water

MDPI

Editorial

Impacts of Landscape Changes on Water Resources

Manoj K. Jha

Civil, Architectural, and Environmental Engineering, North Carolina A&T State University,
Greensboro, NC 27411, USA; mkjha@ncat.edu

Received: 30 July 2020; Accepted: 7 August 2020; Published: 10 August 2020

Abstract: Changes in land use and land cover can have many drivers, including population growth, urbanization, agriculture, demand for food, evolution of socio-economic structure, policy regulations, and climate variability. The impacts of these changes on water resources range from changes in water availability (due to changes in losses of water to evapotranspiration and recharge) to degradation of water quality (increased erosion, salinity, chemical loadings, and pathogens). The impacts are manifested through complex hydro-bio-geo-climate characteristics, which underscore the need for integrated scientific approaches to understand the impacts of landscape change on water resources. Several techniques, such as field studies, long-term monitoring, remote sensing technologies, and advanced modeling studies have been contributing to better understanding the modes and mechanisms by which landscape changes impact water resources. Such research studies can help unlock the complex interconnected influences of landscape on water resources for quantity and quality at multiple spatial and temporal scales. In this Special Issue, we published a set of eight peer-reviewed articles elaborating on some of the specific topics of landscape changes and associated impacts on water resources.

Keywords: landscape change; water resources analysis; water modeling; impact assessment

1. Introduction

Landscape change and its impact on water resources is a vast topic that encompasses fundamental and applied research in multiple dimensions including water resources science and engineering, agriculture, geology, geography, economics, and social sciences. Landscape change can have many manifestations, such as changes due to urbanization, industrialization, commercialization of marginal lands, agriculture, farmers' decisions on the use of croplands, increased use of land through deforestation and drainage of wetlands, government policy decisions for environmental regulations, natural disasters such as floods and droughts, changing climatic and environmental conditions, and others. Subsequently, the impacts of these changes in one form or another on water resources are realized at spatial scales (local impacts contributing to regional scales), temporal scales (short-term vs. long-term changes), changes in water footprints through changes in hydrological processes, and changes in water/environmental quality (sediments, nutrients, and pathogens). For example, changing land use through deforestation and/or drained wetland will influence changes in infiltration and runoff characteristics, thereby affecting evapotranspiration, groundwater recharge, and sediment and water yield [1–4].

It is well-known that the changes in land use have large impacts on water resources; however, quantifying these impacts remains among the more challenging problems in managing water resources [5]. One of the major challenges is the complex interconnection of water within the hydro-bio-geo-climate characteristics [6]. As land use changes, it will alter the water balance through changes in groundwater recharge, runoff, and evapotranspiration. Water movement will be affected due to changes in soil physical properties such as moisture content and soil temperature. Variety of land use types will have associated changes in land characteristics affecting the movement of water in variety of ways. Added to this challenge is the response time of the impacts. For example, groundwater systems response to changes in land use may vary widely from days to decades. Similarly, large scale changes in land use will impact evapotranspiration to a large extent that will be propagated through hydrologic systems and may potentially modify regional weather patterns and climate variability in an unknown future time.

Technological advancements over the years and continuous research efforts have pushed the boundary of science to better understand and quantitatively assess the impacts of landscape change on water resources. While field studies have been proven useful to understand the complexity of impacts at local scales [7], analyses at regional or watershed scales adopt modeling and simulation strategies [8,9]. A range of tools, including hydrological, biophysical, ecosystem models have been developed and used (stand alone or in combination) for investigation and inform the decision-making process. These decision analysis tools identify landscape-change impacts, risks, and uncertainties to provide guidance to make key management decisions [10,11].

This Special Issue presents studies [12–19] that describe the application of a variety of observational and modeling tools and techniques to evaluate the impacts of landscape changes on water resources in watersheds. Landscape changes included change due to agricultural best management practices (BMPs), low impact development (LID) in urban settings, conservation agriculture practices, conversion of erosion hot spot cropland into forest, and others. The impact on water resources included the changes in streamflow, stream and soil temperature, evapotranspiration, sediment, and others. The application of methods included study watersheds in U.S., Hungary, China, South Korea, and Ethiopia.

2. Summary of Papers in the Special Issue

Table 1 shows the comparative analysis of all articles of this Special Issue in terms of the type of the land use change analysis, evaluated impact assessment parameters, and the methods used. Brief summaries of each of the eight published papers are also presented.

