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THEMATIC ISSUE

Water resource development and protection in loess areas of the world: a summary to the thematic issue of water in loess

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Abstract
Loess is mainly distributed in arid and semiarid areas of the world, and water is essential and precious in the loess areas. Water is also an important factor inducing various geohazards and soil erosion in the loess areas. The thematic issue of Environmental Earth Sciences was edited to reflect the latest research on water and water-related themes in the loess areas of the world, especially on the Chinese Loess Plateau. This editorial introduced the background and initiative of editing this thematic issue, and it also introduced briefly the water environment projects currently underway on the Chinese Loess Plateau such as the grain for green project, the huge land creation project, and the sponge city project. The papers included in the thematic issue were also introduced to give readers a general understanding of their main research points. Finally, some suggestions to boost further water environment research in the loess areas were put forward. All the papers included in the thematic issue will scientifically support the sustainable socio-economic development in the loess areas of the world.

Keywords Water quality · Water resources · Soil erosion · Grain for green · Sponge city · Land creation · Loess Plateau

Introduction

Widely distributed over the world, loess is a fine-grained aeolian sediment which is homogeneous, porous, friable, pale yellow or buff, slightly coherent, typically non-stratified, and often calcareous (Kovács and Varga 2013). It is mainly discovered in the mid-latitude arid and semiarid areas of the northern hemisphere such as in China, the USA, Russia, the Central Asian, and the Western European countries (Fig. 1), and in Argentina and New Zealand in the southern hemisphere (Isla et al. 2018; Li and Qian 2018a), accounting for 10% of the world land (Zárate 2017). Among these countries, China has the largest and thickest loess deposits in the world with loess covering more than 630,000 km^2 (Li and Qian 2018a; Zhu et al. 2018), while the Loess Plateau of China, with an area of 440,000 km^2, is the main loess distribution area in China and has the most typical loess distribution (Wei et al. 2017a). Loess records the history of environmental change and the evolution of the loess civilization. It is a valuable reference for scientists to judge the past history and predict future trends of environmental change.

The loess region in northern China has long been a key area for interaction between humans and nature. With continuing urbanization, industrialization, and energy exploitation, human activities are increasingly strengthened in the loess areas, increasing water demand and resulting in soil and water pollution (Li et al. 2018a, b; Li and Qian 2018b; Wu et al. 2017a). Two-thirds of the cities on the Chinese Loess Plateau are experiencing a water shortage. In addition, because of the intrinsic collapsibility of the loess, the loess areas have witnessed many geological disasters such as landslides and uneven land settlement (Peng et al. 2015, 2017), many of which are related to water content in the deposits. In addition to these water environment problems, there still are many major environmental challenges on the Chinese Loess Plateau during the construction of ecological civilization, a new stage of human civilization development after

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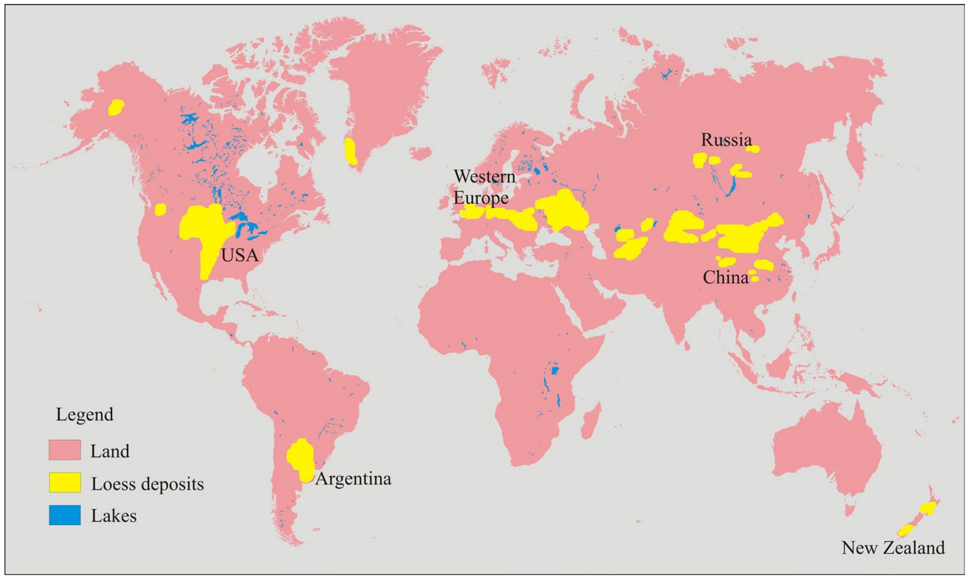

