Water, Food, Energy Nexus Investigation for Human Development

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Abstract. We are investigating the nexus among water, food, and energy systems and their relationship(s) to human development. The aim is to gain a better understanding of the interconnectedness among these sectors and human development in order to assess the potential impacts and implications of a range of policy scenarios on the system. Considering the feedback mechanism between elements in the system, we use system dynamics modelling and simulation technique to represent system structure and capture the dynamics behavior of the system being studied. Our system model comprises five modules, namely water, food, energy, human development, and demographic. The model is purposely built to be implemented in Indonesia on a national scale. The simulation is run on a yearly basis. The model is being built therefore we present only preliminary results here. As part of the future work, once the model is fully constructed, it will be applied to assess the impact of a range of policy scenarios and implications on the water, food, and energy sectors and on human development in Indonesia.

Keywords: water-food-energy nexus, human development index, system dynamics modelling.

1 Rationales

Water, Food, and Energy (WFE) are basic needs crucial to human survival but also pervade many aspects of human development. Systemically, they are vastly interdependent, and hence an effort to secure one sector may destabilizes others [1,2]. Therefore, it is important to understand the complex interactions among these sectors. Few studies have been done to understand the nexus among water, food, and energy systems as reviewed in [3,4], but none of these studies includes human development aspect in their "nexus approaches". Therefore, this study extends the nexus investigation of water, food, and energy to include human development dimensions.
Due to time and financial constraints, this study made use of the secondary data available online together with the aid of computer modelling and simulation techniques to assess the problem. The model being built is to be used for the following purposes:

- As a tool to evaluate the dynamic behaviours of WFE systems and their interlinkages to human development.
- As a tool to assess better policies formation on securing water, food, and energy and sustainably improving human development.

The model is purposely developed to be implemented in Indonesia to assess the impacts and the implications of several development targets in water, food, and energy sectors. Those were set by the government to be achieved by 2019, e.g., improving access to drinking water and sanitation to 100%, increasing electrification ratio to 96.6%, increasing calorie intake to 2150 kCal, and expanding agricultural land by 300,000 ha [5].

2 Methods

A system model comprises water, food, energy, human development, and demographic modules is being constructed using the System Dynamics (SD) modelling technique. The model is built and simulated using the MATLAB/Simulink (R2017a) software. The model is developed for the national scale. The time horizon is the period from 1985 to 2050, with historical data available for 1985 to 2015. Components values are aggregated or set at an annual level. Figure 1 shows the model framework while Table 1 presents several variables of the model and the reference approaches that were adopted into our methodology. Data were collected from several sources such as Indonesia statistics [6], World Bank [7], UN data [8], and BP Statistical Review [9].

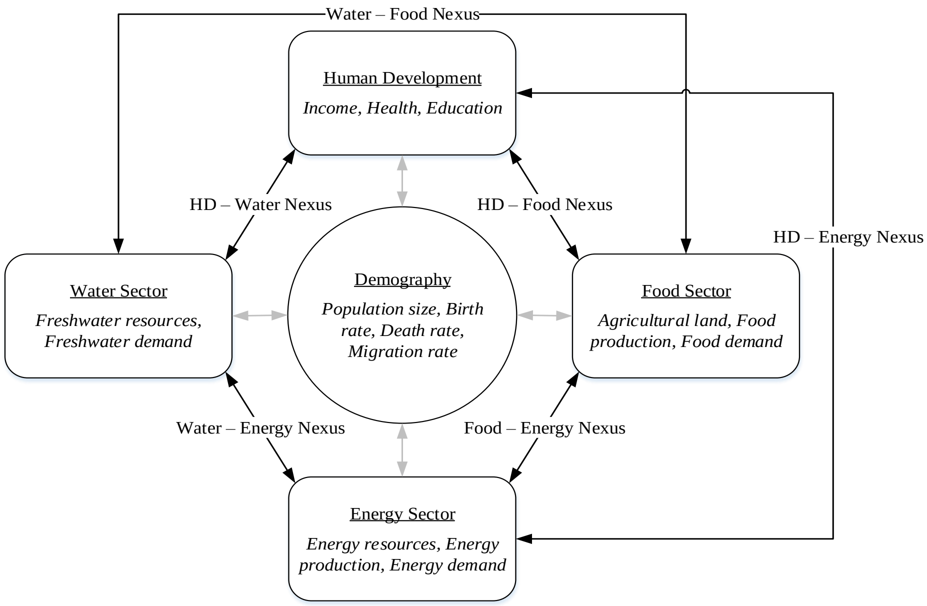


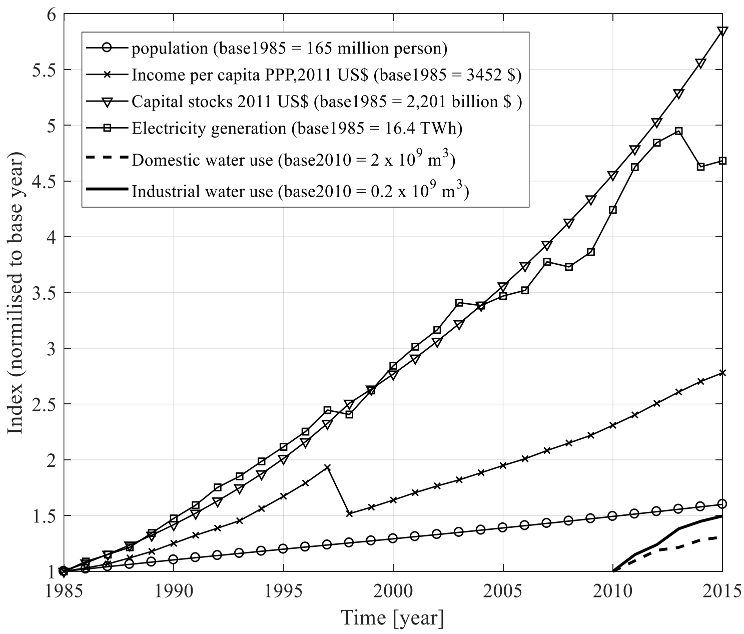
Figure 1 Model Framework

Table 1 – System variables and reference models

Endogenous variables	Exogenous variables	Reference approaches
Total population, birth rate, total fertility rate, death rate, mortality rate, life expectancy at birth, GDP, income per capita, capital stocks, total energy demand and sectoral energy demand, energy production, total water demand and sectoral water demand, food production	migration rate, mean and expected year of schooling, energy intensity	WORLD 3 [10], ANEMI [11], REXS [12], WaterGAP2 [13]

3 Preliminary Results

Figure 2 shows preliminary results for several variables generated endogenously and their corresponding error test except for electricity generation.



Mean-square-error (MSE) and root-mean-square-percent-error (RMSPE) for simulated variables shown in the Figure 2 are as follows:

Population:
MSE = 2.5 x 10^{-4}; RMSPE = 1,08%

PC Income:
MSE = 0.01; RMSPE = 4.85 %

Capital stocks:
MSE = 0.076; RMSPE = 7.92%

Domestic water use:
MSE = 0.0014; RMSPE = 3.14 %

Industrial water use:
MSE = 0.0097; RMSPE = 7.07%

Figure2–Preliminary results

4 Acknowledgments

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5 References

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