Impact of soil erosion and degradation on water quality: a review

Sakinatu Issaka and Muhammad Aqeel Ashraf

School of Environmental Science and Engineering, China University of Geosciences (Wuhan), Wuhan, PR. China; International Water, Air & Soil Conservation Society, Kuala Lumpur, Malaysia

ABSTRACT

Severe soil erosion challenges exist in China as a result of long-term human related activities and its erosion-prone land forms and climate. Anthropogenic forces that alter the physical landscape cause substantial soil erosion which have adverse impact on surface water bodies and therefore necessitating sediment control as important aspects of catchment management planning. In this review we focused principally on the erosion factors and how to prevent and/or mitigate them. The application of soil erosion models such as the universal soil loss equation, its modification and others were also studied. The results established by various researchers showed a relationship between impact of soil erosion and degradation on water quality indicating the source of pollutant as anthropogenic and industrial activities. These are the sources of particles and deleterious material that contribute to the surface water deterioration including the East Lake. The review revealed that erosion causes both on-site and off-site effects on land and also on water bodies thereby affecting its quality.

1. Introduction

Soil erosion has is an old phenomenon as mankind. It has worsened human civilization and the quest for better live by man. It is either caused by natural agents or induced as a result socioeconomic development over the years. The eroded material from soil erosion cause both on-site and off-site effects which are detrimental to both flora and fauna. The effects could be exacerbated by inter and intra reactions within the ecosystem.

In areas with expanding population, agricultural production, construction and urbanization as well as human activities soil erosion is a major problem (Ding, Chen, Cheng, & Wang, 2015; Leh, Bajwa, & Chaubey, 2011; Wu & Xie, 2011). Among the factors that cause soil erosion is poor land management which causes damage to the soil and results in water runoff across landscape instead of adequate infiltration (Liu, 2016; Montgomery, Huang, & Huang, 2014; Nadeu, Berhe, de Vente, & Boix-Fayos, 2012; Niu et al., 2015).

Soil erosion is usually characterized by three actions, involving soil loosening, transport, and deposition. These processes usually result in the relocation of the top soil which is rich in organics, nutrients, and soil life elsewhere on-site where it builds up over time or is transported off-site where it accumulates in drainage channels. It is usually severe on unprotected sloppy areas (Shi et al., 2012).

Soil erosion adversely hinders the growth of plants, agricultural yields, quality of water, and recreation. It is a key cause of degradation of soils as it occurs naturally on all lands (Bai et al., 2010; Ding et al., 2015; Li & Wei, 2011; Posthumus, Deeks, Rickson, & Quinton, 2015). Soil erosion causes are basically water and wind, with each of these contributing to a significant level of yearly soil loss.

The erosion phenomenon is sometimes slow, where it usually occurs immediately unnoticed, it can also occur at a rapid rate resulting in a great loss of the upper part of the soil. Soil erosion on crop lands is manifested in the reduction of the yield potential, surface water quality reduction, and impaired drainage networks (Munodawafa, 2012; Montgomery et al., 2014; Rahman, Shi, & Chongfa, 2009). Among the greatest adverse worldwide environmental concerns is soil erosion. This is because it causes not only soil nutrient deprivation and degradation of land, but it also leads to many noticeable off-site environmental problems such as flooding.
water siltation, and pollution (Al-Wadaey & Ziadat, 2014; Dahal, Holcomb and Socci, 2011; Gao, Li, Li, Jia, & Zhang, 2012; Ouyang, Hao, Skidmore, & Toxopeus, 2010; Yu, 2008). The erosion process is becoming a major setback to the sustainable development of natural resources and the environment, which ultimately calls for suitable monitoring and evaluation.

Soil erosion usually occurs in places that are susceptible, the topography is sloped and when long duration rainfall coincides with inadequate vegetative cover (Rohrmann, Heermann, Kapp, & Cai, 2013; Vrielang, Steven, Sterk, & Rodrigues, 2009; Lee & Lee, 2006; Marques, Bienes, Jimenez, & Perez-Rodriguez, 2007; Zhao et al., 2014). Soil erosion monitoring is a key to recognizing vulnerable areas and for measuring the yield of deposits in the field. Sediment yield and soil erosion constitute key factors which may be used for water quality control activities.

The process of soil erosion cause on-site soil deterioration at an irreversible scale and is measured using average quantity of removed soil from an area within a defined period. The level of soil detached and transported to surface water bodies within a time scale over a specific area is known as the sediment yield, and it serves as an important procedure in catchment erosions (Guo, Hao, & Liu, 2015; Sutherland & Ziegler, 2007).

The nonpoint nutrient contaminants, heavy metals, and chemicals are also transported with soil particles, causing higher sediment levels which eventually lead to water eutrophication and disturbance of delicate aquatic ecosystems (Bing, Wu, Liu, & Yang, 2013; Wilson, Cullum, & Römkens, 2008). Severe soil erosion which leads to excessive silt export to waters or reservoirs result in disturbances of life in water bodies as well as reduced quality of the environmental (Zhai, 2010).

Soil erosion influence, its features and topography are considered constant over a short-term period, so that climatic features and land cover are the main factors inducing the erosion process in a given time (Manyevere, Muchaonyerwa, Mnkeni, & Laker, 2016; Marques, Bienes, Jimenez, & Perez-Rodriguez, 2007; Wang et al., 2016). According to a bulletin of national survey on soil and water conservation of the ministry of water resources and the national bureau of statistics (MWR and NBS, Beijing, 2013), soil erosion is ranked high among the environment problems in China, because of the massive scale of the land it erodes through either water or wind, which is estimated to be approximately 3 million km² (equivalent of 32% its total land area (Li, Niu, Wang, Gao, & Liu, 2016).