Table 1. Comparative analysis of research presented in Special Issue papers.

Landscape Change Analysis	Impact Assessment Parameter(s)	Approach Used	Study Area	Paper
Impact of LID at watershed scale	Surface runoff, subsurface runoff, peak flow, evapotranspiration	Application of an ecohydrological model, Visualizing Ecosystems for Land Management Assessments (VELMA)	East Fork Little Miami River Watershed, OH, USA	[12]
Impact of land use change on stream temperature	Streamflow, stream temperature	Develop a mechanistic stream temperature model in Soil and Water Assessment Tool (SWAT) model	Marys River Watershed, OR, USA	[16]
Impact of open and forested landscapes on soil temperature	Soil temperature	Extending soil temperature model in VELMA	Crest-to-Coast Environmental Monitoring Transect (O'CCMoN) sites, OR, USA	[17]
Impact of landscape on river meandering system	Channel sinuosity vs. forest density and ecological value	GIS analysis of meandering bends between 1952 and 2017 using aerial imagery and UAV (unmanned aerial vehicle)-surveys	Sajó River, Hungary	[18]

Table 1. *Cont.*

Landscape Change Analysis	Impact Assessment Parameter(s)	Approach Used	Study Area	Paper
Impact of optimal placement of BMPs for environmental effectiveness	Streamflow, sediment, BMP cost	Watershed modeling framework using SWAT and optimization algorithm NSGA-II.	Youwuzhen Watershed, China	[13]
Impact of converting erosion hot spot into forested area	Sediment yield	Morgan–Morgan–Finney (DMMF) model	Haean Catchment, South Korea	[14]
Impact of conservation agriculture on a regional scale	Crop yield, water	Agricultural Policy Environmental eXtender (APEX) and GIS-based multi-criteria evaluation (MCE) technique	Ethiopia	[15]
Impact of landscape on vulnerability of flood in an urban watershed	Streamflow, flood extent, inundation	Hydrodynamic model HEC-RAS (Hydrologic Engineering Center—River Analysis System) and hydrologic model SWAT	Blue River, MO, USA	[19]

2.1. Cumulative Effects of Low Impact Development on Watershed Hydrology in a Mixed Land-Cover System, by Hoghooghi et al., 2018

LID practices are designed to reduce the impact of land use change on hydrology. This study used a spatially explicit ecohydrological model VELMA, to assess the impact of LID techniques at the watershed scale. The authors calibrated and validated the model for streamflow. Hydrological effects of three common LID practices (rain gardens, permeable pavement, and riparian buffers) were tested on a 0.94 km^2 mixed land cover semi-urban watershed (27 percent impervious) in Ohio, USA. LID practices were shows to perform as expected for effectively reducing the peak flow and increasing infiltration but with limited efficiency in semi-urban watershed.

2.2. Modeling Landscape Change Effects on Stream Temperature Using the Soil and Water Assessment Tool, by Mustafa et al., 2018

Stream temperature is an important factor in regulating fish behavior and habitat. This study investigates the impact of landscape change on stream temperature. The authors developed a mechanistic stream temperature module within the watershed modeling environment of the SWAT model and applied it to the 782 km^2 watershed in Oregon, USA. The model was calibrated for flow and stream temperature before examining the changes in stream temperature due to change in land use. The model was able to capture the increased stream temperatures in agricultural sub-basins compared with forested sub-basins.

2.3. Improved Soil Temperature Modeling Using Spatially Explicit Solar Energy Drivers, by Halama et al., 2018

Soil temperature affects ecosystem properties including increasing the water temperature. This study demonstrated that local solar energy information improved soil temperature modeling estimates simulated by a soil temperature subroutine within a larger ecohydrological watershed model VELMA. Authors calibrated the model using the data available from Oregon's Crest-to-Coast Environmental Monitoring Transect (O'CCMoN) sites. Results demonstrated the benefit of including spatially explicit representations of solar energy within watershed-scale models that simulate soil temperature.

2.4. Issues of Meander Development: Land Degradation or Ecological Value? The Example of the Sajó River, Hungary, by Bertalan et al., 2018

River channels and their surrounding floodplains enhance landscape evolution and the diversification of environments. This study investigates the geomorphological development and effects of bank erosion along meandering Sajó River in Hungary. Authors performed GIS analysis of three consecutive meandering bends over 10 periods between 1952 and 2017 based on archive aerial imagery and UAV-surveys. Analyses revealed that the meandering (channel sinuosity) was directly proportional to forest density (dominant, compact, and connected) which provided high ecological value.

