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Food Security of Farmers' Households in Watersheds (Case of the Keduang Watershed, Wonogiri Regency, Indonesia)

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***Abstract*— Deforestation around the watershed causes erosion and sedimentation, decreasing land productivity. Climate change causes an increase in the frequency and intensity of drought and plant-disturbing organisms, causing low agricultural production. This issue then affects the socio-economic conditions of the farmer's household due to low income and consumption. This study aimed to determine the proportion of food expenditure, analyze the energy consumption level, and the food security level of farmer households. The location was determined by purposive sampling, a proportional technique with a sample of 344 farmer households. The data analysis method used income and expenditure analysis, food expenditure share, food consumption, and food security analysis. The results showed that the proportion of food expenditure for farmer households was 58.75%, that were categorized as food security. The energy consumption level of 1833.37 kcal / person/day is classified as moderate. The level of food security showed that 39.83% were classified as food secure, 29.65% as food vulnerable, 14.83% as lack of food, and 15.70% as food insecure. Based on these results, to improve food security at the level of food insecurity and lack of food, efforts are made to increase the cropping index by drilling wells or ponds, government support for agricultural production facilities, and strict regulations regarding the conversion of agricultural land. In food vulnerable, farmer households must apply through the promotion of activities that generate non-agricultural income. To maintain food security, made to diversify food to meet ideal nutrition.**

***Keywords*— Food security; energy consumption level; farmers.**

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I. INTRODUCTION

Food security is where food fulfillment for the country with individuals in terms of quantity, quality, safety, variety, nutrition, equity, and affordability does not conflict with religion, belief, or community culture. The components of food security include food availability, food access, utilization, and food stability. The first dimension is that food availability is determined by production and distribution [1]. The second dimension, food access, refers to food affordability and allocation. The inability to access food is caused by land inaccessibility for food production and poverty [2], [3] which is influenced by the gender of the head of the household, the low level of education, and the location of the household that is being in a rural area [4]. The third dimension is food utilization, which refers to food security and access to health facilities. The fourth dimension is food stability, or the ability to occasionally obtain food that can be disrupted due to drought and decreased food availability [1].

Food security can be seen from its level, whether global, national, or household food security [5]. Household food security can indicate regional food security. However, countries with guaranteed food security only sometimes reflect household food security [6]. Food security is a complex and multidimensional phenomenon. Some of the causes of food insecurity include age, gender, education, remittances, unemployment, inflation, assets, disease [7], climate and weather changes [8], and lack of alternative sources of income [1].

The Keduang watershed is part of the Wonogiri Regency, Indonesia. Deforestation around the watershed is caused by population growth, increasing demand for food, building wood, and animal feed. Deforestation resulting in erosion will impact land productivity, decreasing farmers' income and critical land. Apart from impacting decreasing land productivity due to reduced organic matter, erosion also results in the accumulation of material (sediments), which results in the siltation of rivers and reservoirs [9]. The Keduang Watershed contributed 1,218,580 m^3 or about 38

percent of the total 3,178,510 m^3 of sediment which came into the Gajah Mungkur reservoir in Wonogiri, where the Keduang watershed was the largest sediment contributor [10]. The source of sedimentation comes from soil surface erosion, tree cutting in the catchment area, and damage to the watershed, which is tidal land. Erosion of paddy fields, yards, and settlements also supply sedimentation to the reservoir [11]. Sedimentation is seen in the dry season when the water discharge decreases. The catchment area in the dry season turns into land used for corn or soybean cultivation [12].

The topography of the Keduang watershed is a limestone hill area and dry agricultural land. The area of the Keduang Watershed is 39,736.29 ha, with the conversion of non-agricultural land (settlements and others) of around 2.1 ha per year [13]. The farmers' problems in watershed areas are land conversion from agriculture to non-agriculture, a lack of watering, and climate change, which causes a decrease in the frequency and intensity of agricultural production and plant-disturbing organisms. This condition affects the socio-economic of farmer households because it affects food production, which will affect food availability, income and expenditure, and food consumption of farmer households.

