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Factors Affecting Water Demand: Macro Evidence in Malaysia

(Faktor-faktor yang Mempengaruhi Permintaan Air: Bukti Makro di Malaysia)

Zuraini Anang
University Malaysia Terengganu

Jaharudin Padli
University Malaysia Terengganu

Noorhaslinda Kulub Abdul Rashid
University Malaysia Terengganu

Roseliza Mat Alipiah
University Malaysia Terengganu

Haslina Musa
University Malaysia Terengganu

ABSTRACT

Water becomes a crucial issue in the 21st century because of rising population and increasing development. Water is needed for agriculture, energy production, recreation, and manufacturing. This study investigates the impact of economic indicators and climate change on water demand for 13 states in Malaysia. Using annual data from 2007 to 2015, the panel data approach is used to assess the impact of these determinants on water demand. The dependent variable is water resources, and independent variables comprise real income, total consumption per capita, agriculture sector, population density and climate change. The real income is a nonlinear equation and indicates a threshold in economic development because the welfare of residents and industry will decline after the optimum point due to the shortage of water resources. The results indicate that total consumption per capita, agriculture, and population density have a positive impact on water demand. The agriculture sector exerts high demand on water resources. The climate change is a correct sign that represents an increase in demand for water resources during dry periods and leading to water stress. This finding is useful for improving the prediction of climate change to managing the water resources sustainably, particularly in the agriculture sector.

Keywords: Water demand; agriculture; climate change; population density

ABSTRAK

Air menjadi isu penting pada abad ke-21 kerana peningkatan penduduk dan pembangunan yang pesat. Air diperlukan dalam sektor pertanian, pengeluaran tenaga, rekreasi, dan pembuatan. Kajian ini menyelidik kesan penunjuk ekonomi dan perubahan iklim terhadap permintaan air bagi 13 negeri di Malaysia. Dengan menggunakan data tahunan dari tahun 2007 hingga 2015, pendekatan data panel digunakan untuk menilai kesan penentu ini terhadap permintaan air. Pembolehubah bersandar adalah sumber air, dan pembolehubah tak bersandar merangkumi pendapatan benar, jumlah penggunaan per kapita, sektor pertanian, kepadatan penduduk dan perubahan iklim. Pendapatan benar merupakan persamaan tak linear dan menunjukkan satu ambang dalam pembangunan ekonomi kerana kebajikan penduduk dan industri akan berkurang selepas titik optimum disebabkan oleh kekurangan sumber air. Hasil kajian menunjukkan bahawa jumlah penggunaan per kapita, pertanian, dan kepadatan penduduk mempunyai kesan positif terhadap permintaan air. Sektor pertanian didapati mendorong permintaan yang tinggi terhadap sumber air. Perubahan iklim merupakan satu isyarat yang bertepatan mewakili peningkatan permintaan untuk sumber air semasa musim kemarau dan menyumbang kepada krisis air. Dapatan ini adalah berguna untuk menambahbaik ramalan perubahan iklim bagi mengurus sumber air secara mampan, terutamanya dalam sektor pertanian.

Kata kunci: permintaan air; pertanian; perubahan iklim; kepadatan penduduk

INTRODUCTION

Rainwater is Malaysia's primary source of water supply with rivers and streams making up some 90% of its water supply (EPU 2010). Due to rapid economic growth, Malaysia's is experiencing unprecedented stress on its water supply. This supply is channelled predominantly to the agriculture sector which consumes 76% of its total

