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Original Articles

Water use efficiency and TN/TP concentrations as indicators for watershed land-use management: A case study in Miyun District, north China

Guannan Cui[a,b,d], Xuan Wang[a,b,*], Chunhui Li[b], Yangyang Li[a,b], Shengjun Yan[a,b], Zhifeng Yang[a,b,c]

[a] State Key Laboratory of Water Environment Simulation, Beijing Normal University, Beijing 100875, China
[b] Key Laboratory for Water and Sediment Sciences of Ministry of Education, Beijing Normal University, Beijing 100875, China
[c] Beijing Engineering Research Center for Watershed Environmental Restoration and Integrated Ecological Regulation, Beijing Normal University, Beijing 100875, China
[d] Department of Environmental Science and Engineering, Beijing Technology and Business University, Beijing 100048, PR China

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ABSTRACT

Under dual influences of climate change and human disturbances, it is an important measure for sustainable watershed development to conduct land use planning with considerations of water saving and pollution control. In this research, the following tasks has been accomplished: (1) identifying runoff variations due to the land use changes, (2) investigating concentration variations in total nitrogen (TN) and total phosphorus (TP) in overland flow of different vegetation, (3) based on the rules found by the analyses above, determining the optimal land use demand of water, grass, forest, farm and construction lands through the adoption of multi-objective linear programming and a hydrological model (i.e., MIKE-SHE), (4) taking the relationship between land use changes and hydrological factors at the watershed scale as a corrected input of CLUE-S model to visually allocate land use under three scenarios (i.e., the most optimal situation, adjustment planning after the check point and the government planning for 2020), and further making the detailed crops distribution map for agricultural management with aim of improving water use efficiency and controlling TN/TP concentrations. Thus the "top-down" land use optimal allocation combining the macro scale and the field scale was implemented. The results can provide useful decision alternatives for the land use management of the watershed. Pine, chestnut and walnut were distributed on relatively steep hillside above 400 m. Crops like corn, millet and sweet potato were allocated to the flat areas with the slope less than 3° and the altitude below 400 m. The combination of CLUE-S model and MIKE-SHE model improved the accuracy of land use demand and specific vegetation distributions for farmers. The "top-down" land use optimal allocation considering both water saving and pollution control would support decision makers with feasible suggestions of optimizing land management at different scales.

1. Introduction

Under the influence of climate change and human activities, water shortage has become a common problem in the middle of this century, which has seriously restricted the sustainable development of economy and society. China suffered from water shortage as well as the increasingly serious pollution coming with population, industrial and agricultural growth. Recent studies have shown that human activities on land use affected almost all of the nonpoint source pollution directly or indirectly (Xu et al., 2004; Chen and Fu, 2000). Not only the ecological environment, but economic and social development was suffered from water pollution to a certain extent (Li et al., 2003). Therefore, it is significant to promote the water saving and to coordinate the water conflicts in the river basin not only in favor of the unified water resource management, but also the construction of water-saving society. To improve the water quality of river basin and guide the land use optimal allocation, it is significant to instruct land use spatial layout considering both ecological water saving and pollution control.

Optimization of land-use structure was aiming to find a way realizing economic, social and ecological benefits by future land use structure planning (Geng and Wang, 2000). Reasonable use of limited land resources could harmonize the contradiction among departments or industry land use options. To achieve the best economic, social and ecological benefits, it was important to make overall arrangement and reasonable layout through adjusting measures to local conditions for all kinds of land use types (Liu, 2003; Cai et al., 2011). With the maturity and improvement of GIS and other space technologies, spatial structure configuration model was extensively applied to land planning. More comprehensive and visual results were exhibited in the study that filled

* Corresponding author at: State Key Laboratory of Water Environment Simulation, Beijing Normal University, Beijing, 100875, China.
E-mail address: wangx@bnu.edu.cn (X. Wang).