Studies have taken place to monitor China’s soil erosion, but they mostly focused on erosion caused by water and are confined to a local region (Chen, Su, Tian, Zhang, & Xia, 2011; Duan, Xie, Ou, & Lu, 2011; Jiao, Zou, Jia, & Wang, 2009; Rohrmann et al., 2013; Shen et al., 2009; Wang et al., 2009; Wu & Chen, 2012; Xu, Xu, Wu, & Tang, 2012). Water quality issues have brought a daunting task for water environment management.

The spatial temporal differences of water quality could provide dynamic information for the decision-maker of water environment (Wang & Yu, 2008; Wang, Zhang, Zhao, & Sun, 2010; Varol & Sen, 2009). It is imperative therefore to carefully examine appropriate patterns of surface water quality, which are influenced by such multiple-factors. There exist complex processes and many factors in comprehensive quality assessment and several fuzzy events and models are involved in the assessment.

The fuzzy comprehensive analysis with the capacity to capture these characteristics and its results is more reasonable and approximate to the actual situation (Lin & Huang, 2015). The major investigating technique used for the spatial water quality design so far is the multivariate statistical analysis; a vital tool used to study spatial-temporal water quality design (Miao, Ni, & Borthwick, 2010; Huang, Wang, Lou, Zhou, & Wu, 2009; Bu, Liu, & Zhang, 2009; Ge et al., 2014). This was applied in the Jinshui river, Jiangxi river, Du river, upstream of the Hanjiang river (Shen et al., 2009), and the Xiangjiang river in China (Zhang et al., 2009). The same technique was used in areas in other countries, for example, the Pisuerga river in Spain, the estuary of the Fuji river in Japan (Shrestha & Kazama, 2007), and the Bagmati river in Nepal (Kannel, Lee, Kanel, & Khan, 2007).

The fuzzy analysis is widely used in the assessment of surface water bodies such as rivers [Li, Zeng, Li, & Mei, 2006]. The problems associated with soil erosion, sediment carriage, and their eventual deposition in water bodies have persisted through ages across the entire earth surface (Rahman et al., 2009). The situation nevertheless has aggravated lately with the growing interferences of man with the environment (Shao, Tang, Zhang, & Li, 2006).

Another technique used is the Inductively Coupled Plasma Mass Spectrometry (ICPMS) which enables the analysis and determination of heavy metals on-site or off-site. This has been successfully used to investigate selected metals in soil samples exposed to agricultural and automobile activities and in the examination of 14 different heavy metals in collected sediments (Benipal et al., 2017; Topalidis, Harris, Hardaway, Benipal, & Douvris, 2017).

This review is focused on factors affecting soil erosion and degradation and how to control and mitigate them. Therefore, the objective of the research is to access the impact of soil erosion and degradation on water quality at the East Lake in Wuhan, China, by identifying the relevant dominant factors through the application of appropriate models.

2. Study area

East Lake (Donghu), located in the northeast of Wuhan, Hubei Province, the city capital in central china, is the major urban lake in China (Figure 1). The area covered
by the lake is 27.9 km² and its normal average and determined depth are 3–4 m and 4.75 m, respectively. A number of roadway channels have been constructed across the lake, allotting it into numerous water bodies; Guozheng Lake, Tanglin Lake, Yingwo Lake, Shuiguo Lake, and the Miao Lake are the main five basins as a result of the dikes. Inter-basin water only happens through bridge tunnels and culverts under the roadways.

In 1957 when the Qingshan Power plant and the Wuhan Metal Company were constructed, the East Lake, which was an uncluttered lake connected to the Yangtze River was secluded from the River and until now is the largest artificially controlled inland water body. In addition to the commercial activities mentioned early, further industrial plants, such as foundries and cement plants exist (Yang, Liu, Zeng, & Chan, 2009). More importantly, the Lake plays a substantial role in industrial and agricultural production, daily life, aquaculture, and tourism. Recently a lot of social projects have taken place around the East Lake with the increased development of the lake's scenic, culminating in a rise in the economy (Liu, Zhang, An, & Wu, 2014). Moreover, the scale of built-up construction surrounding the East Lake is still expanding and the population is becoming denser (Zhang et al., 2014). Therefore, the East Lake picturesque area faces severe ecological problems such as lake eutrophication affected by the large domestic sewage, oil waste from catering industry and the discharge of industrial and agricultural waste (Huang, Liu, Fang, & Zhao, 2013; Wilson et al., 2008; Yang et al., 2009), coal gasification (tar) and coking plants, and many more have been piled up in the Qingshan industrial vicinity.

The wind direction is predominantly from the northeast all year round. The city has climatic conditions of northern subtropical monsoon with a rainfall pattern of 1150–1450 mm and temperature of 15.8–17.8 °C throughout the year. The rainfall mainly takes place in the months of June and August within the year. It is largely leveled with small hills at the south bank, alluvial natural on the northwest bank hillock plain on the west and east banks.

3. Land degradation

3.1. Global land degradation data

In spite of the universal nature of the issue of water erosion, good information regarding the global extent of data on the harshness of water erosion is limited. The Global Assessment of Human Induced Soil Degradation (GLASOD) (Table 1) study projected that, about 15% of the worlds ice-free land surface is associated by all types of land degradation. Of this, accelerated erosion by soil represented about 56% and water represented about 34% and.

This shows that the location pretentious by erosion by water is estimated to be close to 11 million square km, and the zone affected by erosion by wind is about 5.5 million square km. And tillage erosion is currently not...
known in some affected regions. Because soil is formed gradually, it is essentially a finite resource. The effect of the international erosion problem is only now becoming widely appreciated.

