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Research Article

Studying the extent of scarcity of surface water in Lam Dong according to the socio–economic development plan up to 2030

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Abstract: Studying and assessment the scarcity of surface water resources in Lam Dong province based on the Socio–Economic Development Plan to calculate and forecast the water demand towards 2030 for economic sectors in the region, and based on this basis to calculate the extent of water scarcity occurring in this area by space and time using the calculation and classification method of Pfister (2009) combined with the GIS–RS mapping method. The results show that, the total water use demand of all sectors in the province in the period of 2018–2030 is forecasted to increase at a stable rate of about 6.5%. Although the total amount of surface water in the province is relatively plentiful, it can meet the demand for national economic sectors; However, water scarcity in the province still occurs in the dry season in some districts or cities.

Keyword: Water resources; Surface water resources; WSI; Lam Dong.

1. Introduction

Water resources is considered the top concern in countries around the world. Water resources are associated with human life activities and economic sectors. Today, the development of industries, urbanization and population growth, along with changes in precipitation and temperature caused by climate change, have led to a growing competition for water use. According to the Technical Report of IPCC, by 2050 about 40% of the world's population is at risk of living in severe freshwater scarcity [1]. Water resources tend to be gradually depleted while pollution is increasing. The change in the bad direction of the environment has an opposite effect on the socio–economic development of each country. In the world, there have been many researches on water resources such as: In the US, Pfister calculated the water pressure index of the states, the results showed that Arizona, Texas, Florida were areas under pressure. In terms of water resources, the reason is that the population in these areas is increasing while water is increasingly scarce [2]. Another study by Malin Falkenmark shows that, if the amount of water that can be satisfied is higher than 1,700 m^3/person/year, water shortage will only happen suddenly or locally. Below this threshold, water scarcity has varying degrees: less than 1,700 m^3/person/year, water pressure or stress occurs frequently; less than 1,000 m^3/person/year, water scarcity has constrained socio–economic development; less than 500 m^3/person/year, the study area is in extremely scarce water situation and this problem becomes the main obstacle of life here [3]. In Thailand, SH Gheewala and his colleagues calculated the water stress index on 25 basins; the results show that, in the Chao Phraya and Tha Chin watersheds (central), this is the second largest rice growing area where extreme water pressure has occurred during the dry season [4]. In China, a study using AWSI index to evaluate water scarcity in agricultural production

in China from 1999 to 2014 showed that AWSI index tended to increase during critical period. due to the expanded scale of agricultural production, in 1999 AWSI was 0.32 (medium stress) and in 2000 AWSI was 0.49 (high stress); In particular, the autonomous regions and northern central cities (Delta Huang–Huai–Hai) are facing high water stress (AWSI > 0.8), in the south China has to face with increasingly serious water scarcity [5];… Therefore, the rational and efficient use of water resources to meet the needs of economic sectors is extremely necessary.

Lam Dong is one of 5 provinces in the Central Highlands, located in the South Central Highlands with an average altitude of 800–1500 m above sea level with an area of 9,773.54 km^2. The climate here is relatively cool, and the river system is relatively dense with 7 main river systems. This is the region where the development of perennial industrial crops, forestry, minerals, livestock husbandry and tourism and services is concentrated; attracting a lot of foreign investment capital, bringing many economic values to the province in particular and the whole country in general, helping to stabilize the population and reduce poverty. However, at present, water resources in Lam Dong province have had many warnings about the decreasing trend causing water scarcity in many parts of the province [6]. As for Lam Dong Province, many researches have been carried out for sustainable management and development in the future. Typically, [7] showed that climate change was clearly shown in Da Lat city (2000–2015): Average temperature increased by 0.4ºC, number of sunny hours, average annual rainfall tended to increase, the average annual humidity reduction is 0.15%. The extreme weather phenomena are increasing with more floods, flash floods, cyclones, hail and drought; Climate change has affected the farming industry in the area [8]; [9] used the MI moisture index to assess the level of agricultural drought in the province, the results showed that the drought occurred in most areas in the province; Each year, on average, there are about 1 to 2 droughts, mainly focusing on the winter–spring season lasting from 01 to 03 months. Areas with frequent drought are Don Duong, Lam Ha, Di Linh, Da Huoai, Da Teh and Cat Tien. Areas that are less prone to drought are Bao Lam and Bao Loc [10]; or some reports of the Department of Natural Resources and Environment of Lam Dong province on climate change [11], assessment of water resources in the province [12]. However, the research topics on water resources are still limited. Stemming from that situation, this study is done to calculate the scarcity of surface water occurring in Lam Dong Province in space and time. The results of the study can document follow–up studies and can be used by management planners as the basis for water resource management.

