Journal of Applied Sciences

ISSN 1812-5654

science alert

ANSInet
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http://ansinet.com

Journal of Applied Sciences 8 (21): 3991-3994, 2008
ISSN 1812-5654

Temporal Analysis of the Keetch-Byram Drought Index in Malaysia: Implications for Forest Fire Management

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Abstract: In this study, daily KBDI values were calculated and temporal trends were analyzed at four selected stations; Kota Bharu, Kuching, Sandakan and Subang in Malaysia for the period 1990-1995 using a KBDI software. The highest monthly mean KBDI values were 1550 in February, 1120 in July, 1355 in April, 1370 in July and the lowest were 380 in November, 240 in January, 380 in December, 680 in December at Kota Bharu, Kuching, Sandakan and Subang, respectively. In the frequency analysis, Kota Bharu had 773 Moderate Fire Danger (MFD) days and 684 Low Fire Danger (LFD) days. Kuching had 1497 LFD days and 120 High Fire Danger (HFD) days while Sandakan had 1056 LFD days and 424 HFD days. Subang had 926 MFD days and 366 HFD days. In terms of forest fire management perspectives, the Kota Bharu station faces higher risk in January compared to the other stations in the same month. On the other hand, areas within the Kuching station faces the lowest risk of fire in January compared to the other stations in the same months.

Key words: Forest fire, KBDI, fire danger index, drought, fire risk

INTRODUCTION

Tropical forest fire is becoming an important environmental issue in the Southeast Asia region. This is because the recurrent haze in the region has been attributed to the gas emissions (Radojevic, 2003) and addition of particulates to the atmosphere by periodic forest fire occurring in the region (Heil and Goldammer, 2001; Abbas *et al*., 2004) and also an increased in respiratory diseases such as asthma (Emmanuel, 2000; Kunii *et al*., 2002; Mott *et al*., 2005) during the haze episode. Most of these hazes were from forest fires in Sumatra and transported to Singapore and Kuala Lumpur by prevailing southeasterly wind (Koe *et al*., 2001). It also has an impact on the regions economy such as the tourism industry in the region (Shahwahid and Jamal, 1998).

In order to mitigate these effects there is a need to forecast the potential of fire and this can be done using fire danger indices such as MacArthur Fire Meter (McArthur, 1963), Canadian Fire Weather Index (CFWI) and also Keetch Byram Drought Index (KBDI). Many studies have attempted to use KBDI and relate with forest fire risk (Heim, 2002; Dolling *et al*., 2005) and map KBDI of many stations (Janis *et al*., 2002) to facilitate fire potential monitoring.

Keetch Byram Drought Index (KBDI) is basically a mathematical system for relating current and recent weather conditions to a potential or expected fire behavior. It is a number representing the net effect of evapotranspiration and precipitation in producing cumulative moisture deficiency in deep duff and upper soil layers (Keetch and Byram, 1968). This Index expresses drought as an index on a scale from 0 to 2000, based on the moisture content of the soil. Zero is the point of no moisture deficiency and 2000 is the maximum drought level possible (Buchholz and Weidemann, 2000).

In Malaysia, no study on Keetch Byram Drought Index (KBDI) and its application has been conducted. This study will derive KBDI and analyse the temporal trends of the selected stations.

MATERIALS AND METHODS

Four stations, Kota Bharu (Kelantan), Kuching (Sarawak), Sandakan (Sabah) and Subang (Selangor) were chosen for this study (Table 1). The stations were selected since they represent different climatic variations of the country. Also occurrence of forest fires have been reported in the vicinity of these stations. Maximum daily air temperature and total daily rainfall from 1st January 1990 to 31st December 1995 were used to derive the KBDI.

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Table 1: Location of the 4 selected stations

Station	Location
Kota Bharu	Latitude 06° 10' North
	Longitude 102° 17' East
Kuching	Latitude 01° 29' North
	Longitude 110° 20' East
Sandakan	Latitude 05° 54' North
	Longitude 118° 04' East
Subang	Latitude 03° 07' North
	Longitude 110° 133' East

Table 2: Levels of Keetch Byram Drought Index (KBDI)

Categories	Drought index value range
Low fire danger	0-1000
Moderate fire danger	1001-1500
High fire danger	1501-2000

The KBDI was determined using method developed by Keetch and Byram (1968) and the calculation was automated using a software developed by Ainuddin and Saidy (2001).