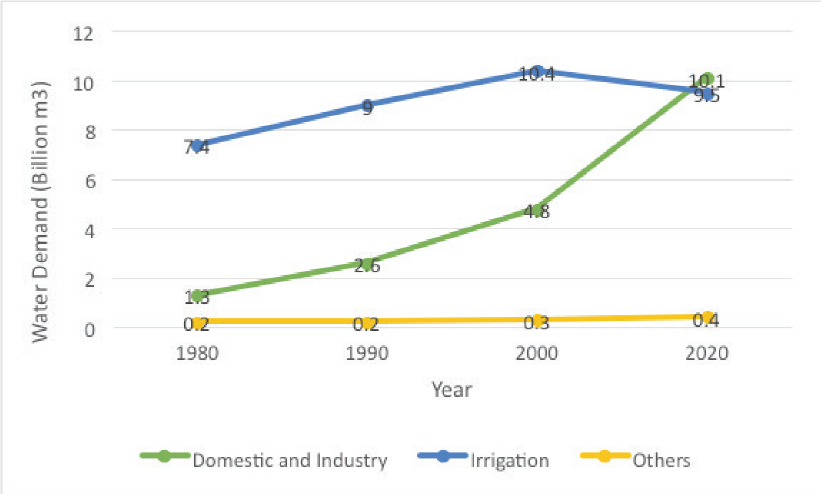

FIGURE 1. The Demand for water in different sectors in Malaysia from 1980 to 2020

water supply. Projections put the anticipated demand for water in Malaysia at 20 billion m^3 by the year 2020 and agriculture is forecasted to remain the major consumer. To prepare for such an eventuality, it is expected that the focus will shift to improving water usage management rather than water supply management.

As can be shown in Figure 1, there is an increasing demand for water in different sectors such as domestic and industry, irrigation and others from 1980 to 2020. Malaysia's total demand for water in was 8.9 billion m^3, and water usage for irrigation was approximately 83% of the total water usage in 1980. In 1990, the demand for water increased to 11.8 billion m^3 for agricultural, industrial and domestic purposes. The demand for water increased steadily to 15.5 billion m^3 in 2000.

The domestic and industrial sectors' annual demand for water increased by 12% from 1980-2000 (EPU, 2006). Since the 2000s, Malaysia's industrial and domestic sectors' demand for water has increased nearly twofold and concentrated on generating hydropower, navigation and recreational activities. Between 1980 and 2000, the highest demand for water came from the agriculture sector with a consumption of 67% of the total water usage. This percentage has decreased since the year 2000.

Malaysia's growing demand for water is to sustain its growing population and industrialisation. No slowdown is expected given the plans for Malaysia's continued economic growth. The domestic and industrial sectors are expected to make up 51% of the total water demand by 2020. Statistically, Malaysia faces a problem of water scarcity as evidenced by The Comprehensive Assessment of Water Management in Agriculture which reported that a third of all Malaysians experienced shortages of water in 2007. In developing countries, some 1.6 billion people lack the infrastructure to take water from rivers and aquifers. On top of that, 1.2 billion people have no water for routine activities. According to PICC (2007), a growing global population, urbanisation, consumption and climate change are the main factors for water scarcity.

Climate change has altered the availability, quantity and quality of global water supplies and cycle. It has also altered the ways in which we want and need water. Droughts increase the demand for water, and floods spoil the quality of water often making it unfit for consumption. It also damages the infrastructure commonly used to make the water potable.

There is no quick solution to the aforementioned factors which forces mankind to rethink the ways in which they use and manage water. The demand for and supply of water for irrigation will be influenced not only by changing hydrological regimes but by concomitant increases in future competition for water with non-agricultural users due to population and economic growth. As a result, this research needs to be carried out to examine the factors of water resources due to the increasing population and ongoing economic growth.

This study determines the impact of economic indicators and the changes in weather on water demand for 13 States in Malaysia. The impact of climate change, real income, total consumption per capita, population density, and agriculture sector could increase the use of water resources in Malaysia. It is, therefore, to be expected that higher income, agriculture and population density will increase water consumption.

The paper is organised as follows. The next section discusses the literature on the topic. Models, method of analysis and sources of data are presented in section 3. Section 4 includes a discussion and interpretation of the empirical results before the paper draws to a close.