### 3.2. Chinese soil degradation data

#### 3.2.1. Extent of land degradation in China: Changes in land cover

Variations in vegetation status are well documented in China. Deforestation has been a historic process in China and the twentieth century witnessed a partial reversal trend of that process so that from 1934 to 1993 forest cover almost doubled, but most of this was visible in the form of plantations. There is continuous depletion of natural forest and biodiversity. In China, the soil loss rate ranged between 30.87 and 107.44 tons ha$^{-1}$ a$^{-1}$ on fallow land and 7.65–49.38 tons ha$^{-1}$ a$^{-1}$ on farmland under conventional tillage. The land use types with permanent cover experienced the lowest soil loss rates, which were 0–1.89, 0.28–8.06, and 3.98–1.57 tons ha$^{-1}$ a$^{-1}$ for forest, shrub, and grassland, respectively (Guo et al., 2015). Grasslands in contrast have also suffered significant degradation (Figure 2) and 32% of grasslands are severely degraded resulting in a reduction in production potential.

Crops and water supplies are suffering severe destruction as the soil surface is splashed and washed away across a third of the nation (Bai, Dent, Olsson, & Schaepman, 2008).

#### 3.3. Factors that enhance soil degradation

Soil erosion takes place when soil is left bare to wind energy or rain drop. The intensive is dependent on the severity of rain drop and wind blowing across the bare land. Among the factors as listed by (Pimentel & Burgess, 2013), include.

### Table 1. Estimation of human-induced soil degradation by GLASOD.

| Kind of degradation | World | Asia | West Asia | Africa | Latin America and Caribbean | North America | Australia and Pacific | Europe |
|---------------------|-------|------|-----------|--------|----------------------------|---------------|----------------------|--------|
| Water erosion       | 1094  | 440  | 84        | 227    | 169                        | 60            | 83                   | 115    |
| Wind erosion        | 548   | 222  | 145       | 187    | 47                         | 35            | 16                   | 42     |
| Nutrient depletion  | 135   | 15   | 6         | 45     | 72                         | –             | +                    | 3      |
| Salinity            | 76    | 53   | 47        | 15     | 4                          | –             | –                    | 4      |
| Contamination       | 22    | 2    | +         | +      | +                          | –             | –                    | 19     |
| Physical            | 79    | 12   | 4         | 18     | 13                         | 1             | 2                    | 36     |
| Other               | 10    | 3    | 1         | 2      | 1                          | –             | 1                    | 2      |
| Sum                 | 1964  | 747  | 287       | 494    | 306                        | 96            | 103                  | 218    |

Source: Bai et al. (2008).

Figure 2. Normalized difference vegetation index from 1981 to 2006 for China. Source: (Bai et al., 2008).
3.3.1. Rainfall and rainwater runoff
This usually involves the breakdown of the soil and dispersing the materials it is made of. A typical rainwater runoff will impact lighter materials like organic matter, silt, and finer sand particles, but in most heavy rainfalls larger material components are also affected as well.

3.3.2. Agricultural activities
Crop production and other farming processes can affect the overall structure of the soil as well as the levels of organic matter, rendering it more vulnerable to the effects of rainfall and rainwater. Land tilling in particular breaks up and softens the structure of soil and serves as a major contributor to soil erosion. Agricultural activities that are less intensive tend to have far less impact on soil erosion.

3.3.3. Vegetative cover
Crops and grasses support the structure of soils, thereby decreasing the amount of soil erosion. Areas with less naturally-occurring flora are more susceptible to soil erosion.

3.3.4. Wind
Wind is a major factor in decreasing soil quality and facilitating erosion, especially when the soil's structure is loose. Lighter winds will usually not cause so much damage. The most susceptible soil to this type of erosion is sandy or lighter soil that are easily transported through the air.

3.3.5. Slope of the land
The physical features of the land also contribute to soil erosion. Land with a high slope will facilitate the process of rainwater flow rate or runoff saturation in the area, particularly due to the faster movement of the water downhill (Chen et al., 2011; Nenadovi, Kljajićevi, Nenadovi, Milanovi, & Markovi, 2013).

There is a reduction in the storage size of the country's 80,000 reservoirs, affected each year by sand and mud. Compared with soil deposits along rivers, which increases the threat of overflowing.

New roads and railways infrastructure are also contributing to the problem and the awareness of people is limited on environmental protection than in different nations.

The northern grasslands in China for several years, scaled back logging after deforestation added to flooding along the Yangtze in the late 1990s. Desertification in China has become a main concern in Beijing, the nation's capital city.

Soil is a valued natural resource that in the short period becomes nonrenewable and is difficult to recover when degraded. The use of soils on a long-term basis requires that their ability to overcome the requirements upon them is not exceeded. If the demands become too high, the soil is degraded. The affected soil results in lower fertility, human poverty, and reduced biodiversity (Duan et al., 2011). Moreover, the biological, physical, and chemical properties as well as the physicochemical features of compounds of soil can seriously affect the degradation capacity of naturally occurring microorganisms for field bioremediations, hence soil erosion is the most general type of soil degradation.

4. Evaluation tools
Soil mineralogy is the key element of many soil functions, for instance nutrient quantities and concentrations of anion and cation, pH and buffering, exchange capacity, aggregate stability, soil carbon protection, dispersion, and resistance to erosion. The recent availability of X-ray diffraction (XRD) technology and improved software for mineral classification and an amount could enable predictable examination of soil mineralogy as well to soil properties forecast (Shepherd, 2010).

XRD analysis results are used to detect the main crystalline phases existing in soil samples. The data can be used to stabilize calibrations across soil types and as well serve as an input into pedo-transfer functions. Because the environmental regulatory framework relies on total element concentration to delineate environmental contamination, XRD can identify in situ 16 contaminant speciation, not achievable via other conventional chemical analyses, and thus constitute an analytical step toward the consistent estimation of contaminant geochemistry (Nenadovic et al., 2010).