Fig. 1 World distribution of loess [Modified after Pye (1984) and Li and Qian (2018a)]

primitive civilization, agricultural civilization, and industrial civilization (Li and Qian 2018a; Xu and Wu 2016). Prominent constraints of the resource and environment on economic development, rapidly rising dependence on important resources such as coal and oil, decreasing arable land, ecological degradation, and frequent natural disasters affect the stability of society and human safety (Li et al. 2018c). Considering the severity of these problems in loess areas, it is imperative for scientists, managers, and policy makers to communicate to reconstruct the history of environmental change, assess the different contributions of natural and human factors to it, and judge the trends and drivers of the environmental change. These will be helpful to propose a sustainable development strategy for the loess areas, and to propose new ideas and effective methods for the construction of ecological civilization. As such, an International Loess Forum with the theme of environmental change and sustainable development in loess areas was held in Qingyang, China during 12–15 August 2016. This forum had over 400 attendees from China, the USA, Australia, and Canada among others. Many of the latest trends and interesting research results were shared and communicated in this forum, which were useful to secure sustainable socio-economic development and to boost further scientific research in loess areas.

Addressing water environment problems, however, is the first step in solving other problems in loess areas. Broadly speaking, the term water environment refers to not only the natural properties of the water itself, such as water quality and quantity, water temperature, and dynamics, but also includes the natural and social factors directly or indirectly affecting the natural properties of the water. These include aquifer properties, surface vegetation, socio-economic development, water resource management policies, and public attitude toward water utilization and protection (Li 2014). Therefore, solving water environment problems is not easy and is associated with many uncertainties, especially in arid and semiarid loess areas with diverse and uncertain human activities (Li 2016; Li et al. 2017a). Fortunately, scholars are working hard to seek effective solutions to these complex problems, and many achievements have been made (Borgnino et al. 2013; Cai et al. 2018; Gu et al. 2017; He et al. 2018; He and Wu 2018; Li et al. 2014a, b, c; Miao et al. 2016; Wu and Sun 2016; Wu et al. 2017b; Zhang et al. 2018; Zerboni et al. 2015; Zotsenko and Vinnikov 2016). This thematic issue was edited to showcase the latest water-related research in the loess areas of the world. This is expected to further advance the knowledge and improve the water situation in the loess areas.

Recent water environment projects on the Chinese Loess Plateau

Loess Plateau is situated in northwest China (Fig. 2), and is one of the areas with the most severe soil erosion problem in China. It is a typical region for the development of arid and semiarid agriculture and animal husbandry in China, and is also an important national energy base with abundant coal and oil resources, development of which has induced serious mine water problems (Li 2018). Most importantly, it is also the core area of the Belt and Road Initiative in China (Li et al. 2015, 2017b), which has attracted worldwide attention due to the developing economic and environmental connection of China with the world (Jiang 2009; Li and Qian 2018b). In general, the Chinese Loess Plateau includes three geomorphological types: mountains, loess hilly–gully regions (including loess tablelands), and large alluvial basins distributed between the mountains and the loess hilly–gully