LITERATURE REVIEW

Water consumption is divided into domestic and non-domestic. Domestic water use refers to water used

TABLE 1. Total volume and proportion of water consumption 2015-2016

State	2014					2015				
	Domestic		Non-Domestic		TOTAL	Domestic		Non-Domestic		TOTAL
	MLD	%	MLD	%		MLD	%	MLD	%	
Johor	823	67.8	391	32.2	1,215	811	64.1	455[r]	35.9	1,266[r]
Kedah	510	73.2	187	26.8	697	511	72.8	191	27.2	702
Kelantan	154	68.3	71	31.7	225	159	68.6	73	31.4	232
F.T. Labuan	17	35.8	31	64.2	48	17	35.2	32	64.8	49
Melaka	196	52.1	180	47.9	376	202	52.0	186	48.0	388
N. Sembilan	259	54.4	217	45.6	476	276	55.9	217	44.1	493
Pulau Pinang	483	59.4	330	40.6	813	483	59.5	329	40.5	812
Pahang	303	58.4	216	41.6	520	309	58.2	223	41.8	532
Perak	623	72.5	236	27.5	858	628	71.5	250	28.5	878
Perlis	81	84.5	15	15.5	95	81	84.2	15	15.8	96
Sabah	330	57.1	248	42.9	577	315	57.1	237	42.9	552
Sarawak	469	57.9	341	42.1	810	478	56.5	368	43.5	846
Selangor	1,779	58.4	1,268	41.6	3,048	1,862	58.6	1,316	41.4	3,178
Terengganu	241	57.7	176	42.3	417	246	57.5	182	42.5	428
MALAYSIA	6,267	61.6	3,909	38.4	10,176	6,378	61.0	4,074	38.9	10,452

Source: Malaysia Water Industry Guide 2016

for indoor and outdoor household purposes such as drinking, preparing food, bathing, washing clothes and dishes, brushing your teeth, and watering the yard and garden. Non-domestic consumption refers to industrial, commercial, and public uses of water such as shops, offices, schools, and hospitals, among others. The levels of industrial consumption depend on the intended output and resource technology. The industrial consumption is commonly expressed in litres per unit of product or raw material. Table 7 presents the proportion of water consumption. The percentage of domestic consumption increased from 6,378 mld (2015) to 6,495 mld (2016) whereas for non-domestic consumption also increased from 4,074 mld (2015) to 4,242 mld (2016).

Based on the National Water Resource Study 2000-2050 the water demand for the domestic consumer will be increased from 2000 till 2050, respectively 2,029 million m^3 to 5,904 million m^3. The total volume also rises from 10,833 million m^3 to 17,675 million m^3 (Table 2).

Water resources are the natural resources of water which hold the potential for future use in various sectors including agriculture, recreational, industrial, environmental and household. Water is essentially required by all living beings to conduct their fundamental life forms including growth and reproduction. However, fresh water only constitutes 3 % of the global water resources, while 97 % are made of salt water.

Ferdoushi Ahmed et al. (2014) examined the current status of water resources in Malaysia. They find that the demand on water resources for agricultural, industrial and domestic activities rose steadily from 8.9 billion m^3 in 1980 to 15.5 billion m^3 in 2000. Additionally, the agriculture sectors use an estimated 76% of available water which is approximately 90% for irrigation for paddy production as well as in heavy industrialisation in developed states. Increasing population and urbanisation also contribute to water demands.

TABLE 2. Water Demand for Peninsular Malaysia (Million m^3/yr)

Demand*	1998	2000	2010	2020	2030	2040	2050
Domestic	1,833	2,029	2,987	3,862	4,606	5,251	5,904
Industry	1,260	1,454	2,592	3,561	4,330	5,016	5,639
Both	3,093	3,483	5,578	7,423	8,936	10,267	11,543
Irrigation	7,350	7,350	6,517	6,517	6,517	6,132	6,132
Total	10,443	10,833	12,095	13,940	15,068	16,399	17,675

*Include losses
Source: National Water Resource Study 2000-2050

Numerous studies have been conducted to identify the determinants that could, directly and indirectly, affect water resources. The importance of supply and demand theory in ascertaining the optimal water level has been continuously highlighted to provide a balance between the demand and resource of water. Naturally, water resources are mainly affected by climate change and population density. Demand for water may further escalate due to water consumption, agriculture and income level. Reckless water consumption has long resulted in water scarcity, while polluted river caused by agricultural activities dampens the sources of fresh water. Meanwhile, income level showcases a positive relationship with water consumption as high-income group tends to consume more water for their relatively bigger houses equipped with parking lots, swimming pools and various water consuming amenities.

