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Editorial

Sustainable Use of Soils and Water: The Role of Environmental Land Use Conflicts

Fernando A. L. Pacheco

CQVR – Chemistry Research Centre, University of Trás-os-Montes and Alto Douro, Quinta de Prados Ap. 1013, Vila Real 5001-801, Portugal; fpacheco@utad.pt

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Abstract: Sustainability is a utopia of societies, that could be achieved by a harmonious balance between socio-economic development and environmental protection, including the sustainable exploitation of natural resources. The present Special Issue addresses a multiplicity of realities that confirm a deviation from this utopia in the real world, as well as the concerns of researchers. These scholars point to measures that could help lead the damaged environment to a better status. The studies were focused on sustainable use of soils and water, as well as on land use or occupation changes that can negatively affect the quality of those resources. Some other studies attempt to assess (un)sustainability in specific regions through holistic approaches, like the land carrying capacity, the green gross domestic product or the eco-security models. Overall, the special issue provides a panoramic view of competing interests for land and the consequences for the environment derived therefrom.

Keywords: water resources; soil; land use change; conflicts; environmental degradation; sustainability

Competition for land is a worldwide problem affecting developed as well as developing countries, because the economic growth of activity sectors often requires the expansion of occupied land, sometimes to places that overlap different sectors. Besides the social tension and conflicts eventually caused by the competing interests for land, the environmental problems they can trigger and sustain cannot be overlooked. In rural catchments, where land uses and occupations are dominated by agriculture, livestock production and forests, a specific conflict is frequently observed, called "environmental land use conflict". This is known to be the deviation between actual land uses and natural land uses set up on the basis of land capability, and has been amply studied for the severe environmental consequences that these conflicts are responsible for. An immediate consequence is amplified soil erosion, which has been documented in catchments with craggy topography that, in spite of being prone to erosion, are being occupied by vineyards because of their favorable geology (metassediments) and sun exposure [1,2]. This amplification of soil erosion could be related to precedent organic matter declines also caused by the conflicts [3], and to a succeeding cascade of other environmental impacts including the amplification of surface and groundwater quality deterioration [4,5], biodiversity declines [6], and extreme events such as floods [7]. Overall, environmental land use conflicts have been claimed to be a major cause of land degradation [8], and have even become a concern for judicial organizations [9].

The role of land competition for specific uses, as well as the environmental consequences of land use changes and conflicts, can, however, be analyzed from other standpoints, besides the aforementioned environmental land use conflicts. The diversity of those perspectives was, in fact, the purpose of this Special Issue "Sustainable Use of Soils and Water: The Role of Environmental Land Use Conflicts". In this context, the Special Issue tackled the problem of the sustainable use of water resources coupled with the strategies of land planning that can ensure recharge and suitable

groundwater resources for multiple uses (drinking water supply, irrigation); water footprints for agriculture and livestock products; land uses, their changes, and the associated consequences for catchment hydrology, as well as for soil and water quality, not ruling out the roles of management practices, climate change and natural hazards; and, finally, balances between resources, the environment and the socio-economic development, based on the concepts of land carrying capacity, green gross domestic product, eco-security, and the overlapping of geosystems. During our working period, we received many submissions, which had significant contributions for the main topics of interest of our special issue. However, only 17 high-quality papers were accepted after several rounds of strict and rigorous review. These 17 contributions are summarized in the forthcoming paragraphs, being integrated in a coherent narrative.

The conjunctive use of surface and groundwater is among the recent strategies to ensure sustainable and secure water supply systems of drinking water. Conjunctive water use may be the way to mitigate overexploitation of groundwater resources, especially in areas where headwater forested catchments surround the urban areas, and therefore can be efficiently used to collect, store and deliver good quality surface water to the population. In Contribution 1, Hugo Henrique Cardoso de Salis, Adriana Monteiro da Costa, Annika Künne, Luís Filipe Sanches Fernandes and Fernando António Leal Pacheco have studied the case of Sete Lagoas town (state of Minas Gerais, Brazil) with ca. 220,000 inhabitants in 2008, which exploits 15.5 hm^3 $year^{-1}$ of karst groundwater for public drinking water supply, while the renewable resources estimated within the enclosing Jequitiba watershed with an area of 571.5 km^2 are solely 6.3 hm^3 $year^{-1}$. This large difference between annual abstraction and aquifer recharge have caused impressive water table declines and sinkhole development in recent decades in Sete Lagoas. Contribution 1 proposed the storage of quality water in a small dam lake in the Marinheiro catchment, a forested tributary of the Jequitiba basin located near the town. According to the authors, this lake would supply the municipality with a sustainable 4.73 hm^3 $year^{-1}$ of quality surface water, and thus would help to slow down the depletion of groundwater resources in the karst aquifer.

