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Eco Hydrological Landscape Management Practice Associated with Health Risk Hazards: A Reappraisal

Nishi Kant Prasoon Kumar Singh and Bijendra Kumar

Department of Environmental Science and Engineering Indian School of Mines, Dhanbad-826004, Jharkhand, India
E-mail: nishikant1490@gmail.com

Abstract—*Scientists and environmental managers alike are increasingly concerned about landscape pattern change and its effect on hydrological and ecological processes. Due to Rapid urbanization the water quality is detoriting, much more attention needs to pay on the water quality as the water is the plays prime role in human health. Water quality is closely connected with the composition and spatial pattern of ''source'' and ''sink'' landscapes. Monitoring and assessment of the water pollution has become a very critical area of the study because of direct implications of water pollution on the aquatic life and the human beings and has become the prime focus of environmental scientists in recent years. Multivariate statistical analysis such as cluster analysis (CA) and principal component analysis (PCA) suggest the possible source of water contamination. In future studies, more attention should be paid to comprehensive multi-scale and integrated research of landscape pattern and eco-hydrological processes. In this paper, progress of research on the main eco-hydrological effects of landscape pattern is reviewed and the key issues of associated health risk assessment were discussed.*

Keywords*: Health risk, Spatio-temporal variation, Landscape function and changes, Water quality parameters.*

1. INTRODUCTION

Scientists and environmental managers alike are increasingly concerned about broad-scale changes in land use and landscape pattern and their cumulative impact on hydrological and ecological processes (Jones et al. 2001; Hillbricht-Ilkowska et al. 2000; Janauer 2000). In recent years, the eco-hydrological effects of landscape pattern change have been discussed intensively, in particular with respect to runoff (Bellot et al. 2001; Felix et al. 2002), water quality (Amatya et al. 2004; Basnyat et al. 1999), soil erosion (Oost et al. 2000; Erskine et al. 2002), soil quality (Sheng et al. 2003; Fu et al. 2003a, 2003b), and climate (Taylor et al. 2002; Radics and Bartholy 2002; Barlage 2001). Land use activities affected water quality by altering sediment, chemical loads and watershed hydrology. Some land uses may contribute to the maintenance of water quality due to a biogeochemical transformation process (Basnyat et al. 1999). Urbanization development also has a major influence on water quality at watershed scale. Water quality was also affected by other landscape components besides land use. A number of studies have shown strong relationships between water quality, water quantity, and runoff to landscape characteristics. Spatial arrangement of landscape pattern could change transportation rate and direction of nutrient materials. A number of studies have shown that rainfall interception and absorption by vegetation cover varied with the differences in vegetation types. Consequently, a vegetation type's ability to hold soil particles varied as well (Zhu et al. 2003). Land-use could result in the changes of soil's physical and chemical properties (Fu et al. 2002a; Guo et al. 1999), which may help to control soil erosion. At watershed or catchment scale, there was a certain correlation between land use types and sediment yields. In different climatic zones, the same landscape pattern change had a different effect on climate. One of the major perturbations to the earth's system is conversion of land to satisfy human needs for food and settlement. Landscape pattern had a pronounced impact on soil microorganism including its biological activity and distribution, which are fundamental for maintaining soil quality by mediating the processes of organic matter exchange and nutrient cycling. Many researchers focused on the relationship between forest changes and runoff (Lørup et al. 1998; Zhao et al. 2001; Zhou et al. 2001). Water is a source of livings, it is considered as a most vital and crucial substances in the environment, its contamination with heavy metals like such as cadmium (Cd), chromium (Cr), copper (Cu), manganese (Mn), nickel (Ni), lead (Pb) and zinc (Zn) is a worldwide environmental threat. The source of heavy metals are different from natural (i.e., weathering, erosion of bed rocks, ore deposits and volcanic activities) and anthropogenic (i.e., mining, smelting, industrial influx and agricultural activities) sources. They can contaminate the surface (river) and ground (spring, dug well and tube well) water that is used for domestic, agricultural and industrial purposes (Ettler et al., 2012; Krishna et al., 2009; Khan et al., 2008). Ingestion of water containing certain amount of heavy metals may cause health problems in human, including shortness of breath and various types of cancers

