The Effect of Climate Change on Water Resources Using Panel Approach: The Case of Malaysia

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Abstract
Water resources are important to society and ecosystems. This paper aims to determine the factors affecting the water resources for 13 states in Malaysia for a period from 2007 to 2012 by using panel data. The model includes the dependent variable, namely water resources and independent variables comprising climate change, water consumption, population density, and income per capita. The results indicate that the climate change will influence the availability, quantity and quality of water resources. As a result, the water consumption will change as consumers use more water during the dry season. This finding is useful in future studies which aim at assessing the impact of climate change in managing the water resources efficiently and effectively towards sustainability of water resources for the future generation.
Key words: *Climate change, water resources, water consumption, sustainability*

1. Introduction

Water is important for human survival and well-being as well as economic activities such as agricultural and industrial activities. Freshwater is only 2.5% of the Earth's water. Our body consists of 75% of water. Water resources can be extracted from rivers, reservoirs and lakes as well as groundwater. Additionally, the increasing demand for water due the world population increases, industrialization as well as urbanization causes the increasing demand for water resources. As reported by the World Water Council, approximately 66% of water consumption was used in agriculture and more than 90% in arid areas, meanwhile 34% for domestic usage, about 10% was consumed in arid regions and in industry sector estimated 20%, while 4 % evaporates from reservoirs (World Water Council).

Statistics illustrate the crucial problem of water scarcity. The Comprehensive Assessment of Water Management in Agriculture reported one of three people experienced water shortage

(2007). An estimated 1.6 billion people live in developing countries lack the water infrastructure to take water from rivers and aquifers. Moreover, 1.2 billion people live in areas of physical scarcity to receive water for routine activities. According to PICC (2007), the main factors aggravating water scarcity are population growth, increasing urbanisation, high level of consumption and climate change.

Climate change becomes an important issue in the global agenda, particularly to support living systems. Causes of climate change can emanate from natural and human activities such as open burning in the agriculture sector. Climate attributes comprise air temperature, solar radiation, cloud cover, wind speed, vapour pressure, precipitation and evaporation (Dallas, 2008). Based on the Intergovernmental Panel for Climate Change (IPCC) 2007, the temperature (~ 0.3°C) and rainfall (~3.0%) increased slightly throughout the Southeast Asia region during the last decade. As mentioned by Wan Azli (2010), there exist changes to climate as compared to the normal trends in Malaysia.

The impact of climate change on water resources alter the availability, quantity and quality of the water supply cycle. These refer to water demand, water resources and the water infrastructure. Climate change also modifies the water demand pattern. For instance, in the dry season, households tend to consume more water for planting and gardening.

IPCC reports four determinants of water scarcity, namely population growth, increased urbanisation, high-level consumption and climate change. However, climate change becomes the main factor which contributes to the water shortage. First, the distribution of precipitation in space and time cause tremendous temporal variability in water resources (Oki et al., 2006). Second, the rate evaporation varies a great deal, depending on temperature and relative humidity, which impacts the amount of water available to replenish groundwater supplies. By determining the factors of water resources, the government and water authorities can take action and provide a solution to overcome the water shortage. The outline of this research comprises introduction, literature review, methodology, discussion, and conclusions.

Malaysia has an abundance of water. Due to an increase in population and economic growth, the demand for water usage increases annually. Based on Table 1, the water deficit or shortage increased in a few states in Peninsular Malaysia such as in Perlis, Kedah, Pulau Pinang, Selangor and Melaka since 2010. In 2010, the crucial water shortage which occurred in Kedah and Selangor was valued at 1,852 (MCM) and 1,278 (MCM), respectively. The values of water deficit are expected to be on an upward trend until 2050.

Based on the Water Resources Study for 2015 to 2050, the North States, namely Perlis, Kedah and Penang have been experiencing water shortage approximately 246 to 221 MCM. This is followed by Selangor and Melaka estimated by more than 1,000 MCM and nearly 200 to 336 respectively. In 2014, Selangor had a water crisis due to drought season which caused the dam level to fall, although the population in Selangor has been increasing over the years.