The efficacy of conjunctive water use can be enhanced if the watersheds selected to store the surface water are located where aquifer recharge is favorable. In this case, besides the positive effect of reducing the groundwater abstractions, conjunctive water use would also contribute to increasing the renewable resources through the induced recharge of dam lake water. This was the purpose of Contribution 2, written by Adriana Monteiro da Costa, Hugo Henrique Cardoso de Salis, João Hebert Moreira Viana and Fernando António Leal Pacheco. In that study, a physically based, spatially distributed method was used to evaluate groundwater recharge potential at the aforementioned Jequitiba River basin. The regions where recharge was classified as more favorable comprised flat areas, porous aquifers and forested regions, including the Marinheiro catchment.

The use of induced recharge as tool for water resource management is not limited to drinking water supply. For example, in arid regions an important focus of induced recharge is irrigation, given the prospective shortage of groundwater resources for this activity in these regions. Another important issue concerning the management of aquifer recharge relates to the engagement of academic, governmental and catchment-level institutions in the problem, because the academics are capable of studying the aquifer systems, including their resource availability, while the governments and water resource planners are empowered to regulate the construction and operation of dams even when they are small. The study of Lydia Kwoyiga and Catalin Stefan (Contribution 3) was developed in Northern Ghana and assessed the institutional feasibility of managed aquifer recharge methods in the Atankwidi catchment, where dry-season farmers may lose their source of livelihood due to limited access to groundwater. The results indicated a favorable political and administrative environment for the implementation of managed aquifer recharge. However, some essential backgrounds were lacking, making it difficult to execute or accelerate the desired task: firstly, quantitative information on groundwater demand for irrigation; secondly, scientific studies on the spatio-temporal distribution of groundwater flow depths, which are essential to assess the aquifer's storage capacity.

The value of detailed descriptions about groundwater flow depths for efficient groundwater resources management, either focused on drinking water supply or the irrigation of cropland, has been recognized by the authors of Contribution 4 and Contribution 5. In the first case, Dianlong Wang, Guanghui Zhang, Huimin Feng, Jinzhe Wang and Yanliang Tian developed a method to study temporal scale effects on groundwater levels and tested it in the Hufu Plain (China), namely in the city of Shijiazhuang, which is the capital of Hebei province. In this area, the population is larger than 17 million. To ensure the people's living, industry and irrigation, huge abstractions of groundwater take place from a water table aquifer for a long period of time. In the period 1960–2010, these abstractions led to the development of a constantly enlarging cone of depression, covering an area of approximately 20 km^2 in 1960 and ≈500 km^2 in 2010. At the center of this cone, the groundwater level varied from nearly 10 to 50 meters in the same timeframe. In spite of being progressive, the depression cone expansion was not regular overtime. Using their method, the aforementioned authors could distinguish five groundwater depth stages representing an equal number of exploitation stages: natural flow field, mild overexploitation, depression cone formation, serious overexploitation, and exploitation reduction. More important than the retrospective analysis, the set-up of a relationship between groundwater depth stages and exploitation stages provided essential knowledge for an eventual long-term monitoring program aiming at the recovery of groundwater levels in the region. In the second case, Ruiyan Wang, Simon Huston, Yuhuan Li, Huiping Ma, Yang Peng and Lihua Ding investigated the spatio-temporal stability of groundwater depth in the Yellow River Delta (North China Plain), with a specific concern for irrigation practices. The results of their research revealed that groundwater depth is highly nonlinear because irrigation, as well as surface water, topography, seawater intrusion and drainage, are heterogeneously distributed in the Delta. The outcomes also showed that a detailed assessment of groundwater depth fields and their stability patterns over time, would help control soil salinization, and hence be used to sustainably exploit the Delta's agricultural potential without saline intrusion.

The concerns about available freshwater for agriculture were extended in this special issue to the assessment of water footprints for agriculture and livestock products. The study by Ik Kim and Kyung-shin Kim conducted in the Republic of Korea (Contribution 6) quantified the water footprints of crops, open field vegetables, and vegetables in facility and fruits, as well as of beef, pork and chicken meat, in 2014. The estimates were presented on the cultivated area (hectare) and production (ton) bases and differed considerably among the products. For the per hectare case, the vegetables in facility contributed the most to the footprint and the open field vegetables contributed the least, representing water consumptions larger than 30,000 m^3/ha in the cases of cherry tomato or pepper, for example, and smaller than 5000 m^3/ha regardless of the type of vegetable produced in the open field. As regards the per ton case, the larger water footprints were estimated for the grapes and strawberries, which represented consumptions larger than 6000 m^3/ton in both cases. Among the livestock products, beef was the most stressful product with a consumption close to 20,000 m^3/ton, whereas chicken meat was the least demanding good with a consumption of <5000 m^3/ton. Overall, the footprint of total agricultural and livestock products in 2014 was approximately 27.9% of the total domestic water resources consumed in Korea.