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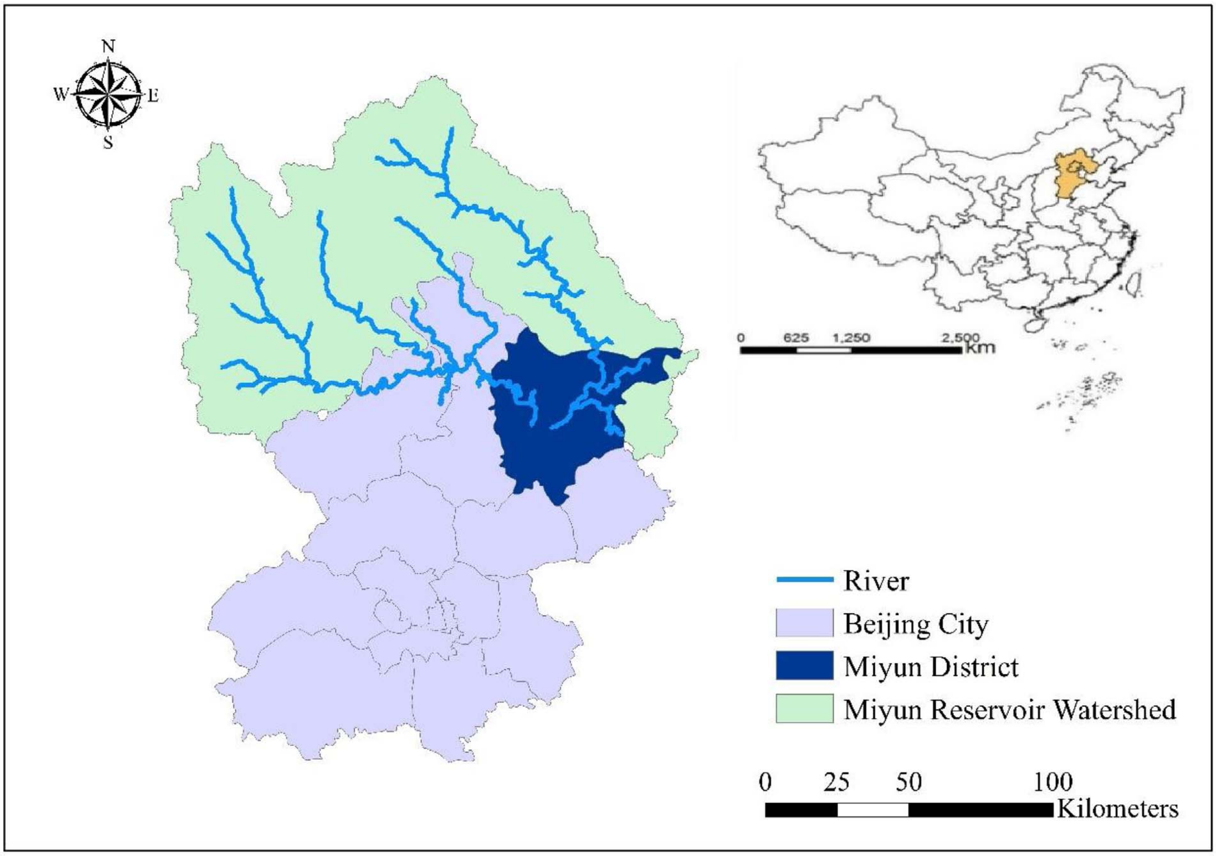

Fig. 1. Location of Miyun District, north China.

up the defects of quantitative structural configuration models. Quantitative structural configuration models had been gradually replaced by the following models: grey forecasting model and single objective linear programming model (Bryan et al., 2011); multi objective programming model (Osgathorpe et al., 2011); Markov chain model (Mitsova et al., 2011) and system dynamics model (Gastelum et al., 2010). Spatial structure configuration model had cellular automata model (Mitsova et al., 2011) and CLUE-S model (Verburg et al., 2002; Santini and Valentini, 2011). The combination of CLUE-S model and other models was a hotspot in the land use spatial structure. Due to the biding, the spatial configuration result error caused by the structure problem of the model itself can be reduced, thus improving the accuracy of land use spatial configuration. Hydrological models had been introduced into CLUE-S model for analysis of hydrological units (Zhang et al., 2014). SWAT model was widely applied together with CLUE-S model to consider the Non-Point Source pollution effects and achieved good practice effect (Zhang et al., 2011; Liu et al., 2014; Zhang et al., 2015). In summary, CLUE-S model could not only carry on the pretty good spatial disposition of land use but gain comprehensive research results by combination of other model simulations as well. However, there were lack of research bringing insight into quantitative relations between not only land use types changes and hydrological factors, but land use types changes and pollutant indicators by field monitoring and mechanism experiment. That led the land use allocation optimization to take actual situation into account less when the land use demand was decided. In order to get the land use allocation optimization plan considering both ecological water saving and pollution control, there was requirements for combining the field scale mechanism experiment or observation results. In addition, as for medium and small scale study area, more detailed information for crops pattern were also needed in the blue print of administrative planning. To give easy operation of the crop configuration in the field of farmland and forest planning could facilitate the agricultural management department from the point of view of the overall optimization of the basin. These two aspects required further investigation in the land use configuration field.

Therefore, the objective of this research is to realize the land use optimal allocation of Miyun District by considering both water use efficiency and TN/TP concentrations. This objective entails the following tasks: (1) identifying runoff variations due to the associated land use changes, (2) investigating concentration variations in total nitrogen (TN) and total phosphorus (TP) in overland flow of different vegetation, (3) based on the rules found by the analyses above, determining the optimal land use demand of water, grass, forest, farm and construction lands through the adoption of multi-objective linear programming and a hydrological model (i.e., MIKE-SHE), (4) taking the relationship between land use changes and hydrological factors at the watershed scale as a corrected input of CLUE-S model to visually allocate land use under three scenarios (i.e., the most optimal situation, adjustment planning after the check point and the government planning for 2020), and further make the detailed crops distribution map for agricultural management with aim of improving water use efficiency and controlling TN/TP discharging. Economic benefit and ecological benefit were chosen as the main optimization goal. Optimal allocation of land resources was realized by the biding of multi objective linear programming model and CLUE-S model through providing explicit land use demand. According to the relationship between the land use changes and the hydrological factors on the field scale, that information was taken as corrected input of the land use model. The combination of CLUE-S model and MIKE-SHE model improved the accuracy of land use demand and specific vegetation distribution on the field scale. The “top-down” land use optimal allocation which combining the macro scale and the field scale would support decision makers with feasible suggestions of optimizing land management on different scales.