2. Research methods

Assessment of the level of scarcity of surface water resources is simulated through the diagram of figure 1. The research was conducted by collecting and synthesizing documents combined with expert methods and forecasting methods to assess surface water resources in the province; at the same time calculating water demand in 2018 and forecast by 2030 of Lam Dong province; from there as a basis for calculating the level of water scarcity occurring in the province by space and time by the method of calculating and classifying [2] together with the GIS–RS mapping method.

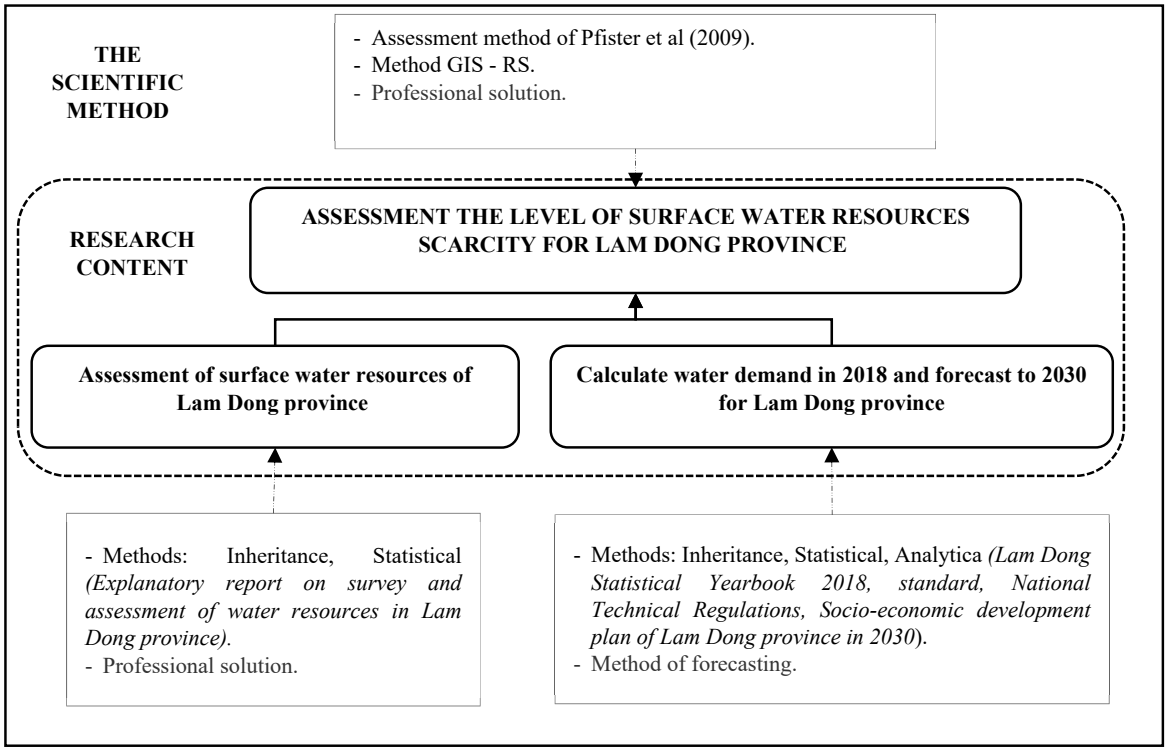

Figure 1. Diagram of assessment of surface water scarcity.