Consumers use water resources for domestic water consumption that include bathing, household activities, gardening and for washing. The Malaysian pattern of water consumption recorded the highest rate compared to other Asian countries. Therefore, the shortage of water resources will influence the pattern of consumption.

Many factors are influencing this situation, namely climate change and non-climatic variables. Climate change contributes to extreme weather such as drought and flood. The direct impact of climate change on water resources will affect the water cycle due to changes in precipitation and evaporation cycle. Meanwhile, the indirect impact was a migration of people in search of food in arid areas, and to safer places due to floods as a result of the rise in sea level. The water consumption pattern and food production, as well as lifestyle, will be affected due to the impact of climate change on the Earth. On the other hand, the impact of the non-climatic drivers will affect the surface water and groundwater availability, and usage patterns. The population growth, food consumption (including the type of diet), economic development (and by extension, changes in lifestyles and societal views on the value of water), technology, and economic policy (including water pricing and trade-in 'virtual water') will play important roles in influencing water use patterns.

Table 1
Malaysia's Water Resource Scenarios - Total Water Availability versus Consumptive Water Demand

States	Land Area sq km	Total Consumptive Water demand (MCM)					Effective rain (MCM/ Year)	Excess/deficit (MCM) – Unregulated Flows				
		2010	2020	2030	2040	2050		2010	2020	2030	2040	2050
Perlis	821	306	299	286	284	281	60	(246)	(239)	(226)	(224)	(221)
Kedah	9,500	2,922	2,976	2,842	2,873	2,876	1,070	(1852)	(1906)	(1772)	(1803)	(1806)
Pulau Pinang	1,048	765	829	835	874	894	130	(635)	(699)	(705)	(744)	(764)
Kelantan	15,099	1,632	1,619	1,586	1,600	1,604	2,650	1018	1031	1064	1050	1046
Terengganu	13,035	884	975	970	999	1,026	3310	2426	2335	2340	2311	2284
Perak	21,035	1,949	1,923	1,798	1,801	1,811	3,140	1191	1217	1342	1339	1329
Selangor	8,396	2,238	2,491	2,570	2,760	2,922	960	(1278)	(1531)	(1670)	(1800)	(1962)
Pahang	36,137	726	946	897	911	959	6,460	5739	5514	5563	5549	5501
Negeri Sembilan	6,686	340	361	358	366	374	640	300	279	282	274	266
Melaka	1,664	323	366	376	409	439	140	(183)	(226)	(336)	(269)	(299)
Johor	19,210	715	881	1,033	1,164	1,301	3,290	2575	2409	2257	2126	1989
Pen Malaysia	132,631	12,800	13,664	13,551	14,040	14,488	21,170	8370	7506	7619	7130	6682
Sabah	73,731	912	1,356	1,392	1,442	1,462	16,210	15298	14854	14818	14768	14741
Sarawak	124,450	1,054	2,162	2,125	2,175	2,247	27,440	26386	25278	25375	25265	15193
WP Labuan	91	18	24	26	28	29	30	12	6	4	2	1
East Malaysia	198,172	1,985	3,541	3.542	3.645	3,745	53,190	51205	49649	49648	49545	49445
Total Malaysia	330,803	14,785	17,205	17,093	17,685	18,233	74,350	59565	57145	57257	56665	56117

**IN RED BOXES: WATER DEFICIT

Source: Review of National Water Resources Study 2015 - 2050
Note: MCM - Million Cubic Metre

This study is conducted to determine the factors of water resources which influence the water usage. The main factor will be the climate change. The findings are very important for the policy makers to arrive at integrated solutions to manage the water resources effectively and in a sustainable manner.

