Jurnal Perspektif Jil. 5 Bil. 1 (97-106)
ISSN 1985 - 496X

Precipitation Indices as Indicators of Water Resource Sustainability: A Study on Developed States of Peninsular Malaysia

Indeks Presipitasi Sebagai Petunjuk Kemampanan Sumber Air: Satu Kajian di Negeri-negeri Maju di Semenanjung Malaysia

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Abstract

Precipitation index has been used to measure droughts. The occurrence of droughts can be damaging to the water supply system in Malaysia. On normal hydrometeorological conditions, the water supply system is already grappling in order to meet the needs of consumers. New developments on global climate change cast a greater doubt on the sustainability of the water supply systems of Malaysia, since there is growing evidence of changing meteorological patterns which may adversely affect the rainfall amount. The developed states in Malaysia refer to Selangor, Pulau Pinang, Melaka and Negeri Sembilan. As developed states, development has placed these states at a very challenging situation; as such its water resources are really overstretched in terms of its ability to meet the ever growing demand. This study evaluates the standardized precipitation indices of these states and analyse them as to whether the indices can be used as precursors to water resource sustainability in these states.

Keywords *standard precipitation index, water resource, sustainability, Peninsular Malaysia*

Abstrak

Indeks presipitasi telah digunakan untuk mengukur kemarau. Berlakunya kemarau memberi kesan merosakkan terhadap sistem bekalan air di Malaysia. Dalam keadaan hidrometteorologi biasa, sistem bekalan air telah sedia sukar untuk memenuhi keperluan pengguna. Perkembangan baru dalam perubahan iklim dunia menyerlahkan kesangsian yang lebih lagi terhadap kemampanan sistem bekalan air di Malaysia, kerana bertambahnya bukti mengenai pola meteorologi yang sedang berubah yang mungkin memberi kesan negatif kepada jumlah hujan. Negeri negeri maju merujuk kepada Selangor, Pulau Pinang, Melaka dan Negri Sembilan. Sebagai negeri negeri maju, pembangunan telah meletakkan negeri negeri ini kepada keadaan yang mencabar, dimana sumber air telah tersangat sukar dalam erti kata kemampuannya untuk memenuhi permintaan yang sentiasa meningkat. Kajian ini menilai indeks

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presipitasi piawai dan menganilisisnya untuk menentukan samada indeks berkenaan boleh digunakan sebagai petunjuk awal kemampanan sumber air di negeri negeri ini.

Katakunci *indeks presipitasi piawai, sumber air, kemampanan, Semenanjung Malaysia*

Introduction

Precipitation index has been used to measure droughts (Ahmad and Low, 2004; Sharma et al., 2011). The occurrence of droughts can be damaging to the water supply system in Malaysia. On normal hydrometeorological conditions, the water supply system is already grappling in order to meet the needs of consumers. Ahmad, Hong and Kardi (1999) studied drought in the Hulu Langat area in Selangor using the Herbst method found that the 1998 drought was most intense and to make it worse, coincided with the 1997–1998 El Nino episode. New developments on global climate change cast a greater doubt on the sustainability of the water supply systems of Malaysia, since there is growing evidence of changing meteorological patterns which may adversely affect the rainfall amount. Siti et al (2011) used the Standardized Precipitation Index (SPI) method to study rainfall patterns in Peninsular Malaysia and identified areas where rainfall is in abundance or inadequate.

The developed states in Malaysia refer to Selangor, Pulau Pinang, Melaka and Negeri Sembilan. Sustainability of water resources in these states is meant to be the ability of the water supply systems to meet the demand. As developed states, development has placed these states at a very challenging situation; as such its water resources are really overstretched in terms of its ability to meet the ever growing demand. Using available data, this study analyzes standard precipitation indices (SPI) of the states mentioned, evaluates the indices and analyse them as to whether these indices can be used as precursors to assess water resource sustainability in these states.

Basis of Study

Study area

The developed states in Malaysia refer to Selangor, Pulau Pinang, Melaka and Negeri Sembilan. As developed states, development has placed these states at a very challenging situation, as such its water resources are really overstretched in terms of its ability to meet the ever growing demand. The most critical sector is the domestic and industrial water supply, because this sector depends almost entirely on surface water. On normal hydrometeorological conditions, the water supply system is already grappling in order to meet the needs of consumers. New developments on global climate change cast a greater doubt on the sustainability of these states' water supply systems, since there is growing evidence of changing meteorological patterns which may adversely affect the rainfall amount. Other challenges are also of equal threat to the sustainability of the water resources in these states, such as ever shrinking watersheds, pollution of surface water in rivers and increased sedimentations due to land surface exposure as a result of development. The situation is further burdened by non-revenue water, which, if not tackled, can prove to work to the disadvantage of the water supply systems.

