# Analysis of Water Stress Index (WSI) for District Surrounding Ulu Sat Forest Reserve, Kelantan, Malaysia

IOP Conf. Series: Earth and Environmental Science **549** (2020) 012015 doi:10.1088/1755-1315/549/1/012015

# Analysis of Water Stress Index (WSI) for District Surrounding Ulu Sat Forest Reserve, Kelantan, Malaysia

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**Abstract** In the present study, the Water Stress Index for the selected area surrounding the Ulu-Sat forest reserve, Kelantan, Malaysia, was calculated. Water Stress Index was derived based on the ratio of water withdrawal to availability serves as an indicator to assess the status of water scarcity in the area. Water consumption for domestic purposes includes the daily water used for drinking and cleaning for households, while the non-domestic water used includes sectors such as agriculture (paddy and non-paddy), industry, and livestock. Estimation of water availability obtained from 3 stations located around Ulu-Sat forest reserve and the climate data obtained from the year 2008 to 2018. The water stress index presented in a range of 0.0 – 1.0. The result shows that the Water Stress Index value for Ulu-Sat forest reserve surrounding area obtained at an average of 0.32 for Machang, Pasir Puteh, and Kuala Krai. The result was implying a current low level of stress in Machang and Kuala Krai but the high-stress level in the Pasir Puteh area. The study also found that moderate to high-stress level occurs during the driest period of the year while low to medium stress level during the monsoon season. However, this ratio expected to further increase soon due to increase in water consumption and application. Hence, the importance of Ulu-Sat forest reserve in maintaining the stress level ratio low viewed as the utmost concern, especially in the dry season.

## 1. Introduction

Water is an essential resource and abundant on earth's and vital to all lives, especially humans in daily life [5]. The river is vital to human, whether for daily life, transportation, electric generation, played an essential role in the economic and social life of people. Due to importance of the river, humans have primarily overlooked, violate and mismanaged rivers in this country and throughout the world because being severely depleted and polluted, degrading and poisoning the surrounding ecosystems, thus threatening the health and livelihood of people who depend upon them for irrigation, daily house use, recreational and industrial water [6,7,8,10,11,14]. Water scarcity, is a term widely used by the media can broadly be understood as the lack of access to adequate quantities of water for human and environmental uses, is increasingly being recognized in many countries as a serious and growing concern [12]. In order to measure the water scarcity of an area, water stress index is a method used to define water scarcity in terms of the availability of total water resources to the population of a region,

measuring scarcity as the amount of renewable freshwater that is available for each person each year [12].

Beside water source, there is another resource that retains water and also known as the leading producer of oxygen called a forest. Forest, especially in highland, is a water catchment area that supplies fresh water to human. According to [4], the quality and availability of water influenced by forests and its catchment area. Forested catchments area serves as guarantors of high-value surface and drinking water (Carina, 2008). Clear felling the rainforests changes the reflectivity of the earth's surface, which affects global weather by altering wind and ocean current patterns, and changes rainfall distribution. If the forests destroyed, global weather patterns may become more unstable and extreme [13]. The availability and quality of water in many regions of the world threatened by overuse, misuse and pollution, and it is increasingly recognized that forests strongly influence both.

Water scarcity is a lack of water adequacy for human use and environment supports [12]. Water stress index (WSI) is the method to define water scarcity in term of availability of total water resources in a region. The nearer the water demand amount to amount of water supply, the more likely stress will occur in natural and human ecosystems.

## 2. Methodology

### 2.1 Study Area

Ulu Sat Forest Reserve Complex situated in between three districts of Machang and Pasir Puteh in Kelantan and Jerteh in Terengganu, coordinate 5°43'N, 102°1'E. The size of Ulu Sat Forest Reserve is about 16,414ha. Ulu Sat Forest Reserve is a part of Central Forest Spine (CFS) which is described as a form of forest landscape that is associated in physical form and has certain functions across eight forest complexes in Peninsular Malaysia, from Johor to the Thai border (and beyond the border until some areas are protected in Southern Thailand).

Secondary data were obtained from the Department of Drainage and Irrigation (JPS), Statistical Department of Malaysia (DOSM), Malaysia Meteorological Department (MET), and National Hydraulic Research Institute of Malaysia (NAHRIM). The rainfall data from the past 10 years (2008 – 2018) were used in the present study. Data for water consumption (domestic and non-domestic sectors) were obtained year 2008 until 2018.

