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MODELING WATER SUPPLY AND DEMAND FOR EFFECTIVE WATER MANAGEMENT ALLOCATION IN SELANGOR

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Graphical abstract

Abstract

Water in Selangor is getting scarce due to its rapid economic growth. A fast growing population and expanding urbanization in the state creates new demands for water availability. Thus, the present study analyses the effects of three different scenarios using Water Evaluation and Planning (WEAP) model to evaluate the plausible future water scenarios of water availability in Selangor. The first scenario is business as usual which is later referred to as reference in this study. Second, higher population growth and the third is the application of the demand side management onto the reference and higher population growth scenario. These scenarios were then used to calculate the impact on the supply – demand gap by the year 2050. Two catchments were used namely Selangor and Langat to illustrate the water supply and demand in the state of Selangor. The study then generates information for use in managing water allocations amongst economic sectors in Selangor as the explicit accounting in the description of the water supply and demand among the urban and industry water usage is advocated. Such detailed scenario simulation and the inclusion of previously unaccounted for factors like the higher population growth and water savings management can help to create awareness of potential future problems, inform water practices and suggest management alternatives. Results show that with proper water savings measures, water deficit within Selangor will be significantly reduced.

Keywords: Integrated Water Resource Management, Selangor, Water Supply and Demand, WEAP

1.0 INTRODUCTION

Water availability has an impact on the socioeconomic development of a country. The rapid increase in population along with the enhanced standard of living has led to significant growth in the urbanization and industrialization sectors. This in turn has created increased water demand and water conflicts which need to be addressed [1].

Water conflicts arise when the demand exceeds the available supply and its water allocation fails to meet the demand. This would be aggravated further by the intensified demands from the users and the increase in the frequency of these demands [1]. Thus, in order to avoid the present as well as future water conflicts between the competing demands, researchers and scientist have given increased emphasis in developing tools and techniques for improved management of the water resources [2]. The development of various models, which provide a good insight into the intricacies related to water allocations and balancing mismatch between supply and demand through integrated water management is therefore necessary.

Among the different existing methods for integrated water management (mental models, Bayesian networks, metamodels, risk-assessment approaches, knowledge elicitation tools, Artificial Neural Network), hydro-economic tools provide relevant insights about how best to optimize the use of water resources [3, 4, 5]. They constitute useful tools to help policy-makers identify the most efficient and sustainable water management strategy [6, 7, 8]. Integrated hydro-economic models have been widely and successfully used to study water quality problems [9, 10], global water and food policy questions [11, 12], the impact of drought [13], land use changes [14], and water management and policy strategies [15, 16].

The present study analyses the effects of three different scenarios using a novel hydro-economic model based on the integration of a multiscale economic optimization model and a hydrology water management simulation model built in Water Evaluation and Planning (WEAP) model. Scenario analysed are business as usual which is later referred to as reference in this study, higher population and demand side management on the supply and demand in the state of Selangor. These scenarios were then used to calculate the impact on the supply –demand gap by the year 2050. The application of the model was carried out in the Selangor and Langat catchments, which are the main catchments for the state of Selangor.

2.0 MATERIALS AND METHOD

2.1 Study Area

The Selangor and Langat River catchments in the state of Selangor were used as study catchments as both constitute the largest water supply and demand in the state. The total area of the study catchments is around 2514.13 sq. km. and the climate is tropical with hot, dry season and wet monsoon season. The catchments are divided into 34 sub catchments (20 in the Selangor catchment and 14 in the Langat catchment), each of which has a source of surface runoff as well as an independent groundwater aquifer. Figure 1 shows the schematic localities of the catchments in the study area.

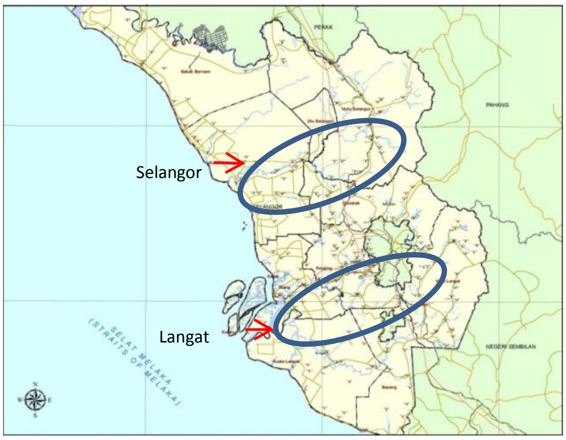

Figure 1 Location of the Selangor and Langat catchment

2.2 Data Collection and Analysis

In this hydro-economic study a vast amount of information and data processing is required. Table 1 summarizes the type of input data required for the development of the economic and hydrology models, data sources used and methodology employed to process all information.