The Standard precipitation Index (SPI)

The understanding that a deficit of precipitation has different impacts on groundwater, reservoir storage, soil moisture, snowpack, and streamflow led McKee, Doesken, and Kleis to develop the Standardized Precipitation Index (SPI) in 1993. The SPI was designed to quantify the precipitation deficit for multiple time scales. These time scales reflect the impact of drought on the availability of the different water resources. Soil moisture conditions respond to precipitation anomalies on a relatively short scale. Groundwater, streamflow, and reservoir storage reflect the longer-term precipitation anomalies. For these reasons, McKee et al. (1993) originally calculated the SPI for 3–, 6–,12–, 24–, and 48–month time scales.

The SPI calculation for any location is based on the long-term precipitation record for a desired period. This long-term record is fitted to a probability distribution, which is then transformed into a normal distribution so that the mean SPI for the location and desired period is zero. Positive SPI values indicate greater than median precipitation, and negative values indicate less than median precipitation. Because the SPI is normalized, wetter and drier climates can be represented in the same way, and wet periods can also be monitored using the SPI.

Justification of the Study

Water resource is an important requirement of the country for various reasons. Even though Malaysia is blessed with hot equatorial climate which is characterised by heavy yearly rainfall, water shortages do happen in this country. The situation is compounded by the fast-paced development that takes place in many parts of the country which results in the increase in population to the more developed regions. These regions, found in the developed states of the country attract people to them as such there occurs increase in the needs of services in almost sectors, water resource included.

This study is determine whether or not the developed states where water resources are on greater demand as compared to other areas are at risk of having less rainfall in comparison to other areas of lesser level of development. The Standard Precipitation Index is a technique that can elucidate areas with chances of having rainfall.

Water Resource Sustainability

Using the definition of World Commission on Environment and Development (WCED, 1987) the word *sustainable* is the ability to meet the needs of the present generation without compromising the ability of future generations to meet their own needs. In the study states, water resource sustainability vary according to current situation of each state.

Selangor The water resource situation in this state is indicated in Table 1, which means that the present situation can hold for a very short term. According to this table, the sustainability of the water resource may last up to 2014 only, and beyond that new sources of water has to obtained in order for the system to able to meet the demand.

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The Selangor-Pahang Water Transfer project is already under way (Ismail, 2009). Under this scheme, water from the neighbouring state of Pahang is stored in a dam called Kelau Dam on the Kelau River which is a tributary of the Semantan River. Water released from the dam will then be drawn at intake points near Kampung Kuala Pertang on the banks of the Semantan River. The water will then be transferred to Kampung Kuala Pangsun in Hulu Langat, Selangor via 44.6 km tunnel before it is treated at water treatment plants in Selangor. This scheme will able to supply 1,890 mld of water to Selangor. The project is expected to be completed in 2014.

Table 1 Current Water Supply Situation in Selangor (in mld)

Year	Demand	Supply
2010	4000	4500
2011	4100	4500
2012	4200	4500
2013	4400	4500
2014	4500	4500

Pulau Pinang The three dams operating in Penang are able to sustain water supply for the state up to 2020. This ability is due to upgrading of the Mengkuang dam which is now capable on storing 23 m^3 of water to a new capability of 78 m^3 when works on it complete (The Star, 2009). At the same time the Sungai Dua water treatment plant was also under going upgrading to increase its capacity from 1,091 mld to 1,963 mld (Malaysiakini, 2010).

Even though Penang is in a comfortable situation at least up to 2020, sources of raw water may not stay unchanged in the near future. Besides getting its raw water supply from the three dams, the Penang water authority also draws water from Muda river in Kedah. This river is heavily utilized since it does not only supply Penang its raw water, it is also depended upon to supply water to the huge agricultural irrigation scheme of MUDA. For this reason, the water authority in Penang had already worked on another alternative of drawing raw water from the Perak River (The Star, 2011).

