Water's Role in Ensuring Food Security: An Analysis of Malaysia from 1991 to 2020

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Abstract. Food security has been a prominent economic issue in the world which is gradually gaining global attention, especially climate change, population growth and socio-economic disparities has been a global challenge these days. Undoubtedly food security has emerged as a pressing issue worldwide. The COVID-19 pandemic has further intensified existing vulnerabilities in food systems, highlighting the urgent need for resilient and sustainable approaches to ensure adequate food supply for all. This study aims to analyze the relationship between water resources, economic growth (economical aspect), population growth (social aspect), carbon dioxide emission (environmental aspect) and food security in Malaysia over the period from 1991 to 2020. Moreover, there are 3 prominent theories supporting our study, namely, Keynesian Theory, Neo-Malthusian Theory, and Photosynthesis Theory. Water resources will serve as our focus in this study. Data of all independent variables was collected from international sources - World Bank Data. Statistical analysis including Unit Root Test, ARDL Cointegration Bounds Test, Error Correction Model, ARCH Test, LM Test, CUSUM Test, VIF Test, and Normality Test was employed in this study. The findings indicate a significant positive correlation between water resources and food security indicators in Malaysia over the period of 1991 – 2020.

Keywords: Food Security, Malaysia, Water Resources, Economic Growth, Population Growth, Carbon Footprint.

1 Introduction

Since 2012, the Sustainable Development Goals (SDGs) 2030 have recognised the importance of food security by making the elimination of hunger, attaining food security, and improving nutritional standards the second target [1]. The 1996 World Food Summit established the concept of food security, which includes the following components: food availability, food accessibility, food utilization, and food stability [2]. However, Malaysia's food security remains at low level mainly due to insufficiency of domestic food production. In this paper, 4 determinants on food security will be evaluated namely water resources, economic growth, population growth, carbon dioxide emissions.

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Currently, Malaysia’s domestic food production is insufficient to satisfy the nation food consumption [3]. This can be reflected by the low self-sufficiency level of the staple food – rice. Only 70% of the population can be met by the country's existing rice supply, and 30% of Malaysians rely on imports for their rice consumption [4]. Lack of domestic food production has made Malaysia heavily reliant on food imports, making it vulnerable to disruptions in the global food supply chain [5]. Given the most recent global supply chain disruption caused by the COVID-19 epidemic, some nations have placed restrictions on food exports [6]. Thereby, World Bank’s survey reveals that 17% of households with low income facing food insecurity because their food affordability has been reduced as a result of global food inflation [7]. There are four determinants included in this paper to determine the factor affecting food security in Malaysia.

Firstly, progress on economic growth could affect food security positively, thereby eliminating famine, poverty, and undernourishment. However, a global slowdown and declining exports caused Malaysia's economic growth to reach its lowest level in over two years. According to the central bank's most recent figures, 2023's second-quarter annual growth was only 2.9% [8]. This was the slowest growth since the third quarter of 2021, when the COVID-19 epidemic caused the economy to decline by 4.2% [8]. In addition, the growth is 5.6% slower in comparison with the first quarter of the year [8].

Secondly, because population expansion coincides with food demand and consumption, increased population growth results in worse food security. Malaysia’s population increase from 18 million in 1991 to 33 million in 2020 [9]. The amount of rice consumed increased significantly from 2.75 million MT in 2019 to 2.9 million MT in 2022 [10]. However, only 1.86 million MT of rice have been produced in 2021 [11]. Despite 36.3 billion in subsidies from 1980 to 2021, rice and paddy still grow relatively slowly [12]. As a result, it threatens food availability, causing there to be inadequate food to feed the expanding population [13].

Thirdly, due to extreme climate change, Malaysia's food supply and production are drastically declining [14]. In Malaysia, food production is frequently disrupted by natural disasters like floods and droughts, which are clearly caused by carbon footprints. Between 2017 and 2021, there were 1,057 recorded flood episodes, resulting in the destruction of 40,828 hectares of paddy fields nationally by flooding and an additional 9,336.45 hectares of damage from drought [15]. Consequently, Malaysian rice farms produce between 3 and 5 tonnes of rice per hectare, although the ideal output is 7.2 tonnes, addressing the inefficiency in rice production. Furthermore, since Malaysia is a tropical country, the agriculture and animal production industries may be significantly impacted by extreme weather brought on by an increased carbon footprint, which might result in problems with food security [16][17].