2. LITERATURE REVIEW

2.1 Climate Change

As defined by the United Nations Framework Convention on Climate Change (UNFCCC), climate change is attributed directly or indirectly to human activities that alter the composition of the global atmosphere and which is beyond the natural climate variability observed over comparable periods. It impacts on changes in weather either through drought or flood seasons which influence the water cycle in terms of availability, quantity and quality of water resources. For instance, the demand for water resources increased significantly during drought periods due to higher temperatures.

Malaysia lies on the equatorial zone. The climate is governed by the regime of the northeast and south-west monsoons. The northeast monsoon blows from October to March and is responsible for the heavy rains which hit the East Coast of the Peninsula and frequently cause widespread floods. It also triggers heavy rains in Sabah and Sarawak. The south-west monsoon period occurs between May and September, and cause a dry season throughout the country. Heavy rainfall marks the period between these two monsoons.

The average temperature throughout the year is very stable (26°C), and the mean annual rainfall is 3,000 millimetres (mm). Regional variations in temperature and rainfall are mainly due to topographic attributes, e.g. the Cameron Highlands have a mean temperature of 18°C and an annual rainfall of over 2500 mm, compared to 27°C and 2,400 mm in Kuala Lumpur. In general, Sabah and Sarawak experience more rainfall (3,000 - 4,000 mm) than the Peninsula. The humidity is higher (80%) due to the high evaporation rate.

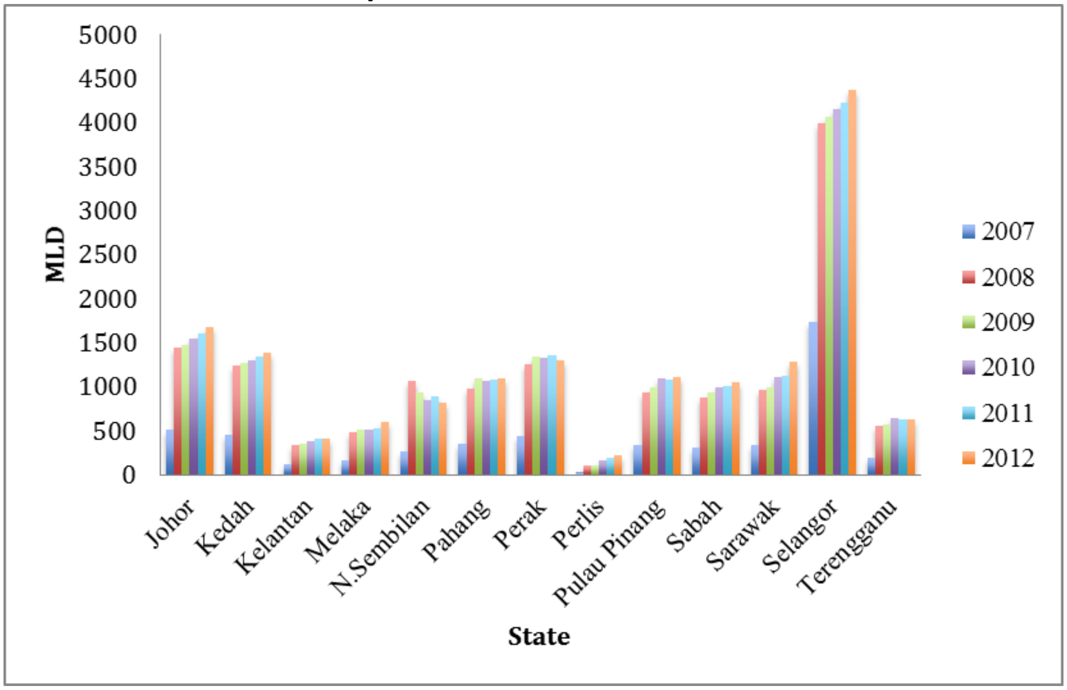
Climate change projections for the region derived from global climate model driven by socioeconomic scenarios (Intergovernmental Panel on Climate Change, 2001; Iglesia et al., 2000) manifests an increase in temperature (1.5 to 3.6°C in the 2050s) and lower precipitation in most of the territories (lower by about 10% to 20%, depending on the seasons in the 2050s). Climate change projections also indicate an increase of droughts likelihood (Kerr, 2005) and variability of precipitation – in time, space, and intensity – that would directly influence water resources availability. The combination of long-term changes (e.g., warmer average temperatures) and greater extremes (e.g., droughts) can have vital impacts on water demand, with further impact on the ecosystems.