Negri Sembilan The sustainability of water resources in Negri Sembilan depends on what the picture is like for Seremban. This is because Seremban is the biggest urbanized area in the state, and at the same time it is experiencing the spill-over effects of the development that takes place in the Putrajaya area.

The Seremban area has always been a tight situation area since the mid 1990s in the sense that its water supply system was struggling to keep pace with the ever increasing water demand. In the year 2000, the total available treated water to the consumers was about 247 mld (Table 2), and this amount remained stagnant for quite a number of years. Anticipating shortage situation in the years ahead, the water authority started inter-basin water transfer Kelichi Dam to the Terip Dam.

Table 2 Water Supply Production in the Seremban area

Plant	Capacity*
Sg. Linggi	90.92
Sg. Terip	132.33
Pantai	18.18
Sg. Ngoi Ngoi	4.54
Sg. Mahang	1
Broga	0.81
Total	247.78

** mld^{-1}*

Source: *Jabatan Bekalan Air Negri Sembilan (JBANS, 1999)*

Even with the inter-basin water transfer effort, the water supply system in the Seremban area finds it difficult to cope with the ever-growing demand. As such Seremban is a problem area in terms water supply. It seems that among all the study states, Negri Sembilan in the state that has the most uncomfortable future in terms of water resources. Water rationing in 2005 was a bad enough experience for residents of Seremban and the surrounding areas, but to experience incessant water cuts is almost unbearable. 2010 witnessed the return of water rationing in the area, and there seems to be no end in sight for the problem.

Melaka The water authority in Melaka is in the view that the state can sustain water supply up to 2018. Raw water intakes are from the Melaka, Kesang and Muar Rivers by utilising facilities of the Durian Tunggal and Jus Dams are sufficient for water demand if there were no drop in rainfall. The hot weather in the months of January through March 2010 saw frantic efforts to smoothen the effects of reduced water levels in dams and rivers which brought back bitter memories of water crisis in the state in 1991 and 2002.

In view of the short-term nature of water resource sustainability in the state, the idea of having another dam was mulled, and a location at Sungai Jernih in Alor Gajah was initially identified as a possible site of the dam (The Star, 2010).

Methodology

The Malaysian Meteorological Department (MMD) maintains a monitoring of drought situation in Malaysia. Standard Precipitation Indices of rainfall stations maintained by the department are calculated on regular basis. This study uses the SPI calculated by the Malaysian Meteorological Service and and apply them to the study areas. Results of SPI of the study areas are shown in Tables 3(a-c).

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Table 3(a) February 2011 SPI of the Study Area

Penang	**1-month**	**2-month**	**3-month**	**4-month**	**5-month**	**6-month**
P. Langkawi	-0.89	-1.27	0.22	0.89	0.36	-0.21
Bayan Lepas	-0.7	-0.67	0.18	0.8	-0.38	-1.14
Butterworth	-1.26	-0.56	0.38	0.57	-0.52	-1.46
Alor Setar	-0.43	-0.44	-0.01	0.72	0.48	0.08
Selangor	**1-month**	**2-month**	**3-month**	**4-month**	**5-month**	**6-month**
Subang	-1.3	-0.81	-0.55	-0.69	-1.21	-0.75
Petaling Jaya	1.54	1.19	1.48	0.9	0.55	0.72
Negri Sembilan	**1-month**	**2-month**	**3-month**	**4-month**	**5-month**	**6-month**
KLIA Sepang	-1.53	-0.72	-1.26	-1.36	-1.6	-1.5
Melaka	**1-month**	**2-month**	**3-month**	**4-month**	**5-month**	**6-month**
Melaka	-0.78	1.09	0.89	0.98	0.49	-0.22

Source: *MMD (2011)*

Table 3(b) August 2011 SPI of the Study Area

Penang	**1-month**	**2-month**	**3-month**	**4-month**	**5-month**	**6-month**
P. Langkawi	1.79	1.05	1.04	0.7	0.25	1.19
Bayan Lepas	-0.72	-0.97	-1.59	-1.5	-1.47	-0.21
Butterworth	1.01	0.55	-0.01	0.31	-0.25	0.88
Alor Setar	1.11	0.45	-0.11	-0.42	-0.94	-0.42
Selangor	**1-month**	**2-month**	**3-month**	**4-month**	**5-month**	**6-month**
Subang	0.96	0.62	0.45	0.37	0.36	0.53
Petaling Jaya	1.53	1.27	1.09	0.98	1.17	1.23
Negri Sembilan	**1-month**	**2-month**	**3-month**	**4-month**	**5-month**	**6-month**
KLIA Sepang	-0.16	-1.81	-1.55	-2.05	-2.1	-1.81
Melaka	**1-month**	**2-month**	**3-month**	**4-month**	**5-month**	**6-month**
Melaka	-0.87	-1.58	-1.43	-0.97	-1.18	-1.44