This is in line with the direct relationship between water supply and household income highlighted by Saladi and Salehe (2017). The study on the accessibility of water supply and its implications on household income in Tanzania found incidences of water shortages in low-income community.

Charles W. Howe (1976) investigates necessary and/or sufficient conditions for the successful growth of water projects. This study finds that water development has its greatest impact in the earlier stages of regional economic growth because of the importance of agriculture in the industry mix.

Investing in water management technologies and sanitation services is crucial for helping to reduce poverty and support the sustainable use of water and continued economic growth as reported by The Stockholm International Water Institute (2005). To this end, Elisa Gatto and Matteo Lanzafame (2005) explore how reduced water supplies would affect the economy and how water can be used more productively. They also study the tools available to government and public bodies to regulate water more efficiently across diverse stakeholders. The anticipated water shortages and reduction in water quality emphasise the need for measures to ensure water resources are protected and managed optimally.

As for agriculture as a vital part of food production and human survival, irrigation practices need to be revisited and improved through the advancement of agricultural technologies. Options to adapt to changing climates and weather trends also need to be explored as studied by Cynthia Rosenzweig et al. (2004). Additionally, this research developed a model of climate change scenarios consisting of hydrologic, agricultural, and planning models for economies to adjust to the inevitable changes to ecosystems and current production processes.

While agricultural goods and services hold the potential to generate and boost national income, water plays an important role in the continuity of the sector. In fact, the agriculture sector consumes the highest amount of water (Piamchan Doungmanee, 2016). With this regard, this paper investigates the relationship between water use for agricultural purposes and the economic development of 154 countries. In the study, water usage for agricultural activities proportionately increases with the increment of income level. Agricultural sector forms the second largest water consumer in the high-income countries, falling behind more dominant industrial and technological sectors following these countries' shift from agricultural to the industrial based economy. In this notion, the economic development of a country can also be used to indicate the level of water consumption by its respective agriculture sector.

Ringler (2010) claimed that economic growth prompts higher water consumption in all sectors including domestic, agricultural, and industrial sectors. However, consumption levels may vary across sectors and different levels of economic development. In contrary to developed nations, the agricultural sector in developing countries consumes the highest amount of water and accounts for 70-90% of the overall water withdrawal. The extensive study on agricultural water usage has also tackled various related issues including water management in the agricultural sector (OECD 2010) and the relationship between agricultural water use and food security (FAO 2010).

World Bank (2008) reported poverty reduction and economic growth in the Sub-Saharan African countries resulted from improved water infrastructure in the region, particularly in the agricultural sector. Hence, it is evident that economic growth and development are influenced and supported by the well-being of the water resources infrastructure and management in a particular country. This was further proven by Musouwir (2010) who found a significant relationship between Gross Domestic Products (GDP) and the national budget for water supply and sanitation projects in 22 developing African countries. Considering the importance of water particularly on the agricultural sector, water resources are forecasted to be in stiff demand.

In the Middle East and North Africa, studies have concentrated on demographic and climatic characteristics that affect the quality of water resources (e.g., Hulme 1996; Sánchez et al. 2004; Milly et al. 2005; Suppan et al. 2008; Alpert et al. 2008). Shilong Piao et al. (2010) concentrated on the impact of climate change on water resources and agriculture. China is a particularly important problem requiring an immediate response as it has 7% of the world's arable land but 22% of the world's population.

