg. J. Agric. Sci*, Vol. 18, No. 6, pp. 873-882. 2012.

SEZER, İ. Effects of different fertilizer sources and weed control practices on plant growth, yield and quality in organic paddy farming in Kızılırmak Delta. TÜBİTAK Project No: 113O915. 747 p. Ankara. Türkiye.

(https://search.trdizin.gov.tr/tr/yayin/detay/618067/kizilirmak-deltasinda-farkli-gubre-kaynaklari-ve-yabanci-ot-kontrolunun-organik-celtikte-bitki-gelismesi-verim-ve-kalite-uzerine-etkileri. 09.02.2024). 2017.

SHANTHA, A. A.; ASAN ALI, B.G.H.; BANDARA, R.A.G. Efficiency and managerial ability of paddy farming under minor irrigation conditions: A Frontior Production Function approach. The Journal of Agricultural Sciences, Vol. 7, No. 3, pp.145-158. 2012.

SHENDE, N. V. ; BAGDE, N. T. Economic consequences of pesticides use in paddy cultivation. *American International Journal of Research in Humanities, Arts and Social Sciences*, Vol. 4, No. 1, pp. 25-33. 2013.

SIAGIAN, V.; SIREGAR, H.; FARIYANTI, A.; NAINGGOLAN, K. Analysis of factors that influence the production of wetland rice in Banten Province. IOP Conf. Series: Earth and Environmental Science 399. (https://doi.org/10.1088/1755-1315/399/1/012073) Bogor. Indonesia. 2019.

SIKDAR, M.M.H.; ALAM, M.A.; HOSSAIN, M.I. Factors affecting the technical efficiency of Boro rice production in Bangladesh a Cobb-Douglas stochastic frontier analysis. *J. Bangladesh Agril. Univ.*, Vol. 6, No. 1, pp. 215-226. 2018.

SINGH, G.; SINGH, S.; SINGH, J. Optimization of energy inputs for wheat crop in Punjab. *Energy Conversion and Management*, Vol. 45, No. 3, pp. 453-465. 2004.

SINGH, S.; GAURAHA, A.K.; CHAUDHARY, V.K.; PATHAK, H. Assessing resource use efficiency of paddy crop in tribal and non-tribal farm households: A case study of Chhattisgarh. *The Pharma Innovation Journal, Vol.*12, Issue 6, pp. 496-499. 2023.

SINHA, J.K. Economies of the factors affecting crop production in India: Analysis based on Cobb-Douglas Production Function. *Sumerianz Journal of Economics and Finance*, Vol. 6, No. 1, pp. 10-18. 2023.

SOMJAI, S.; CHANKOSON, T.; JERMSITTIPARSERT, K. 2020. An economic analysis of agricultural production function on the paddy fields of Thailand. *Entrepreneurship and Sustainability Issues, Vol.* 7, No. 3, pp. 2012-2025. 2020.

SONAWANE, K.G.; NIRGUDE, R.R.; KADAM, S.A. Impact assessment of paddy production technology on farm income and productivity. *Trends in Biosciences. Vol.* 10, No. 29, pp. 6111-6118. 2017.

SUBEDI, S.; GHIMIRE, Y.N.; KHAREL, M.; SHARMA, B.; SHRESTHA, J.; SAPKOTA, B.K. Profitability and resource use efficiency of rice production in Jhapa district of Nepal. *Int. J. Soc. Sc. Manage.* Vol. 7, Issue-4: 242-247. ( DOI: 10.3126/ijssm.v7i4.32487). 2020.

SURESH, A.; KESHAVA REDDY, T.R. Resource-use efficiency of paddy cultivation in Peechi Command Area of Thrissur District of Kerala: An economic analysis. *Agricultural Economics Research Review, Vol.* 19 (January-June), pp. 159-171. 2006.

SUSWADI; AGUNG PRASETYO; MAHANANTO; ASTRIYANINGSIH. The efficiency of use of production factors for rice through mechanization in Sukoharjo. International

Conference on Food Science and Engineering 2022 International Conference on Food Science and Engineering 2022. IOP Conf. Series: Earth and Environmental Science IOP Conf. Series: Earth and Environmental Science 1200 1200 (2023) 012037 (2023) 012037 IOP Publishing IOP Publishing doi:10.1088/1755-1315/1200/1/012037. 2023.