Lastly, the growing problem of water pollution in the nation is making it more and more difficult for Malaysia to sustain food security through its domestic agricultural production [18]. The Global Food Security Index's sustainability and adaptability dimension had a low score of 46.6 out of 100, mostly because one of its indicators—water resources—was rated insufficiently; it only received a score of 27.6 out of 100. In Malaysia, 43% of rivers have a slightly polluted water quality, while 10% have a polluted water quality [19]. Bacteria, viruses, and parasites can be spread to crops and cattle through contaminated water used in agricultural cultivation [20]. The presence of contaminated residues in the crops has breached food safety regulations, which may pose a risk to human health. As a result, there are now less safe and usable water supplies available for irrigation.

Malaysia is ranked 41st on the Global Security Food Initiative based on the four factors of food security: availability, accessibility, utilisation, and stability. The country scored poorly in "availability" dimension which is 59.5 out of 100 [21]. With a score of 59.5 out of 100, the nation did badly in the "availability" component. Specifically, one of its indicator - food supply sufficiency received a score of 27.2 out of 100 on the index, which is a very poor rating [21]. The co-occurrence of childhood obesity and stunting has increased due to inadequate food security. For example, the proportion of stunted and underweight children under five years old increased from 16.6% and 11.6%, respectively, in 2011 to 21.8% and 14.1%, respectively, in 2019 [22].

Malaysia's food security is under risk due to its heavy reliance on imports rather than local food production. As a result, it is believed that this nation requires further investigation in this study. Subsequently, this study assists future researchers in comprehending the ways in which the factors assessed impact Malaysian food security. According to earlier research, one of the elements influencing Malaysia's food security is the water resource, which is usually overlooked. Water is essential to agriculture in general, and Malaysia's water is particularly contaminated [18], this will undoubtedly help to refocus attention on the issue preventing Malaysia from achieving sustainable food production.

In order to address the complexity of factors affecting food security, this study offers a broader perspective by combining three separate perspectives: environmental concerns (carbon footprint; water resources), social factors (population growth), and economic factors (economic growth) in total. The problem of food security has drawn more attention in Malaysia in recent years. The Department of Statistics Malaysia states that the nation is heavily reliant on food imports, which is closely related to the underlying lack of attention paid to the agriculture sector as a result of an excessive emphasis on industrial yield [23]. Any alterations to the global food supply network will eventually endanger our food supply. As a result, this study can give authorities and politicians a more comprehensive perspective so they can make appropriate policy changes.

2 Literature Review

2.1 Theoretical Review

Keynesian theory states that government intervention is a tool for controlling economic activity, namely the country's inflationary and recessionary gaps, with the ultimate goal of stabilising the economy [24]. For example, enacting fiscal policies like lowering income taxes to boost consumers' purchasing power or increasing expenditure on the private sector to recover and stimulate the economy [25]. The underlying Keynes-ian multiplier effect provides more insight into this idea. The multiplier effect centred on the idea that one man's expenditures equal another's income, wherein government expenditures can boost other people's incomes, resulting in a repeating cycle of expenditures that benefits the economy as a whole. [26].

According to Neo-Malthusian theory, the linear expansion of the food supply cannot sufficiently meet the food demand of an exponentially rising population [27]. [13] states that if population expansion outpaces the development of food production, there may not be enough food available to feed everyone, which might result in rising food costs [27]. As a result, food security and eventually famine are at danger. Malthus also pointed out that since there would be more people than there is food, a lack of food will cause many deaths [28], this phenomenon is generally referred to as ''population trap".

According to Photosynthesis Theory, photosynthesis is the foundation of our food supply while water and carbon dioxide is the key element for photosynthesis. The process of photosynthesis involves the conversion of water, sunlight, and carbon dioxide into oxygen and simple sugars that plants use as fuel. Through photosynthesis, plants able to generate energy by its own. This energy is then transferred through the food chain, with herbivores consuming plants and carnivores feeding on herbivores [29]. Human, as omnivore, obtain energy by consuming both plants and animals, highlighting photosynthesis as the primary source of food and energy for human beings [30].