2.5. Effects of Different Spatial Configuration Units for the Spatial Optimization of Watershed Best Management Practice Scenarios, by Zhu et al., 2019

Variation in spatial configurations of BMPs at the watershed scale may have significantly different environmental effectiveness. This study investigated and compared the effects of four main types of spatial configuration units for BMP scenarios optimization. Optimization was conducted based on a fully distributed watershed modeling framework, the Spatially Explicit Integrated Modeling System (SEIMS) using SWAT, and an intelligent optimization algorithm Non-dominated Sorting Genetic Algorithm II (NSGA-II). Results showed that the different BMP configuration yielded significant differences in near-optimal Pareto solutions, optimizing efficiency, and spatial distribution of BMP scenarios. BMP configuration units that support the adoption of expert knowledge on the spatial relationships between BMPs and spatial locations (e.g., hydrologically connected fields, slope position units) are considered to be the most valuable spatial configuration units for watershed BMP scenarios optimization and integrated watershed management.

2.6. Evaluating the Effectiveness of Spatially Reconfiguring Erosion Hot Spots to Reduce Stream Sediment Load in an Upland Agricultural Catchment of South Korea, by Choi et al., 2019

Soil erosion has a negative impact on the environment and socioeconomic factors by degrading the quality of both nutrient-rich surface soil and water. This modeling study demonstrated the effectiveness of converting soil erosion hot spots within the watershed into forest for reducing the sediment yield significantly.

2.7. Scaling-Up Conservation Agriculture Production System with Drip Irrigation by Integrating MCE Technique and the APEX Model, by Assefa et al., 2019

Conservation agriculture, which promotes no-till, mulching, and diverse cropping, provides higher water use efficiency in addition to improving soil fertility and crop yield. This study demonstrated the scaling-up impacts of conservation agriculture on a regional scale. The calibrated biophysical model APEX in combination with GIS-based multi-criteria evaluation (MCE) technique was used to extend the modeling analysis to the national scale in Ethiopia. Results indicated that the conservation agriculture with drip irrigation technology could improve groundwater potential for irrigation up to five folds and intensify crop productivity by up to three to four folds across the nation.

2.8. Flooding Urban Landscapes: Analysis Using Combined Hydrodynamic and Hydrologic Modeling Approaches, by Jha and Afreen, 2020

Urban landscape dictates the extent of inundation during a flood event, affecting vulnerable infrastructures. This study presents a systematic approach of combining hydrodynamic model HEC-RAS with hydrologic model SWAT in delineating flood inundation zones, and subsequently assessing the vulnerability of critical infrastructures in the Blue River Watershed in Kansas City, Missouri. Results demonstrate the usefulness of such combined modeling systems to predict the extent of flood inundation and thus support analyses of management strategies to deal with the risks associated with critical infrastructures in an urban setting.

3. Conclusions

Landscape changes have direct linkages with changes in hydrology in terms of water balance components. As land use characteristics change, it will alter the hydrology at the local scale, leading to the impacts on water availability and associated water quality to regional scales and at various temporal scales. The papers in this Special Issue describe the applications of a variety of observational and modeling tools and techniques to evaluate the impacts of landscape changes on water resources. The studies can be categorized into four subject areas: (1) impact assessment due to implementation of management practices [12–15], (2) impact of landscape on stream and soil temperature [16,17], (3) landscape and river meandering [18], and (4) landscape for flood inundation [19].

Funding: This received no external funding.

Conflicts of Interest: The author declares no conflict of interest.