(Kavcar et al., 2009). Some essential metals like Cu, Mn and Zn are required for normal body growth and function. However, excess amount of these metals could also be harmful. High concentrations of Cd, Cr, Ni and Pb are considered highly toxic in human and aquatic organisms (Ouyang et al., 2002). Their accumulation in the body can cause serious diseases (Khan et al., 2010). The adverse effects of heavy metals include toxic, neurotoxic, carcinogenic, and mutagenic and teratogenicity effects depending upon the heavy metal species (Sharma et al., 2008; Patra et al., 2010). Monitoring and assessment of the water pollution has become a very critical area of study because of direct implications of water pollution on the aquatic life and the human beings. The contamination of surface water by heavy metals is a serious ecological problem as some of them like Hg and Pb are toxic even at low concentrations, are non-degradable and can bio-accumulate through food chain. Though some metals like Fe, Cu and Zn are essential micronutrients, they can be detrimental to the physiology of the living organisms at higher concentrations. Different multivariate and univariate statistical analyses such as one-way analysis of variance (ANOVA), inter-metals correlation and principal component analysis (PCA) to understand the relationships between contaminated water and human health (Muhammad et al., 2011). In this paper, progress of research on the main eco-hydrological effects of landscape pattern is reviewed and the key issues of associated health risk assessment were discussed.

2. LANDSCAPE PATTER AND COMPONENT COMPOSITION ON WATER QUALITY

2.1 Effects of land use structure on water quality

Landuse change is one of the most significant factors that influenced nutrient flow in rural catchments (Mander et al. 2000). Ha et al. (1998, 2001) analyzed the quantitative impact of a municipal wastewater treatment operation on the long-term water quality changes in a tributary of the Han-river, Korea from 1994 to 1999. During this period, the average increase of land use area in terms of housing, cultivation, and barren was 5.89, 0.13, and 0.12%, respectively, and the corresponding decrease in water and forest area was 0.21 and 0.16%.With respect to the total stream, water quality recovery usually include the negative contribution resulting from increased land use and a positive contribution due to the wastewater treatment operation. A time-series analysis of airborne photographs, Landsat Thematic Mapper images and hydro-chemical data were used to examine the effects of land-use change from 1930 to 2001 on solute inputs to Lake Calado, a floodplain lake in the central Amazon. Deforestation from slash-and-burn agricultural activities has dramatically decreased the amount of primary growth upland and flooded forests in the basin. The increasing area that was converted to agricultural plots and pasture in the Lake Calado basin has increased solute loading to the lake from upland tributaries (storm and base flow), bank seepage and overland flow, and decreased through fall inputs (Williams et al. 2004). Urbanization development also has a major influence on water quality at watershed scale. Bhaduri et al. (1997) applied the L-THIA model to assess the long-term effect of land-use change in the LEC catchment in Indiana, USA, from 1973 to 1991. Results showed that when the percent of the urban impermeable area was 18%, annual runoff was increased by 80% and the quantity of heavy metals in the annual runoff was increased by 50%. In addition, nutrient pollutants decreased by 15% because of the decrease in agricultural land area.