Source: *MMD (2011)*

Table 3(c) September 2011 SPI of the Study Area

Penang	**1-month**	**2-month**	**3-month**	**4-month**	**5-month**	**6-month**
P. Langkawi	0.62	1.66	1.08	1.08	0.83	0.47
Bayan Lepas	-0.99	-1.2	-1.47	-1.93	-1.84	-1.74
Butterworth	-0.19	0.48	0.23	-0.31	0.05	-0.5
Alor Setar	-1.57	-0.11	-0.48	-0.84	-0.99	-1.44
Selangor	**1-month**	**2-month**	**3-month**	**4-month**	**5-month**	**6-month**
Subang	0.16	0.77	0.5	0.39	0.34	0.34
Petaling Jaya	-0.47	1.1	0.75	0.72	0.66	0.92
Negri Sembilan	**1-month**	**2-month**	**3-month**	**4-month**	**5-month**	**6-month**
KLIA Sepang	0.23	0	-0.95	-1.24	-1.66	-1.75
Melaka	**1-month**	**2-month**	**3-month**	**4-month**	**5-month**	**6-month**
Melaka	0.06	-0.69	-1.35	-1.36	-0.94	-1.14

Source: *MMD (2011)*

The figures shown in Tables 3(a-c) show the SPI scores for stations in the study areas for the months of February, August and September 2011. The month of February was chosen because it is on the onset of the Southwest Monsoon and states in the western coast of peninsular Malaysia can expect rain to fall during this months and months following it as the wind fromSumatra usually brings moisture and precipitate them along the coast of western peninsular Malaysia. The month of August lies in the intermonsoonal period in which a change of wind direction from southwest to northeast usually occurs within the first weeks of September, and it can be expected that the months of July and August to be dry. September is the month during which the northeast wind starts to arrive and along with it comes moisture. Even though the study states are in the western coast of peninsular Malaysia, some of the moistures do arrive during the month of September and are usually precipitated as rain. At the same time the role of convectional rains in adding to the rainfall events in these selected months can also affect the amount of rainfall collected.

SPI and Water Resource Sustainability

Sayang et al. (2009) studied the spatial trends of dry spells in Peninsular Malaysia and concluded that areas northwestern portion had a slightly higher mean of maximum dry spells than other regions during the northeast monsoons. Deni (2008) in another study concluded that Alor Star is the regions with the longest dry spells, while Melaka has the shortest wet spells. This study attempts to extricate the rainfall potential of the study states and it will have implications on the sustainability of water resources in those states.

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Findings

Table 4 (a) Rainfall rating for February 2011

	1-month	2-month	3-month	4-month	5-month	6-month
Penang	n	n	n	n	n	md
Selangor	w	mw	n	n	n	n
Negri Sembilan	sd	n	md	md	sd	sd
Melaka	n	mw	n	n	n	n

Table 4(b) Rainfall Rating for August 2011

	1-month	2-month	3-month	4-month	5-month	6-month
Penang	n	n	n	n	n	n
Selangor	mw	n	n	n	n	n
Negri Sembilan	n	sd	sd	ed	ed	sd
Melaka	n	sd	md	n	md	md

Table 4(c) Rainfall Rating for September 2011

	1-month	2-month	3-month	4-month	5-month	6-month
Penang	n	n	n	n	n	n
Selangor	n	n	n	n	n	n
Negri Sembilan	n	No data	n	md	sd	sd
Melaka	n	n	md	md	n	md

Table 4(d) Rainfall ratings based on SPI scores

SPI score	**2.0 and >**	**1.5 to 1.99**	**1.0 to1.49**	**-0.99 to 0.99**	**-1.0 to -1.49**	**-1.5 to -1.99**	**-2.0 or less**
Rainfall condition	Extremely wet (ew)	Wet (w)	Moderately wet (mw)	Normal (n)	Moderately dry (md)	Severely dry (sd)	Extremely dry (ed)

The findings of this study are summarized in Tables 4 (a through c). The rainfall ratings are based on the SPI scores as showed in Table 4(d). For states which have more than one station used, the average SPI score was calculated.

