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Dynamics of Indonesia's Water System: A Modelling Approach

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EXTENDED ABSTRACT

Introduction

Despite having abundant water resources, including over 4,426 billion m^3/year total freshwater with the surface water about 3,906 billion m^3/year and the ground water about 520 billion m^3/year and about 2,350 mm annual rainfall on average [1], Indonesia will eventually face scarcity if the water is not properly managed. This is likely to happen because of the population growth, economic development and urban expansion. These changes lead to greater interventions on water resources that in turn will change water catchment areas and decrease water quality. At present, only about 12 per cent of the water resources have been utilized for domestic, irrigation, and industrial needs [2]. Climate change is also affecting the global water resources system in Indonesia [3].

This paper presents a modelling exercise aimed at capturing the behaviour of the global water system in Indonesia considering the socio-economic factors and the interactions with energy and food sectors. The purpose of this exercise is to gain insight into the dynamic behaviour of the water system in Indonesia at a national scale. It is shown that by understanding the dynamics change of water system and the underlying structure that gave rise to such dynamics, better policy interventions regarding water system management in Indonesia may be formed.

Methods

We employed the System Dynamic Modelling (SDM) technique using MATLAB/Simulink software to assess the dynamics of the water system in Indonesia. The SDM is chosen because it is capable to contrive feedback mechanism that gives rise to nonlinear behaviour of most complex system [4]. Figure 1 shows the top layer of the causal structure of the model while Table 1 provides model parameters values. The model is deliberately focusing on Indonesia to capture the water system behaviour at the national scale over an annual timestep that spans the period from 2000 to 2015. Part of the model structure and the corresponding mathematical relationships were tailored from previously developed models (i.e., [5]–[7]) subjected to calibration. The demand for the domestic sector is influenced by income per capita and population, for the industrial sector is influenced by income per capita and electricity generation and for the agricultural sector is influenced by the net irrigation requirement and the total wetland area. Data for population, income per capita, wetland area, and electricity generation are treated as exogenous dynamic variables in the model following data obtained from [8]–[11].

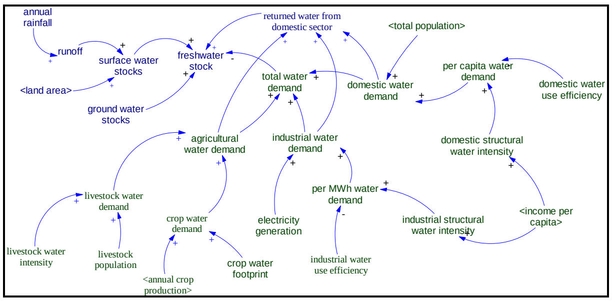

Figure 1. causal structure of the water system

Table 1. Parameters value

Parameters	Value	Unit
Average annual rainfall	2702	mm/year
Land area	191093	thousand km^2
Initial water stocks	45.3	km^3
Minimum income per capita	1000	$/person
Minimum domestic structural water intensity	7.3	m^3/person
Maximum domestic structural water intensity	98	m^3/person
Minimum industrial structural water intensity	2	m^3/MWh
Net irrigation requirement	266	mm/year
Growth of net irrigation requirements	0.007	dmsl

Results and Discussion

Figure 2 shows the total exploitable water and sectoral water withdrawals per year in Indonesia and the structural water intensity for the domestic and industrial water demand. The total exploitable water in Indonesia is about 2,200 billion m^3, which is about 10 times more than the total demand. Overall, this means that at national scale Indonesia has sufficient water to meet the demand. However, the case would not be the same if we are looking at the sub-national level (i.e., by major islands) where Java island is having water scarcity issue due to high population density compared to other islands [3], [12]. National water demand increases from 114 billion m^3 to about 210 billion m^3 (i.e., 85% growth) over the course from 2000 to 2015. This number is lower than the reported value in [2], which is about 222 billion m^3 because we did not include demand for livestock and fish farming. Out of the total water withdrawn, about 85 per cent is used for agricultural activities, 10% is used for domestic, and 5% is used for industry. Water intensity in the domestic sector increases gradually overtime (i.e., from 65.2 m^3/capita to 67.5 m^3/capita over the period from 2000 to 2015). The average income elasticity of domestic water demand is about 0.05 per cent. The industrial water intensity, on the other hand, is decreasing at a faster rate of about 4% per year on average (i.e., from 79 m^3/MWh to 41.5 m^3/MWh for the year 2000 to 2015). The average income elasticity of industrial water demand is about 66 per cent.

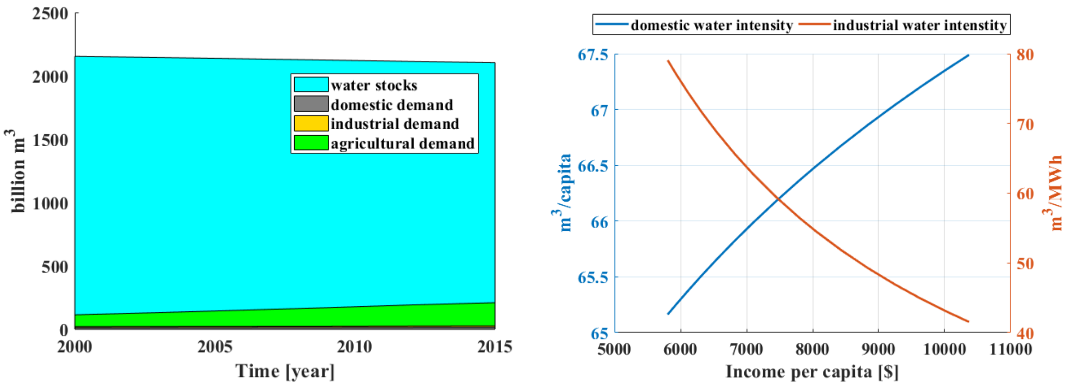

Figure 2. [left] water stocks and demands; [right] domestic and industrial water intensity

Concluding Remarks

We have demonstrated through modelling exercise that water demand in Indonesia is structurally influenced by the national income per capita, population, electricity production and wetland area. Agricultural sector demands more water than domestic and industrial sectors. At the national level, Indonesia has no water scarcity issue, however, there might not be the case at the sub-regional level (e.g, by major islands). Therefore, assessing the water sector at the sub-national level is part of our future work. We also will look for the long-term behaviour of the water system under different socio-economic and climate scenarios.

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