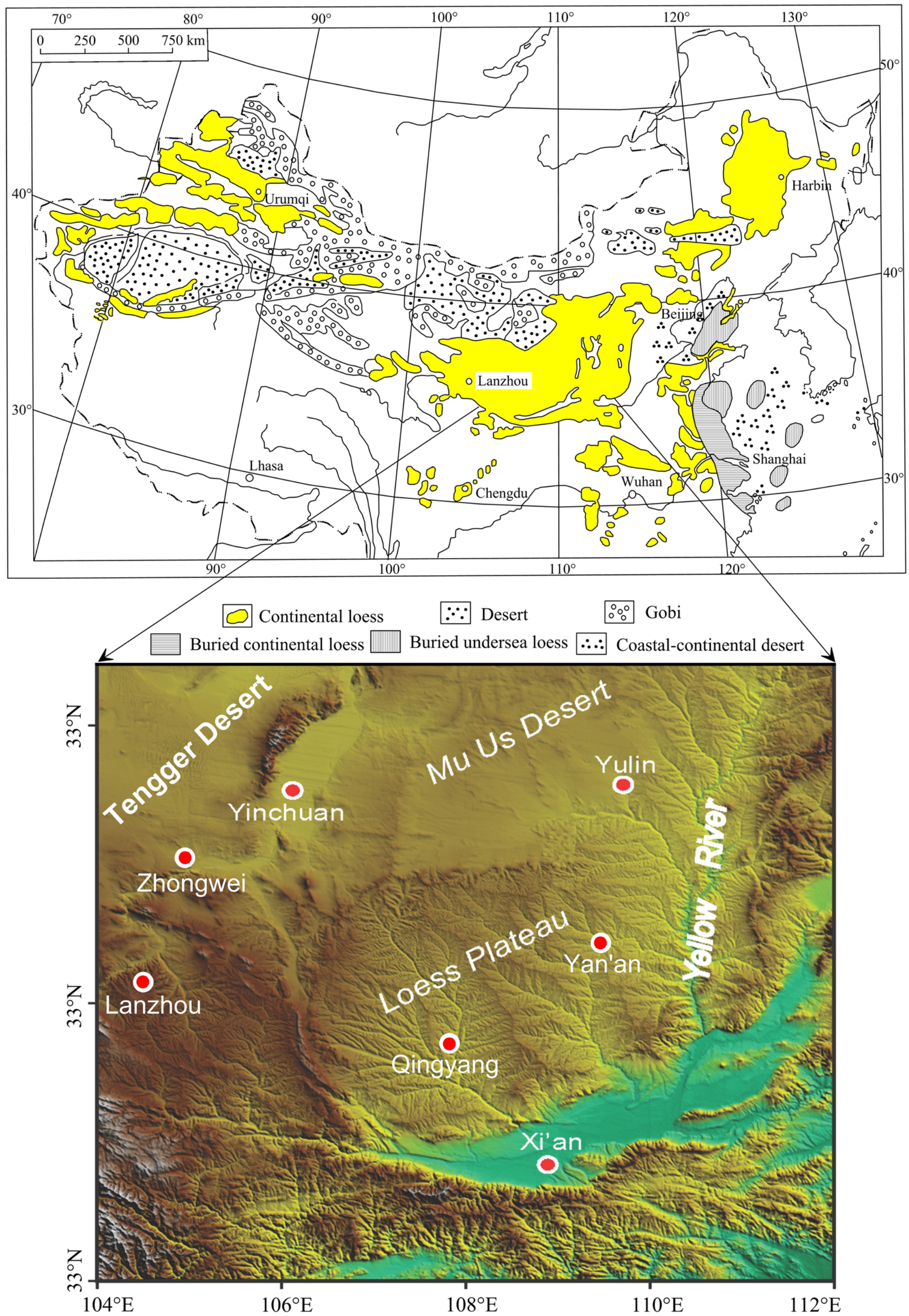

Fig. 2 Loess distribution in China and the major part of the Chinese Loess Plateau. Qingyang is the Chinese city where the International Loess Forum was held [modified after Li and Qian (2018a, b) and Li et al. (2018a)]

regions (Li et al. 2008). The basins where major cities are situated are densely populated and well developed; however, the loess tablelands and the hilly–gully regions are usually underdeveloped.

The advance of water environment research in the Chinese Loess Plateau is encouraging with much scientific achievement (for example, Chen et al. 2016; Currell et al. 2011; Guo et al. 2012; Li et al. 2016a, b, c; Wei et al. 2017a; Wu et al. 2015; Xiao et al. 2015). However, in recent years, China has implemented some big water environment projects on the Chinese Loess Plateau. Some of the projects benefit the sustainable development of the Loess Plateau, while others may produce potentially negative impacts on the local ecology and water resources. Below is the general information of these water environment projects.

