Analysis of Water Security Using Causal Loop Diagram

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Introduction

Water security has been a heated topic discussed by environmentalists all over the world, particularly in Australia as the dries continent. The definition of water security has various versions, however, the essence of water security has been achieved the agreement for a long time. Water security refers to the sustainable use and protection of water systems, and the prevention of water related hazards including water-borne diseases, droughts and floods (Schultz & Uhlenbrook, 2007 and FAO, 2000). Emphasis has been put on two significant factors in terms of water security. One is to make sure that the quantity of water constantly meets human beings demand without causing harm. The other refers to the quality aspect of water, that is to protect water against water contaminants and hence to provide reliable drinking water supply. Although nature itself alters water security somehow, for centuries, human interventions have done more harm than good to the natural water cycle and therefore greatly threatened water security. The enormous consequences are well documented as the long-term drought, serious floods, water-borne diseases, and decline in agricultural productivity and so forth. In other words, human beings are facing the biggest challenge for their survival. In order to tackle with it, it is necessary to investigate the causes and the pathways that trigger and reinforce water security decline.

Keywords; Causal loop diagrams

Methodology

In this paper, the factors that may influence security of water are identified. Causal relations are described via Causal Loop Diagrams (CLDs). The key variables are identified as population growth, social development and climate change. The investigation of intermediate variables is undertaken by tracing effects. For the purpose of simplifying water issues, water security is divided into two basic categories: water quality and water quantity to be discussed. Therefore the whole system is presented through two related Causal Loop Diagrams (CLDs). At last, a detailed explanation of causal links or feedbacks is provided to depict the system dynamics.

