



Research article

Understanding the relationship of land uses and water quality in Twenty First Century: A review



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ABSTRACT

Rising food, housing and energy demand of increasing population creates an immense pressure on water resources, especially on water quality. The water quality around the globe is degrading primarily due to intense agricultural activities associated with rapid urbanization. This study attributes to cause of water quality problem, indices to measure water quality, methods to identify proper explanatory variables to water quality and its processing to capture the special effect, and finally modeling of water quality using identified explanatory variables to provide insights. This would help policymakers and watershed managers to take necessary steps to protect water quality for the future as well as current generation. Finally, some knowledge gaps are also discussed which need to be addressed in the future studies.

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1. Introduction

Water quality is defined as a measure that can evaluate the usage of water for different purposes (drinking, agricultural, industrial, recreational, and habitat) using various parameters such as physical, chemical, and biological. Water quality plays a pivotal role in all aspects of living organisms in the earth which entices attention of environmental scientists, ecologist, hydrologist, watershed managers, and agricultural scientists. Water quality varies based on location, time, weather, and presence of pollution sources. Maintaining proper water quality is challenging task primarily due to presence of point and non-point sources (NPS) of pollution. Point source is confined, easily identifiable and is regulated by the different state and Federal agencies (USEPA, 2009). However, NPS pollution is difficult to identify due to complex and diffuse nature of interaction between runoff and landscape (Chiwa et al., 2012; Carpenter et al., 1998).

Land use is one of the components of landscape which has a vital role in generation of pollution. Increase in population changes land use primarily due to 1) need of housing, 2) food for life, and 3) development of infrastructure for easy transportation which fosters

urbanization and agricultural activities. Urbanization increases impervious surface such as parking lots, roof tops, roads, and sidewalks resulting into increase in runoff which creates additional avenue for transportation of pollutants from landscape into waterbodies (Wilson and Weng, 2010). On the other hand, agricultural activities increases amount of fertilizers, pesticides, herbicides, and dairy manures in the cropland to fulfill the food demand of human population and some of those enters into the nearest waterbodies. Direct and indirect impact of urbanization and agricultural activities degrade water quality (Yu et al., 2013) which is the consequences of land use change.

Degradation of water quality increases algal bloom and phytoplankton biomass, taste and odor of water, and drinking water purification cost (Tsegaye et al., 2006) which ultimately creates negative impact on both terrestrial and aquatic ecosystems (Zhang et al., 2012). For example, increase in suspended solids increases turbidity in water reducing lesser light penetration into waterbodies, which has a detrimental effect on fish and other aquatic animals due to lesser photosynthesis (Giri, 2013).

Finding solutions to above mentioned problems as well as other environmental issues are based on following factors: i) providing environmental education, ii) forming environmental legislation, iii) use of new technology, and iv) environmental awareness by society. Environmental education is one of the solutions to sustainable

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development both in developed and developing countries. Environmental education provides direction to human behavior towards nature and promotes environmental ethics. One of the methods to introduce environmental education is by introducing environmental courses both in primary and higher educational institutions as well as engaging students in different extracurricular activities such as planting of trees. This creates awareness among the students and promotes positive attitude towards environment. For example, [Rangel et al. \(2015\)](#) conducted a study in Marine Beach at South coastal of Portugal in an effort to reduce negative ecological impacts during snorkeling by enhancing public awareness. They found that on site education and interpretation would be able to reduce negative ecological impacts. [Simsekli \(2015\)](#) examined the effect of environmental education practices on elementary school students in Turkey. The students were taught regarding importance of water resources, water pollution and its effect for two hours a week for two weeks. They compared the same open ended question before and after the two weeks course among the same students and observed that environmental education increased awareness among the students. [Erdogan \(2011\)](#) assessed the ecology based education program on 64 elementary school student in Ankara, Turkey. He found that the education program had significantly positive impact towards the students' environmental behavior.

Second pillar to mitigate environmental issue is the environmental regulatory framework by governmental agencies. [Yin et al. \(2015\)](#) performed a study to determine the effect of environmental regulation in reducing CO₂ emission in China. They found that environmental regulation had significant impact on decreasing CO₂ emission. Another study, by [Zhao et al. \(2015a, b\)](#) also found that environmental regulation helps different companies (such as electric power, steel, and iron) to introduce more greener technology to improve environmental condition. [Ford et al. \(2014\)](#) evaluated the effect of environmental regulation on oil and gas industry in Australia. They found that collaborative regulatory framework spurs innovation which can address environmental concern. For example, Murphy Pipe and Civil developed a high quality water and sewer pipe against an electric cable which has minimal environmental impact.