In XRD analysis, sample particle size must be well prepared (i) attain suitable statistical illustration of the constituents and their different diffracting crystal planes and (ii) avoid diffraction-related artifacts (Koutsospyros, Braida, Christodoulatos, Dermatas, & Strigul, 2006). This shows that sand-sized particles require grinding, either by ball milling, mortar, and pestle or pounding using a blender. Samples with platy or fibrous minerals are most effectively ground using bladed devices such as blenders. It is also recommended that a cooling liquid, for example alcohol, be applied in grinding to avoid sample degradation from heat. It is also recommended that, particles be ground to 0.01 mm for quantitative assessments (Nenadovic et al., 2010).

The soil material and grain size analysis will be selected in the required study area for the analysis of the distribution and property of the soil. It will also provide important clues regarding the size and allocation of the soil fraction, the predominant soil attribute used to characterize soil physical conditions can as well determine its mechanical, hydrological, chemical behaviors erosion resistance, thermal conductivity, dynamics of organic matter, infiltration processes, supply of nutrients, development of seal and crust, among others (Paz-Ferreiro, Vidal, & Miranda, 2010). Approved methods applied used for grain-size examination are dependent on sieving rates for coarse fractions and sedimentation rates of
Soils provide insight into features such as the material parent origin, weathering frequency and uniformity and mostly contain elementary minerals, which are formed from magma. They also contain other minerals, which develop through the weathering process, and sometimes exhibit crystallographic features that intensely affect their chemical and physical properties. Major research time and space are devoted to the progress of models of soil erosion (Pimentel & Burgess, 2013).

Degradation of land resources and soil erosion are significant problems in many countries. Quantitative assessment is required to conclude on the level and size of erosion of the soil problems, so that comprehensive handling approaches can be developed on a continental scale using field measurements.

Furthermore, evaluation of alternative land management scenarios in gauged or un-gauged basins is accomplished by simulation models. As in the case of management of water, the choice of management of resources of land are achieved by developing a quantity of different land application scenarios and by their performance using soil erosion models (Wang et al., 2010).

The problem related to erosion risk models is validation, because of the scarcity of available data for comparing the estimates of the models with real soil losses (Gitas et al., 2009; Lazzari, Gioia, Piccarreta, Danese, & Lanorte, 2015). Models of soil erosion are available with varying levels of complication (Laflen & Flanagan, 2013). One of the broadly used empirical models designed for measuring rill and sheet erosion is the Universal Soil Loss Equation (USLE), developed by Smith and Wischmeier in 1965. The handbook of soil erosion modeling, first edition (Renard, 2010) serves as a reference for preservation planning and is further revised into the USLE known as the Revised-USLE (RUSLE). Initially, USLE was established to facilitate estimations of soil erosion in croplands (Renard, Yoder, Lightle, & Dabney, 2010). RUSLE and the modified version (MUSLE) (Lee & Lee, 2006; Terranova, Antronico, Coscarelli, & Iaquinta, 2009), are still being applied within many researches on soil loss approximation. Other models of erosion range in various degrees of complexity. The European soil erosion model systeme hydrologique Europeen or European hydrological system (EUROSEM/SHE) is a newly developed comprehensive model for soil erosion and comes with a distributed and really based properties.

Soil erosion models are grouped into three categories, thus, Conceptual (partly empirical/mixed), Physically-based, and Empirical [40]. Examples for first two classes are made up of the empirical USLE, its modifications and few broad models like the areal nonpoint source watershed environment response simulation (ANSWERS) (Molla & Sisheber, 2016), chemicals, runoff and erosion from agricultural management systems (CREAMS), and modified answers (MODANSW).

ANSWERS and CREAMS are basically conceptual and event-based models. The importance of a model of soil erosion used to estimate its loss at the lake and to integrate different kinds of land practices on urban land, grassland, and forested areas was the motivation for the changes to USLE. RUSLE is most effective when applied on water bodies. RUSLE takes into consideration various types of erosion, excluding gulley and stream bank erosion. The factors captured by the RUSLE model are expressed as: \[ A = \frac{1}{4}RKSCP \] A represents the total yearly soil loss in tones per acre, per year from sheet, rill and inter-rill erosion; R represents rainfall and runoff factor; K represents the soil erodibility factor; LS represents the slope length and steepness factor; C is the land use and cover factor; and P represents the management support practice factor. This technique allows for analysis at a high resolution which affords for the recognition of dominant factors of soil erosion.

The inductively coupled plasma mass spectroscopy has been used effectively in metal analyses for several decades. The plasma is created by passing a stream of argon gas through very-high-energy radio frequency radiation. The argon gas atoms absorb this radiation and ionize at temperatures exceeding 5000 °C. Metals are introduced into the plasma in an aerosol form, which is then ionized for detection and quantification. Solid and liquid samples require a preparation or digestion step prior to introduction into the ICP-MS. In general, this preparation is an acid digestion, which mobilizes metals that are adsorbed onto particle surfaces in the sample matrix and moves them into the liquid (acid) phase. It is this liquid digestate that is passed through a nebulizer to create the aerosol that enters the plasma. Based on the evidence presented literature studies, it is clear that ICP-MS is the preferred method for generating accurate results of samples. The ICP-MS can be a more definitive and accurate method of analysis for arsenic in most samples (Dahal et al., 2011).

5. Mitigation measure or erosion management

Landscape alteration and related vegetation does not only alter the balance of water, but most importantly the processes that regulate its quality. Also the assumption of pollution control from nonpoint (Huang et al., 2013) agricultural source in the erosion program is adequate to cater for high value water resources. Impacts on resources of water include pollution by pesticides and nutrients intrusion and leaching into ground and surface waters.

With the challenges of urbanization, growth of population, management of wastewater, providing food to feed the people, and exports, variations in water value is expected. Regardless of the multiple pressures from pollution sources, the deterioration of quality of water in lake is attributed to the low quality of discharged water coming from surrounding activities and erosion-related.
events. Runoff in urban areas is the third vital source of lake deterioration, affecting ~28% of the lake’s capacity that does not satisfy standards of water quality. Point causes of pollution of water in urban areas include industrial and sewage discharges, which are very important and are often managed intensively. Based on this review of scientific literatures, it is stated clearly that eutrophication is a predominant problem in water sources brought about by over enrichment with phosphorus and nitrogen (Wu & Xie, 2011).