Grain for green project

Grain for green project was implemented in 1999 to halt soil erosion and this project has achieved remarkable conversion of cropland to natural land cover on the Chinese Loess Plateau (Chen et al. 2015a, b). The aim of the project is to protect and improve the ecological environment in western China, especially on the Loess Plateau, by transforming sloping cropland, which easily causes soil erosion, to forest landscape in a step-by-step manner. This is the biggest reforestation program in the world (Chen et al. 2015a). After years of implementation of the project, the former barren hills have been covered with green clothes. A green ecological barrier with water and soil conservation as the main functions has been initially established, and the local ecological environment has been greatly improved. Maintaining the achievements is difficult, because such programs are not only a natural scientific issue, but also a social issue. Although the area of forests on the Loess Plateau has expanded year by year, forest resources in some areas are characterized with single-structure and low-level vegetation, and a complete ecosystem has not yet been formed. These projects may also affect the socio-economic livelihoods of peasants and the economic activities of the whole region (Xu et al. 2014). Some researchers believe that the nonstop increase of forestation may endanger the safety of farmland and may cause more harm than good to communities and the environment. In this case, vegetation should not be expanded further as planned (Chen et al. 2015a).

Huge geoengineering projects

As most parts of the Loess Plateau are typically covered by gullies and valleys, and the space for city development is limited, local governments and construction enterprises joined hands to carry out some land creation projects on the Loess Plateau, i.e., bulldoze the loess hill tops and fill in the gullies to create flat land for city construction. The most typical projects are carried out in Yan'an and Lanzhou, two famous cities on the Loess Plateau. Through the land creation project, the two cities can create hundreds of square kilometers of flat land. This is a controversial issue, however, and has been discussed and commented on by Li et al. (2014d). There is no doubt that land creation projects can produce hundreds of square kilometers of flat land available for city development. The huge geoengineering projects not only change landscapes significantly, but also ruin some grain for green achievements obtained during the past decades. Most importantly, the basement of the land is not stable due to the special soil properties, and it would be dangerous to build high buildings above the created land. Water is also a problem for these huge geoengineering projects. The fast expansion of cities will call for more water resources for citizens, which will increase the water crisis on the Loess Plateau. It would be troublesome if the cities on the Loess Plateau grow too big. More people means greater water demand, therefore, before solving the water crisis on the Loess Plateau, it would be wise to slow down the speed of city expansion in such a water stress area.

Sponge city project

Sponge city is a term used by Chinese, and internationally, it is more widely known as low impact development (Damodaram et al. 2010; Wang et al. 2018a). It is a new concept of city development to solve urban water problems, especially the urban storm water problem (Liu et al. 2017). The sponge city can realize the maximum resource utilization of rainwater resources by adopting permeable materials, changing the nature of urban underlying surfaces, and using advanced rainwater and sewage discharge technologies to treat rainwater and sewage (Shi and Yao 2017). During the past 5 years, over 30 pilot sponge cities have been developed and many of these projects are already fully operational (Wang et al. 2018a). Though most regions of the Loess Plateau are governed by arid and semiarid climate, rainwater in summer is sometimes concentrated, which causes waterlogging, water pollution, soil erosion, and even geohazards. Sponge city concepts provide a new way for city development on the Loess Plateau, however, challenges are great. Sponge city construction is expensive, and facilities should be constructed according to the specific conditions of the city to ease financial burden and avoid resource waste. Sponge cities can also be a potential source of contamination, as the rainwater stored for use may contain different kinds of contaminants. If not treated properly, further contamination to land and groundwater may arise.

Papers in this thematic issue

This thematic issue of Environmental Earth Sciences includes 23 papers (Table 1). These papers can be grouped into three themes: hydrology and water resources, water quality and water pollution, and loess properties and geohazards. All three themes are closely related to sustainable societal development and safety of local residents in loess areas and, thus, are important to study. Figure 3 illustrates the topical clusters of the papers published in the thematic issue and highlights the most used terms in the paper titles. The font size of the words represents the number of times that they appear in the paper titles (Kolditz et al. 2018). As shown in Fig. 3, the paper topics in this thematic issue dealt with "Loess, China, groundwater, plateau, loess area, quality, pollution, risk…", which indicates that China is the center for world loess research, while groundwater is the

