

The development of land use planning scenarios based on land suitability and its influences on eco-hydrological responses in the upstream of the Huaihe River basin

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ABSTRACT

Agricultural activities are one of the leading causes of influencing deforestation and land degradation, which desperately needs reasonable land use planning schemes. Land use planning is a beforehand task that needs to estimate the possible eco-hydrological consequences of land use changes at the watershed scale. The method based on combination of land use scenarios and hydrological model simulations usually provides guidance suggestions for land use planning and land management. However, the setting of land use scenarios often ignores the objective natural conditions in local region.

In this paper, a suitability evaluation method was developed, which synthetically considered the topographic, soil, meteorological and water supply conditions on the agriculture land, to obtain land use planning scenarios in the upstream of the Huaihe River basin. Subsequently, the Soil and Water Assessment Tool (SWAT) model was employed to evaluate the influences of land use scenarios on eco-hydrological responses. Model calibration and validation were performed based on the land use status in 2000, after which the validated simulations were conducted based on the planning scenarios.

Suitability evaluation results demonstrated that 40.83% of the existing agriculture land in 2000 was considered to be unsuitable, especially in the northern part of the studied area, where plantations of grass and forest were implemented to derive the short-term and long-term land planning scenarios, respectively.

The SWAT model with daily time step was set up for the studied area. It simulated reasonably the relationship between rainfall and runoff with the Nash–Sutcliffe efficiency (*NSE*) values of 0.72 and 0.66 for the calibration and the validation periods. Relative changes of eco-hydrological components simulated by the validated SWAT model were analyzed both temporally and spatially. The simulation results counted at multiple temporal scales showed that both short-term and long-term land use planning operations reduced the maximum runoff and total water yield as well as the total sediment loads, meanwhile, increased the evapotranspiration. For runoff components, the decreasing surface runoff and the increasing groundwater were much more significant than the increasing lateral flow. Sub-basin analyses revealed that the simulated changes in eco-hydrological responses varied spatially, whereas the decreases in total water yield and the surface runoff and the increase in evapotranspiration were closely related to the percentages of de-farming in sub-basins. Overall the eco-hydrological responses to long-term land use planning were more profound than that to short-term land use planning. This study provides a synthetic suitability evaluation method for creating land use planning scenario, which overcomes the shortcoming of traditional way of assigning land use scenario that being lack of objectivity.

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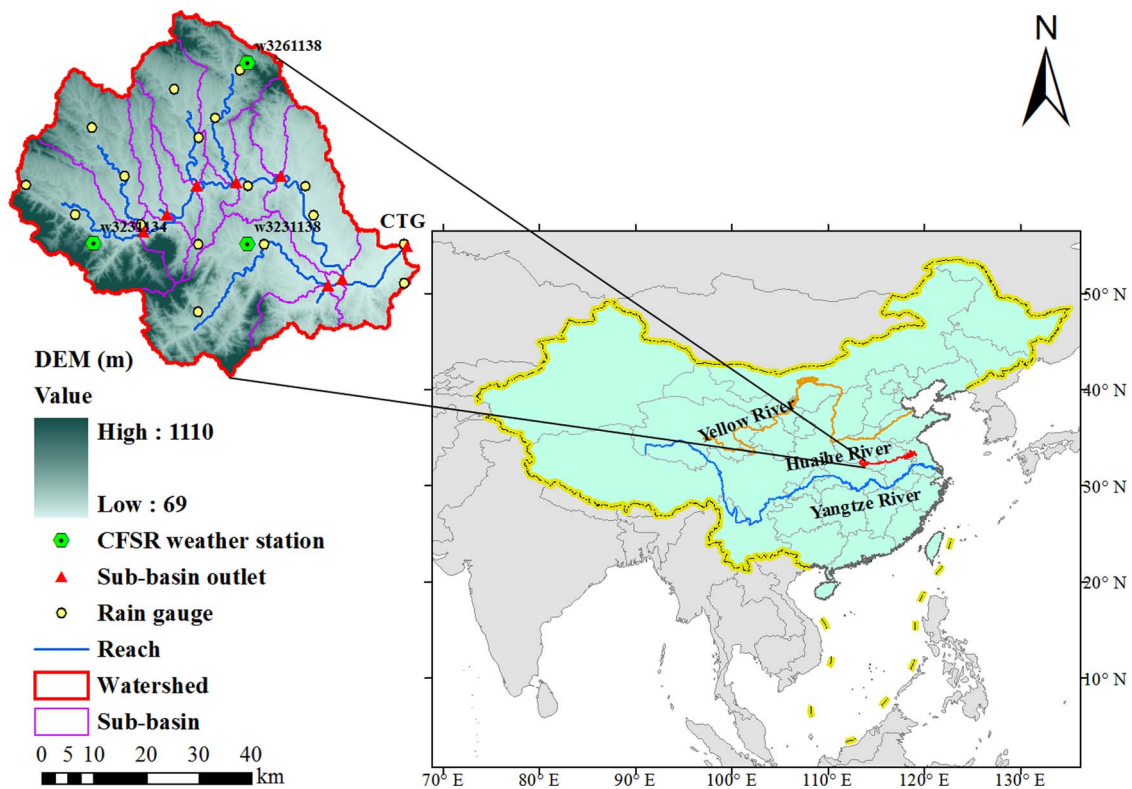