Farmers in the Keduang watershed are food crop farmers. Cultivated crops are rice, corn, soybeans, and cassava. In the downstream and middle areas, farmers can only plant rice during two growing seasons, in the rainy season (October - January, February - May). Meanwhile, paddy fields cannot be planted during the dry season (June - September) due to a lack of water, and most are rainfed. Farmers can plant paddy three times a year in the upstream areas due to water sufficiency.

Previous research mentioned several effects of drought, such as decreased food production, crop failure, and a lack of food supply, thereby increasing food prices and directly affecting people experiencing poverty [8], [14]. The effects of drought pose a severe threat, harm, and affect people's food security. Therefore, collaboration from stakeholders is needed to ensure food security for farmers [8].

One indicator to measure household food security is to calculate household food expenditure. The greater the food expenditure, the lower the food security. Whereas [15] created different standards in classifying food security, that is, based on a combination of calorie availability and food expenditure.

This study used indicators of share of food expenditure and calorie adequacy. The greater the income spent on food, the more vulnerable the household is to food. For households in the lowest expenditure quintile, nearly 60 percent of total expenditure is used for food, compared to only 40 percent for households in the highest quintile. Calorie availability is measured by calculating food intake based on the recommended level of energy adequacy by comparing household consumption [16].

Many previous researchers have studied the food security of farmer households, such as the effect of climate change on the food security of farmers [17], [18], household food security of farmers in dry land [19], the impact of commercial crop production (tobacco, cotton, sunflower) on the food security of farmer households [20]. However, this research focused on farmer households in watershed areas, where farmers could only plant paddy for two growing seasons due to rainfed rice fields' lack of water. This study aimed to determine the proportion of food expenditure, analyze the energy and protein consumption level, and the level of food security of farmer households.

II. Materials and Method

A. The Research Area

This study was conducted in the Keduang watershed, Wonogiri, Indonesia, using purposive sampling with specific criteria. Figure 1 shows that the Keduang watershed flows through 12 sub-districts in Wonogiri Regency. The upstream area includes Girimarto, Jatipurno, Slogohimo, Bulukerto, Kismantoro, Tirtomoyo, and Purwantoro. The middle area includes Ngadirojo, Jatisrono, Jatiroto, and the downstream area includes Sidoharjo and Nguntoronadi.

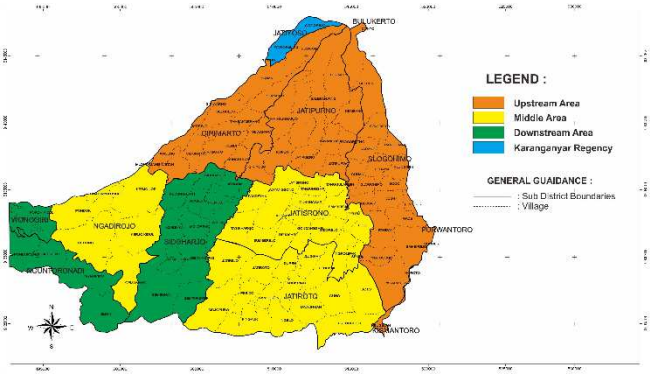

Fig. 1 Map of the Keduang Watershed Area

The category of the research locations was upstream, middle, and downstream areas, where the sub-districts selected are areas that have the most significant percentage flowed by the Keduang watershed. In this study, the upstream area was represented by Jatipurno, Jatisrono represented the middle area, and Sidoharjo represented the downstream area.

B. Sampling Design and Data Collection

The population in this study were farmers who cultivated food crops in the Keduang watershed, Wonogiri Regency, Indonesia. The farmer sampling method used a purposive sampling technique. The total number of farmers in Jatipurno, Jatisrono, and Sidoharjo is 23,019 people (The regent's decree No 334/2017 Wonogiri Regency). Based on the sample size determination table developed by Isaac and Michael at an error level of 5%, 344 samples were obtained [21]. The samples were taken by proportional sampling, consisting of 82 Jatipurno farmers, 154 Jatisrono farmers, and 108 Sidoharjo farmers.