Table 1 List of papers included in this thematic issue

No.	Authors	Article titles	Topics	DOI
1	Deng L, Wang W, Cai Y, Hu A, Sun D	A 70-year groundwater recharge record from sandy loess in northwestern China and its climatic implications	Hydrology and water resources	https://doi.org/10.1007/s12665-017-7155-y
2	Zhang X, Li P, Li ZB, Yu GQ	Soil water-salt dynamics state and associated sensitivity factors in an irrigation district of the loess area: a case study in the Luohui Canal Irrigation District, China	Hydrology and water resources	https://doi.org/10.1007/s12665-017-7066-y
3	Yang Y, Li Z, Li P, Ren Z, Gao H, Wang T, Xu G, Yu K, Shi P	Variations in runoff and sediment in watersheds in loess regions with different geomorphologies and their response to landscape patterns	Hydrology and water resources	https://doi.org/10.1007/s12665-017-6851-y
4	Liu Z, Li L, Wang L, Wang Q, Li Q	Hydrological situation of a typical watershed in the Loess Tableland Area of China over the past 30 years	Hydrology and water resources	https://doi.org/10.1007/s12665-017-6915-z
5	Fu C-F, Bian Z-H, Xi J-J, Zhao J-B	Spatial distribution characteristics of soil moisture in different types of sand dune in the Mu Us Sandy Land, adjacent to north of Chinese Loess Plateau	Hydrology and water resources	https://doi.org/10.1007/s12665-018-7307-8
6	Wen M, Cheng D, Song J, Zhang G, Lai W, Jiang W	Impacts of climate change on aridity index and its spatiotemporal variation in the Loess Plateau of China, from 1961 to 2014	Hydrology and water resources	https://doi.org/10.1007/s12665-018-7304-y
7	Wang W, Lv J, Xu D, Li L, Jia Y	Migration of induced-infiltration stream water into nearby aquifer due to a transverse horizontal well in loess areas	Hydrology and water resources	https://doi.org/10.1007/s12665-017-6904-2
8	Isla F, Quiroz Londoño OM, Cortizo L	Groundwater characteristics within loessic deposits: the coastal springs of Los Acantilados, Mar del Plata, Argentina	Hydrology and water resources	https://doi.org/10.1007/s12665-018-7766-y
9	Du S, Liu Y, Zhang L, Li H, Huan H	Assessment of non-carcinogenic health risks due to water contamination in a loess distribution area, northeastern China	Water quality and water pollution	https://doi.org/10.1007/s12665-017-7097-4
10	Su H, Kang W, Xu Y, Wang J	Evaluation of groundwater quality and health risks from contamination in the north edge of the Loess Plateau, Yulin City, Northwest China	Water quality and water pollution	https://doi.org/10.1007/s12665-017-6781-8
11	Zhang Y, Wu J, Xu B	Human health risk assessment of groundwater nitrogen pollution in Jinghui canal irrigation area of the loess region, Northwest China	Water quality and water pollution	https://doi.org/10.1007/s12665-018-7456-9
12	Zuo R, Chen X, Li X, Shan D, Yang J, Wang J, Teng Y	Distribution, genesis, and pollution risk of ammonium nitrogen in groundwater in an arid loess plain, northwestern China	Water quality and water pollution	https://doi.org/10.1007/s12665-017-6963-4
13	Wei Y-N, Fan W, Wang W, Deng L	Identification of nitrate pollution sources of groundwater and analysis of potential pollution paths in loess regions: a case study in Tongchuan region, China	Water quality and water pollution	https://doi.org/10.1007/s12665-017-6756-9

Table 1 (continued)