### 2.2 Data Analysis

Water Stress Index was derived based on the ratio between water withdrawal and water availability following [9]:

$$\mathrm{WSI} = \frac{1}{1 + e^{-6.4 \cdot \mathrm{WTA}^{*}} \left( \frac{1}{0.01} - 1 \right)}$$

where:

WTA= Withdrawal to availability

The value of WSI is ranges from 0 to 1. The WSI value closes 1.0 implying an extreme water stress condition. The values of Water Stress Index were classified into five categories (Table 1).

**Table 1.** Water Stress Index indicator

| WSI | Level |
|---|---|
| <0.02 | |
| 0.02-0.04 | low |
| 0.05-0.09 | |

| | |
|---|---|
| 0.10-0.19 | medium |
| 0.20-0.49 | moderate |
| 0.50-0.79<br>0.80-0.89 | high |
| 0.90-0.95<br>>0.95 | extreme high |

## 3. Results and Discussion

### 3.1 Rainfall of Ulu Sat

Rainfall in Kelantan and other states in East Coast of Peninsular of Malaysia was influenced by north-east monsoon which occur from November to March [2]. During this monsoon raining season, most of the outdoor activity was limited and almost all tourist attraction especially in East Coast Island was closed due to heavy rain. Based on rainfall data from Department of Irrigation and Drainage (JPS), average rainfall for 10 years (2008-2018) in Ulu Sat forest reserve shows raining season in this area starts from November to January as show in Figure 1. Other than these three months the rainfall gauge was moderate from February to October. Total rainfall in Ulu Sat forest reserve for last 10 years are between 2000 mm to 4500 mm annually as shown in Figure 2. According to Malaysia Meteorological Department, average annual rainfall in Peninsular of Malaysia is 2420mm while in Sabah are between 2630mm and 3830mm for Sarawak. Ulu Sat forest reserve receive plenty of rainfall for last 10 years with the highest rainfall recorded in 2011 around 4300mm.

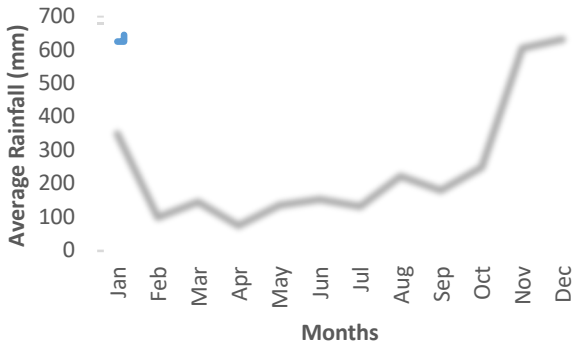


**Figure 1.** Average monthly rainfall in Ulu Sat from 2008 to 2018.

With high yearly rainfall average, district surrounding the Ulu Sat Forest Reserve Complex is susceptible to flooding. In Malaysia, flood is the major problem that happens especially in east coast of Peninsular Malaysia. Figure 3 shows flood prone areas (green shaded) extracted from Department of Drainage and Irrigation (DID) for the Peninsular Malaysia. Ulu Sat forest reserve also in the green shaded area. Flash flood normally occurs after heavy rainfall associated with severe thunderstorm by a timescale less than six hours while monsoonal flood triggers by the prolonged heavy widespread rain leads to land inundation during December to January in east coast of Peninsular Malaysia [1]. Without the forest as a natural flood abatement for the heavy rainfall, high volume of water will end up flowing freely into rivers and waterways. This movement of water is modulated by forest vegetation.

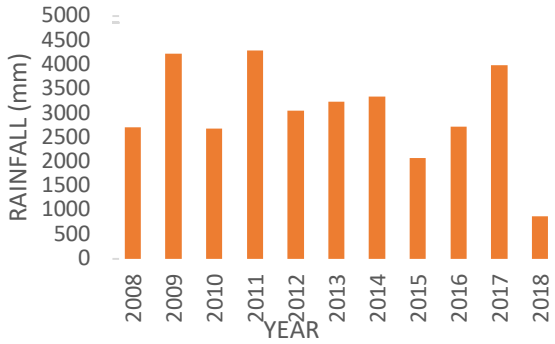


**Figure 2.** Average annual rainfall in Ulu Sat.

Vegetation increases the ability of soils to retain water, preventing floods and erosion. Since a forest can intercept as much as 50% of the rainfall, it will prevent much soil loss which might otherwise occur from the impact of rain on the land surface. Water passes from rainforests into rivers and streams with much less force, reducing erosion and the threat of floods.