2.2 Empirical Review

Primarily, the study found that economic growth (Gross Domestic Product GDP) is significantly correlated to food security in Malaysia. With a coefficient of 1.015345, economic growth has a positive impact on food security issues. On average, food security will increase by 1.015345 if economic grows by 1%. Therefore, the finding is consistent with the Keynesian Theory. The result of our finding is in tune with numerous researchers that theorized economic growth can positively affect food security [31]. As the wellbeing of the nation will improve according to the improvement of the economy, according to Gillani et al. (2022), the results show a significant reduction of malnutrition among the South African children as the economy improves [32]. Furthermore, the past studies of Kamenya et al. (2022) demonstrated that government intervention in improving economic growth has a positive effect on food security issues, the result shows that in 9 ECOWAS countries there is a 0.2% decrease in undernourishment and an enhanced average dietary energy supply sufficiency with 1 unit increase in public agricultural spending in between 2000 – 2016 [33]. As a result, economic growth has a positive impact on food security issues.

Secondly, the study found that population growth has an adverse relationship with food security with a coefficient value of -1.296823. For every 1% growth of population leads to 1.296823 decreases in food security. The result was consistent with the Neo-

Malthusian Theory, where population growth has an adverse relationship with food security. Agarwal (2022) and Kousar et al. (2021) both stated that as the food production grows arithmetically while population grows exponentially [28] [34], which population grows is crucial in causing the heightened demand for food [35]. Our results are consistent with many of the past research. Obinna (2021) conducted research between the population growth and food security in Nigeria, it was resulted as a negative relationship [36]. Moreover, Ceesay and Ndiaye (2022) also obtained a consistent result [37]. Population growth leads to overexploitation of land and natural resources, leading to a drop of arable land eventually reducing the food production and threatening food security [38]. Consequently, a rise in population growth significantly decreases the food security in a nation.

Thirdly, the result of carbon dioxide emission with a coefficient value of 1.876049 has a positive relationship with food security. If CO2 increases by 1%, food security will increase by 1.876049%. The finding is however consistent with the Photosynthesis Theory stating that agricultural growth relies on carbon dioxide. Carbon dioxide is one of the vital elements to facilitate the photosynthesis process. This finding of our study is in sync with much past research stating that carbon dioxide emission has a positive impact on food security [39][40][41][42]. In accordance with the research of Ejemeyovwi et al. (2018), the study obtained a positive relationship between CO2 emission and crop production in Africa [40]. Besides, Chansdio et al. (2020) has also obtained the positive relationship between CO2 emission and agriculture production in China in both short-run and long-run [42]. Therefore, this proof that carbon dioxide (CO2) emission will positively affect food security by prompting crop productions through photosynthesis.

Lastly, our fourth objective - water resources is too consistent with the Photosynthesis Theory where water has a positive impact on food security in Malaysia in terms of prompting crops production. If water resources increase by 1%, food security will increase by 0.494251%. Water is the vital element in agricultural production in terms of nourishing the crops and promotes photosynthesis to increase crop yields. In the finding of Asibi et al. (2019), polluted water resources pose a potential threat to food security as it will reduce the crop yields [43]. According to Qureshi et al. (2013), lower water availability in a nation will adversely affect the overall food production, resulting in insufficient food supply, and a spike in food price in the agricultural market [44]. Besides, Hadush (2018) stated in his research in Tigrai, Ethiopia, it is found that water availability has a positive impact on household food security through livestock production [45]. Hence, increasing water resources will increase food production, gradually improving food security issues in Malaysia.

3 Research Methodology

Time series data has been employed to examine the connection between the dependent variable and independent variables from 1991 to 2020. Food security (food production index (2014-2016 =100) serves as dependent variable, whereas economics growth

(GDP - constant LCU), population growth (Population Growth - annual %), carbon footprint (CO2 emissions – kg per PPP $ of GDP) and water resource (annual freshwater withdrawals, total – billion cubic meters) are independent variables. The data has been obtained from World Bank. Additionally, this study utilized an Autoregressive Distributed Lag Model (ARDL) Bounds Cointegration Test to access the long term relationship among the variables. In the conditions of small sample size, and variables that are integrated in different orders I(0), I(1) or a combination of both, ARDL model is preferable as it is reliable when there is only one long-run relationship between the underlying variables [46].