C. Data Analysis

Farmer's income is the sum of on-farm and non-farm income. On-farm income is obtained from people who farm on paddy fields and dry land. On-farm income consists of income from paddy, corn, cassava, and soybeans. Non-farm income is income earned outside the agricultural sector. Farmer household expenditure is food (consisting of grains, tubers, fish, meat, vegetables, nuts, oil and fat, cigarettes, etc.) and non-food (consisting of housing, goods and services, education, tax, social needs and so on). The Proportion of Food Expenditure (PFE) calculation was analyzed by calculating the total food and non-food expenditures.

$$PFE = \frac{FE}{TE} x\ 100\% \quad (1)$$

PFE = proportion of food expenditure (%)
FE = Food expenditure (IDR/month)
TE = Total expenditure (IDR/month)

The Nutrition Consumption Level (TKG) is calculated by combining the total nutrients consisting of energy and protein consumed by household members for 24 hours using the following method.

$$TKG = \frac{C}{AKG} x\ 100\% \quad (2)$$

C = consumption intake: energy (kcal), protein (grams)
AKG = Indonesian Nutrition Adequacy Standard by gender and age.

The level of household nutritional intake was classified into four groups:

- Good: TKG 100% AKG
- Moderate: TKG 80 – 99% AKG
- Low: TKG 70 – 80% AKG
- Deficit: TKG < 70% AKG

Food security category of farmer households adopted from Maxwell [16]:

- Food security: >80% energy adequacy and food expenditure portion <60% total expenditure
- Food vulnerability: >80% energy adequacy and food expenditure portion >60% of total expenditure
- Lack of food: <80% energy adequacy and food expenditure portion <60% of total expenditure
- Food Insecurity: energy adequacy <80% and food expenditure portion > 60% of total expenditure.

III. Results and Discussion

Farmer household income combines on-farm and non-farm activities. Based on Table I, on-farm income is lower than non-farm income. On-farm income is derived from rice, corn, soybeans or cassava. Paddy cultivation can only be carried out twice a year in the downstream and middle areas. This phenomenon is due to a lack of water, and most of the paddy fields are rainfed, so during the dry season, they choose crops resistant to drought. The cropping pattern is paddy–unplanted or paddy-corn/soybean/cassava. Farmers prefer drought-resistant paddy varieties such *as Ciherang, Sunggal, Inpari* and *Slegreng*. This is similar to what farmers do in Bangladesh, where they select paddy varieties depending on the season [22]. In the upstream area, farmers plant paddy three times a year. The average rice production per planting season is 1,997.07 kg, so farmers have an income of around IDR 1,224,487.42 monthly. The average income from other cultivation is around IDR 133,541.67 per month.

Non-farm income is obtained from income outside the agricultural sector, such as trade, construction labor, transportation services, and others. Viewed from the amount of income in Table I, it is known that non-farm income is IDR 1,911,051.33, so the total income of farmer households is IDR 3,269,080.42. Non-farm income contributes more than on-farm income. Farmer households with non-farm income have better access, utilization, and food stability [23]. The causes of low on-farm income are the small amount of agricultural land, lack of water, high input costs of farming, and climate change affecting agricultural products. Each farmer owns about 2534m^2 due to the conversion of agricultural land. The area of agricultural land will determine food availability [24], [25]. Strict rules from the government are needed to reduce the conversion of agricultural land. This aligns with [26] research, which confirms that extensive agricultural land ownership is closely related to food security. While access to land is still important for improving farmers' food security and nutritional status, there is a trend towards better off-farm livelihoods and less dependence on agriculture, especially among landless farmers and peasants.

TABLE I
FARMER HOUSEHOLD INCOME

Source of income	Amount of income (IDR/month)	Percentage (%)
Agriculture		
a. Rice	1,224,487.42	37.46
b. Corn/Soybean/ Cassava	133,541.67	4.08
Non agriculture	1,911,051.33	58.46
Total	3,269,080.42	100.00

The fulfillment of water for irrigation is an obstacle for dry land. Irrigation is an essential factor affecting household food security. Land with good irrigation will get optimal results to overcome food insecurity [27]. Farmers have to drill wells if they want to cultivate rice in a dry season. The obstacle experienced by farmers is the high cost of drilling wells on the ground. Therefore, it is necessary to cooperate with the government, agricultural extension workers, farmers' groups, and community leaders to manage sustainable agricultural dry land [28].