Yan Wang and Hongrui Wang (2005) designed the water policies in Beijing which have the most water-scarce metropolises in the world to solve the water scarcity in the agriculture sector. This study proposes to alleviate the situation by developing water-saving agriculture, adjusting planting structure and developing appropriate sewage irrigation.

Murdoch P.S. et al. (2000) studied in potential impacts of climate change on surface-water quality in North America. The changes in climate have a significant effect on water quality. Zhang et al. (2012) find that from 1961 to 1989, the radiation levels in the Yangtze River basin decreased significantly, but from 1990 to 2010 the levels increased significantly. This spike in global radiation levels is driven by fuel, while meteorological factors contributed to modestly. A study by Oliveira et al. (2011), radiation also affects the water cycle, particularly the in-and outflow of freshwater. It also affects the productivity and form of flora reported by Michael L. Roderick (2001).

Another research by Chowdhury and Al-Zahrani (2013) discovered precipitation, temperature, humidity, wind speed and solar radiation are all affected by climate change. These factors have a direct and significant effect of on water resources and aquatic ecosystems stated by Kenneth (1999).

It is anticipated that climate change and socioeconomic factors will determine the water sources in the future conducted by Alcamo et al. (2007). Another study by Alcamo et al. (1997) also revealed population growth and economic systems will also play decisive roles in defining water consumption and availability.

In conclusion, many factors contribute to water demand, particularly in the agriculture sector given its high demand for water usage. Extreme weather also influences the level of water resources. Moreover, water is a factor of production, and the growing global population raises the demand for water to new heights and developed pressure on water resources.

METHODOLOGY

In order to determinant the of water resources, this study applied the pooled OLS. The pooling technique examines variations among cross-sectional units simultaneously with variations within individual units over time. It offers opportunities for more complex analysis than cross-section or time series analysis individually. Also, pooled regression uses pooled data sets for a greater number of data points, which generates additional degrees of freedom. Moreover, using cross-section and time series variables reduced the problems that arise when variables are omitted.

This study employs the following general functions for the determinants of water demand:

$$water\ demand = f\{rincome, rincome2, watercp, agri, pdens, climate\} \quad (1)$$

The following regression equation (1) in a log-log regression

$$lwaterdd_{it} = \beta_0 + \beta_1\, lrincome_{it} + \beta_2\, lrincome2_{it} + \beta_3\, lwatercp_{it} + \beta_4\, lagri_{it} + \beta_5\, lpdens_{it} + \beta_6\, lclimate_{it} + \varepsilon_{it} \quad (2)$$

Where *i* denotes country 1, 2, 3,..... N, while *t* refers to time t, 1, 2, 3,.... N and ε_{it} represents the error term. $Water_{it}$ is the water resources which uses a million litres per day (MLD) from various places (e.g.: direct extraction from river, storage dams and groundwater). As regressors, $rincome_{it}$ is the real gross domestic product, $rincome2_{it}$ is the square of real gross domestic product which measures for a nonlinear relationship. In addition, $watercp_{it}$ is water consumption per capita (in million litres per day), $agri_{it}$ is agriculture which measures output in the agriculture sector, $pdens_{it}$ is the population density, $climate_{it}$ is mean of cloud cover to measure climate change. Finally, in equation (2) denotes the natural logarithm for all variables used in this study.

THEORETICAL EXPECTATION OF EXPLANATORY VARIABLES

From equation (1), the expected result for *rincome* can vary depends on the level of income to the water resources. The higher income group tend to have higher water usage due to their lifestyle and amenities. Rich and healthy people always look for a better quality of water. However, this relationship is negative for low-income groups.

Population density and water consumption per capita are expected to have a positive relationship with water resources. With an increase in population density and water consumption per capita, it will increase the demand for water resources. Water is the basic needs for a living. However, human attitudes on using water in daily activities will also affect the water scarcity. In the case of residential activities, wastage in using water and the polluted river will increases the demand for water. Furthermore, the agriculture sector is also expected to have a positive impact on water resources. With an increased demand for agricultural goods will lead to the cultivation of new land use and efficient irrigation the usage of water.