Causal Loop Diagrams Demonstration

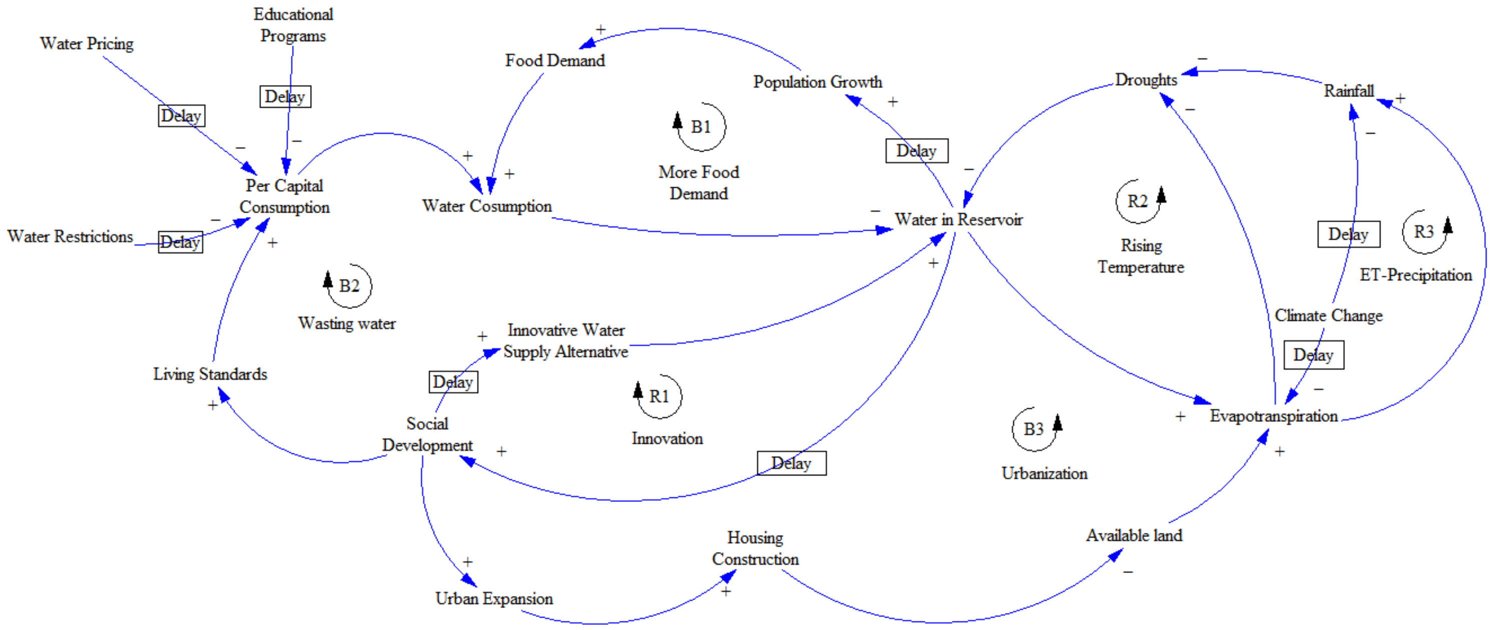

Figure 1 Causal Loop Diagram for water quantity

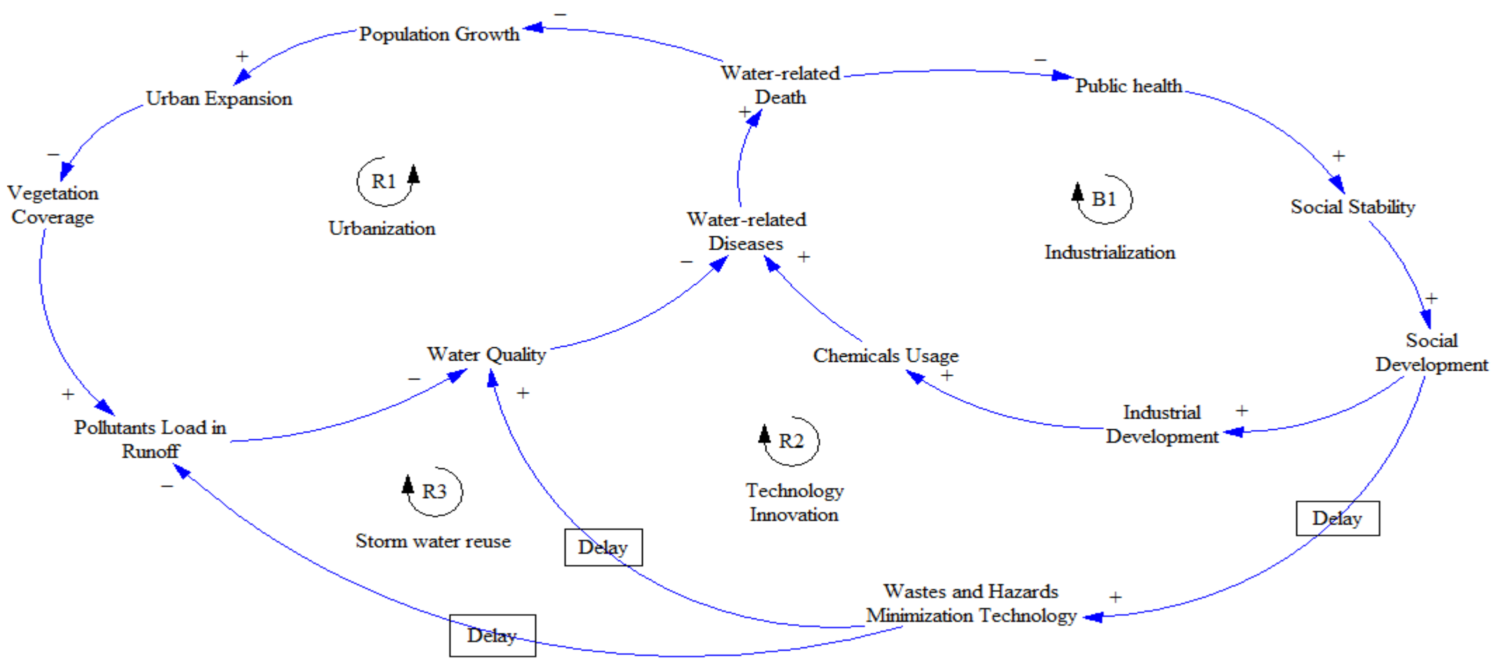

Figure 2 Causal Loop Diagram for water quality

Explanation of Causality

Water quantity

Figure 1 shows a causal diagram developed to explore the causes of water storage fall in the reservoir. The Australian Capital Territory (ACT) has already perceived that the Australia is facing growing pressure on water storage driven by population growth, climate change effects and water-intensive lifestyle (Sawah et al., 2009). Starting from population growth – **Loop B1**. The increase in population means the provision of more food and energy. The study done by Schultz & Uhlenbrook (2007) shows that the largest water consumption is dominated by the agricultural sector (approximately 70% of its global water supply). Base on the study, the global agricultural yield will be doubled in the next 30 years. However, agricultural production is generally based on water-intensive style currently, with high water consumption rate. Sustainable water management in agricultural sector, with more efficient use of water resources is only realized in the minority of developed countries. In this case, increasing amount of water will be extracted from reservoir and consumed to satisfy human needs for food. In the short term, people can hardly perceive the change in water storage, and they may keep consuming water for personal use. In the long run, people will realize the harmful situation where there is no water to consume, and search for alternatives or sustainable use of water. **Loop R1** shows that advances in technology and engineering science driven by social development, will promote water supply transition from traditional fresh water supply to advanced water supply alternatives. In Australia, nondrinking water demand including toilet flushing and laundry has been satisfied by supplying recycled water and treated storm water in few areas (Fletcher et al., 2007 and Hatt et al., 2004). Also, only a small proportion of drinking water supply is replaced with the alternatives mostly in developed countries where they face serious water scarcity. However, various issues, such as high initial cost, reliability of supply and so forth, lower the social acceptance of water supply alternatives (Hatt et al., 2004 and Philp M. et al., 2008). Studies and research suggest four major impediments to the adoption of new water supplies, particularly for stormwater reuse scheme (Fletcher et al., 2007; Hatt et al., 2004 and Philp M. et al., 2008). Recently, lack of monitoring programs and data, together with low disclosure of the processes, impact social acceptance. In the studies, fewer people tend to storm water reuse due to the lack of confidence in reliable supply. The other reason is the high initial costs that drive customers away.

Nevertheless, These studies also predict a great future for innovative water supply alternatives (Fletcher et al., 2007; Fletcher et al., 2008 and Hatt et al.). With the advances in reuse and monitoring technologies, increasing number of people will built up trust in water supply alternative. Meanwhile the provision of the government subsidies will further facilitate the transition from traditional fresh water supply to advanced options.

Obviously, most of countries are experiencing a migration from rural to urban areas and additionally a rapid increase in the standard of living (Schultz & Uhlenbrook, 2007). Instead of using water to fulfill the drinking purposes, excessive fresh water has been consumed via recreational use, household use such as showering. As **Loop B2** shows, a huge incline in the water consumption per capital was observed in developed countries (Schultz & Uhlenbrook, 2007). Meanwhile the pressure over land resulting from rapid population growth tends to intensify the progress of urbanization, causing deforestation in most of farm forest areas (Barbieri & Carr, 2007). In Schmidt (2009) ‘s paper, he commits to the notion that sprawling urbanization generally causes the reduction of fertile agricultural land, and subsequently triggering significant losses to global evapotranspiration (ET). In effect, he emphasizes that ET is the key source of precipitation. Therefore it is clear that reduction in ET will lead to less rainfall, which in turn worsens water issues (See Loop **B3** and **R3**). On the other hand, Schmidt believes that this unsustainable use of land driven by urbanization is responsible for enhancing local climate change and global warming. In other words, reduced ET results in higher surface temperature, allowing droughts to be much more serious (See **Loop R2**).