Also eroded material result in salinity increases emanating from waste water discharge which has caused the main water quality problem in the East Lake (Huang et al., 2013). Aquatic ecosystem nutrients reduction causes diverse problems such as toxic algal blooms, loss of oxygen, dying of fishes, and loss of biodiversity. It also results in damage to aquatic plants coral reefs and beds and creates water treatment problems (Liu et al., 2014).

The level of pollutants has expanded recently resulting in the degradation of the quality water. The degradation process of these important water bodies can be considered as natural resource loss because of the recreation that they offer (Yoo, Fisher, Ji, Aufdenkampe, & Klaminder, 2015).

 Provision of secure and safe water for people globally, and promoting the lasting use of its resources are important objectives of the millennium development goals. The international community has recognized the important relationship that exists between the ecosystem, mankind’s health, and well-being. Mathematical water quality modeling presents a special challenge to the systems analyst because it demands integration of so many disciplines.

It also depends on hydrology and hydromechanics for the description of the movement of water and the mechanisms of mixing. Researchers call upon climatologist, meteorologist, and atmospheric physicist to specify conditions at the air–water interface. Water quality draws on the chemistry of dilute solutions, chemical kinetics, and biochemical for the assessment of the fate of substances suspended or dissolved in water. It requires ideas of the associations of aquatic life forms and their environment: an understanding of aquatic ecology.

Every deterministic model of water quality is founded on the following general principles: mass conservation and elements narrow bands of biomass composition, energy conservation, conservation of momentum, boundary conditions and initial conditions governing chemical, biological and biochemical processes known as the second law of thermodynamics (Yoo et al., 2015).

The following are some models generated by researchers for water quality: Erosion prediction project (WEPP) (Laflen & Flanagan, 2013). It is a generalized modeling framework for contaminant fate in surface waters including rivers, estuaries, and lakes. Exposure analysis modeling system (EXAMS-II)—which is both a steady state and a quasi-dynamic model designed for rapid evaluation of the behavior of synthetic organic chemicals in aquatic ecosystems and water bodies (Chen, Wang, Li, & Li, 2015).

The very well-known vollenweider, Rigler, and Dillon models used for eutrophication control in lakes serves as a measure of biomass concentration. Zero-dimensional models are applied to simulate series of lakes or lake networks.

6. Final remarks

In china severe soil erosion is a major environmental problem. The government of china in 1999 carried out a well-rounded program of ecological reconstruction to help control the country’s soil erosion problems known as the Grain-for-Green Program (Hayashi et al., 2015). For the goals of this program to be achieved, individuals, farmers, tourist, contractors, and many more should in one way or the other participate in abiding with policies, rules and regulations in all aspects of the environments to reduce and manage the soil degradation rate in the country.

Most Researchers focus their attention to the appropriate sustainable strategies for coming up with an accurate soil quality monitoring system at multiple scales based on an efficient appraisal of soil. Although science alone cannot solve the problem, our evaluation of literature suggests that the necessary scientific understanding is well developed and could be readily mobilized in the search for solutions.

In the meantime, positive signs can be seen at national and regional levels as water quality monitoring programs and lake management plans which should be implemented to improve the water quality and biodiversity. Improving water quality is another challenge for urban cities; whether they would have strong support and participation from the people and government is a major concern.

7. Future work

The future work, following this review will involve studies on soil erosion activities and other pollution sources in the East Lake. It will further entail water quality testing by using lake sediments sampled from the East Lake in Wuhan, in order to examine the link between the soil erosion and water quality of the lake. Figure 3 summarizes the entire study process. Therefore the core objective of this research is to access the impact of soil erosion and degradation on water quality at the East Lake in Wuhan City, Hubei Province of China, by identifying the relevant dominant factors through the determination and usage of simple, physically based models and survey of water quality.

The role of sediment in chemical pollution is tied both to the particle size of sediment, and to the amount of particulate organic carbon associated with the sediment. Many of the persistent, bio-accumulating and
toxic organic contaminants, especially chlorinated compounds including many pesticides, are strongly associated with sediment and especially with the organic carbon that is transported as part of the sediment load in surface water. Therefore the distribution of sediments concentration of heavy metals in the lake will be analyzed to know the variation in acceleration and rate of accumulation. This difference will result in the selection of samples for statistical analysis to assess their physical and chemical changes that occur during their transportation to the lake.

A feasible intervention will involve the development and use of empirical models to handle the challenges that come about as a consequence of our interferences.
The research pathway used to identify the variations in the nutrient contents of the lake and relating them to such factors as anthropogenic pollution and short-term hydrologic alterations comprise three stages. Firstly, it involves the studying of water quality monitoring in various study sites and depths of the lake, immediately followed by hydrologic estimation for the whole monitoring period that comprise the second stage and finally the trophic status estimation is made using a designed empirical model. These stages are then followed by a relative valuation of the results relative to agricultural pollution rates and hydrologic changes during the study period.

Acknowledgment

I wish to express my deepest appreciation to Yahaya Yakubu for his editorial support.

Disclosure statement

No potential conflict of interest was reported by the authors.

References

Alkarkhi, A. F. M., Ahmad, A., & Easa, A. M. (2009). Assessment of surface water quality of selected estuaries of Malaysia. Multivariate statistical techniques. *Environmentalist*, 29, 255–262.

Al-Wadaey, A., & Ziadat, F. (2014). A participatory GIS approach to identify critical land degradation areas and prioritize soil conservation for mountainous olive groves – case study. *Journal of Mountain Science*, 11, 782–791.