Third factor to address environmental issues and maintain a sustainable growth both in developed and developing countries is development of new technology. Technology improves the quality of life whether it may be introducing new medical equipment or providing clean water and electricity to people. The example of new technology that helps our society in water resources is Geographic Information Systems (GIS). We use this technology in different field of water resources such as study of scarcity of water resources, water pollution, domestic and industrial water demands, and food security. [Wang et al. \(2015\)](#) used GIS to delineate aquatic eco region in the Heihe River Basin in China for policy and management decisions to address water scarcity as well as severe water pollution. Another example of technological advancement solving water resource demand is application of physically based computer model for simulation of water quantity and quality. [Sharma et al. \(2015a, b\)](#) used a physically based hydrological model to predict the water quantity in Giri Watershed which was one of the sources of drinking water to the Shimla City in India. This research work provided solution to increasing drinking water demand.

The fourth pillar to address environmental issue is the social pro-activeness by corporates. Increasing awareness in environmental, social, and governance has prompted increase in corporate social responsibility which is designed to implement strategies or principles lead to sustainable development ([Ortas et al., 2015](#)). In response to this call, many corporates have incorporated environmental factor in their business agenda. For example, KPMG is

actively involved in environmental programs such as developing ISO14001 certification ([Mazurkiewicz, 1998](#)) which controls business activities that has a tremendous impact on environment. Another example would be Bhopal gas leak tragedy in India which created Responsible Care Program in chemical industries. This is a self-regulatory program that sets code of conduct against lack of government regulation. This improved the environmental condition and overall performance of the companies ([Gamper-Rabindran and Finger, 2013](#)).

The fifth factor to address environmental challenges is acceptance of technology in the society. Introduction of technology into grass root level (producers or farmers) needs formation of supporting institutions with technologically educated work force. [Chhetri et al. \(2012\)](#) studied the involvement of multilevel institutions including farmers and non-governmental organization in developing location specific solution to agricultural adaption to mitigate climate change in Nepal. They found that involvement of farmers and other non-governmental organization facilitate adaptation of new technology in the society. [Adenle et al. \(2015\)](#) examined the innovation and diffusion of technology in agriculture in order to address climate change in developing countries. They suggested that collaborative approach with farmers during the process of identifying best solution would foster the implementation of technology to tackle climate change in agriculture.

This paper examines the third factor which is development of new technology in the field of water resources, specifically, recent developments in land use and water quality both in developing and developed countries.

Assessment of relationship between land use and water quality is of great importance to protect fresh water, which would fulfill the water demand in different sectors such as increased agricultural activities, industrial usage, municipal usage, supply of drinking water, and recreational use. Additionally, understanding the relationship between land use and water quality would help assessing the water quality in the unmonitored watershed as monitoring is expensive and time consuming. Also, this knowledge would provide guideline to watershed managers and policymakers to prioritize the future land use development in the rapidly urbanizing world. Therefore, this requires a thorough understanding of advantage and disadvantage of techniques applied, scale of study area, focus of land use metrics, and relationship observed by different studies. The motivation for this research work is due to increase in land use changes by anthropogenic activities such as intensive agriculture, rapid urbanization, and deforestation in developed as well as developing countries.

The objective of this study is to review the fundamental relationship between land use and water quality as well as the recent developments in this area. This paper is presented as follows. Section 1 entails a brief description of water quality, source of pollution, land use, factors affecting land use change and its effect, impact of water quality degradation, factors to address environmental issues, and importance of understanding the relationship between land use and water quality, Section 2 presents a conceptual visualization of water quality assessment, Section 3 reviews factors affecting water quality degradation, Section 4 describes about the indices to measure water quality, Section 5 presents indices to process explanatory variables to water quality, Section 6 entails techniques to analyze water quality problem, Section 7 depicts determination of water quality explanatory variables, Section 8 presents water quality and land use study around the globe, and Section 9 tells about the conclusion of this study along with some knowledge gaps.

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