No.	Authors	Article titles	Topics	DOI
14	Wu J, Wang L, Wang S, Tian R, Xue C, Feng W, Li Y	Spatiotemporal variation of groundwater quality in an arid area experiencing long-term paper wastewater irrigation, Northwest China	Water quality and water pollution	https://doi.org/10.1007/s12665-017-6787-2
15	Wu J, Xue C, Tian R, Wang S	Lake water quality assessment: a case study of Shahu Lake in the semiarid loess area of Northwest China	Water quality and water pollution	https://doi.org/10.1007/s12665-017-6516-x
16	Li P, He Song, Yang N, Xiang G	Groundwater quality assessment for domestic and agricultural purposes in Yan'an City, Northwest China: implications to sustainable groundwater quality management on the Loess Plateau	Water quality and water pollution	https://doi.org/10.1007/s12665-018-7968-3
17	Li XA, Li L	Quantification of the pore structures of Malan loess and the effects on loess permeability and environmental significance, Shaanxi Province, China: an experimental study	Loess properties and geohazards	https://doi.org/10.1007/s12665-017-6855-7
18	Gao Y, Qian H, Li X, Chen J, Jia H	Effects of lime treatment on the hydraulic conductivity and microstructure of loess	Loess properties and geohazards	https://doi.org/10.1007/s12665-018-7715-9
19	Peng J, Tong X, Wang S, Ma P	Three dimensional geological structures and sliding factors and modes of loess landslides	Loess properties and geohazards	https://doi.org/10.1007/s12665-018-7863-y
20	Cheng S, Li Z, Xu G, Li P, Zhang T, Cheng Y	Temporal stability of soil water storage and its influencing factors on a forestland hillslope during the rainy season in China's Loess Plateau	Loess properties and geohazards	https://doi.org/10.1007/s12665-017-6850-z
21	Peng J, Huo A, Cheng Y, Dang J, Wei H, Wang X, Li C	Submersion simulation in a typical debris flow watershed of Jianzhuangchuan catchment, Loess Plateau	Loess properties and geohazards	https://doi.org/10.1007/s12665-017-6797-0
22	Qiao X, Li XA, Guo Y, Ma S	In-situ experimental research on water scouring of loess slopes	Loess properties and geohazards	https://doi.org/10.1007/s12665-018-7593-1
23	Li J, Li Z, Guo M, Li P, Cheng S, Yuan B	Effects of vegetation restoration on soil physical properties of abandoned farmland on the Loess Plateau, China	Loess properties and geohazards	https://doi.org/10.1007/s12665-018-7385-7

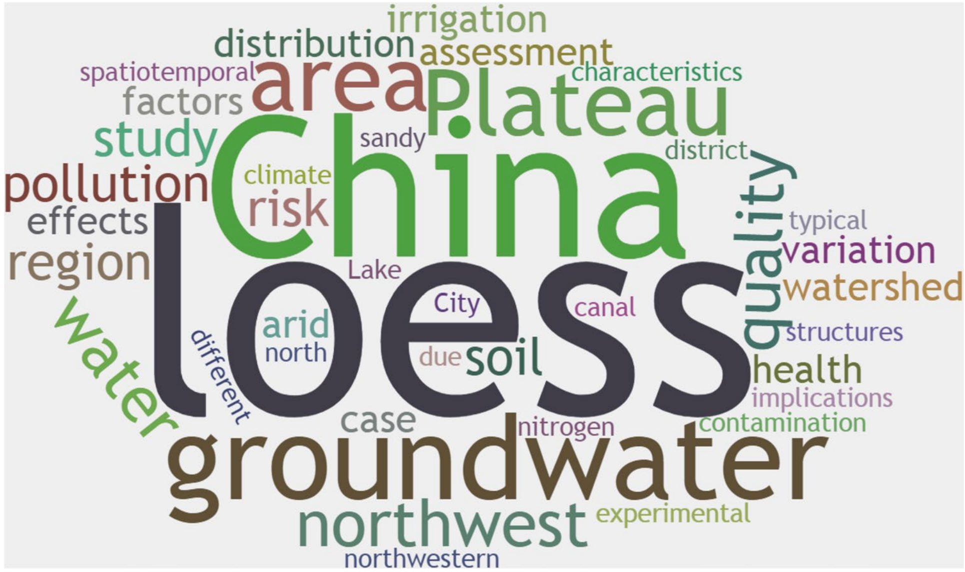

Fig. 3 Word Cloud based on the paper titles in this thematic issue, generated from http://timdream.org/wordcloud/

most valuable water resource in the loess areas, and water quality and water pollution issues are of wide concern. Among the 23 papers published in the thematic issue, eight papers belong to the hydrology and water resources theme, eight papers belong to the water quality and water pollution theme, and the other seven papers belong to the topic of loess properties and geohazards.