Bai, Z. G., Wu, Y. J., Dent, D. L., Zhang, G. L., Dijkshoorn, J. A., van Engelen, V. W. P., & van Lynden, G. W. J. (2010). Land degradation and improvement in China 2. Accounting for soils, terrain and land use change. ISRIC Report 2010-05. Retrieved from http://www.isric.org/sites/all/modules/publdcnt/publdcnt.php?file=isric_webdocs/docs/ISRIC_Report%202010_05_Land_Degr_Stratification_China_June%202010.pdf&nid=331

Bai, Z. G., Dent, D. L., Olsson, L., & Schaepman, M. E. (2008). Proxy global assessment of land degradation. *Soil Use and Management*, 24, 223–234.

Benipal, G., Austin, H., Srirajayatsayai, C., Tate, A., Topalidis, V., Eswani, Z., … Douvis, C. (2017). Examination of Al, As, Cd, Cr, Cu, Fe, Mg, Mn, Ni, Pb, Sb, Se, V, and Zn in sediments collected around the downtown Houston, Texas area, using inductively coupled plasma-optical emission spectroscopy. *Microchemical Journal*, 130, 255–262.

Bing, H., Wu, Y., Liu, E., & Yang, X. (2013). Assessment of heavy metal enrichment and its human impact in lacustrine sediments from four lakes in the mid-low reaches of the Yangtze River, China. *Journal of Environmental Sciences*, 25, 1300–1309.

Bu, H. M., Liu, W. Z., & Zhang, Q. F. (2009). Application of multiple statistical analysis to spatial-temporal variations of water quality of the Jinshui River. *Resources Sciences*, 31, 429–434.

Chen, K., Wang, X., Li, D., & Li, Z. (2015). Driving force of the morphological change of the urban lake ecosystem: A case study of Wuhan, 1990-2013. *Ecological Modelling*, 318, 204–209.

Chen, S. H., Su, H. B., Tian, J., Zhang, R. H., & Xia, J. (2011). Estimating soil erosion using MODIS and TM images based on support vector machine and à trous wavelet. *International Journal of Applied Earth Observation and Geoinformation*, 13, 626–635.

Dahal, G., Holcomb, J., & Socci, D. (2011). Surfactant-oxidation co-application for soil and groundwater Remediation. *Remediation Journal*, 2, 101–108.

Ding, L., Chen, K. L., Cheng, S. G., & Wang, X. (2015). Water ecological carrying capacity of urban lakes in the context of rapid urbanization: A case study of East Lake in Wuhan. *Physics and Chemistry of the Earth, Parts A/B/C*, 89–90, 104–113.

Duan, X., Xie, Y., Ou, T., & Lu, H. (2011). Effects of soil erosion on long-term soil productivity in the black soil region of northeastern China. *Catena*, 87, 268–275.

Gao, H., Li, Z., Li, P., Jia, L., & Zhang, X. (2012). Quantitative study on influences of terraced field construction and check-dam siltation on soil erosion. *Journal of Geographical Sciences*, 22, 946–960.

Ge, J., Liu, M., Yun, X., Yang, Y., Zhang, M., Li, Qing X., & Jun Wang (2014). Chemosphere Occurrence, distribution and seasonal variations of polychlorinated biphenyls and polybrominated diphenyl ethers in surface waters of the East Lake, China. *Chemosphere*, 103, 256–262.

Gitas, I. Z., Douros, K., Minakou, C., Silleos, G. N., & Karydas, C. G. (2009). Multi temporal soil erosion risk assessment in N. Chalkidiki using a modified USLE Raster model. *EARSeL eProceedings*, 1, 40–52.

Guo, Q., Hao, Y., & Liu, B. (2015). Rates of soil erosion in China: A study based on runoff plot data. *Catena*, 124, 68–76.

Hayashi, S., Murakami, S., Xu, K., & Watanabe, M. (2015). Simulation of the reduction of runoff and sediment load resulting from the Gain for Green Program in the Jialingjiang catchment, upper region of the Yangtze River, China. *Journal of Environmental Management*, 149, 126–137.

Huang, F., Wang, X. Q., Lou, L. P., Zhou, Z. Q., & Wu, J. P. (2009). Spatial variation and source apportionment of water pollution in Qiantang River (China) using statistical techniques. *Water Research*, 44, 1562–1572.

Huang, P., Liu, Y., Fang, L., & Zhao, J. (2013). Research article study on non-point source pollution of East Lake in Wuhan, China. *Journal of Chemical and Pharmaceutical Research*, 12, 675–680.

Jha, M. K., & Paudel, R. C. (2010). Erosion predictions by empirical models in a mountainous watershed in Nepal. *Journal of Spatial Hydrology*, 1, 1–14.

Jiao, J., Zou, H., Jia, Y., & Wang, N. (2009). Research progress on the effects of soil erosion on vegetation. *Acta Ecologica Sinica*, 29, 85–91.

Kannel, P. R., Lee, S., Kanel, S. R., & Khan, S. P. (2007). Chemometric application in classification and assessment of monitoring locations of an urban river system. *Analytica Chimica Acta*, 582, 390–399.

Koutsospyros, A., Braida, W., Christodoulatos, C., Dermatas, D., & Strigul, N. (2006). A review of tungsten: From environmental obscurity to scrutiny. *Journal of Hazardous Materials*, 136, 1–19.

Laflin, J. M., & Flanagan, D. C. (2013). The development of U.S. soil erosion prediction and modeling. *International Soil and Water Conservation Research*, 1, 1–11.

Lazzari, M., Gioia, D., Pica, P., Danese, M., & Lanorte, A. (2015). Sediment yield and erosion rate estimation in the mountain catchments of the Camara artificial reservoir (Southern Italy): A comparison between different empirical methods. *Catena*, 127, 323–339.
Lee, G.-S., & Lee, K.-H. (2006). Scaling effect for estimating soil loss in the RUSLE model using remotely sensed geospatial data in Korea. *Hydrology and Earth System Sciences Discussions*, 3, 135–157.