2.2 Water Resources

Peninsular Malaysia is drained by a dense network of rivers and streams (there are about 150 major river basins), the longest being the Pahang River which follows a course of 434 km before reaching the South China Sea. It drains a catchment area of 29,000 km^2. Other major rivers that also drain into the South China Sea are the Kelantan, Terengganu, Dungun, Endau, and Sedili rivers. Major river basins in the east of Malaysia tend to be larger than those in Peninsular Malaysia. Malaysia's longest river is the Rajang River (563 kilometres) in Sarawak.

Out of an annual rainfall volume of 990 cubic kilometres (km^3), 360 km^3 (36%) are lost to evapotranspiration. The total surface runoff is 566 km^3, and about 64 km^3 (7% of the total annual rainfall) contribute to groundwater recharge. However, about 80% of the groundwater flow returns to the rivers and is, therefore, not considered an additional resource. The total internal water resources of Malaysia are estimated at 580 km^3/year.

Figure 1. **Water Resources in Malaysia from 2007-2012**



Sources. Water Resources Industry Guide (2013)

2.3 Water Consumption

Based on the study by the Federation of Malaysian Consumers Associations (FOMCA), the average consumer needs only 80 litres of water a day which includes 3 litres for drinking. Unfortunately, Malaysians have the highest water consumption of approximately 220 to 250 litres which is the highest in the Southeast Asia. The neighbouring countries such as Thailand recorded water usage estimated at 160 to 170 litres per day per person, while Singapore about 130 to 150 litres and Indonesia roughly about 140 to 160 litres per day per person.

Additionally, water usage can be divided into two groups, namely domestic consumption and non-domestic consumption. Domestic consumption is water used for indoor and outdoor household purposes includes drinking, preparing food, bathing, washing clothes and dishes, brushing your teeth, and watering the yard and garden. Meanwhile, non-domestic consumption known as industry consumption means water consumption for technological goals of industry, for power engineering, as well as transportation such as cooling, steam generation and hydraulic transportation.

Table 2 presents the water consumption in Malaysia for 2013 and 2014. In 2014, the total water consumption increased approximately by 3.2% to 10,176MLD compared with 9,855MLD in 2013. The highest water consumption is Selangor approximately 2,989MLD (2013) and 3,047MLD, respectively (2014). It is followed by Johor, and the lowest is Labuan. The water consumption for domestic is higher than non-domestic in 2013 and 2014.

Table 2
Water Consumption in Malaysia

States	2013					2014				
	Domestic		Non-Domestic		TOTAL	Domestic		Non-Domestic		TOTAL
	MLD	%	MLD	%	MLD	MLD	%	MLD	%	MLD
Johor	797	68.5	366	31.5	1,163	823	67.8	391	32.2	1,215
Kedah	487	74.4	164	25.6	651	510	73.2	187	26.8	697
Kelantan	140	69.5	62	30.5	201	154	68.3	71	31.7	225
Labuan	16	34.2	31	65.8	46	17	35.8	31	64.2	48
Melaka	193	51.4	182	48.6	375	196	52.1	180	47.9	376
N. Sembilan	255	54.5	213	45.5	468	259	54.4	217	45.6	476
Pulau Pinang	481	59.5	327	40.5	809	483	59.4	330	40.6	813
Pahang	299	59.3	205	40.7	504	303	58.4	216	41.6	520
Perak	607	72.6	228	27.4	835	623	72.4	236	27.5	858
Perlis	65	81.5	15	18.5	80	81	72.5	15	15.5	95
Sabah	314	59.2	216	40.8	530	330	84.5	248	42.9	577
Sarawak	446	56.4	345	43.6	790	469	57.1	341	42.1	810
Selangor	1,735	58.0	1,254	42.0	2,989	1,779	57.9	1,268	41.6	3,048
Terengganu	230	55.8	183	44.2	413	241	58.4	176	42.3	417
MALAYSIA	**6,064**	**61.5**	**3,790**	**38.5**	**9,855**	**6,267**	**61.6**	**3,909**	**38.4**	**10,176**