Water resources are valuable in loess areas, as loess is mainly distributed in arid and semiarid regions where precipitation is quite limited. In this thematic issue, eight papers investigated the water resources situation and hydrological occurrence and circulation of groundwater, surface water, and soil water. Impacted by climate change and human activities, hydrological occurrence and circulation of water resources in the loess areas have changed significantly. Deng et al. (paper 1 in Table 1) used the chloride mass balance of the unsaturated zone to estimate the groundwater recharge history and past climate changes in Northwestern Chinese Loess Plateau. This study provides a possible way of reconstructing groundwater recharge history in the loess region. Zhang et al. (paper 2 in Table 1) predicted the soil water–salt dynamics in a local loess irrigation district using a back-propagation artificial neural network and studied the associated sensitivity factors, while Yang et al. (paper 3 in Table 1) investigated the relationship between landscape and runoff and sediment in a loess watershed. Both studies demonstrate that water resource situations in the loess areas are affected by multiple factors and involve complex dynamic processes. As revealed by research performed by Liu et al. (paper 4 in Table 1) and Fu et al. (paper 5 in Table 1), land cover and geomorphology can play a predominant role in hydrological variation and spatial distribution of soil moisture in loess areas. Wen et al. (paper 6 in Table 1) studied the impacts of climate change on aridity and the spatiotemporal variation of drought on the Chinese Loess Plateau, which suggests that the boundary of arid regions is expanding due to climate change. Wang et al. (paper 7 in Table 1) reported on a method using a particle-tracking technique to evaluate the transport of river water flowing into a transverse horizontal well. The transverse horizontal well technique has been recently developed to get fresh water from underneath the river bed. This study is quite important for groundwater abstraction in the loess areas. Isla et al. (paper 8 in Table 1) reported on the groundwater characteristics (groundwater level, groundwater quality, groundwater age, and groundwater occurrence) in the coastal loess deposits of Argentina. This paper gives readers general insight into loess research outside China.

In addition to hydrological conditions and water resources quantity, water quality and water pollution are also very important issues in loess areas. Due to increased human activities, both surface water and groundwater in the loess areas have been locally contaminated in recent years (Li et al. 2018a; Zhang et al. 2018). In this thematic issue, Du et al. (paper 9 in Table 1), Su et al. (paper 10 in Table 1), and Zhang et al. (paper 11 in Table 1) reported research results on human health risk assessment due to groundwater contamination in different loess areas. Human health risk is defined as the probability of adverse health effects in humans who are exposed to contaminants through various exposure pathways in contaminated environmental media, now or in the future (Li and Qian 2011; Rajasekhar et al. 2018). In recent years, research in this field has expanded and has become a necessary part of water-quality assessment. Zuo et al. (paper 12 in Table 1) and Wei et al. (paper 13 in Table 1) investigated the distribution and sources of ammonium nitrogen and nitrate in two loess areas, respectively. Their research has indicated that nitrogen contamination of groundwater is predominated by human activities such as industrial effluent, sewage, or manure from livestock and fertilizer application in agriculture. In addition to these topic centered studies, Wu et al. (papers 14 and15 in Table 1) presented research results in their papers on groundwater quality impacted by wastewater irrigation and lake water quality impacted by tourism, respectively. These human activities are typical on the Chinese Loess Plateau and the results may provide researchers and local decision-makers with more understanding and insights into sustainable water resource management in loess areas. Interestingly, Li et al. (paper 16 in Table 1), in their paper, proposed some very useful groundwater-quality management measures based on comprehensive groundwater-quality assessment results. Measures such as enhancing rainwater harvesting, implementing water-quality improvement programing and water-quality monitoring, and encouraging further water-quality research are all quite specific and useful to improvement of groundwater-quality management in loess areas (Li et al. 2018a, d).

In addition to the issues of water scarcity and water pollution, geological hazards such as landslides and soil erosion are also quite common in the loess areas because of the loose and collapsible structure of loess and intensification of human activities (Gao et al. 2018; Peng et al. 2015, 2017; Qiao et al. 2018). In this thematic issue, Li and Li (paper 17 in Table 1) reported on research on pore structure of loess and its effects on loess permeability. Similarly, Gao et al. (paper 18 in Table 1) presented some experimental research results on the effects of lime treatment on the hydraulic conductivity and microstructure of loess. Both studies reveal some interesting research results on the relationship between micro-structures of loess and permeability, and are beneficial to further research on the flow of water and transport of contaminants in loess media. Peng et al. (paper 19 in Table 1), from the middle- to large-scale geological structures perspective, revealed the factors affecting loess landslides. It is no doubt that water is one of the most important factors affecting the stability of loess slopes. When water and geological structures, either natural or artificial, meet, loess landslides are triggered (Peng et al. 2015), which is also confirmed by the research carried out by Cheng et al. (paper 20 in Table 1) and Peng et al. (paper 21 in Table 1). Loess areas are also prone to soil erosion. Due to the loose structure of loess and sparse vegetation cover on the ground surface, the loess particles are easily transported by the water, inducing soil erosion. Soil erosion is responsible for the Yellow River to be yellow. Qiao et al. (paper 22 in Table 1) presented in situ water scouring experiment to determine the critical erosion slope gradient for loess slopes and the mechanisms and factors regulating soil erosion in loess areas, while Li et al. (paper 23 in Table 1) reported research results on the effects of vegetation restoration on soil physical properties. Land cover in loess areas is important to regulate erosion, which is the main reason for China implementing the Grain for Green program.