Leh, M., Bajwa, S., & Chauhey, I. (2011). Impact of land use change on erosion risk: An integrated remote sensing, geographic information system and modeling methodology. *Land Degradation & Development*, 1, 1–13.

Li, G. X., & Wei, X. (2011). Soil erosion analysis of human influence on the controlled basin system of check dams in small watersheds of the Loess Plateau, China. *Expert Systems with Applications*, 38, 4228–4233.

Li, L. F., Zeng, X. B., Li, G. X., & Mei, X. R. (2006). Water quality assessment in Chaohe River by fuzzy synthetic evaluation method. *Journal of Agro-Environment Science*, 25, 471–476.

Li, X., Niu, X., Wang, B., Gao, P., & Liu, Y. (2016). Driving forces of dynamic changes in soil erosion in the Daihe Mountain ecological restoration area of northern China based on GIS and RS. *PLoS One*, 3, 1–15.

Lin, R., & Huang, W. (2015). Fuzzy assessment on reservoir water quality. *Journal of Marine Science and Technology*, 2, 231–239.

Liu, Q. J., Zhang, H. Y., An, J., & Wu, Y. Z. (2014). Soil erosion processes on row sides lopes within contour ridging systems. *Catena*, 115, 11–18.

Liu, Y. (2016). Landscape connectivity in Soil Erosion Research: concepts, implication, quantification. *Geographical Research*, 1, 195–202.

Manyevere, A., Muchaonyerwa, P., Mnkeni, P. N. S., & Laker, M. C. (2016). Examination of soil and slope factors as erosion controlling variables under varying climatic conditions. *Catena*, 147, 245–257.

Marques, M. J., Bienes, R., Jimenez, L., & Perez-Rodriguez, R. (2007). Effect of vegetal cover on runoff and soil erosion under light intensity events. Rainfall simulation over USLE plots. *Science of the Total Environment*, 378, 161–165.

Miao, C., Ni, J., & Borthwick, A. G. L. (2010). Recent changes of water discharge and sediment load in the Yellow River basin, China. *Progress in Physical Geography*, 34, 541–561.

Molla, T., & Sisheber, B. (2016, September). Estimating soil erosion risk and evaluating erosion control measures for soil conservation planning at Koga Watershed, Ethiopian Highlands. *Solid Earth Discussions*, 1, 1–23.

Montgomery, D. R., Huang, M. Y. F., & Huang, A. Y. L. (2014). Regional soil erosion in response to land use and increased typhoon frequency and intensity, Taiwan. *Quaternary Research* (United States), 1, 15–20.

Munodawafa, A. (2012). The effect of rainfall characteristics and tillage on sheet erosion and maize grain yield in semiarid conditions and granitic sandy soils of Zimbabwe. *Applied and Environmental Soil Science*, 1, 1–8.

Nadeu, E., Berhe, A. A., de Vente, J., & Boix-Fayos, C. (2012). Erosion, deposition and replacement of soil organic carbon in Mediterranean catchments: A geomorphological, isotopic and landscape change approach. *Biogeosciences*, 9, 1099–1111.

Nenadovi, S., Klajievi, L., Nenadovi, M., Milanovi, M., & Markovi, S. (2013). Physico-chemical soil analysis of Rudovci region. *Geonauka*, 1 (2), 1–8.

Nenadovic, S., Nenadovic, M., Klajic, L., Pavlovic, V., Dordevic, A., & Matovic, B. (2010). Structure and composition of soils. *Processing and Application of Ceramics*, 4, 259–263.

Niu, X. Y., Yan-Hua, W., Hao, Y., Jia-Wen, Z., Jun, Z., Mei-Na, X., … Biao, X. (2015). Effect of land use on soil erosion and nutrients in Dianchi Lake Watershed, China. *Pedosphere*, 25, 103–111.

Ouyang, W., Hao, F., Skidmore, A. K., & Toxopeus, A. G. (2010). Soil erosion and sediment yield and their relationships with vegetation cover in upper stream of the Yellow River. *Science of The Total Environment*, 409, 396–403.

Paz-Ferreiro, J., Vidal, V. E., & Miranda, J. G. V. (2010). Assessing soil particle size distribution on experimental plot with similar texture under different management systems using multifractal parameters. *Geoderma*, 160, 47–56.

Pimentel, D., & Burgess, M. (2013). Soil erosion threatens food production. *Agriculture*, 3, 443–463.

Posthumus, H., Deeks, K. L., Rickson, R. J., & Quinton, J. N. (2015). Costs and benefits of erosion control measures in the UK. *Soil Use and Management*, 31, 16–33.

Rahman, M. R., Shi, Z. H., & Chongfa, C. (2009). Soil erosion hazard evaluation-an integrated use of remote sensing, GIS and statistical approaches with biophysical parameters towards management strategies. *Ecological Modelling*, 220, 1724–1734.

Renard, K. G., Yoder, D. C., Lightle, D. T., & Dabney, S. M. (2010). Universal soil loss equation and revised universal soil loss equation. *Handbook of Erosion Modelling*, 1, 137–167.

Rohmann, A., Heermance, R., Kapp, P., & Cai, F. (2013). Wind as the primary driver of erosion in the Qaidam Basin, China. *Earth and Planetary Science Letters*, 374, 1–10.

Shao, M., Tang, X., Zhang, Y., & Li, W. (2006). City clusters in China: Air and surface water pollution. *Frontiers in Ecology and the Environment*, 4, 353–361.

Shen, Z. Y., Gong, Y. W., Li, Y. H., Hong, Q., Xu, L., & Liu, R. M. (2009). A comparison of WEPP and SWAT for modeling soil erosion of the Zhangjiachong Watershed in the Three Gorges Reservoir Area. *Agricultural Water Management*, 96, 1435–1442.