Source. Water Malaysia Industry Guide 2015

2.4 Factors Affecting the Water Resources

R.K. Mall et. al (2006) conducted a study on climate change and water resources, particularly on the sustainable of surface water and groundwater in India. As reported by Kenneth D. et al. (1997), climate change influences the demand and supply of water including reservoir operations, water quality, hydroelectric generation, and navigation. Specifically, the demand for water in agriculture sector tends to increase during dry seasons. Water resources become scarce and expensive due to climate change. The factors that influenced the water demand were population, income, as well as the appreciation of ecology system and recreational uses. Therefore, the efficiency in consuming water will need to have a balance between the water supply constraint and increasing demand. Additionally, Kenneth (1997) stressed that the effect of global climate change would cause a crucial impact on water resources and aquatic ecosystems.

Joseph Alcamo et al. (2007) stated that climate change and socioeconomic factors are the drivers of future water resources. They also stated that climate change and socioeconomic factors are not the only contributors to the water resources but also the effect of income, electricity production and water use efficiency and other driving forces of water resources. Similarly, Alcamo et al. (1997) attempted to determine the influence of climate change, population, and economy on the water usage and availability. They used the assumptions of the driving forces of water use trend in domestic, industrial, and agricultural sectors.

There are many other studies which link the climate change and demographic growth that contribute to the availability and quality of water resources in the Middle East and North Africa (MENA). Such studies include Conway and Hulme (1996), Suppan et al. (2008), Alpert et al. (2008), Sánchez et al. (2004), and Milly et al. (2005).

Dan Zhang et al. (2012) analysed the changes in global radiation in the Yangtze River basin during 1961 to 2010. The results presented that global radiation decreased significantly from 1961 to 1989 and turned around to increase from 1990 to 2010. The fuel consumption contributes to variation in global radiation, whereas changes in meteorological variables had a limited contribution. Subsequently, the impact of changing global radiation on the water cycle was examined.

As mentioned by Shakhawat Chowdhury and Muhammad Al-Zahrani (2013), the research examined the effects of climate change on water resources in Saudi Arabia. The factors comprise changes in precipitation, temperature, relative humidity and wind speed as well as net solar radiation.

The study anticipates significant reductions in water sources, which can impose further stress on agriculture and drinking water sources. Deterioration of source water quality is also expected. The study sheds light on the need for appropriate measures to protect water resources in Saudi Arabia.

Furthermore, Paulo J. et al. (2011) revealed that the knowledge of the radiation impacts on the water cycle should affect projections of river flow and freshwater availability for water consumption. Michael L. Roderick (2001) reported that the clouds affect the productivity and structure vegetation.

3. Materials and Methods

Based on the data collected, it is challenging to source continuous time series data set of water resources, water consumption and climate change in Malaysia. As a result, data were collected for 6 years, from 2007 to 2012 for 13 selected states in Malaysia. The panel data approach was employed to test the factors. The water resources and water consumption data are sourced from the Malaysia Water Industry Guide (WMIG) in 2013. The income per capita and population density from the Department of Statistic of Malaysia and the climate change data are from the Malaysian Meteorological Department.