Farmer household incomes are also affected by climate change. Climate change is an important factor affecting crop yields and farmers' income [29]. Climate change [18], rainfall, and poor soil conditions are challenges in increasing rice productivity [30]. Climate change's effects, such as temperature changes, rainfall patterns, and growing seasons, contribute to food insecurity [31]. This condition is related to a decline in agricultural production, household income and expenditure, limited access to credit due to a lack of collateral and economic resources, and higher food prices [32]. Climate change negatively impacts farmers' livelihoods as increasing temperatures and decreasing rainfall patterns affect food security [2]. The solution to maintaining rice production is done with suitable irrigation arrangements, and adjusting the planting time will reduce the negative impacts of climate change [33]. Research in Ethiopia concluded that the implementation of rainwater harvesting technology has a positive and significant contribution to farmers' livelihoods in annual household farm income and food security [34].

One effort to increase the productivity of dry land is by applying relay or multiple cropping technology [35]–[37]. During the dry season, the land can be planted with corn and soybeans [38], corn and peanuts, and cassava and soybeans. To increase the cropping index, drought-resistant plants can be planted in alley cropping, which is planted at the end of the rainy season so that sufficient water and plant nutrients are met for growth during the vegetative period of the plants. Farmers implemented strategies to increase on-farm income by planting drought-resistant and short-maturing paddy varieties and advancing the planting date. This is in line with

the study [39]. Farmers conduct this to increase land productivity, and under research [40] in Nigeria that concluded that to improve food security, it is necessary to increase agricultural productivity.

Most farming households in the study area have non-agricultural jobs to support their livelihoods. Non-farm income positively affects food [41]. The characteristics of respondent farmers in managing their farms are that after cultivating the soil, planting seeds, and fertilizing, the head of the family will usually migrate to meet their daily needs. In this following research [42], the male, as the head of the family, will send remittances to his family in the village to meet their daily needs. A study by [43] found that off-farm income significantly improves household food security. Non-farm income sources have a strong relationship in improving dietary diversity and enhancing household food security [44]. Diversification of non-agricultural income is to overcome malnutrition problems [45]. The study by [46] concluded that farmers' households with both on-farm and non-farm income are more likely to be food secure than farmers' households relying solely on agriculture. Non-farm income positively impacts the household's food security [47].

Farmer household expenditure consists of food and non-food expenditure. Table II reveals that the highest food expenditure is grains, while rice is a staple food and the primary source of carbohydrates for farmers in the research area. The preference of farmer households to consume food is influenced by several factors, including welfare and tastes [48].

TABLE II
AVERAGE FOOD AND NON-FOOD EXPENDITURE OF FARMER HOUSEHOLDS

Food Expenditure	Amount (IDR/month)	Percentage (%)
Food		
Grains	249,425	10.42
Tubers	35,407	1.48
Fish	136,471	5.70
Meat	139,240	5.82
Vegetables	243,099	10.16
Nuts	65,076	2.72
Fruits	80,436	3.36
Oil and Fat	79,240	3.31
Beverages	101,634	4.25
Seasoning	79,171	3.31
Other foodstuffs	50,686	2.12
Fast food and Beverage	39,636	1.66
Cigarettes and Tobacco	106,512	4.45
Sub Total (1)	**1,406,033**	**58.75**
Non-Food Expenditure		
Housing	151,997	6.35
Good and Services	359,813	15.04
Education	66,717	2.79
Health	33,480	1.40
Clothing	104,654	4.37
Durable Goods	42,180	1.76
Tax and Insurance	33,590	1.40
Social Needs	194,626	8.13
Sub Total (2)	**987,057**	**41.25**
Total (1) + (2)	**2,393,090**	**100.00**

Although farmers are producers, they also buy rice to meet their food needs. Some crops are consumed by themselves, and some are sold significantly if the price of grain increases harvest sales by cutting or selling rice. Research [49] shows that smallholder households usually consume most of their produce. Table II also reveals that the smallest proportion of food expenditure is tubers. The tubers have the potential as a source of carbohydrates to substitute rice. Tubers are a local food rarely consumed by farmer households due to habitual factors or a need to understand processing tubers into valuable food. Farmers can consume local food sources of carbohydrates such as sweet potatoes, cassava, corn, and tubers. Consumption of local food will reduce dependence on rice, affecting food expenditure and as a source of food diversity for achieving food security.