Table 1 Input data required for the development of the economic and hydrologic models

Type of data	Source	Format / Methodology	Used in hydrology / economic model
Land use data			
Digital elevation and land cover	Agensi Remote Sensing Malaysia (ARSM)	Digital maps processed in GIS	Hydrology model
Climate data			
Precipitation, Temperature, Humidity, Wind speed, Evaporation, Soil moisture	National Hydraulic Research Institute Malaysia (NAHRIM)	Monthly time series processed in PRECIS model	Hydrology model
Water supply data			
Rivers, streamgauges	Department of Drainage and Irrigation Malaysia (DID)	Data records in Excel	Hydrology model
Reservoirs	Suruhanjaya Perkhidmatan Air Negara (SPAN)	Excel files	Hydrology model
	Syarikat Bekalan Air Selangor (SYABAS)	Excel files	
Water demand data			
Land use data	Selangor District Land Offices	Text files	Hydrology model
Urban sector			
- Population	Malaysian consensus (Jabatan Statistik Malaysia)	Excel files	Economic model
- Water use rates			Economic model
- Water consumption	Suruhanjaya Perkhidmatan Air Negara (SPAN)	Excel files	Economic model
Industry sector			
- Population			Economic model
- Water use rates			Economic model
- Water consumption			Economic model

2.3 Model Development

The Water Evaluation and Planning (WEAP) modelling platform was used to represent the water supply and demand in Selangor. WEAP is an object oriented computer modelling package that operates on the basic principle of water accounting, and determine the optimal allocation of water for each user defined time step according to demand priorities (e.g. urban, industrial user), supply preferences (e.g. surface water system), mass balance and other physical and regulatory constraints [17]. A schematic representation of the Selangor and Langat catchments in WEAP application is depicted in Figure 2.

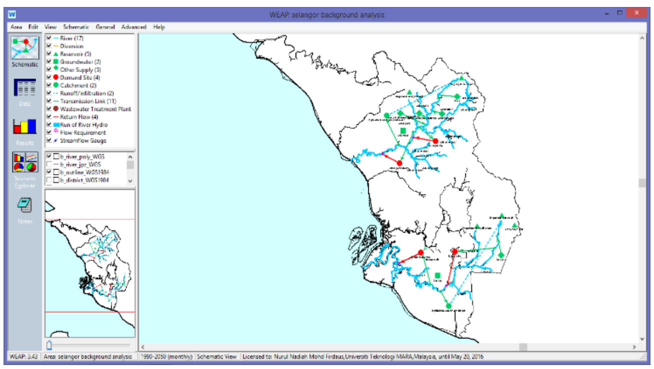

Figure 2 Schematic representation of the Selangor and Langat catchments in WEAP application

2.3.1 Hydrology Model

The study area for the hydrology study includes 7 main rivers in the Selangor catchment (Sg. Batang Kali, Sg. Serendah, Sg. Kuang, Sg. Ranching, Sg. Buloh, Sg. Kerling and Sg. Garing) while the Langat catchment has 3 main rivers (Sg. Langat, Sg. Semenyih and Sg. Lui); 5 reservoirs with a total storage capacity of 468.08 Mm^3; 10 key stream flow gauges. In addition, the study area has been characterized into fractional sections that represents areas of similar land use classes (urban or city, industrial land, irrigated agricultural land and forest). Natural hydrology processes within each catchment unit and fractional area have been simulated on a monthly time step using WEAP 2-bucket hydrology module (see [18, 19] for details).

2.3.2 Economic Model

The economic model in this study represents the water demand nodes in Selangor. The water demand is the total water required to meet the urban (domestic, commercial and institutional) and the industrial uses which then are presented as city and industry nodes in the WEAP model. The current water demand for the urban sector is 1735 MLD while for the industrial sector is 1254 MLD. Estimated population for both catchments was 1.153 million (2015) and the population is projected to increase with the growth rate of 1.3 per annum. Major districts considered in the calculation of the model include Hulu Langat, Putrajaya, Cyberjaya, Kuala Langat, Sepang, Seremban, Hulu Selangor and Kuala Selangor. Linkages between the raw water supply and the treated water demand was modelled via the transmission link that calculates a linear program algorithm between the hydrology (raw water supply) and the economic (water demand) model. The nodes which are closer to the sources of water supply were given higher priorities.

2.4 Scenario Simulation

In order to assess the capability of raw water supply in meeting the demand for treated water in Selangor, three scenarios were simulated:

2.4.1 Reference Scenario (Business As Usual)

Under the reference scenario (with growth rate of 2.2%), water usage for the year span of 1991 – 2050 is used to project the water supply and demand network in Selangor. Current scenario is set at 1990 for the purpose of calibration and validation.