2.2 Effects of landscape component spatial distribution on water quality

A number of studies have shown strong relationships between water quality, water quantity, and runoff to landscape characteristics. Spatial arrangement of landscape pattern could change transportation rate and direction of nutrient materials. Changes in landscape conditions in the riparian zone and in areas surrounding water quality sample sites may have a greater influence on water quality than broader scale, watershed conditions, although the importance of near-site, landscape conditions may vary, depending on the biophysical setting (Jones et al. 2001). A study has been conducted by Hillbricht-Ilkowska in the lake land region of northeastern Poland. It was found that the stream network and wetland patches dispersed among the fields and wetland zones close to lakeshores played a crucial role in transporting and transformation of nutrient compounds before they eventually reached the lake ecosystems. It was also found that the concentration of both nutrients in that period significantly decreased towards the lakeshore, particularly in the case of nitrate–nitrogen. In the summer (drought period) there was a significant decrease of dissolved phosphorus but no change in the case of nitrate–nitrogen. In addition, Hillbricht-Ilkowska et al. (2000) pointed out that wetland belts or patches around the lakes function as effective buffer zones with respect to nitrate–nitrogen during the period of long-lasting saturation conditions in the soil layer of the wetland. Spatial arrangement of source and sink at watershed scale has a major impact on water quality and non-point source pollution. Four watersheds in the upper reaches of the Yuqiao Reservoir Basin, Zunhua, Hebei province, China, were chosen to identify the relationship between landscape pattern and water-soluble nitrogen concentration. There was no clear relationship between watershed shapes, relative importance of landscape types and nitrogen concentration.

2.3 Spatial distribution of landscape structure and its functioning

The wide theme of landscape structure assessment would fill up a review on its own. Here we focus only on the basic methodological approaches which have significance for landscape- functional aspects, and also data types which are most commonly used in this field. Changes in landscape structure are most commonly observed through changes in land use or land cover. Landscape pattern analysis (Turner et al., 2001) is based on landscape spatial indices, or landscape spatial metrics. Satellite images have been generally available since 1960 (Herold et al., 2003) and their importance for studying landscape change, especially in large regions, is crucial. Besides the landscape pattern, the multispectral images also carry information on thermal parameters of vegetation and other land cover types, which enables us to study landscape functional aspects (Singh et al., 2012). The earlier periods can be studied using historical maps; for example the Central European region can benefit from well preserved surveys of Stable Cadastre (1:2 880) and military surveys (1:28 800), which are frequently used for modelling the 18th and 19th century landscape (Timar and Gabris, 2008; Olah and Boltižiar, 2009). There are also other sources that can enhance or verify information acquired from the spatial sources (maps and remote sensing images), e.g. the land use changes database of Czechia (Bicik et al., 2001), archival photographs or old paintings (Blazkova and Matousek, 2008), works of early scholars (Racova and Chrastina, 2014). Landscape functions were classified into three groups of flows (Forman and Godron, 1986) – energy, material and information fluxes between landscape elements. Following this classification we can describe some exemplary methods of tracking and quantification of these fluxes. Energy fluxes in landscape are most frequently observed through satellite imagery analysis, which can provide an estimation of water evaporation and evapotranspiration of the landscape cover (Liou and Kar, 2014) through various vegetation indices calculated from the thermal values. There are a number of studies relating land use/landscape structure to the water quality using various test areas and miscellaneous approaches in last 15 years. Sliva and Williams (2001) compared the land use proportion in the catchment as well as in the 100m buffer zones around the water courses. The most significant result in that case was the influence on the urban areas proportion on water quality in both the whole catchment and buffer zone. In their large study on both real and artificial landscapes, Uuemaa et al. (2005) were unable to prove an independent correlation between landscape metrics and water quality indicators, whereas the proportion of land cover classes (namely the fens and urban areas) responded to the water quality clearly. Lowicki (2012) examined intensively farmed lowland watersheds and compared the water quality indices with selected landscape spatial metrics.

3. HUMAN HEALTH RISK ASSESSMENT

Human health risk assessment is considered as the characterization of the potential adverse health effects of humans as a result of exposures to environmental hazards (USEPA, 2012). A human health risk assessment involves four steps which are: hazard identification, dose-response assessment, exposure assessment, and risk characterization. Health risk assessment classifies elements as, carcinogenic or non-carcinogenic. Risk assessment is defined as the processes of estimating the probability of occurrence of any given probable magnitude of adverse health effects over a specified time period and is a function of the hazard and exposure.