Household size affects the amount of food consumed. The average number of family members in farmer households is about four people. The household size determines food security status and positively affects food expenditure [41]. The more the number of household members in households with low incomes, the lower the per capita income will reduce food expenditure [50]. Large household size tends to weaken household income because it increases consumption expenditure [51], [52]. The study found that the family size of the household affects food security, the larger the number of family members, the greater the food expenditure and the lower the food security. This study contradicts the notion that households with a larger number of family members are more likely to be food secure. This is because they have more food to share, making it less likely that someone in the household will be starving [47], [53], [54].

The highest non-food expenditure is on goods and services. Expenditures on goods and services consist of daily necessities for all respondent members, such as toothpaste, toothbrush, bath soap, laundry soap, shampoo, communication and transportation costs, and gasoline. Based on the calculation of the proportion of food expenditure, food expenditure is 58.75%, which indicates that farmer households are categorized as food secure. The population's welfare dramatically affects household economic access to food availability and food consumed in quantity and quality. Based on the income-expenditure comparison, we concluded that farmer households in the study area are categorized as prosperous. However, the majority of this welfare comes from non-farm income. Income in the non-farm sector plays an important role in reducing household poverty and food insecurity [55]

The recall method determines energy and protein intake by recording the intake of all farmer household members in 24 hours. Each household member's energy and protein intake is compared to the AKG. The AKG for each individual is different (but usually 2150 kcal/person/day for energy and 57 grams/person/day for protein) depending on the gender and age group of the individual.

TABLE III
THE AVERAGE CONSUMPTION AND LEVEL NUTRITION INTAKE OF FARMER HOUSEHOLD MEMBER

Nutrient	Consumption	TKG	AKG (%)
Energy (kcal/person/day)	1833.37	2162.23	84.79
Protein (gram/person/day)	58.90	60.81	96.86

Table III reveals that the level of energy adequacy is 84.79%, and protein is 96.86% of the AKG. Thus, the level of

energy and protein adequacy is moderate. The farmer's weekly household diet includes rice, vegetables, and side dishes. Meal frequency 2-3 times a day. Based on Table II, the finding shows that vegetables are the second largest food expenditure after grains. Farmer households meet nutritional adequacy from vegetables and side dishes in the form of tofu and tempeh. Tofu and tempeh are sources of vegetable protein cheaper than animal sources. Tofu or tempeh consumed by farmer households every day. Tempeh is a food substitute for meat and fish. Tempeh can be processed as fried tempeh or tempeh chips [56]. Farmer households usually consume fish or chicken only twice a week. Farmers' households will buy cheaper food or reduce the amount and variety of food consumed to meet their needs [57].

Regarding food consumption, all farmer households consume rice as an energy source. This phenomenon shows that food consumption patterns are less diverse because they only depend on rice, which is in line with previous research [58]; the average quality of the Indonesian population's diet is still low and less diverse. Table IV illustrates that most of the farmer households (54.07%) are at a moderate level of energy sufficiency, which is 186 households. Food diversification needs to be done to reduce dependence on rice and as an effort to fulfill balanced nutrition. The government needs to conduct education and training on food diversification so that people understand the nutritional value of alternative foods. Local food substitutes for rice available in the study area are cassava and corn.

TABLE IV
DISTRIBUTION OF NUTRITION INTAKE LEVEL CATEGORIES OF FARMER HOUSEHOLD

Nutrient intake level	Energy		Protein	
	Number of households	%	Number of households	%
Good	53	15.41	155	45.06
Moderate	186	54.07	145	42.15
Low	49	14.24	34	9.88
Deficit	56	16.28	10	2.91

Table IV shows the level of protein adequacy of farmer household is in good category (45.06%) in 155 households and moderate (42.15%) in 145 households. Foodstuffs consumed are tofu, tempeh, chicken, eggs, and fish. Farmer households have no difficulty buying food at traditional markets because of easy access to roads and transportation. Market access has a substantial and significant role in food diversity [59], [60]. To meet protein needs, several farmer households also raise native chickens, goats and cows. Livestock is also used as savings for farmer households.