Shepherd, K. D. (2010, August 24–27). *Soil spectral diagnostics – infrared, X-ray and laser diffraction spectroscopy for rapid soil characterization in the Africa Soil Information Service*. World Congress of Soil Science, Soil Solutions for a Changing World; Brisbane, Australia.

Shi, Z. H., Fang, N. F., Wu, F. Z., Wang, L., Yue, B. J., & Wu, G. L. (2012). Soil erosion processes and sediment sorting associated with transport mechanisms on steep slopes. *Journal of Hydrology*, 454–455, 123–130.

Shrestha, S., & Kazama, F. (2007). Assessment of surface water quality using multivariate statistical techniques. A case study of the Fuji river basin. *Environmental Modelling & Software*, 22, 464–475.

Sun, W., Shao, Q., Liu, J., & Zhai, J. (2014). Assessing the effects of land use and topography on soil erosion on the Loess Plateau in China. *Catena*, 121, 151–163.

Sutherland, R. A., & Ziegler, A. D. (2007). Effectiveness of coir-based rolled erosion control systems in reducing sediment transport from hillslopes. *Applied Geography*, 3–4, 150–164.

Terranova, O., Antronico, L., Coscarelli, R., & Iaquinta, P. (2009). Soil erosion risk scenarios in the Mediterranean environment using RUSLE and GIS: An application model for Calabria (southern Italy). *Geomorphology*, 112, 228–245.

Topalidis, V., Harris, A., Hardaway, C. J., Benipal, G., & Douvis, C. (2017). Investigation of selected metals in soil samples exposed to agricultural and automobile activities in Macedonia, Greece using inductively coupled plasma-optical emission spectrometry. *Microchemical Journal*, 130, 213–220.

Varol, M., & Sen, B. (2009). Assessment of surface water quality using multivariate statistical techniques: A case study of Behrimaz Stream, Turkey. *Environmental Monitoring and Assessment*, 159, 543–553.
Vrieling, A., Steven, M. D. J., Sterk, G., & Rodrigues, S. C. (2009). Timing of erosion and satellite data: A multi-resolution approach to soil erosion risk mapping. *International Journal of Applied Earth Observation and Geoinformation, 3*, 267–281.

Wang, K., Wang, H. J., Shi, X. Z., Weindorf, D. C., Yu, D. S., Liang, Y., & Shi, D. M. (2009). Landscape analysis of dynamic soil erosion in subtropical China: A case study in Xingguo County, Jiangxi Province. *Soil and Tillage Research, 105*, 313–321.

Wang, L. Q., & Yu, W. D. (2008). Water resources and water environment problems and countermeasures in the Zhangweinan river basin. *Haihe River Conservancy, 5*, 6–8 (in Chinese).

Wang, X., Zhao, X., Zhang, Z., Yi, L., Zuo, L., Wen, Q., … Liu, B. (2016). Assessment of soil erosion change and its relationships with land use/cover change in China from the end of the 1980s to 2010. *Catena, 137*, 256–268.

Wang, Y. Y., Zhang, R. B., Zhao, Y. W., & Sun, Y. (2010). Application of fuzzy mathematical method in lake water quality evaluation. *Jiangsu Agricultural Sciences, 1*, 326–328 (in Chinese).

Wilson, G. V., Cullum, R. F., & Römkins, M. J. M. (2008). Ephemeral gully erosion by preferential flow through a discontinuous soil-pipe. *Catena, 73*, 98–106.

Wu, J., & Xie, H. (2011). Research on characteristics of changes of lakes in Wuhan’s main urban area. *Procedia Engineering, 21*, 395–404.

Wu, Y., & Chen, J. (2012, November). Modeling of soil erosion and sediment transport in the East River basin in southern China. *Science of The Total Environment, 441*, 159–168.

Xu, H. S., Xu, Z. X., Wu, W., & Tang, F. F. (2012). Assessment and spatiotemporal variation analysis of water quality in the Zhangweinan River Basin, China. *Procedia Environmental Sciences, 13*, 1641–1652.

Yang, T., Liu, Q., Zeng, Q., & Chan, L. (2009). Environmental magnetic responses of urbanization processes: Evidence from lake sediments in East Lake, Wuhan, China. *Geophysical Journal International, 179*, 873–886.

Yoo, K., Fisher, B., Ji, J., Aufdenkampe, A., & Klaminder, J. (2015). The geochemical transformation of soils by agriculture and its dependence on soil erosion: An application of the geochemical mass balance approach. *Science of The Total Environment, 521–522*, 326–335.

Yu, W. D. (2008). Water pollution and control in Zhangweinan River Basin. *Water Resources Protection, 24*, 83–86 (in Chinese).

Zhai, K. (2010). Reservoir water quality assessment based on fuzzy evaluation method. *Journal of Hubei University for Nationalities, Natural Science Edition, 28*, 10–12.

Zhang, Q., Li, Z. W., Zeng, G. M., Li, J. B., Fang, Y., & Yuan, Q. S. (2009). Assessment of surface water quality using multivariate statistical techniques in red soil hilly region: A case study of Xiangjiang watershed, China. *Environmental Monitoring and Assessment, 152*, 123–131.

Zhang, Z., Wang, X., Zhao, X., Liu, B., Yi, L., Zuo, L., … Hu, S. (2014). A 2010 update of national land use/cover database of China at 1:100000 scale using medium spatial resolution satellite images. *Remote Sensing of Environment, 149*, 142–154.

Zhao, Q., Li, D., Zhuo, M., Guo, T., Liao, Y., & Xie, Z. (2014). Effects of rainfall intensity and slope gradient on erosion characteristics of the red soil slope. *Stochastic Environmental Research and Risk Assessment, 2*, 609–621.