The KBDI is calculated by adding the change in the dryness index on each day to the KBDI from the previous day. On each day, a value for the soil water depletion in mm is computed as the KBDI from the previous day minus the net rainfall (mm) on the current day. The net precipitation (mm) is calculated as the recorded precipitation (mm) minus 5.08 mm, which corresponds to the rainfall in inches minus 0.2 inch that was used by Keetch and Byram (1968). The soil moisture depletion is calculated as 203.2 mm minus Q (mm), which corresponds to 800 (hundredths of inches) minus Q (hundredths of inches) (Snyder *et al*., 2006).

Daily maximum temperature and daily total precipitation of each stations were used to derive daily KBDI to give a total of 2191 daily KBDI. Daily KBDI were analysed using frequency analysis and descriptive statistics.

In translating KBDI values into operational practicality, Keetch and Byram (1968) categorized KBDI into three levels (Table 2); low fire danger, moderate fire danger and high fire danger. Low fire danger means that soil and fuel moisture is high. Most fuels will not readily ignite or burn. At moderate fire danger, fires more readily burn and will carry across an area with no gaps. Heavier fuels will still not readily ignite or burn. At high fire danger fires will readily burn in all directions exposing minerals soils and large fuels may burn or smolders for several days creating possible smoke and control problems (Keetch and Byram, 1968).

RESULTS

Table 3 shows the descriptive statistics of daily Keetch Byram Drought Index (KBDI) value for 4 stations. The Kota Bharu stations KBDI values for mean, maximum and minimum were 1191 units, 1982 units and 53 units respectively. As for the Kuching station, the KBDI value for mean, maximum and minimum were 728 units, 1769 units and 36 units respectively. Meanwhile at the Sandakan station, the daily KBDI value for mean, maximum and minimum were recorded 993 units, 1868 units and 43 units respectively. Lastly, the KBDI values for mean, maximum and minimum at Subang station each recorded 1055 units, 1896 units and 41 units.

Table 3: Mean, maximum, minimum and standard deviation of daily KBDI values of selected stations

Stations	Mean±SD	Maximum	Minimum
Kota Bharu	1191±520	1982	53
Kuching	728±458	1769	36
Sandakan	993±527	1868	43
Subang	1055±451	1896	41

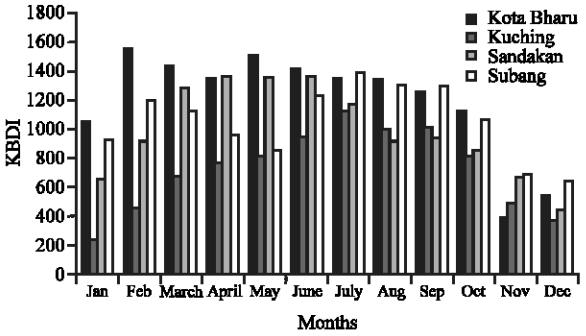

Fig. 1: Monthly mean KBDI for the four stations (1990 to 1995)

The highest mean KBDI was recorded in Kota Bharu station with the value of 1191 units while the lowest KBDI value for mean was recorded in Kuching station with the value of 728 units.

Kota Bharu highest monthly mean KBDI value was recorded in February with the value of 1550 in 6 year period, while the lowest was in November with the value of 380. Beginning from May, the KBDI value decreases until December and from January to March, the KBDI value increases constantly and then dropped in April.

Highest monthly mean KBDI value for Kuching during the study period was 1120 in July; meanwhile the lowest was recorded 240 in January. The KBDI value increases from February to September, but the value dropped from the month of October to December.

From the Fig. 1, the highest monthly mean KBDI value for Sandakan was recorded 1355 in April in six-year period, while the lowest was 380 in December. From January to June, the KBDI value increased constantly and then dropped from July to December.