In the ARDL Bounds Test, the null hypothesis (H0) is rejected if the F-statistic exceeds the upper critical value for I(1), indicating that the variables are indeed cointegrated. Otherwise, H0 is not being rejected. The ARDL equation for the base model is as follows:

$$LnFOOD_t = a + \sum_{i=1}^{p} \beta_0 \, LnFOOD_{t-1} + \sum_{i=0}^{q} \beta_1 \, LnGDP_{t-i} + u_t$$

The ARDL equation for the extension model is as follows:

$$\begin{aligned} LnFOOD_t = a &+ \sum_{i=1}^{p} \beta_0 \, LnFOOD_{t-1} + \sum_{i=0}^{q} \beta_1 \, LnGDP_{t-i} \\ &+ \sum_{i=0}^{r} \beta_2 \, LnPOPULATION_{t-i} + \sum_{i=0}^{r} \beta_3 \, LnCO2_{t-i} \\ &+ \sum_{i=0}^{s} \beta_4 \, LnWATER_{t-i} + u_t \end{aligned}$$

Where,

$LnFOOD_{t-1}$ = first lagged of Food production index (2014-2016=100)
a = Intercept of the model
$LnGDP_{t-i}$ = lagged of GDP growth (Annual %) at time t
$LnPOPULATION_{t-i}$ = lagged of Population Growth (annual %) at time t
$LnCO2_{t-i}$ = lagged of CO2 emissions (kg per PPP $ of GDP) at time t
$LnWATER_{t-i}$ = lagged of Annual Freshwater Withdrawals, total (billion cubic meters) at time t
u_t = Error term at time t

In this paper, ECM is employed in examining both long-run and short-run relationships between the independent variables and dependent variables at the time the variables are cointegrated which indicates that both DV and IVs shared stable long-run relationships over a period of time. Based on Alogoskoufis and Smith (1991), ECM reproduces the process of the variables returning to the long run equilibrium after a short-term deviation from shock events [47]. The ECM model for base model is as follows:

$$\Delta LnFOOD_t = \beta_0 + \sum_{i=1}^{p} \beta_1 \Delta LnFOOD_{t-1} + \sum_{i=0}^{q} \beta_2 \Delta LnGDP_{t-i} + \lambda U_{t-1} + e_t$$

The ECM model for extension model is as follows:

$$\Delta LnFOOD_t = \beta_0 + \sum_{i=1}^{p} \beta_1 \Delta LnFOOD_{t-1} + \sum_{i=0}^{q} \beta_2 \Delta LnGDP_{t-i}$$

$$+ \sum_{i=0}^{r} \beta_3 \Delta LnPOPULATION_{t-i} + \sum_{i=0}^{s} \beta_4 \Delta LnCO2_{t-i}$$

$$+ \sum_{i=0}^{t} \beta_5 \Delta LnWATER_{t-i} + \lambda U_{t-i} + e_t$$

Where $Ut{-}1$ refers as error correction term which included into the equation to construct the ECM model.

4 Research Methodology

4.1 Unit Root Test

Table 1. Results of Augmented Dickey Fuller Test

Variables	Constant Level (p-value)	First Difference (p-value)	Constant Level (p-value)	First Difference (p-value)
	Intercept without trend		**Intercept with trend**	
Ln FOOD	-0.246547 (0.9213)	-3.751803 (0.0086)**	-2.041734 (0.5542)	-3.714756 (0.0379)**
Ln GDP	-4.906471 (0.0005)**	-7.320619 (0.0000)**	-5.225347 (0.0011)**	-7.149222 (0.0000)**
Ln POPULATION	1.400432 (0.9985)	-2.865538 (0.0623)**	-2.073763 (0.5373)	-4.078071 (0.0178)**
Ln CO2	-0.323160 (0.9096)	-5.518439 (0.0001)**	-1.635703 (0.7534)	-5.580140 (0.0005)**
Ln WATER	-3.531779 (0.0142)**	-5.198590 (0.0002)**	-3.019221 (0.1449)	-3.60933 (0.0481)**

Remarks: All variables had been changed to natural logs while (**) indicates that variables are statistically significant at 5%

For intercept without trend, LnGDP and LnWATER are stationary at both level form and first difference; LnFOOD, Ln POPULATION and LnCO2 are stationary at first difference only. Besides, for intercept with trend, LnGDP are stationary at both level form and first different; LnFOOD, LnPOPULATION, LNCO2 and LnWATER are stationary at first difference only. In conclusion, all data is stationary or does not have a unit root at first differencing (at significant level of 5%), hence, spurious regression problem should not be worried.

