CLIMATE CHANGE AND ECOLOGICAL SYSTEMS: A CONCEPTUAL FRAMEWORK FOR THE UNDERSTANDING OF SOCIO-HYDROLOGICAL DYNAMICS

Y. E. WOYESSA AND W.A. WELDERUFAEL

Abstract

A functioning ecological system results in ecosystem goods and services which are of direct value to human beings. Ecosystem services are the conditions and processes which sustain and fulfill human life, and maintain biodiversity and the production of ecosystem goods. However, human actions affect ecological systems and the services they provide through various activities, such as land use, water use, pollution and climate change.

Climate change is perhaps one of the most important sustainable development challenges that threaten to undo many of the development efforts being made to reach the targets set for the Millennium Development Goals. Understanding the provision of ecosystem services and how they change under different scenarios of climate and biophysical conditions could assist in bringing the issue of ecosystem services into decision making process. Similarly, the impacts of land use change on ecosystems and biodiversity have received considerable attention from ecologists and hydrologists alike. Land use change in a catchment can impact on water supply by altering hydrological processes, such as infiltration, groundwater recharge, base flow and direct runoff. In the past a variety of models were used for predicting land-use changes. Recently the focus has shifted away from using mathematically oriented models to agent-based modelling (ABM) approach to simulate land use scenarios. The agent-based perspective, with regard to land-use cover change, is centred on the general nature and rules of land-use decision making by individuals. A conceptual framework is being developed to investigate the possibility of incorporating the human dimension of land use decision and climate change model into a hydrological model in order to assess the impact of future land use scenario and climate change on the ecological system in general and water resources in particular.

Keywords: Ecological systems, socio-hydrological dynamics

1. INTRODUCTION

Land-use/land-cover change occurs through complex interactions between land users (agents) on one hand and biophysical and socioeconomic factors on the other hand. The complex interaction between environment and social factors could bring emergent changes in land uses. As a consequence of land use change, the water balance of a specific catchment could significantly be affected.

The altered hydrological cycle resulting from the land use change may significantly affect a local climate such as the precipitation and temperature of a particular ecology. This may impact on the sustainable usage of water resources and ecological balance of an environment.

For a given environment land use change can be predicted by an agent based model (ABM), based on the possible interactions between agents (land users), socio economic and the biophysical factors. An ABM consists of autonomous decision making entities (agents), an environment through which agents interact, rules that define the relationships between agents and their environment, and rules that determine sequence of actions in the model. Agents in ABMs are considered as components that can learn from their environments and change their behaviours accordingly. Purnomo and Guizol (2006) described agents as entities with defined goals, actions and domain knowledge which operate and exist in an environment. Adhering to the emerging paradigm shift, decision to change land use would only be obtained after a complex interactions of the socioeconomics and environmental factors which influences the behaviour of the farm manager.

2. PROCEDURE

An integrated conceptual socio-hydrological model for the prediction the impact of land use and climate change on water resources was developed for the central region of South Africa in the Upper Modder River basin (Fig. 1). The focus of this exercise was on C52A, a quaternary catchment in the Upper Modder River basin. The catchment is characterized by semi-arid climate and dominated by soil type which is susceptible to surface crust formation. The annual mean rainfall is about 588 mm. The maximum mean daily temperature is 29°C while the minimum mean daily temperature is -0.1°C. The catchment is dominated by the slope range of 0-3% which comprises 57% of the catchment area followed by the slope range of 3-8% which covers 34% of the catchment area.

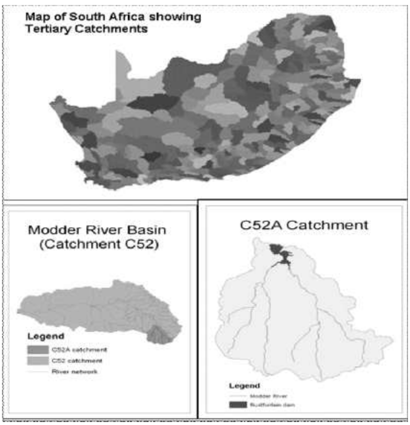

Figure 1. The study area

The interactions which was assumed to take place in the catchment was conceptualized rationally through an interactive process with different stakeholders, namely hydrologist, soil scientist, socio-economist and information technologist. Similarly, a climate change scenario will be built in using appropriate climate change model that will link up with the climate database.

2.1 The conceptual model

Figures 2 and 3 present the integrated conceptual model for the quaternary catchment C52A. In Figure 2, it can be seen that the environment comprises of all resources, agents and socioeconomic interactions that are taking place. The environment is assumed to include both external as well as internal agents.