However, climate change is expected to have a mixed impact on water resources. Global radiation leads to a higher temperature causing the evaporation which reduced the water supply. In addition, climate change is proxies by global radiation and cloud cover which play vital roles determining the water levels in dams. *Ceteris paribus*, increased cloud formation will increase the level of rainfall and increase the availability of water resources.

SOURCES OF DATA

This study uses the secondary data of water resources and economic indicators for 13 States in Malaysia, namely Perlis, Kedah, Pulau Pinang, Perak, Selangor, Negeri Sembilan, Melaka, Johor, Pahang, Terengganu, Kelantan, Sarawak, and Sabah. The period of study ranges from 2007 to 2015 using annual data from the Malaysia

TABLE 3. Sources of Data Used in Study

Variables		Brief Description	Sources of Data
lwaterdd	Water resources	Total water resources including direct extraction from the river, storage dam and groundwater	WMIG (Malaysia Water Industry Guide)
lwatercp	Water consumption	Total number of water consumption	WMIG (Malaysia Water Industry Guide)
lrincome	Income	Real Gross Domestic Product	DOS
lpdens	Population density	Total population divided by land area sq/km	DOS
lagri	Agriculture	Total output (in Ringgit Malaysia/million)	DOS
lclimate	Cloud cover	Mean of Cloud Cover (Oktas)	Malaysian Meteorological Department

TABLE 4. Correlation between variables

	Lwtr_res	*Lrincome*	*lwatercp*	*lagri*	*lpdens*	*lclimate*
Lwtr_res	1.000					
Lrincome	0.803	1.000				
lwatercp	0.355	0.199	1.000			
lagri	0.443	0.531	-0.394	1.000		
lpdens	0.056	-0.016	0.476	-0.684	1.000	
lclimate	0.188	0.004	0.127	-0.047	0.081	1.000

Water Industry Guide (WMIG) yearbook. Data for income, population, population density and agriculture are sourced from the Department of Statistic of Malaysia and the climate change data from the Malaysian Meteorological Department (see Table 1).

EMPIRICAL RESULTS

Table 5 offers an empirical analysis of the factors influencing the water resource. It illustrates the estimation results for the pooling technique of the total water consumption per capita, real gross domestic product (income), agriculture, climate change: mean global radiation, mean cloud cover and total population density of water resources. This empirical analysis attempts to identify the independent variables of water resources. The results reveal that all factors are significant on water resources at the 5% level. The null hypothesis that β's is zero can easily be rejected.

From the results in Table 5, the relationship between water resources and the level of economic performance is nonlinear. Both variables *lrincome* and *lrincome*2 are statistically significant, and the sign for *lrincome* is positive and negative for *lrincome* 2. This result suggests that although the level of wealth of a country provides basic amenities such as utilities, it is nevertheless reduced. This suggests that there is a threshold where the level of economic development will take care of the welfare and the comforts of the residents, but after an optimum point of higher economic growth, the level of welfare and comfort will decline due to limited water resources. In addition, the relationship between water consumption per capita has a positive impact on water resources. The result implies that with the growing demand for water from industry, higher levels of income, and growing populations, new technologies will develop for optimised use of water and new water resources will be identified similar Saladi J.A and Salehe F. S. (2017).

Furthermore, from Table 3, the result indicates that agriculture and population density have a positive effect on the demand for water resources. Agriculture sector consumes almost 70% of global water resources and up to 95% in agriculture-based countries. Current agricultural practice is highly inefficient when it comes to using water as stated by FAO (2010) and OECD (2010). This dilemma is due to the growing population which then increase the demand for more food. Population growth and economic development will double global food demand by 2050 putting additional strain on already stretched water resources as mentioned in the study by Alcamo et al. (1997).