2.1. Methods of inheritance, statistics, analysis

The study uses selectively the research results from the Lam Dong water resources survey and assessment project report of Lam Dong department of natural resources and environment [11], to assess the current state of resource use. Surface water resources in the province; Using socio–economic statistics from Lam Dong Statistical Yearbook 2018 [13], to calculate the water use demand of sectors in the province, based on reference to the documents, that issued by the authorities of the State of Vietnam [14–16].

2.2. Prediction method

Based on Malthus' findings to forecast future water demand of sectors in the province, the model takes the form:

$$P_t=P_0(1 + r)^t \quad (1)$$

where P_t is forecast period composition; P_0 is the original period component; r is the rate of increase in the composition; t is time.

2.3. The method of consulting experts

With the desire to complete the report with the best possible results, this study has consulted and contributed by experts to clarify the problems in the research topic and contribute to the achievement of research results the best possible.

2.4. The ArcGIS map method

From the calculated results, the study used GIS–RS software to develop maps showing the level of water scarcity in Lam Dong Province.

2.5. Method of assessing water scarcity

Water scarcity is calculated based on WSI water pressure index. The Water Stress Index (*WSI*) is an indicator to quantify the pressure on water in an area or a country. It is related to the quantity of available water and the amount of water used, and is defined as the ratio between the annual water withdrawals and the total amount of fresh water recoverable. Therefore, the high water pressure index may be due to a small amount of available water or due to too high water demand. The WSI index has been verified for its effectiveness and reliability and is being used around the world [12].

Based on the results of interpretation and evaluation of the feasibility of each calculation method (advantages and disadvantages), combined with Lam Dong Province conditions and availability of calculation data of the topic, and requirements/research objective of the topic "Assessment of the stress level of surface water resources in Lam Dong province according to the socio–economic development planning period 2020–2030". Therefore, the study has selected one of the appropriate methods to calculate the scarcity of surface water in Lam Dong Province, which is Pfiter's method of calculation and classification [3, 12].

To calculate the WSI index, the WaterGAP2 global model is applied, describing the withdrawals–to–availability (*WTA*) ratio, the ratio between the amount of water withdrawn and the available water in more than 10,000 single river basins. This model includes the hydrological and socioeconomic component, the annual amount of available freshwater (WA_i) and the amount of water drawn by different users (WUij), respectively, for each basin i:

$$\mathrm{WTA_i} = \frac{\sum_j \mathrm{W_{ij}}}{\mathrm{WA_i}} \quad (2)$$

where $\mathrm{WTA_i}$ is the ratio of water withdrawn to water availability WTA in Basin i; and user group j is industrial and household.

The author just adjusted the water pressure index to a logistic function to achieve a continuous value between 0.01 and 1.

$$\mathrm{WSI} = \frac{1}{1+e^{-6.4\cdot WTA*(\frac{1}{0.01}-1)}} \quad (3)$$

The WSI index according to Pfister can be categorized as follows:

< 0,1	Water scarcity is zero
0,1 – 0,4	Water scarcity is low
0,4 – 0,6	Water scarcity is moderate
0,6 – 0,9	water scarcity is high
> 0,9	Water scarcity is severe

Pfister's method of calculation and classification of input data is similar to that of OCED, Smakhtin and WRI; however, the calculation of the result to 0–1 by the logistic function and the classification level to determine water scarcity is different from the above methods. Therefore, this study can use the calculation and classification Pfister method [2] to suggest WSI index for Lam Dong Province.

3. Results and discussions

3.1. Surface water resources in Lam Dong Province

There are 3 major river systems in Lam Dong Province, including the Dong Nai River system, Krong No River, Luy River–Cai Phan Thiet. River and stream systems are divided into 7 river basins (Krong No River basin and vicinity; Da Dang River basin and vicinity; Da Nhim River basin and its vicinity; Thuong Dong Nai 1 River basin; Thuong Dong Nai 2 River basin; La Nga River basin and its vicinity; Luy River basin–Cai Phan Thiet and

vicinity). The total average water volume in Lam Dong Province for many years is about 11 billion m^3. In particular, the total volume of water in the flood season in many years is about 6.9 billion m^3 (63%), the corresponding dry season is about 4 billion m^3 (37%). In the whole province, the amount of water is unevenly distributed across the province in both space and time [11].