SÜREK, H. Çeltik Gübrelemesi, Trakya Tarımsal Araştırma Enstitüsü, Edirne. Türkiye. 2015.

SÜREK, H.; BEŞER, N.; NEĞİŞ, M.; KUŞKU, H. Bölgemizde ekonomik bir çeltik tarımı için yerine getirilmesi gerekli şartlar. *Marmara'da Tarım*, Vol. 68 ss. 43-45. 1998.

TARU, V. B.; KYAGYA, I. Z.; MSHELIA, S. I.; ADEBAYO, E. F. Economic efficiency of resource use in groundnut production in Adamawa State of Nigeria. *World Journal of Agricultural Sciences*, Vol. 4, No. 5, pp. 896-900. 2008.

TCMB, 2024. Indicative Exchange Rates Announced at 15:30 on 12/28/2018 by the Central Bank of Turkey. Bulletin No: 2018/248. (https://www.tcmb.gov.tr/wps/wcm/connect/EN/TCMB+EN/Main+Menu/Statistics/Exchange+Rates/Indicative+Exchange+Rates). 2024.

VURAL, H.; TURHAN, Ş. Bursa İlinde şeftali üretiminin ekonometrik analizi. *U. Ü. Zir. Fak. Derg.*, Vol. 25, No. 2, pp.1-6. 2011.

WANG, Z.; ZHENG, H.; LUO, Y.; DENG, X.; HERBERT, S.; XING, B. Characterization and influence of biochars on nitrous oxide emission from agricultural soil. *Environmental Pollution*, Vol. 174, pp. 289–296. 2013.

YAMANE, T. Elementary Sampling Theory. Englewood Cliffs, New Jersey: Prentice- Hall, Inc., 405 pp. USA. 1967.

YILMAZ, S.; YURDAKUL, O. İkinci ürün tarımının Aşağı Ceyhan Ovası'ndaki işletmelerin faaliyetleri üzerine etkileri. *Çukurova Ün. Zir. Fak. Derg*, Vol. 15, No. 1, pp. 39-48. 2000.

YUAN, S.; PENG, S. Input-output energy analysis of rice production in different crop management practices in central China. *Energy*, 141 (2017) 1124e1132 (https://doi.org/10.1016/j.energy.2017.10.007). 2017.

YUMNAM, A.; KUMAR, A.; CHAUHAN, S.K. Comparative economics of rice cultivation in Himachal Pradesh and Manipur States of India. *Indian Journal of Hill Farming*, Vol. 30, No. 2, pp. 227-232. 2016.

YUSUF, R.; FUADI, I.; SWASTIKA, N.S.; SINAGA, P.H. The Study of economic factors affecting sustainability of rice farming. *Advances in Biological Sciences Research. (*Proceedings of the International Seminar on Promoting Local Resources for Sustainable Agriculture and Development (ISPLRSAD 2020). Vol. 13, pp.533-540. 2020.

YUZBASIOGLU, R.; ABACI, N.I. Paddy rice production costs and factors affecting paddy rice productivity: Case study in Sinop Province, Turkey. *Custos e* @gronegócio *on line,* Vol. 19, No. 1, p. 147-162. 2023.

ZHANG, F.; TAN, Q.; ZHANG, C.; GUO, S.; GUO, P. A regional water optimal allocation model based on the Cobb-Douglas production function under multiple uncertainties. *Water*, Vol. *9, No.*12, 923. (https://doi.org/10.3390/w9120923). 2017.

ZORAL, K. Cobb-Douglas üretim fonksiyonunun Yukarı Pasinler Ovası'ndaki patates üretimine uygulanması. Atatürk Ün. Yay. No:303, Sevinç Matbaası, p. 102. Ankara. Türkiye. 1973.

ZORAL, K. Üretim Fonksiyonları. Dokuz Eylül Ün. Müh. -Mim. Fak. Yay. (MM/END-84 EY 052), İzmir. Türkiye. 1984.