This analysis found that climate change has adverse effects on water resources. Given the relationship between climate change and water levels, will alter the availability, quantity and quality of water resources or supplies and also the ways in which we want and need water. As mentioned in the previous section, droughts will increase the demand for water, and floods will spoil the quality of water often making it unfit for consumption.

TABLE 5. Estimating factors affecting water demand in Malaysia (2007-2015)

Lres_wat	coef.	Std. error	t-stat	P-value	95% conf. interval	
$Lrincome_{it}$	2.672**	1.186	2.25	0.026	0.322	5.023
$lrincome2_{it}$	-0.031**	0.015	-2.03	0.045	-0.061	-0.001
$lwatercp_{it}$	0.637**	0.095	6.73	0.000	0.450	0.824
$lagri_{it}$	0.554**	0.106	5.22	0.000	0.344	0.764
$lpdens_{it}$	0.204**	0.056	3.62	0.000	0.092	0.316
$lclimate_{it}$	-0.980**	0.428	-2.29	0.024	-1.828	-0.131
_cons	-52.149**	22.503	-2.32	0.022	-96.745	-7.553
No. of obs	117					
No. states	13					
R-square	0.748					

Note: all estimations are based on White (1980) A Heteroscedasticity-Consistent Covariance Matrix Estimator. (**) Indicates statistically significant at the 5% level.

It also damages the infrastructure commonly used to make the water potable. Since we use the cloud cover as a proxy to climate change, which indicates the rainfall rate, it is a correct sign that there is low water usage during rainfall season in agricultural. This finding similar with Hulme, (1996); Sánchez et al. (2004); Milly et al. (2005); Suppan et al. (2008); Alpert et al. (2008) studies have concentrated on demographic and climatic characteristics that affect the quality of water resources in Middle East and North Africa. Studies by Murdoch P.S. et al. (2000) also found that changes in climate have a significant effect on the water quality in North America.

CONCLUSION

This study applies the pooling technique to determine the factors influencing water resources, namely total water consumption per capita, real gross domestic product, agriculture, climate change: mean global radiation, mean cloud cover, and total population density. The results indicate a positive impact of total water consumption, real gross domestic product (income), agriculture, and total population density on increasing water resources. As mentioned, agriculture uses 76% of water resources as the main source for irrigation of plants and vegetables.

The total water consumption by household influences the water resources due to being a vital resource for daily activities. Real gross domestic product (income) also contributes to increasing water resources due to increased productivity. The water coverage is almost 100% in the urban and rural area. The welfare economics on basic amenities will decline after a maximum point of economic growth due to limited water resources.

Additionally, the higher the cloud cover, the more water resources will be available from the rainfall to these areas. Surprisingly, climate change is an incorrect sign related to water resources. It means that during drought seasons, the water resource in reservoirs will decline leading to water stress and will adversely affect industry and agriculture. Finally, these findings are meaningful to policymakers to design integrated policies to ensure the water resource is sufficient for the consumption of households, industry and agriculture.

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Zuraini Anang*
School of Social and Economic Development
Universiti Malaysia Terengganu
21030 Kuala Terengganu Terengganu
MALAYSIA
E-mail: zura@umt.edu.my

Jaharudin Padli
School of Social and Economic Development
Universiti Malaysia Terengganu
21030 Kuala Terengganu Terengganu
MALAYSIA
E-mail: jaharudin@umt.edu.my

Noorhaslinda Kulub Abdul Rashid
School of Social and Economic Development
Universiti Malaysia Terengganu
21030 Kuala Terengganu Terengganu
MALAYSIA
E-mail: lindarashid@umt.edu.my

Roseliza Mat Alipiah
School of Social and Economic Development
Universiti Malaysia Terengganu
21030 Kuala Terengganu Terengganu
MALAYSIA
E-mail: roseliza@umt.edu.my

Haslina Musa
School of Social and Economic Development
Universiti Malaysia Terengganu
21030 Kuala Terengganu Terengganu
MALAYSIA
E-mail: mhaslina71@yahoo.com.my

*Corresponding author