The sustainable use of freshwater bears on the conservation of quality, besides all the issues related to quantity brought into the discussion so far. In the present special issue, one study was concerned with water quality and the nexus agriculture plus livestock activities > surface and groundwater pollution > compliance with the Nitrates Directive. The study was co-authored by Ewa Szalińska, Paulina Orlińska-Woźniak and Paweł Wilk (Contribution 7), and corresponded to a modeling exercise taking place in the Słupia River Basin (Poland) between 2002 and 2016. This European country is a main contributor to the excessive nutrient loads into the Baltic sea catchment, because it occupies a large portion of this catchment (ca. 18%) with a very large share in agricultural land area (ca. 50%). To reverse the situation, new rules are being proposed by the Polish authorities whereby the periods for which the application of nitrogen fertilizers is allowed are redefined (restricted). The modeling results make evident the decline in total nitrate released from farmlands within the Slupia basin, when

a 20 day reduction is imposed on the fertilization period, maintaining the current application doses. On average, the reductions were 762 kg/month during the summer season, 7171 kg/month during the winter season, and 3966 kg/month for the entire period. Despite the promising results, the co-authors highlighted the financial and organizational costs resulting from the proposed action program, which are likely to meet discontentment from farmers.

Before being leached to surface water via runoff or to groundwater through infiltration, contaminants loaded by natural processes and/or anthropogenic activities stay in the soil compartment. Therefore, a full analysis of contamination, involving land use, soil and water, requires an understanding of soil contamination. In the present special issue, the examination of soil contamination covered the important theme of metal contamination (Contribution 8). The co-authors, Shixin Ren, Erling Li, Qingqing Deng, Haishan He and Sijie Li, while working in Lankao County (China), showed that heavy metal contents in arable soil (Cr, Ni, Cu, Zn, Cd, and Pb) depend on the planting mode, generally decreasing from vegetable greenhouse to garlic land and then to traditional crop farmland. Moreover, these metal concentrations were classified as "slight pollution" in ≈5% and "moderate pollution" in ≈1% of the studied soil samples. The areas where these samples were collected would benefit from mitigation measures, namely land circulation and the aggregation of smaller patches into larger ones, as proposed by the co-authors.

The sustainability of soil and water resources is inherently connected to the natural use of land, which means use that respects land capability, under predefined climatic conditions. Numerous studies have reported the negative impacts of land use and cover changes on the hydrology of catchments that inevitably alter the fertility of soils through amplified erosion, as well as the availability and quality of surface and groundwater through contaminant transport and infiltration. To document land use and cover changes, and the consequent hydrologic response, Contribution 9, co-authored by Xin Jin, Yanxiang Jin and Xufeng Mao, presented the case of Heihe River Basin located in Northwest China's arid region. The authors used a modified version of SWAT model capable of updating land use and occupation during the tested period (1990–2009), according to the historical evolution portrayed in the available maps. The results indicated the spreading of farmland, forest, and urban areas, while grassland and bare land areas showed decreasing trends. It was also made clear that key land use changes in the studied area were from grassland to farmland and from bare land to forest. The hydrologic response could be characterized by decreasing trends in surface runoff, groundwater runoff, and total water yield, while lateral flow and ET volume showed increasing trends under dry, wet, and normal conditions.

Another publication from this special issue (Contribution 10) studied the role of land use changes under climate change, based on land use, runoff and climatic data from the 1995–2015 period. This study was co-authored by Qun Liu, Zhaoping Yang, Cuirong Wang and Fang Han, and was developed in the Xinjiang region located in the Northwest of China. This is an arid region, where the water sources comprise river, lake and underground water provided by the melting of glaciers and snow. During the studied period and before, runoff significantly increased in response to the regional warming that accelerated this process. In the sequel, the cropland expanded rapidly. However, with the glacier's storage decreasing, the glaciers and snow melt water will also decrease, with inevitable consequences for runoff, that will drop proportionally. In some catchments within the studied area (Kai-Kong River Basin), the runoff has been decreasing in recent decades, while the cropland area is still large. This is placing a large pressure on groundwater for irrigation, with negative consequences for water levels (lowering), as already noted in other contributions.

