WORLD CONTINENTAL MODELING FOR WATER RESOURCES USING SYSTEM DYNAMICS

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The aim of this research is to grasp the relationship between the socio-economic activities concerning the water demand and the water supply mechanism at the continental scale. Moreover, the model considers the mass transfer and migration between continents. The model consists of seven main sectors of activities, such as: population, capital, agriculture, nonrenewable resources, persistent pollution, water quantity and quality. The simulation for future scenarios is carried out using GCM (Global Circulation Model) data as the input of water budget calculation for the available water estimation. Because of data and information availability, the regional scale as modeled unit is chosen to be handled in a continental level, with six main units representing continents, namely: North and South America, Europe, Australia, Africa and Asia. Monthly temperature and precipitation results from the HadCM2 are used. Two scenarios in which CO^2 concentration is increased 1% annually, and both CO^2 and aerosols concentrations are increased 1% annually are tested. The model is built and run from 1960 to 2100 at yearly time steps.

The trade mechanism of the industrial sector is considering being proportional to the import and export of manufacturing goods among continents. Moreover, foreign investment in service sector is including the exchange of service output across the continents. Both mechanisms which determine the volume of industrial output trade and service output for foreign investment are almost the same. Also the trade mechanism of migration, food and nonrenewable resources are almost the same. The effects of water deficiency to population, food and industrial sector are considered. This section just focuses on the effect to industrial sector. Water deficit multiplier is defined as a restrictive factor for industrial output when industrial water demand exceeds industrial water withdrawal. Because of extensive range of industrial water usage, it is simplified the relationship between water deficit multiplier and industrial output as a linear relation. The causal loop diagram is shown in Fig. 1.

Three sources of water supply are considered; namely renewable water resources, water reuse and desalinization of sea water. The deficit in water resources is found by subtracting withdrawals from the supply volumes. Restrictive effects of water deficit are fed back to the respective sectors. Water quality is designed as parameters affecting human life-expectancy. A water quality variable called "life-expectancy multiplier from water quality" is statistically derived from the percentage of population that has access to improved sanitation and water supply in rural and urban areas. It is found that the percentage of population with access to improved sanitation and water supply has the strongest correlations with industrial output per capita and renewable water resources per capita

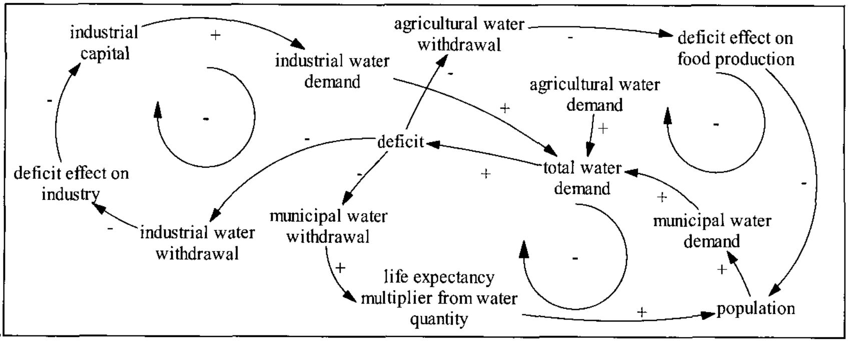

Fig. 1 Simplified Casual Loop Diagram of Water Quantity Sector

Fig. 2 shows five important outputs representing the world development in a multi-axes graph. Irregular fluctuations in industrial output per capita and food per capita seen after 2015 are due to water resources shortage in certain regions of the world. Results of net food imports are shown in Fig. 3. The fluctuations in the graphs are influences of water shortages on food production which lead to irregular trade patterns.

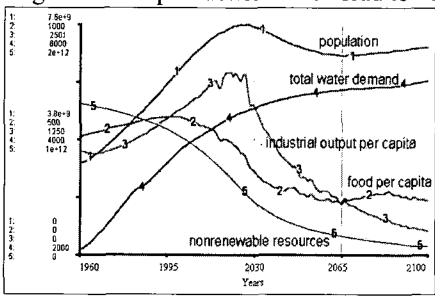

Fig. 2 Five Outputs in the world

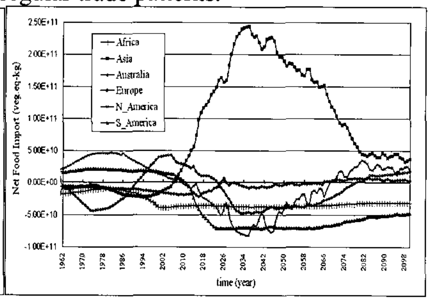

Fig. 3 Net import of food

Results of material movements across continents can be examined to identify the major importing, exporting; and immigrating, emigrating continents. Although water shortages occur only in Asia and North America in the standard run, their impacts on trade over all regions are seen. This shows that water scarcity has widespread effects on the world even when its occurrence is local. Under the conditions that usable water resources are restricted to half of that in the standard run by 2100 starting from 2015. The world population falls under the standard run level due to shortened human life-expectancy and decrease in food output. The effects of water resources deficiency are quite sensitive to the development of the world. Notably, the effects of water resources deficiency affect agriculture product and population increase. Furthermore, the local water deficiency affects all regions through the food and goods trade. Results under unlimited resources are that the industrial outputs of all continents are extremely above the results of the standard run. These increase of industrial output drives the enhancing the growth of other sectors. Food production increases as a result of more agricultural inputs, and more arable lands are exploited at the same time. Growth of industrial and agricultural activities generates the strain on water resources. On the whole, the world faces the extensive water shortage.