Table 1. Flow, average total volume of water per month and year in the basins in Lam Dong province [11].

Months / River basin	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	TB	Wi (10^6 m^3)
Krong No	20.8	15.2	14.2	13.5	18.9	30.6	38.5	68.6	74.3	87.0	55.2	37.5	39.5	1,246.6
Da Dang	17.5	13.8	14.1	23.1	33.9	39.6	43.2	57.6	78.2	90.6	48.6	27.1	40.6	1,280.5
Da Nhim	27.4	21.7	22.1	36.1	53.1	62.0	67.6	90.3	122.4	141.9	76.1	42.5	63.6	2,005.6
Upstream Dong Nai 1	9.6	6.1	5.3	7.6	14.9	31.6	53.9	85.5	90.9	79.1	38.7	19.5	36.9	1,163.2
Upstream Dong Nai 2	22.2	14.2	12.3	17.6	34.6	73.4	125.0	198.4	210.9	183.6	89.8	45.3	85.6	2,699.5
La Nga	15.4	9.7	10.0	20.6	37.6	77.8	92.8	152.9	142.2	135.8	64.8	35.2	66.2	487.2
Luy–Cai Phan Thiet	2.7	1.4	1.4	2.4	8.9	11.1	12.0	12.6	23.6	41.9	17.8	6.2	11.9	373.8

3.2. Water use demand of sectors in 2018 and forecast to 2030 of Lam Dong Province

Water demand of the national economic sectors in the period of 2018 and 2030 is calculated specifically based on standards and norms (for living, agriculture, industry, tourism–services) according to regulations. Current regulations and available statistics from Lam Dong Statistical Yearbook 2018. Water demand estimate for 2030 is based on provincial planning data (socio–economic development orientation).

The calculation results of water use demand by sectors over the years are shown in Figure 2. According to the calculation results, the water demand for the entire Lam Dong province increases from 2018 to 2030. Total water demand the province's calculated for 2018 is about 1,225.42 million m^3/year. It is estimated that by 2030, the demand for this water will be about 1,305.54 million m^3/year, an increase of 80.12 million m^3 (ie an increase of 6.5%) compared to 2018. In 2030, water demand for the crop sector still accounts for the highest proportion (about 91.89%) of the total water demand in this period. The structure of water use demand has little change compared to 2018: the structure of water use in the farming sector tends to decrease slightly, down 1.43% and the rest tends to increase slightly. Demand for water increased mainly in December, January, February and March. The water demand of the sectors increases over time here, showing the population growth and strong development in socio–economic areas in Lam Dong Province, this puts great pressure on water resources; requires the response of water sources in both quality and quantity for the essential needs of life.

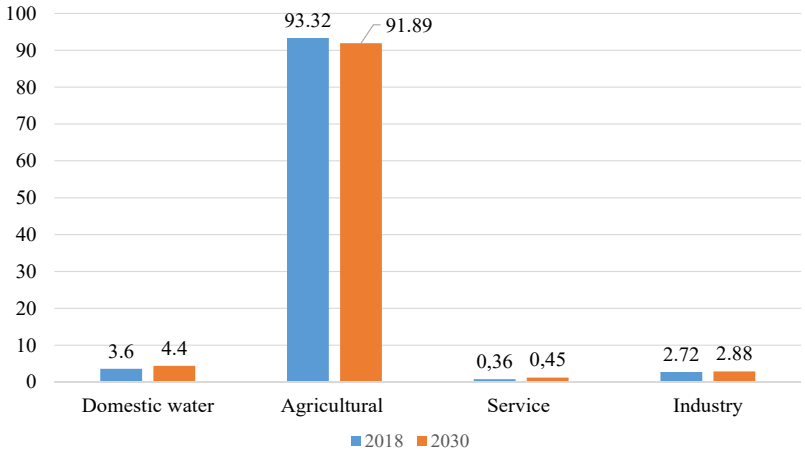

Figure 2. Water demand structure in Lam Dong Province in 2018 and 2030.3.3. Evaluate the level of scarcity of surface water resources in Lam Dong Province.