References

1. Vandas, S.J.; Winter, T.C.; Battaglin, W.A. Water and the Environment. American Geosciences Institute (AGI) Environmental Awareness Series. 2002. ISBN 0-922152-63-2. Available online: http://www.agiweb.org/environment/publications/water.pdf (accessed on 25 July 2020).
2. Kling, C.L.; Panagopoulos, Y.; Rabotyagov, S.S.; Valcu, A.M.; Gassman, P.W.; Campbell, T.; White, M.J.; Arnold, J.; Srinivasan, R.; Jha, M.K.; et al. LUMINATE: Linking agricultural land use, local water quality and Gulf of Mexico hypoxia. *Eur. Rev. Agric. Econ.* **2014**, *41*, 431–459. [CrossRef]
3. Jha, M.K.; Schilling, K.E.; Gassman, P.W.; Wolter, C.F. Targeting land-use change for nitrate-nitrogen load reductions in an agricultural watershed. *J. Soil Water Conserv.* **2010**, *65*, 342–352. [CrossRef]
4. Rabotyagov, S.; Jha, M.K.; Campbell, T. Impact of crop rotations on optimal selection of conservation practices for water quality protection. *J. Soil Water Conserv.* **2010**, *65*, 369–380. [CrossRef]
5. Stonestrom, D.A.; Scanlon, B.R.; Zhang, L. Introduction to special section on impacts of land use change on water resources. *Water Resour. Res.* **2009**, *45*, W00A00. [CrossRef]
6. Panagopoulos, Y.; Gassman, P.W.; Jha, M.K.; Kling, C.L.; Campbell, T.; Srinivasan, R.; White, M.; Arnold, J.G. A refined regional modeling approach for the Corn Belt—Experiences and recommendations for large-scale integrated modeling. *J. Hydrol.* **2015**, *524*, 348–366. [CrossRef]
7. Assefa, T.T.; Jha, M.K.; Reyes, M.R.; Tilahun, S.A.; Worqlul, A. Experimental evaluation of conservation agriculture with drip irrigation for water productivity in sub-Saharan Africa. *Water* **2019**, *11*, 530. [CrossRef]
8. Assefa, T.T.; Jha, M.K.; Reyes, M.R.; Worqlul, A. Modeling the impacts of conservation agriculture with drip irrigation system on hydrology and water management in sub-Sahara Africa. *Sustainability* **2018**, *10*, 4763. [CrossRef]
9. Jha, M.K. Evaluating Hydrologic Response of an Agricultural Watershed for Watershed Analysis. *Water* **2011**, *3*, 604–617. [CrossRef]
10. Schilling, K.E.; Gassman, P.W.; Kling, C.L.; Campbell, T.; Jha, M.K.; Wolter, C.F.; Arnold, J.G. The potential for agricultural land use change to reduce flood risk in a large watershed. *Hydrol. Process.* **2013**, *28*, 3314–3325. [CrossRef]
11. Jha, M.K.; Gassman, P.W.; Arnold, J.G. Water quality modeling for the Raccoon River Watershed Using SWAT. *Trans. ASABE* **2007**, *50*, 479–493. [CrossRef]
12. Hoghooghi, N.; Golden, H.; Bledsoe, B.; Barnhart, B.; Brookes, A.; Djang, K.; Halama, J.; McKane, R.; Nietch, C.; Pettus, P. Cumulative effects of low impact development on watershed hydrology in a mixed land-cover system. *Water* **2018**, *10*, 991. [CrossRef] [PubMed]
13. Zhu, L.; Qin, C.; Zhu, A.; Liu, J.; Wu, H. Effects of different spatial configuration units for the spatial optimization of watershed best management practice scenarios. *Water* **2019**, *11*, 262. [CrossRef]
14. Choi, K.; Maharjan, G.; Reineking, B. Evaluating the effectiveness of spatially reconfiguring erosion hot spots to reduce stream sediment load in an upland agricultural catchment of South Korea. *Water* **2019**, *11*, 957. [CrossRef]
15. Assefa, T.; Jha, M.; Worqlul, A.; Reyes, M.; Tilahun, S. Scaling-up conservation agriculture production aystem with drip irrigation by integrating MCE technique and the APEX model. *Water* **2019**, *11*, 2007. [CrossRef]

16. Mustafa, M.; Barnhart, B.; Babbar-Sebens, M.; Ficklin, D. Modeling landscape change effects on stream temperature using the Soil and Water Assessment Tool. *Water* **2018**, *10*, 1143. [CrossRef]
17. Halama, J.; Barnhart, B.; Kennedy, R.; McKane, R.; Graham, J.; Pettus, P.; Brookes, A.; Djang, K.; Waschmann, R. Improved soil temperature modeling using spatially explicit solar energy drivers. *Water* **2018**, *10*, 1398. [CrossRef]
18. Bertalan, L.; Novák, T.; Németh, Z.; Rodrigo-Comino, J.; Kertész, Á.; Szabó, S. Issues of meander development: Land degradation or ecological value? The example of the Sajó River, Hungary. *Water* **2018**, *10*, 1613. [CrossRef]
19. Jha, M.; Afreen, S. Flooding urban landscapes: Analysis using combined hydrodynamic and hydrologic modeling approaches. *Water* **2020**, *12*, 1986. [CrossRef]