The econometric techniques are applied to obtain estimators of the coefficients. To determine the relationship between water consumption, income, population density and climate change on the impact of water resources, by using the panel data approach for a period between 2007 to 2012 to estimate the coefficients for 13 states in Malaysia namely Perlis, Kedah, Pulau Pinang, Perak, Selangor, Negeri Sembilan, Melaka, Johor, Pahang, Terengganu, Kelantan, Sarawak, and Sabah. The model used is as follow;

$$\log water\_res_{it} = \beta_0 + \beta_1 \log incomePc_{it} + \beta_2 \log climate_{it} + \beta_3 \log density_{it} + \beta_5 \log water\_cons_{it} + e_{it} \quad (1)$$

where water_res is the logarithm of the total of water resources (direct extraction from the river, storage dam and groundwater), income Pc is the logarithm of real income per capita, climate is measured of climate change; which includes the component of the logarithm of global radiation and cloud cover. Density is a measure of population density; water_cons is the logarithm of water consumption; e is the error term in the district of Malaysia *i* during a period *t*.

4. Results and Discussion

Table 3 summarises the estimation results for random effect and fixed effect. The Hausman test suggests that it is more appropriate to use fixed effect for estimation, which offers a more efficient estimator.

Table 3
Estimation of Climate Change and Water Usage on Water Resources in Malaysia: (Dependent: Water Resources)

Variables	Random Effect	Fixed Effect
Log incomePc	-0.149	2.246**
	(0.140)	(1.038)
Log glob_rad	-1.447***	0.237
	(0.554)	(0.710)
Log cloud	6.261***	5.742***
	(1.945)	(2.006)
Log density	-0.034	4.083*
	(0.042)	(2.090)
Log water_cons	0.948***	0.710
	(0.065)	(0.569)
Cons	-5.709	-52.038***
	(4.122)	(12.122)
Hausman Test	102.96	
	[0.000]	
# of Obs	78	78
# of group	13	13
R-square	0.302	0.446

Note: number in parenthesis is Robust Standard Error. ***, ** and * indicates 1 percent, 5 percent and 10% significant level respectively.
[..] Indicate *P*-value

From Table 3, income is a significant factor in enhancing water resources. Holding all other factors constant, the magnitude of the coefficient implies that, when the level of wealth of a state increases by 1%, the water resources will increase by 2.2% due to change in the level of income. The finding also coincides with the results found by Joseph Alcamo et al. (2007), whereby the increase in water resources is also due to increasing water usage caused by the increase in income.

As mentioned in the previous section, the global radiation and the cloud cover, which is the proxy of climate change indicates that the cloud cover plays an important role in the rise of the level of dam water. By assuming the other factors constant, if the level of the coefficient of cloud cover increases by 1%, the total of water resources will rise by 5.7%. This result shows that the increase in cloud forming due to the change in climate will result in higher levels of rainfall, which will cause the available water resources to increase.

The global radiation has no significant effect on the water resources. Although the water consumption variable is found not to be significant in the model, nevertheless, its crucial role in water consumption cannot be denied, whereby the water supply depends on the demand for water. The more demand for water due to higher income, higher population and higher demand from firms and industrial sector will subsequently increase the water supply available by the technological advancement or newly identified locations of water resources.

In summary, these findings are useful to government for creating a better policy in order to sustain consume of water in all sectors, particularly in agriculture due to the high percentage approximately 70% of water resources. In addition, residential customers will use water wisely.

5. Conclusions

This study showed the panel random effect and fixed effect model to analyse the relationship between the income, climate change, population and water consumption on water resources in 13 states of Malaysia. The results indicate that the positive impact of income presumes that an increase of water resources is due to the increase of water usage from the household as the most important hygienic agent and utility in daily life. Besides, the climate change and higher population density were also found to be significant and positively related to the water resources. The higher the cloud cover, the more water resources will be available from the rainfall to these areas. It is because of the close connections between the climate and hydrologic cycle. In addition, areas with higher population density might have a higher demand for water usage and resources. The water consumption is very important to the water resources in this study. However, the finding is beyond the expectation. Further research with better or more sophisticated models, such as non-climate factors like the political, technological, the values of the societies, the alternative method controlling the water usage and the availability of data will be able to contribute positively to the results and findings in the future.

Such information better enables policy makers to handle the water shortage for domestic and non-domestic water consumption in a move toward a green economy which is important to economic growth and sustainable living.

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