### 3.2 Evaporation in Ulu Sat

Evaporation is the water cycle process which water becomes vapor by gaining heat energy [1]. Evaporation is contrast with rainfall which mean warming atmosphere will cause more evaporation. In Ulu Sat forest reserve, total evaporation in Ulu Sat was highest in 2015 at 1872.2 mm contrast with the rainfall during the same year which also the lowest between 2008 until 2018. Besides that, lower evaporation was recorded during higher rainfall year as show in Figure 3.

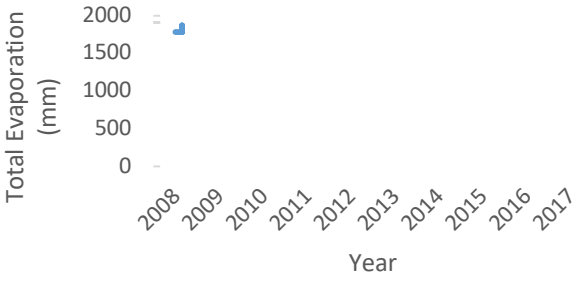


**Figure 3.** Total evaporation of Ulu Sat from 2008 to 2017.

Lowered levels of atmospheric water vapor reduce the cloud cover and rainfall, which consequently reduced the rainfall in the region if forest is removed. This will have dire consequences for even large rainforest reserves. When the forest can't generate sufficient rain, the water stress index in the surrounding area will be increase.

### 3.3 Water stress index in Ulu Sat

The closer water use is to water supply, the more likely stress will occur in natural and human systems. WSI in Ulu Sat is calculated based on data for three districts of Machang, Pasir Puteh and Kuala Krai for 2017 and 2018. This data is shown in Figure 4.

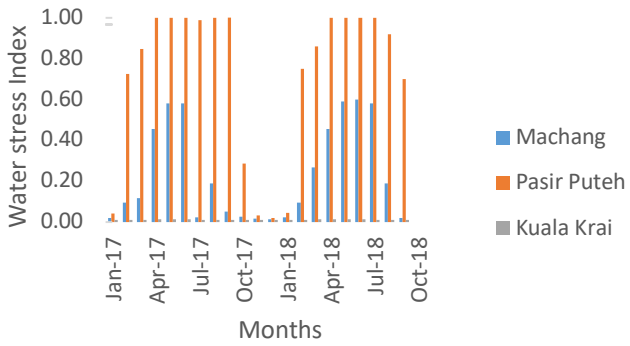


**Figure 4.** Water Stress Index towards different district surrounding Ulu Sat Forest Reserve for 2017 and 2018.

Data calculation of Pasir Puteh district shown a heavy reliance on water from Ulu Sat Forest Reserve during the dry season. This can be clearly seen from the graph, the WSI index for March to September (2017 & 2018) was extremely high ranging from 0.7-1.0 (refer to Table 1). Machang district is moderate while for Kuala Krai is low. During this dry season, all source of water including groundwater is at stress due to limited natural recharge option. With the future increment of consumption through agriculture, residential and land opening, the water supply for Pasir Puteh district during the dry season is under serious treat.

## 4. Conclusion

Based on this study, it is proven that Ulu Sat Forest Reserve Complex is important in producing, maintaining and reserving water for natural and human consumption. The high WSI was calculated for Pasir Puteh district show the heavy reliance of water during the dry season. While for the wet season, Ulu Sat Forest Reserve complex act as a first line of defence against flooding. The current situation shows that without proper plan and management between stakeholders, the sustainability of this water catchment is at serious treat.

## Acknowledgements

The authors would like to thanks Kelantan State Forest Department for inviting our group to participate in the Ulu-Sat Scientific Expedition. Faculty of Earth Science and Universiti Malaysia Kelantan for the research supports.

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