4.2 Model Estimation

ARDL Bounds Test Result

Table 2. Results of ARDL Bounds Test for Extension Model

Test statistic	Value	Significant Level	I(0)	I(1)
f-statistic	7.718516	1%	3.29	4.47
k	4	5%	2.56	3.49
		10%	2.2	3.09
Conclusion		Cointegrated		

Table 3. Results of Long Run Coefficient for Extension Model

Variables	Coefficient	Significant Level	I(0)	I(1)
Ln GDP	1.015345	3.296084	0.0064**	0.308046
Ln POPULATION	-1.296823	-3.327703	0.0060**	0.4498007
Ln CO2	1.876049	3.573414	0.0038**	0.525002
LnWATER	0.494251	3.151762	0.0083**	0.156817
C	-0.036209	-1.767667	0.1025	0.020484

Remarks: All variables had been changed to natural logs while (**) indicates that variables are statistically significant at 5%.

From table above, the value of F-statistic is 7.718516 which is greater than upper critical value of 3.49 at the significant level of 5%. Therefore, we draw a conclusion that there is cointegration and LnGDP, LnPopulation, LnCO2 and LnWater do exist long run effect on food security. Based on Table 3, all variables are significant at the significant level of 5%.

Error Correction Model

Table 4. Results of Error Correction Model for Extension Model

Variables	Coefficient
ECT Coefficient	-0.878298
P-value	0.0000**
T-statistics	-8.099839
Standard Error	0.108434

Remarks: All variables has been changed to natural logs while (**) indicates that variables are statistically significant at 5%.

Based on table 4, it is evident that the ECM coefficients is statistically significant, as indicated by a p-value (0.0000) at the 5% significant level. The ECM coefficients for the extension model is -0.878298 which has fallen within the range of 0 and -1. The value of -0.878298 indicates that approximately 87.83% of any deviation from the long-term equilibrium relationship among the variables is corrected within one year.

Diagnostic Checking

Empirical tests such as Autoregressive Conditional Heteroscedasticity (ARCH) Test, Breusch-Godfrey Serial Correlation LM Test, Variance Inflation Factor (VIF) Test, CUSUM Test and Normality Test have been used.

Table 5. Results of ARCH Test, LM Test and VIF Test for Extension Model

Diagnostic Checking	Chi-Square/P-value/VIF	Conclusion
ARCH Test	0.6006**	No Heteroscedasticity
LM Test	0.4473**	No Serial Correlation
VIF Test		
LnGDP	1.192396	No Multicollinearity
LnPOPULATION	1.092087	No Multicollinearity
LnCO2	1.119700	No Multicollinearity
LnWATER	1.142283	No Multicollinearity

Remarks: All variables has been changed to natural logs while (**) indicates that variables are statistically significant at 5%.

The p-value for the ARCH test is 0.6006 and for the serial correlation LM test, it is 0.4473, both of which exceed the 5% siginificance level. Consequently, there are no issues of heteroscedasticity and autocorrelation present in the model. Collinearity is deemed present in a variable if its Variance Inflation Factor (VIF) approaches or exceeds 5. Conversely, if the VIF value falls below 5, it indicates the absence of multicollinearity issues within the model. Since VIF for all variables are lesser than 5, we could conclude that there is no multicollinearity problem within the model.