Fig. 1. Location of the studied Changtaiguan (CTG) watershed.

1. Introduction

More and more demands of food, fuel, fiber, water and other resources coming from the rapid development of human society have resulted in a great pressure on ecological system. Of the many human activities, agriculture may be one of the major causes of the rapid deforestation and land degradation, especially in developing counties (Barbier, 2004; Dolisca, 2005; Giliba et al., 2011; Marshall, 2012). This is also the case in China. The fast-growing economy in China is at the cost of environmental degradation. To address this issue, China's central government has launched the so called "Grain for Green Project" (GGP) since 1999 (Corchero et al., 2013). The GGP is to resume forest system, so as to reduce the soil erosion on sloping farmland, where the farmland is actually inefficient. After a long-term implementation of the GGP, according to the observed data of 11 rivers in China, runoff and soil erosion significantly decreased (Li et al., 2012). Therefore, there is no doubt that the appropriate planning policy for agriculture land does provide an effective way to protect the ecological environment and promote the sustainable development of human society.

Land suitability evaluation can provide a reliable way to assist in land use planning at a regional level since it takes into account various limiting factors that are essential for specific land use types, while the GGP only emphasizes the importance of slope gradient (Wang et al., 2007). Land suitability evaluation is, by broadly definition, identifying the spatial appropriateness for possible land uses according to geo-environmental conditions (Hopkins, 1977). Agriculture land suitability evaluation represents an important issue in many research papers and associated applications (Gong et al., 2012; Hossain and Das, 2010; Kurtener, 2008; Mendas et al., 2013). The final evaluation result usually presents a map that spatially allocates the agriculture land into different suitability classes, in such terms as most suitable, moderately suitable and not suitable. All the information can provide evidence for constructing the land use planning scenario quantitatively and qualitatively.

Hydrological models can present a better interpretation of the

interactions among the various physical systems in a watershed, and predict the eco-hydrological responses to proposed land use planning scenarios (Bedient et al., 2007; Beven, 1989). Distributed and semi-distributed hydrological models show better performances in such applications since they can take account of the spatial inhomogeneity of the underlying surface (Kinouchi and Watanabe, 2012). The Soil and Water Assessment Tool (SWAT) model (Arnold and Fohrer, 2005; Arnold et al., 1998; Srinivasan et al., 1998), developed by the United States Department of Agriculture (USDA) in 1994, is a typical semi-distributed eco-hydrological model that can simulate long-term surface and subsurface discharge, sediment deposition, nutrient transport and transformation processes under varying soil conditions, land use types and management conditions. Numerous studies have used scenario-based methods to quantify the impacts of land use scenarios on hydrologic components with SWAT model (Cai et al., 2012; Deng et al., 2015; Githui et al., 2009; Memarian et al., 2014; Nie et al., 2011; Wang et al., 2012; Zhang et al., 2013). Designs of these land use scenarios mainly include extreme land use patterns, historical land use information and trend extrapolation of historical land use, ignoring the guidance of land use planning in practice. Even for those studies which considered the policy of land use planning, land use scenarios seemed to be rather simplistic and qualitative. However the land use planning, as a beforehand task, should conform to objective reality in local regions. Complex issues involving meteorology, topography, landform, etc., need to be taken into account when making decisions.

Due to the unreasonable utilization of land resources, the Huaihe River basin has experienced severe soil erosion during recent decades, particularly in the upper mountainous regions (Cai et al., 2012). In this study, a land suitability evaluation for agriculture land in the upstream watershed of the Huaihe River basin is presented. Multiple criteria that involve terrain, soil properties, climatic conditions and water sources are included for the evaluation process. Given the land use status in 2000, land use planning scenarios are developed by identifying and recovering the unreasonable areas. Eco-hydrological responses are evaluated by using a validated SWAT model for land use in 2000 as well

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