It is shown in this study that the states of Penang and Selangor record normal expectation of rainfall. It may be viewed that the two states can expect their water resources in sustainable situation based of this rating, even though actual water resource sustainability depends on other factors. On the other hand, the states of Negri Sembilan and Melaka do record dry situation of mild to severe. This should be of concern to the water authorities of those states because the present water resource sustainability in

those states is precarious. The state of Negri Sembilan recorded extremely dry ratings for the month of August, and this may foretell future performace of rainfall reception in the state in the future.

Conclusion

This study is an initial attempt to measure and gaian insight into water resource sustainability in the developed states in Malaysia. Even though the study analyzed only three selected months in a particular year, it is actually an attempt to extricate the effects of other parameters in influencing water resource sustainability. This study was able to identify the states which have potential water resource weakness in the sense that their SPI ratings may be indicative of situations in years ahead.

Funding for this research was granted by UPSI through GPU grant number 2011-0007-102-01, and is gratefully acknowledged.

References

Ahmad Jamalluddin, Hong K.A and Kardi, J. (2004). Characteristics of the 1998 Drought Affecting Langat Valley. In Rahim N.A. (ed.) *Water: Forestry and Land Use Perspectives*; I'ntl Hydrol. Progr., IHP-VI, Tech. Doc. In Hydrology, UNESCO, Paris.

Ahmad Jamalluddin & Low, K.S. (2004). Droughts in Malaysia: A Look at Its Characteristics, Impacts, related Policies and Management Strategies. Water and Drainage 2003 Conference, K. Lumpur;Nat'l Hydraulic Research Inst. M'sia (NAHRIM) (proceeding page); Kuala Lumpur: Ministr. Nat. Resources & Envi., M'sia.

Deni, S.M., A.A. Jemain and K. Ibrahim (2008); The Spatial Distribution of Wet and Dry Spells Over Peninsular Malaysia, *Theor. Appl. Climatology*, 94: 163-173, DOI 10.1007/s00704-007-0355-8

Ismail, M.T. (2009). The Interbasin Water Transfer: The Pahang-Selangor Water Transfer-Challenges and Opportunities. *Water Malaysia 2009*. *Int'l Confer. On Water Industry Best Practices*, Kuala Lumpur: Minist. Energy, Green Tech. & Water, Malaysia.

JBANS (Jabatan Bekalan Air Negeri Sembilan=Negeri Sembilan Water Supply Dept.) (1999); Laporan Tahunan (Annual Report).

Malaysiakini (2010). Menambah Air Pulau Pinang. http://www.malaysiakini.com/news/151840 28/12/2010. . Accessed 26.4.2011

McKee, T.B., N. J. Doesken, and J. Kliest (1993); The Relationship Of Drought Frequency And Duration To Time Scales. In *Proceedings of the 8th Conference of Applied Climatology, 17-22 January, Anaheim, CA*. American Meterological Society, Boston, MA. 179-184.

MMD (Malaysian Meteorological Department) (2011). Official Portal, Minstr. Sci, Tech. and Innovtn, M'sia; http://www.met.gov.my/

Sayang,M.D., S. Jamaludin, W. Z. Wan Zawiah and J. Abdul Aziz (2009), Spatial Trends of Dry Spells Over Peninsular Malaysia During Monsoon Seasons; *Theor. Appl. Climatology*, 99:357-371, DOI 10.1007/s00704-009-0147-4

TheStar(2009).MengkuangDamExpansion.http://thestar.com.my/news/story.asp?file=/2009/7/21/nation/4356691&sec=nation. Accessed 26.4.2011.

The Star (2010). Sungai Jernih Identified as the source of Melaka's Third Dam. http://thestar.com.my/metro/story.asp?file/2010/3/1/southneast/5758086&sec=southneast. Accessed 26/4/2011.

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ISSN 1985 - 496X

TheStar(2011).RiseDampensState'sEfforts.http://thestar.com.my/metro/story.asp?file=%2F2011%2F4%2F4%2Fnorth%2F8409118&sec=North.

WCED (World Comission for Environment and Development) (1987); *Our Common Future*; , Oxford:Oxford Univ. Press.