Agents represented by farmers or farm managers, after a complex interaction with similar agents and/or other agents and with the environment, will be assumed to undergo a behavioural change. These agents who may acquire an immense knowledge from the interaction and the environment can react individually or as a group. A reaction may lead to a decision towards change of land use. Land use changes could occur spatially as well as temporally within the environment. The environment may contain spatially different soil types and physiographic features which can be considered static for a considerable period. This in combination with climatic changes could contribute to the generation of surface runoffs depending on the land-use, soil type and topography of the explicitly situated land/farmland.

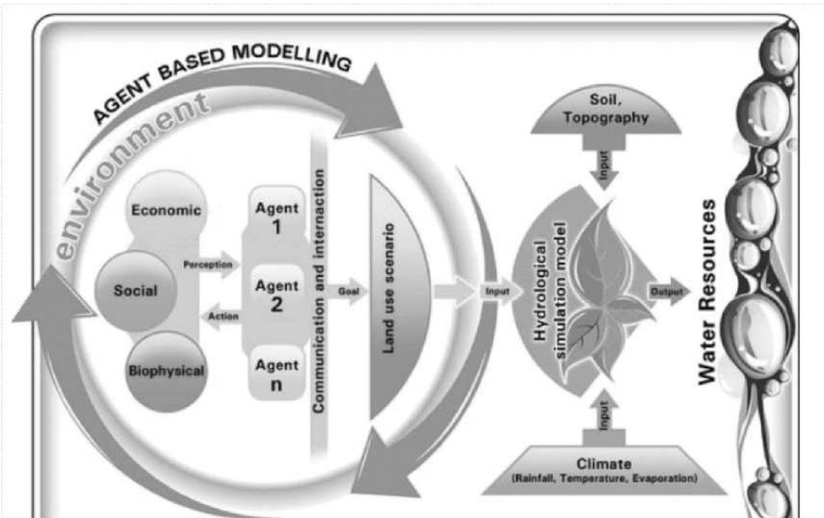

Figure 2. Socio-hydrological conceptual framework

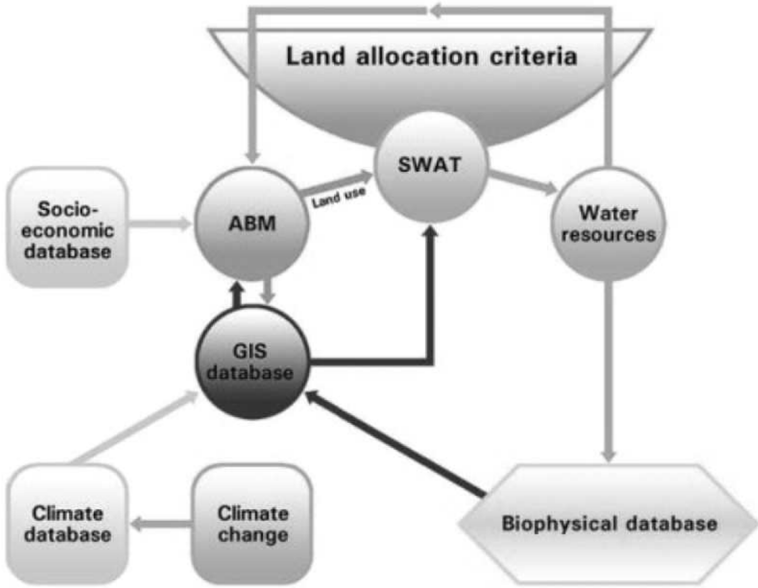

Figure 3. Integration of land use and climate change model.

Figure 3 shows the conceptual model illustrating the database types and its linkage to the different nodes in the process of the model. The socioeconomics factors and the interaction that lead to decision in land use change would be captured by the ABM module while changes in the stream flow would be dealt by the hydrologic module integrated in the system (SWAT). In this way all land use changes resulted by the interactions will be simulated by the ABM while climate change scenario is captured and linked to the climate database within the GIS system. The cyclic effect of climate and land use change will be continuously updated in the GIS database module. The GIS database supplies data both to the ABM and hydrological models, creating a means of investigating the impact of one on the other in addition to their combined impact on the water resources.

3. CONCLUSIONS

Global climatic changes threaten the livelihoods of the farming community in the developing countries and in most of the Sub-Saharan African countries. The cyclic effects of climate and land use change may cause a double fold negative impact on the water resources of the aforementioned countries. As most of the populations of these countries income and food depend on agricultural production, water is the most critical natural resource.

To minimize the future crises on water resources to be brought by land use and global climatic change and in order to take proactive measures for sustainable water resources utilization, development of an integrated socio-hydrological model could be a step in the right direction for decision support system.

4. ACKNOWLEDGMENTS

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