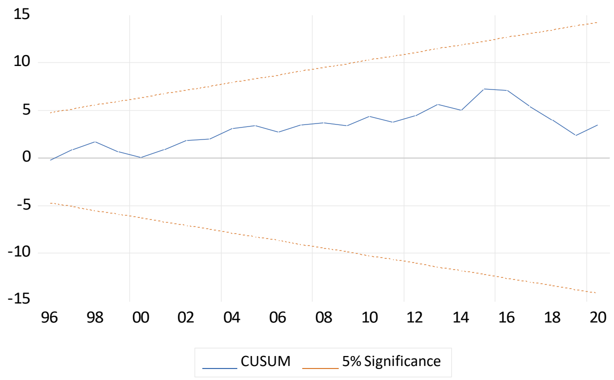

Fig 1: Result of Cumulative Sum of Recursive Residuals Test for Extension Model

The CUSUM test is to test the stability of the coefficient. Figure 1 illustrates that the CUSUM statistics remain within the range of the critical bounds at the 5% significance level. Consequently, the null hypothesis is retained, signifying the stability of the parameter.

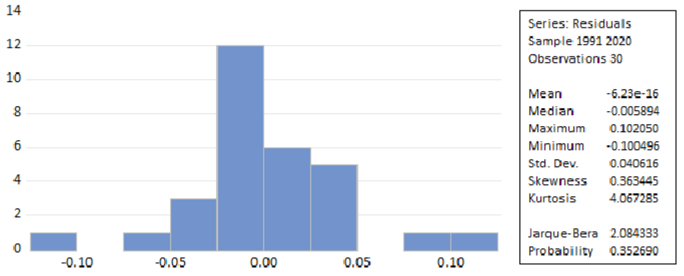

Fig 2: Result of Normality Test for Extension Model

The outcome of the normality test conducted on the model indicates that we do not reject the null hypothesis, as evidenced by a p-value of 0.352690, surpassing the 5% significance level. Therefore, it can be inferred that the time series data adheres to a normal distribution.

5 Conclusion and Recommendations

The research aims to study factors that influence food security in Malaysia. A total of 4 independent variables namely economic growth, population growth, carbon footprint, and water resources had been identified to investigate their relationship with food security in Malaysia from 1991-2020. Firstly, the study indicates that economic growth has a positive impact on food security issues. On average, food security will increase by 1.015345 if economic grows by 1%. Therefore, the finding is consistent with the Keynesian Theory. Secondly, the study found that population growth has an adverse relationship with food security with a coefficient value of -1.296823. For every 1% growth of population leads to 1.296823 decreases in food security. The result was consistent with the Neo-Malthusian Theory, where population growth has an adverse relationship with food security. Thirdly, the result of carbon dioxide emission with a coefficient value of 1.876049 has a positive relationship with food security. If CO_2 increases by 1%, food security will increase by 1.876049%. The finding is however consistent with the Photosynthesis Theory stating that agricultural growth relies on carbon dioxide. Lastly, water resources also consistent with the Photosynthesis Theory where water has a positive impact on food security in Malaysia in terms of prompting crops production. If water resources increase by 1%, food security will increase by 0.494251%.

In terms of limitations, this study is still limited to only one country and there are many potential factors that could bring the impact on food security from different context of the country's structure. Therefore, future research should include more emerging and developing countries to prove the significance of the factors towards food security and consider more variables that they are facing to gain in depth insights into the subject matter.

In addition, based on the findings of this study, three policies are recommended. In order to meet the growing demands of food consumption and to foster economic growth with finite natural resources, smart farming is recommended to achieve higher crop yields and utilize natural resources efficiently. Smart farming encompasses the utilization of modern information and communication technologies to effectively manage agricultural operations, with the aim of increasing both the quantity and quality of products while simultaneously optimizing resource utilization [48]. The technologies utilized in smart farming include sensors, big data analytics, drones, satellites, robots, and the Internet of Things (IoT).

On the other hand, Water Resources Tax Scheme which consists of water resource tax and water pollution tax could restrain water wastage and water pollution. The water resource tax operates under the principle of "user pays," where those who withdraw water resources are responsible for paying the tax; the water pollution tax operates based on the "polluter pays" principle, where polluters bear the costs of pollution prevention and control measures mandated by public authorities [49][50].

Last but not least, Wastewater Recycling Policy is proved to ensure an adequate water supply for the agricultural sector. A key element of policy has been the substantial investment in wastewater treatment infrastructure. The transition from primary treatment standards to tertiary treatment ensuring the effluent quality is safe for irrigation of all agricultural crops, enabling the use of treated wastewater for unlimited irrigation [51]. Hence, all these recommendations could serve a platform for Malaysia to sustain the food security in future.

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