Further considerations for water environment research in loess areas

Fruitful progress has been achieved during past decades in water environment research in loess areas, especially on the Chinese Loess Plateau. However, with increasing human interference and continuing climate change, the situation of water resources is also changing rapidly in loess areas (Sun et al. 2018; Wang et al. 2018b; Wei et al. 2017b). Especially, the Chinese Loess Plateau is an essential part of the Belt and Road Initiative, and the sustainable development of the Loess Plateau is critical for achieving the sustainability of the Belt and Road Initiative (Li et al. 2015, 2017b). As such, more efforts should be made to guarantee the sustainable development in the fragile but promising loess areas. The following aspects may be considered.

Energy development in the loess areas

Environments in the loess areas are vulnerable, but the energy resources such as coal and oil are fruitful (Liu et al. 2016; Yang et al. 2004; Shi et al. 1995). Development of energy resources in the loess areas should be cautious, as unplanned energy development can cause serious environmental degradation and geological disasters, threatening the safety of local residents. For example, coal mine development in loess areas has caused acid mine drainage problems in New Zealand (Rufaut et al. 2015). The development of coal and oil on the Loess Plateau has induced environmental pollution and land-quality degradation (Shi et al. 1995). Therefore, energy development in loess areas should be implemented with a rational plan.

Sustainable water resource management in the loess areas

The loess areas are mostly water stressed areas, and thus, sustainable water resources development and management in these areas should be considered, fully acknowledging the fragile environment and the need for sound scientific research and reliable data (Li and Qian 2018b). Sustainable water resource management not only involves balancing the available water resources to satisfy users' demand, but also sustaining water quality and environmental diversity (Chen et al. 2018). Therefore, it requires collaboration from both natural scientists and social scientists. In addition, finding more sources of water to meet the increasing water demand is no longer the best solution to this problem. It would be more promising to balance the demand and the availability of water by lowering the limit of water requirement for daily use. However, setting the appropriate daily water requirement limit is not easy and the limit may differ according to the human race, human body conditions, and geographical locations.

Critical zone study

Critical zone is defined as the near-surface environment extending from the top of the vegetation canopy down to the bottom of the aquifer (Lin 2010). It is the interface linking the lithosphere, the hydrosphere, the atmosphere, and the biosphere (Montanarella and Panagos 2015). The loess contains information of past climate and is quite useful for the critical zone study. Especially, the Chinese Loess Plateau contains great thick loess deposits, and the loess profiles are useful for understanding the past climate change. In addition, the trees, soil, water microorganism living in the soil and water, as well as diverse human activities on the Loess Plateau make it a perfect place for critical zone observation. As such, the critical zone observation program should be conducted and promoted on the Loess Plateau.

Data sharing and citizen science

Data sharing problems in China have been criticized several times by researchers (Chen et al. 2018; Li et al. 2017a, 2018b; Li 2016), although this is actually a universal problem. As pointed by Li et al. (2018b) data sharing can raise the efficiency of scientific research and policy making. Without efficient and effective data sharing, scientific research will become more difficult. In addition, international collaboration and data sharing should be enhanced in addition to data sharing within local institutes. International data sharing would make the entire world better. Citizen science, a term defined as the practice engaging the public in a scientific project, is an essential supplement to professional science and is a powerful tool benefiting conservation science, natural resource management and environmental protection (McKinley et al. 2017). Involvement of the public in scientific research can fill data gaps when monitoring is insufficient (Li 2018). Water research in loess areas may require a large amount of data monitoring, and the number of professional researchers may be small and inadequate for the research. Therefore, citizen science should be encouraged in water research in loess areas.

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Compliance with ethical standards

Conflict of interest No potential conflict of interest was reported by the authors.

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