The negative consequences of land use changes for soil were also addressed in this special issue in two studies. A first-order concern refers to the competing interests for land, which in some countries, such as Slovakia, resulted in preoccupying withdrawals of agricultural land, which means the conversion of these areas for non-agricultural purposes. The case of Slovakia was the focus of Contribution 11, co-authored by Lucia Palšová, Katarína Melichová and Ina Melišková. In this country, when the demand for investment activities and the convergence to the EU standards of living occurred

(after 2004), many landowners who were receiving an agricultural land fund from the government abdicated from this income, but received a larger profit when they released (sold) their lands for other uses, such as residential. The most notable extreme in the amount of withdrawn agricultural land happened in 2008, which was the last year when the contributions for withdrawal were not levied on those that withdrew agricultural land from the top four quality categories. Besides the withdrawals for housing, conversions were also important for industry, transport and mining development purposes, especially in the western part of Slovakia. In keeping with the authors' opinion, the state should adopt a long-term conceptual document where the areas for agricultural land use are defined, taking into account the impact of developmental factors on land protection.

A second-order concern about the impact of land use changes on soil refers to inappropriate agricultural practices that are causing soil degradation worldwide. The study of Sameh Kotb Abd-Elmabod, Noura Bakr, Miriam Muñoz-Rojas, Paulo Pereira, Zhenhua Zhang, Artemi Cerdà, Antonio Jordán, Hani Mansour, Diego De la Rosa and Laurence Jones (Contribution 12), allowed the mapping of soil suitability classes in the El-Fayoum depression (Egypt) for a diversity of Mediterranean crops (wheat, corn, melon, potato, soybean, cotton, sunflower sugar beat, alfafa, peach, citrus fruits and olive). The maps were drawn for the current situation of soil factors and projected this for a scenario of improved manageable soil factors such as salinity, sodium saturation and drainage, using the Almagra model. The results were clear about the current situation of soil factors, for which the dominant soil suitability classes were the moderate and marginal classes. On the other hand, the highly suitable class was dominant under the projected scenario of improved manageable soil factors. Moreover, under this later scenario, the suitability for all crops improved except for the perennial crops, but one should recall that the most limiting factors for these crops are soil texture, depth, soil profile development and carbonate content, which are inflexible to modification. Overall, the maps of soil suitability classes published in this study are unequivocally valuable to decision makers for appropriate land-use planning and sustainable development in the El-Fayoum depression.

In some regions, land use changes related to anthropogenic pressures such as population or industrial growth are not the main driving force of a changing landscape. Instead, the observed changes are mostly the result of natural factors. This is particularly evident in regions that are prone to natural hazards such debris flows, landslides or earthquakes. In these areas, land use changes frequently occur where the consequences of a disaster were the most severe and/or extensive, involving the destruction of houses, roads and fields used for agriculture or livestock production. In general, the option in these cases is to move the uses or occupations in the affected areas to other places. A comprehensive study addressing this particular type of land use change has been published in the present special issue as Contribution 13. The study described land use changes and their driving forces in a debris flow active area of Wudu District, Gansu Province, China, and has been co-authored by Songtang He, Daojie Wang, Yong Li and Peng Zhao. This region is characterized by heavy torrential rains, loose entisols and moderate magnitude earthquakes, and as it is periodically affected by debris flow hazards, land use changes have occurred in the sequence of these natural events. The case of Houba village is given as an example. This village has been affected by five large-scale mudslides in the period 1956–2005, which destroyed private residences and various acres of farmland, burying livestock and damaging a stretch of a state highway. For security reasons, these lands were developed into woodland.

The last four papers published in the present Special Issue present panoramic views of many topics discussed thus far. These papers describe balances between resources, the environment and the socio-economic development, based on various concepts. For example, Contribution 14 discusses the concept of land carrying capacity, which can be defined as the number of people with a certain level of activity that can be sustained in a region without causing resource depletion or environment degradation. In their study, the co-authors Guangming Cui, Xuliang Zhang, Zhaohui Zhang, Yinghui Cao and Xiujun Liu used an index composed of cost-benefit indicators related to water and soil resources, eco-environment, society, economy and technology, to measure the land carrying capacity of eastern China, namely of seven cities from the Shandong Peninsula Blue Economic Zone, between

2007–2014. The results uncovered declines in carrying capacities for water and soil resources in most cities within the studied area, and increases in the eco-environment and social resources, as well as for in economy and technology of all cities. To revert the declines and improve the overall index, the authors proposed several mitigation measures, such as decreasing the proportion of added value of the primary industry to total Gross Domestic Product, promoting energy saving and emission reductions.