This study used the calculation and classification Pfister method [2] to assess the level of water scarcity in Lam Dong Province in the period of 2018 and 2030. This calculation method is based on water using demand by sectors and the total amount of available water in the province. For a comprehensive assessment, the study has calculated the WSI water pressure index according to the Pfister method on two cases: 1) The total available surface water in all basins in Lam Dong province; 2) The total amount of surface water available in 2 basins (Da Dang River basin; Da Nhim River basin), where there is a key economic region of the province in space and time.

When considering the total available surface water of all basins in Lam Dong Province, the WSI index for the entire region by 2018 and 2030 is 0.02 (<<< 0.1), so it is classified as at a level without water scarcity. The results show that on the whole Lam Dong province, the WSI index is positive; The total amount of surface water in the province is relatively abundant, meeting the needs of the national economy. However, according to each month of the year in the dry season months (especially January, February and March), WSI index is higher than the rest, but most of the months do not have any pressure or insignificant pressure (Figure 3).

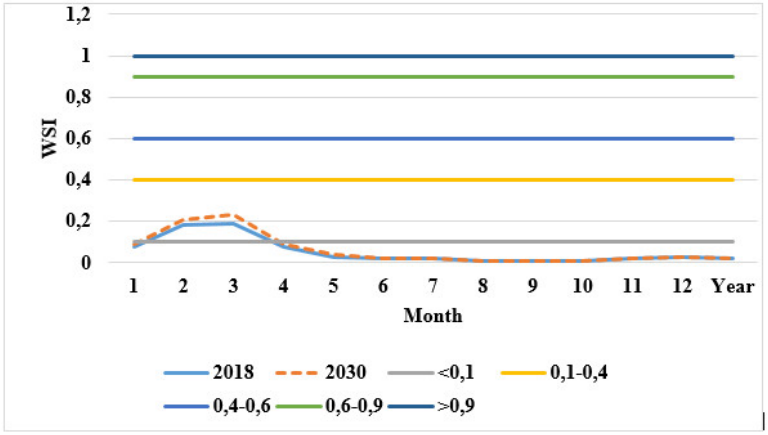

Figure 3. The level of water pressure according to Pfister method in the province through each stage considering the amount of available water by surface water.

However, considering the total amount of surface water available in 2 basins (Da Dang River basin and its vicinity; Da Nhim River basin and vicinity), where there is a key economic

region of the province, the WSI index has obvious change. The research results show that the WSI index for the whole region by 2018 and 2030 is 0.03 and 0.04 respectively (<<< 0.1), so it is classified as no water scarcity. But, when looking at each month, the WSI index has differences by month in the present time (in 2018) as well as in the future (in 2030). The scarcity of water resources in the whole region occurs mainly in the dry season (December, January, February, March) of both times (Figure 4). In 2018, the serious water scarcity in January, February and March is 0.94 respectively; 0.99; 0.95 (> 0.9) and low water scarcity in December is 0.2 (0.1–0.4). In 2030, the serious water scarcity in January, February and March is 0.9; first; 0.96 (> 0.9) and low water scarcity in December is 0.2 (0.1–0.4). The level of water scarcity of districts in the key economic region of Lam Dong province is relatively similar; districts of Lam Ha, Don Duong, Duc Trong, Da Lat City has low water scarcity, only Lac Duong district has medium water scarcity (Figure 5).

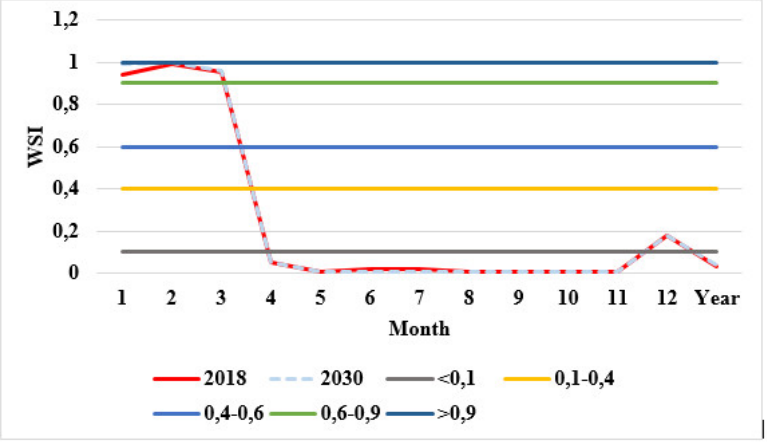

Figure 4. Diagram of the level of water pressure according to Pfister method in the key economic region of the province through each period, considering water availability equal to surface water volume over time.