2.4.2 Higher Population Growth Rate (7%)

In order to foresee the impact of possible population rate growth on the model, high population growth was added to the model with a growth rate of 7%.

2.4.3 Demand Side Management

Water savings initiatives were taken into the calculation of the model (13.79% from toilet water savings, 4.09% from washing machines, 7.33% from shower heads and faucets) and the amount of water demand that can be reduced was translated in this scenarios.

3.0 RESULTS AND DISCUSSION

3.1 Model Testing: Calibration and Validation

The hydroeconomic model was calibrated and validated for the period of 1990 to 2010 for both hydrology and economic data used in the study. The accuracy of the model was quantified using the Bias and the Nash-Sutcliffe efficiency index [17, 20]. Values of bias ranged between -11% to + 14% with an average of 2%. While the Nash-Sutcliffe parameter varied from 0.88 to 0.98 with an average of 0.91.

3.2 Scenario 1: Reference Scenario with Current Water Supply and Use

Under the current system of water use, the average annual unmet demand for a period from 2010 to 2050 in Selangor is 25.154 MCM. With growth rate of 2.2% (National Consensus of Malaysia for the year 2010-2050), the projection showed that Selangor will face water deficits for both urban and industrial sectors by the year 2041. Prior to that, as in agreement with Ali *et al.*, [21], Selangor's water availability for both economic sectors is relatively sufficient as the graph shows that the unmet demand for the year of 2010 – 2040 is zero. Figure 3 shows the average annual unmet demand for the urban and industry uses for both catchments; Selangor and Langat.

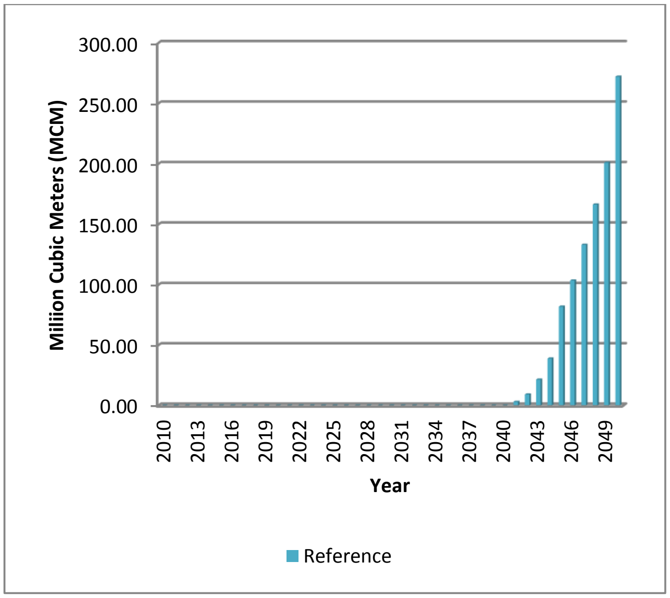

Figure 3 Average annual unmet demand for the urban and industry uses for Selangor

3.3 Scenario 2: Higher Population Rate

In order to forecast the impact of possible condition to the model, a new scenario was created that evaluate the impact of population growth in Selangor towards the water supply and demand for the period of 2010 to 2050 in Selangor. Figure 4 shows the projection of water demand based on both scenarios; higher population rate and the Reference. The total water demand for the higher population rate scenario indicated to be a total amount of 8404.71 MCM as compared to the Reference year which resulted in 1031.34 MCM. This results show that Selangor will face water deficits in 2033 seven years earlier than the reference scenario should the population growth rate increase by 7%.

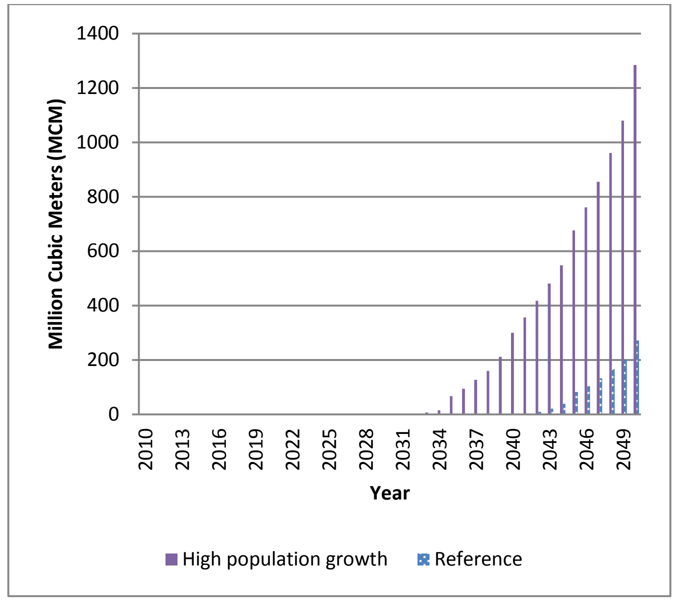

Figure 4 Projection of water demand based on both scenarios; higher population rate and Reference