The highest KBDI value for Subang was 1370 in July; meanwhile the lowest KBDI value recorded 680 in

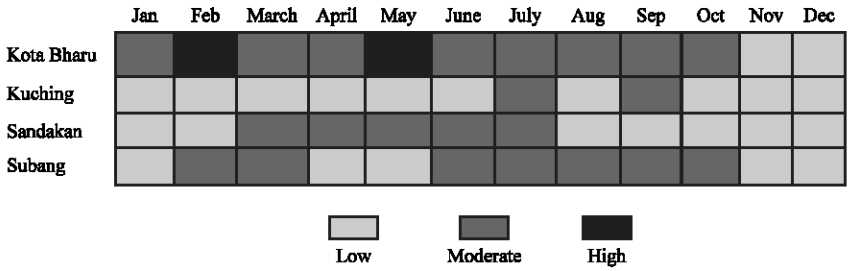

Fig. 2: Monthly fire danger severity for 4 stations (1990 to 1995)

Table 4: Frequency analysis of KBDI during the study period (1990-1995)

Stations	Low fire danger 0-1000	Moderate fire danger 1001-1500	High fire danger 1501-2000
Kota Bharu	684	773	734
Kuching	1497	574	120
Sandakan	1056	711	424
Subang	899	926	366

December. From January to February, the KBDI value increase constantly, then dropped from March to May. Beginning from July, the KBDI value decreases until December.

Figure 2 shows monthly variations of three categories of KBDI according to stations. Each station shows different monthly patterns with Kota Bharu exhibits 9 months of moderate and high fire danger categories. Kuching shows only two months of moderate fire danger while the rest falls under low fire danger.

In Table 4, Kota Baru has the highest number of days in the high fire danger with 734 days fall into that category. KBDI level showed that the areas within the Kuching station faces low fire danger as 1497 days the KBDI falls under low fire danger while high fire danger occur 120 days. This is also true for Sandakan station which 1056 days falls under low fire danger. However, for 424 days the KBDI falls into high fire danger category. Areas within the Subang station face moderate fire risk with 926 days recorded in moderate fire danger and 366 days of KBDI recorded in high fire danger category.

DISCUSSION

Monthly mean KBDI variations among the stations show different patterns. Monthly mean KBDI for Kota Bharu station is lowest during December while highest during March. For the Kuching monthly mean KBDI, the pattern shows more irregularity but has lowest KBDI value in December with high KBDI values in March and June. KBDI monthly mean variation for Sandakan shows low value during December with high KBDI during March to June. KBDI trend for Subang is following the trend of other stations with KBDI value lowest during December. The KBDI value increases in March and peaked in June.

Figure 2 visually expressed monthly fire danger severity (Hall and Gwamela, 1985) for the four stations. Among the stations Kota Bahru has two months of high fire risk and eight months of moderate fire risk. In fact among the stations studied, only Kota Bahru has months of high fire risk. Subang station has seven months of moderate fire risk while Sandakan has continuous five months of moderate fire risk. Kuching has the lowest risk which has only two months of moderate risk. The pattern in which months occurred is different at each station. This is due to the geographical location of each station that influenced the different rainfall pattern each station.

The daily KBDI in each station shows temporal trend and can be used for forest fire management. Hall and Gwamela (1985) analysis of fire danger indices at Tanzania shows that this information can be used to develop fire control activity time table. Period of days when KBDI's are in high fire danger category can be determined and this information can be used to plan for presuppression activities such putting the forest fire management team on alert and be ready to fight the fire. Period when the KBDI's are low, the forest fire management team can use this occasion for training and maintenance of the equipment. Understanding the period of high and low of KBDI can be used to relate with total areas burnt (Dolling *et al*., 2005) and also help to plan allocation of resources (Chan *et al*., 2000) for forest fire management and planning.

CONCLUSION

The highest monthly mean KBDI value was Kota Bharu station during the month of January, meanwhile the lowest KBDI was Kuching station also in January. In terms of forest fire management perspectives, the Kota Bahru station faces higher risk in January compared to the other stations in the same month. On the other hand, areas within the Kuching station faces the lowest risk of fire in January compared to the other stations in the same months. The information from the daily KBDI can be used for forest fire management purposes.