Farmer household diet tends to be monotonous and not diverse. This habit could be due to the respondent farmer's housewife age of around 57 years with an education equivalent to elementary school. Habits, environment, social culture, age, education and experience of homemaker's influence diet. The education and experience of homemakers also influence household nutritional adequacy. Housewife education is vital in household food security because homemakers provide a variety of food to meet family nutrition [7]. Counselling heads of families or homemakers about quality food consumption will increase household food security [43]. However, food consumption is also influenced by income and food access [61].

At the village, nutrition cadres can provide counseling to improve the knowledge and skills of homemakers in implementing a diverse, nutritious, balanced, and safe diet, so that farmer households are provided with adequate nutrition, energy, protein, and vitamins. According to [62], nutritionists and cadres can contribute by transferring nutritional knowledge to the community.

Table V shows food security (39.83%), food vulnerability (29.65%), lack of food (14.83%), and food insecurity (15.70%). Jatipurno sub-district is an area that has the highest percentage of food security compared to other regions. Jatipurno is the upstream area of the Keduang watershed. The upstream watershed has the potential for agricultural sector activities such as paddy fields, plantations, protected forests, and production forests. However, the upstream areas also face pressure to exploit the potential of water resources. The condition of Jatipurno is a hilly or mountainous area with higher rainfall, so farmers in this area can plant paddy for three growing seasons. Farmer households have implemented family-based food security through which each household grows vegetables and fruits in their yard, also by raising native chickens or catfish to meet the nutritional needs of the family. Research [63] explains that households with gardens at home experience increased dietary diversity and better nutrition, and livestock ownership affects food consumption [64]. Therefore, to maintain food security, it is necessary to diversify food to meet the needs of ideal nutrition.

TABLE V
THE CATEGORIES OF FOOD SECURITY BASED ON FOOD EXPENDITURE AND ENERGY CONSUMPTION

Food security categories	Sub-district							
	Jatipurno	%	Jatisrono	%	Sidoharjo	%	Number of households	%
Food secure	42	51.22	67	43.51	28	25.93	137	39.83
Food vulnerable	20	24.39	58	37.66	24	22.22	102	29.65
Lack of food	6	7.32	11	7.14	34	31.48	51	14.83
Food insecure	14	17.07	18	11.69	22	20.37	54	15.70

Most farmer households in the middle area (Jatisrono sub-district) are classified as food secure and vulnerable. The majority of farmer households have jobs outside of agriculture. Jatisrono is a trade center in the three regions. Efforts to improve food security is by promoting activities that generate non-agricultural income, such as self-employment. It takes support from the government and financial institutions to make it happen. Apart from this, there is a need for outreach efforts on food diversification. The middle regions can imitate upstream areas to improve their food security.

Sidoharjo is an area that has the highest percentage of lack of food and food insecurity. This area is a downstream area of the Keduang watershed. This area is dry land where farmers can only plant paddy for two growing seasons during the rainy season, while the agricultural land does not cultivate paddy for the dry season. Efforts are needed to increase the planting index so that productivity increases and can increase farmers' income. According to research [65], households must be encouraged to diversify income sources and generate social

capital and assets. To improve food security, government support regulates land conversion, construction of drilled wells or ponds, and government support for agricultural production facilities.

IV. Conclusions

Farmers' household income in the watershed relied on income from on-farm and non-farm. Non-farm income was higher than on-farm income. The small agricultural land, lack of water, and climate change caused the low income. Income affected food and non-food consumption patterns of farmer households. Based on the calculation of the proportion of food expenditure, food expenditure was 58.75%, meaning that farmer households were food security.

The most significant household food consumption of farmers was used for spending on grains. Farmer households consumed rice as a staple food and energy source. Based on the level of energy adequacy of 84.79% and protein of 96.86% of the AKG, the level of energy and protein adequacy was moderate. The degree of household food security based on the criteria for cross-classification of food expenditure and adequacy of energy consumption showed that 39.83% of farmer households were food secure, 29.65% were food vulnerable, 14.83% were lack of food, and 15.70% were food insecure.

Improving food security at the level of food insecurity and lack of food in the downstream areas can be applied to increase the cropping index. This effort can enhance productivity by drilling wells or ponds, government support for agricultural production facilities, and strict regulations regarding the conversion of agricultural land. At the later stage, food security and food vulnerability maintenance in the upstream and middle areas is conducted to diversify food to meet balanced and ideal nutrition.

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