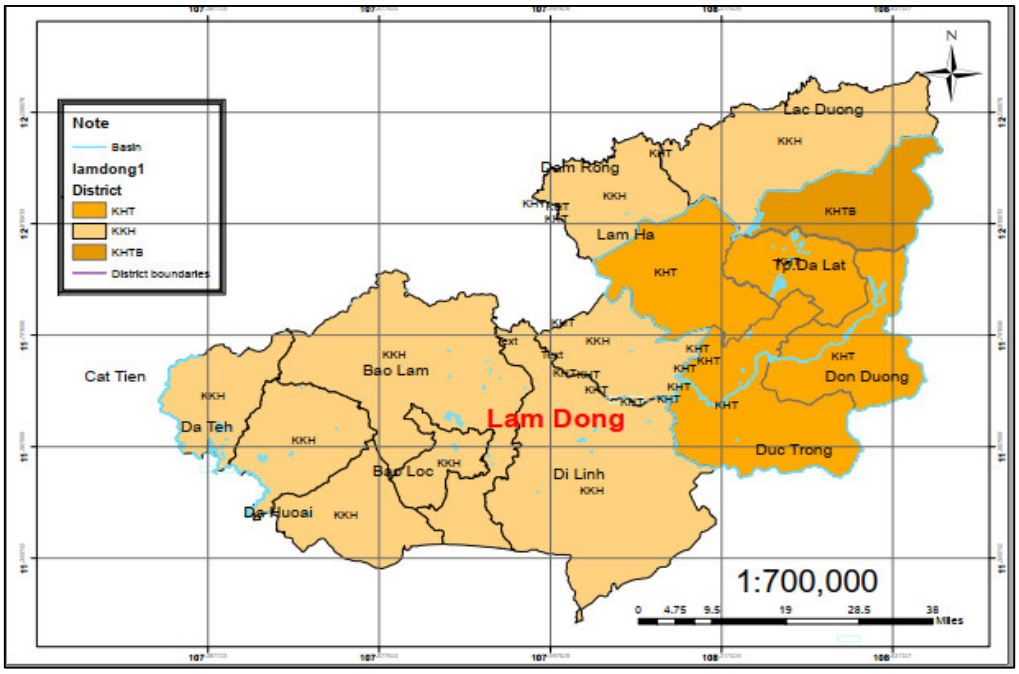

Figure 5. Map showing the level of water scarcity in Lam Dong Province.

4. Conclusions

The total water demand for all sectors in Lam Dong Province by 2030 increases in a stable direction (up 6.5%). The calculation is based on the socio–economic development planning of Lam Dong province in 2035 with a vision to 2050 (the orientation of population growth, changes in industry structure...) with accuracy and high reliability. Therefore, the calculation results of water use demand of the above mentioned sectors are considered reasonable, consistent with actual needs and exploited and used at an optimal level. Based on these results and assessments, we need to propose effective management methods to apply the plan well to socio–economic development in accordance with the proposed orientation. However, the results of calculating water scarcity in 2018 still take place in the dry season (12, 1, 2, 3) in some districts/cities in the province; By 2030, the level of water scarcity will not increase much compared to 2018 (because it is assumed that the water demand in 2030 is calculated according to the socio–economic development plan of Lam Dong province), so the calculation results do not show. The trend of water scarcity fluctuations between 2030 compared to 2018. Thus, it can be said that water pressure in Lam Dong province is mainly due to inadequate distribution of water resources. Therefore, it is necessary to develop an early water resource management plan in the area and incorporate the development of centralized water resources policies towards improving existing management capacity. At the same time, the results of this study can be a reference document in the planning for exploitation and use of water resources in Lam Dong Province.

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