ACKNOWLEDGMENTS

We would like to express my appreciation to the Malaysian Meteorological Department for supplying the meteorological data used in this study.

REFERENCES

Abas, M.R., D.R. Oros and B.T. Simoneit, 2004. Biomass burning as the main source of organic aerosol particulate matter in Malaysia during haze episodes. Chemosphere, 55: 1089-1095.

Ainuddin, A.N. and M.Y. Saidy, 2001. Keetch-byram drought index calculator (KBDIC). A windows-based software for forest fire risk assessment. Abstract. Symposium Programme and Abstract Malaysian Science Technology Congress 2001. Sept. 24-26, Sabah, pp: 65-65.

Buchholz, G. and D. Weidemann, 2000. The use of simple fire danger rating systems as a tool for early warning in forestry. Int. For. Fire News, 23: 32-27.

Chan, D.W., J.T. Paul and A. Dozier, 2000. Keetch-byram drought index: Can it help predict wildland fires? Fire Manage. Today, 64: 39-42.

Dolling, K., P.S. Chu and F. Fujioka, 2005. A climatological study of the Keetch/Byram drought index and fire activity in the Hawaiian Islands. Agric. For. Meteorol., 133: 17-27.

Emmanuel, S.C., 2000. Impact to lung health of haze from forest fires: The Singapore experience. Respirology, 5: 175-182.

Hall, J.B. and W.N.K. Gwalema, 1985. Drought indices and fire danger indices at Morogoro, Tanzania. For. Ecol. Manage., 10: 125-134.

Heil, A. and J. Goldammer, 2001. Smoke-haze pollution: A review of the 1997 episode in Southeast Asia. Regional Environ. Change, 2: 24-37.

Heim, R.R., 2002. A review of twentieth century drought indices used in the United States. Bull. Am. Meteorol. Soc., 83: 1149-1165.

Janis, M.J., M.B. Johnson and G. Forthun, 2002. Near-real time mapping of Keetch-Byram drought index in the south-eastern United States. Int. J. Wildland Fire, 11: 281-289.

Keetch, J.J. and G.M. Byram, 1968. A drought index for forest fire control. USDA Research Paper SE-38, pp: 1-32, http://www.treesearch.fs.fed.us/pubs/40.

Koe, L.C.C., A.F. Arellano Jr. and J.L. McGregor, 2001. Investigating the haze transport from 1997 biomass burning in Southeast Asia: Its impact upon Singapore. Atmospheric Environ., 35: 2723-2734.

Kunii, O., S. Kanagawa, I. Yajima, Y. Hisamatsu, S. Yamamura, T. Amagai and T.T. Ismail, 2002. The 1997 haze disaster in Indonesia: Its air quality and health effects. Arch. Environ. Health, 57: 16-22.

McArthur, A.G., 1963. Forest Fire Danger Meter. Foreat Res. Institute. M. No. 3 Canberra, Australia, pp: 90-100.

Mott, J.A., D.M. Mannino, C.J. Alverson, A. Kiyu, J. Hashim, T. Lee, K. Falter and S.C. Redd, 2005. Cardiorespiratory hospitalizations associated with smoke exposure during the 1997 Southeast Asian forest fires. Int. J. Hyg. Environ. Health, 208: 75-85.

Radojevic, M., 2003. Chemistry of forest fires and regional haze with emphasis on Southeast Asia. Pure Applied. Geophys., 160: 157-187.

Shahwahid, M. and O. Jamal, 1998. Transboundary cost of the Indonesian forest fire on neighbouring Malaysia: A need for regional economic cooperation. Paper Presented at the 6th Convention of the East Asian Economic Association. 4-5 September 1998. Kitakyushu, Japan, pp: 25-25.

Snyder, R.L., D. Spano, P. Duce, D. Baldochi, L. Xu and U.K.T. Paw, 2006. A fuel dryness index for grassland fire-danger assessment. Agric. For. Meteorol., 139: 1-11.