However, it is noted instead of receiving a quick negative response, the effects of climate change on water storage has been taking at a slow rate although the situation is exacerbating due to urbanization and deforestation. (Refers to **Loop R2and R3**)

In order to maintain secure water storage, it is proposed to introduce innovative water supply alternatives to increase supply as mentioned before. In contrast, on the demand side, possible government policies including pricing signals and water restrictions are able to function to reduce per capital consumption. However, the results have been observed as being not successful currently due to the insufficient economic inducements and lack of regulatory instruments (Sawah et al., 2009). Nevertheless, Sawah et al. (2009) strongly presents that as communication strategies are going to be adopted, more and more education programs will guarantee achieving long-term reductions by ultimately promoting behavioral alternations. And reasonable water pricing and relevant water regulations will further encourage the elimination of wasting water.

Water quality

It is inadequate to fully concentrate on the quantitative side of water security. Increasing number of people has begun to recognize the significance of water quality for the maintenance of our life-support systems since several water-related deaths strike the public (FAO, 2000). **Figure 2** demonstrates the main factors and pathways causing water quality deterioration. **Loop R1** depicts how the degradation of water quality presents due to the expansion of urban areas. In order to accommodate increasing number of the newborn and immigrants, more and more land has been occupied to provide housing services, causing hydrological disturbance. It is found that water quality has been greatly influenced by the intensive land use through a great variety of studies (Fletcher et al., 2008 and Philp M. et al., 2008). Many studies show that natural purification processes, such as filtration through unpaved soils and biological uptake by microorganisms and plants, are diminished due to the loss of vegetation and absence of soils (Fletcher et.al, 2007). Subsequently, water contaminants accumulate and contribute to the receiving water via runoff, lowering water quality in water body.

It is proposed that possible waste and hazards minimization technology have offered an opportunity to improve water quality (Refer to **Loop R2** and **R3**). Especially, storm water reuse harvesting is proved to be able to mitigate the impacts of urban runoff on water quality. As a typical example, Water Urban Sensitive design (WUSD) technologies enable the restore of soil property by the means of integrating various the storm water harvesting technologies into the urban landscape design. As a result, the major effects of urbanization on water quality will be gradually reduced and finally eliminated. In effect, various studies and research suggest that it will take few years to build up adequate storm water reuse scheme due to current technology limits and high costs (Fletcher et al., 2007; Hatt et al., 2004 and Philp M. et al., 2008).

Loop B1 shows how the promotion of industrialization affects water quality via a series of intermediate variables. It is unfair to neglect the benefits of industrial development. However, more often, industrialization is notorious for causing water pollution nowadays. The introduction of chemicals into industrial processes diminishes the quality of effluent, narrowing the range of further use options. Instead of consuming water, industrial activities degrade water quality to a lower level where water may pose a potential threat to people's health (FAO, 2000). Moreover, due to the inadequacies of environmental regulations and acts and lack of monitoring activities, manufacturers are inclined to discharge effluents directly to the receiving water without processing waste water treatment for the purpose of costs minimization. Gleick (2002) believes that hazardous chemicals contained in water body forms great harm to the public health when people access water, causing water-related deaths and other significant health consequences. In effect, it is predicted that 135 million people would die from water-related diseases until the year of 2020 (Gleick, 2002). The devastating human health problems would in turn shock the public, shake the social stability, and subsequently impede industrial and even social development.

Conclusion

In summary, to provide sufficient water of appropriate quality is essential for satisfying current and future needs. Therefore sustainable water use is in great need to maintain water security and protect precious natural water resource. Identified by the CLDs, a combination of supply and demand strategies is able to function to resolve the problem of falling water security. On demand side, government policy and education programs will be in place to reduce per capital consumption and minimize water contamination. From the perspective of supply side, recycling and reuse technology innovation will be of great help to purify water to a certain level where treated water is reliable as being water supply alternatives. However, it is identified that there are still limitations underlying this study on water security due to the problems of simplifying the complex issue and knowledge gap existed. Therefore, further research is needed for delivering an adequate study of water security.

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