3.4 Scenario 3: Demand Side Management (DSM)

Through this scenario, implementation of water savings devices as part of the initiatives in reducing the water demand in Selangor has been analysed. Figure 5 and Figure 6 show the amount of water savings that can be reduced through the implementation of DSM via the reference scenario and the high population scenario. Should the Selangor and Langat catchments applies the water savings devices to half of the population, the amount of water that can be saved is 13.79% for the urban sectors while for the industrial sectors water savings is 4.09%. On overall consumption, under the reference scenario, urban sector has recorded 14.81% in the changes of water demand while industrial sectors show 4.18%. High population scenario on the other hand projects 9.53% in the urban sector while the industrial sectors show 1.23% reduction in the water demand.

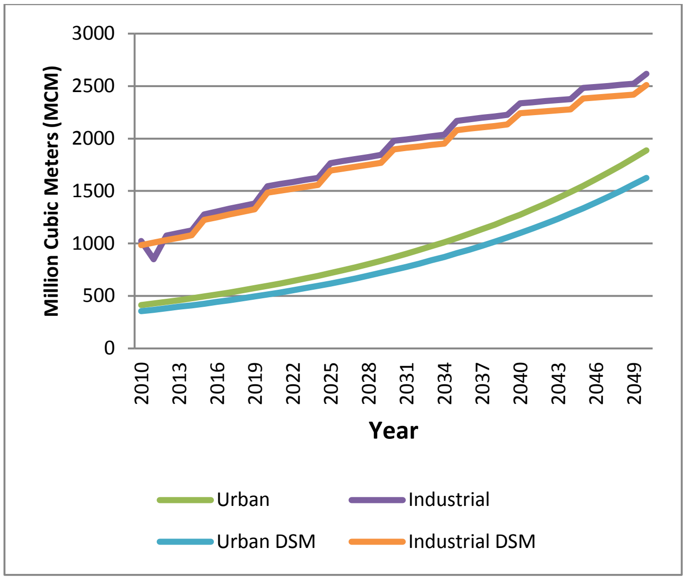

Figure 5 Implementation of DSM on the reference scenario

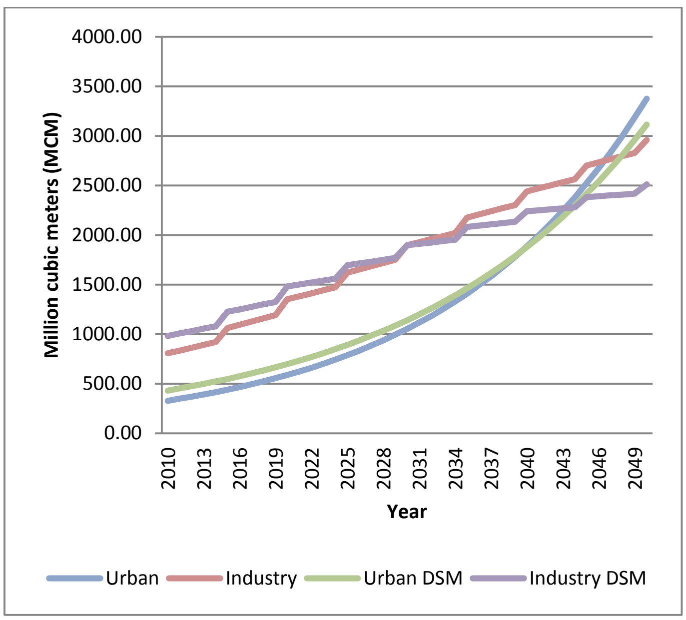

Figure 6 Implementation of DSM on the Higher Population Scenario

4.0 CONCLUSION

This study used the WEAP model to evaluate the water supply and demand in Selangor. Based on the reference projections, the water availability of Selangor is adequate until the year of 2041. Based on the higher population projection, the water shortages can be expected by 2033. However, with the implementation of DSM into the water economics the savings that can be achieved for the urban areas are 14.81% under the reference scenario and 9.53% under the higher population scenario. While the industrial sector records water savings of 4.09% for the reference scenario and 1.23% for the higher population growth.

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