3.1 Approaches for assessing health risks

To assess health risks in the study area, participants randomly selected and interviewed for information about age, body weight, monthly income, smoking habits, occupational exposure, drinking water sources and other health related problems. Local people use both surface and groundwater for drinking and other domestic purposes. Therefore, the health risk indicators such as chronic daily intakes (CDIs) and health risk indexes (HRIs) of metals for both surface and ground drinking water samples.

Heavy metals enter the human body through several pathways including food intake, dermal contact and inhalation. In comparison to oral intake, however, all other pathways are considered negligible (Muhammad et al., 2011). The CDI (μg/(kg·day)) of heavy metal through water ingestion. (Shah et al., 2012; Muhammad et al., 2011).

$$CDI = Cm \times Iw/Wb$$

where, Cm (μg/L) means the heavy metal concentration in water, Iw (L/day) is the average daily intake of water (assumed to be 2 L/day for adult and 1 L/day for child) (US EPA, 2011), and Wb (kg) is the average body weights (assumed to be 72 kg for adult and 32.7 kg for child), respectively (Muhammad et al., 2011; Khan et al., 2010; Jan et al., 2010).

3.2 Health risk indexes of metals

Chronic health risks, HRIs (Shah et al., 2012; Muhammad et al., 2010).

$$HRI = CDI/RfD$$

Where, the oral toxicity reference dose (RfD, μg/ (kg·day)). The HRI value less than one is considered to be safe for the consumers (Khan et al., 2008).

The daily environmental exposures to metals usually assessed for carcinogenic and non-carcinogenic elements. There are two main exposure pathways: intake of the metals through water consumption, and by skin absorption through bathing. Assessment of non-carcinogenic risks can be achieved by estimating the hazard quotient (HQ). Basic statistics such as min., max, mean, and relative standard deviation (RSD) along with the multivariate statistics. Principal component analyses (PCA) used to identify the possible heavy metal sources. PCA by the method of Varimox normalized rotation on the dataset. It is mainly used to explain the major variation within the data.

Hierarchical methods, which form clusters sequentially, beginning with the most similar pair of objects and forming higher clusters stepwise. Cluster analysis (CA) was applied to produce a dendrogram that provide a visual summary of the clustering process, describing clustering groups with a reduction in dimensionality of the original data to revealed that natural processes and anthropogenic activities were the main sources of water contamination and cause many health issues in humans.

4. CONCLUSION

Changes in landscape pattern and their eco-hydrological effects have been regarded as a hotspot and leading issue in scientific research in many disciplines such as ecology, hydrology, and geography. Changes in landscape pattern had a major impact on material and energy movement by changing a series of eco-hydrological processes, such as runoff, water quality, and soil erosion. It is necessary to discuss in depth landscape pattern changes and their eco-hydrological effects, which will be helpful to integrated management and exploitation, and of positive significance to the research focusing on regional sustainable development and global environmental changes. Consequently, more attention should be paid to the interaction mechanism between watershed scales and other scales and multi-scale studies are needed in future work. Attention should also be paid to integrated research about landscape pattern and Eco hydrological effects, mainly focusing on the dynamic mechanism of landscape pattern and its effect on Eco hydrological processes in the same watershed; models of landscape pattern and eco-hydrological effects should eventually be integrated. The knowledge of risks assessment shall be a priority considering continuous increase in heavy metal and general environmental pollution globally in water. Urbanization development also has a major influence on water quality at watershed scale. Water quality was also affected by other landscape components besides land use. The present review may be helpful scientist, environmental mangers and stakeholders as the present progress of the research on the main eco-hydrological effects of landscape pattern are discussed in brief and assessment of pollution levels, health risks, exposure assessment and spatial variation of heavy metals in water.

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