In Contribution 15, the co-authors Yuhan Yu, Mengmeng Yu, Lu Lin, Jiaxin Chen, Dongjie Li, Wenting Zhang and Kai Cao were interested in the Green Gross Domestic Product (GGDP), which reproduces the trade-off between ecosystem and economic systems. In their study, they were able to calculate and map the GGDP for China in the 1990–2015 period, based on historical data about Ecosystem Services Values (ESV) and Gross Domestic Product (GDP). They were also able to predict the evolution of ESV, GDP and GGDP until 2050 based on land use/land cover changes simulated by a Cellular Automata (CA) Markov model. The results indicated huge increases in GGDP (78%) from 1990 to 2015, which were also forecasted for the 2020–2050 period. However, the spatial patterns point to huge rises in the GGDP solely in the eastern territory, while the western part remained relatively unchanged in this regard. Moreover, in the regions where the GGDP was larger, the contribution of GDP to GGDP was substantial ($\approx$ 90%), while, in the other regions, this contribution was $<$ 45%. Therefore, in the latter case, the green GDP is dependent on the preservation of the ESV to a large extent, while in the former case the regions sustain the green GDP with socio-economic development, eventually depressing the importance of preserving the ESV. The huge spatial differences detected for the green GDP, GDP and ESV among the regions, are likely to become the cause of social problems, both now and in the future. The co-authors finally advise decision makers to determine the hotspot regions where the problems may become more severe and make policies accordingly to preserve GDP or ESV.

The co-authors of Contribution 16 assessed the balance between societal development and the preservation of environmental values through the eco-security concept, which has been defined by the Insurance Accounting and Systems Association in 1989 as the "ecologically sustainable development that meets the environmental and ecological needs of the present generation without compromising the ability of future generations to meet their own environmental and ecological needs". In their study, Qiuyan Liu, Mingwu Wang, Xiao Wang, Fengqiang Shen and Juliang Jin developed a novel, multi-dimensional connection cloud model to determine land eco-security, and tested the method in the Wanjiang region, Anhui Province, eastern China. This region experienced extensive economic growth in the past 50 years, namely through the introduction of chemical plants, cast iron and forging plants, and building materials plants. This has caused a significant increase in population density and unbalanced the land eco-security in the region, because the cultivated area and forest coverage declined concurrently. The modeling results show that land eco-security in the studied area behaves unfavorably because the marginally unsafe and unsafe levels are dominant. The results are explained by the excessive use of chemical fertilizers and pesticides, excessive industrial gas and solid wastes, and ineffective cleaning, which contribute substantially to the negative impact of economic and social industry development on land eco-security. The co-authors indicated some measures for improving land eco-security through environmental protection, reasonable employment of resources, proper adjustment of industrial structure, and possible abatement of pollution.

The last published article, Contribution 17, co-authored by Zita Izakovičová, László Miklós and Viktória Miklósová, used an integrated analysis of three geosystems to identify competing interests for land among local activity sectors in the Trnava district, Slovakia, as well as the environmental problems derived therefrom. The geosystems comprise the space and the natural resources potentially used by the sectors (called primary landscape structure), the current use of these resources (secondary landscape structure), and the regulations and legal provisions for use of these resources (tertiary landscape structure). The intersections among the geosystems expose potential environmental problems that include endangering the ecological stability of the landscape, the natural resources and the immediate human environment. The identified competing interests and associated environmental problems could be summarized as follows: (*a*) the sectors "fight" for land to broaden their own territory. It is not

uncommon to observe the use of high quality soils for non-agricultural purposes, such as industry, transport and residential areas, because developers find ways to change existing territorial plans and gain land even at the cost of compensation for the occupied land; (*b*) the sectors of forestry, agriculture, water management, nature conservation and recreation utilize large areas where their activities overlap, and sometimes are at conflict. This is the case where high quality soils overlap water protective zones, because the use of agrichemicals to increase productivity potentially endangers and pollutes the water resources; (*c*) there are "internal" conflicts within the sectors, exemplified by the competing occupation of shallow soils or steep slopes, with agriculture ignoring the severe consequences for erosion; (*d*) air and water pollution, with a specific concern about the presence of Jaslovské Bohunice nuclear power plant. Overall, the integrated analysis proved efficient to identify and map the areas of competing and conflicting interests, as well as the most preoccupying environmental problems. To increase efficiency, it would be necessary to bring the results from this study into official land use management plans.

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