Reviewing Soil Erosion in Greece

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***Abstract*—**Mitigating soil erosion, especially in Mediterranean countries such as Greece, is essential in order to maintain environmental and agricultural sustainability. In this paper, scientific publications related to soil erosion studies in Greece were reviewed and categorized. To accomplish this, the online search engine of Scopus was used. The key words were "soil", "erosion" and "Greece." An analysis of the published articles was conducted at three levels: i) type of publication, ii) chronologic and iii) thematic. A hundred and ten publications published in scientific journals were reviewed. The results showed that the awareness regarding the soil erosion in Greece has increased only in the last decades. The publications covered a wide range of thematic categories such as the type of studied areas, the physical phenomena that trigger and influence the soil erosion, the negative anthropogenic impacts on them, the assessment tools that were used in order to examine the threat and the proper management. The analysis of these articles was significant and necessary in order to find the scientific gaps of soil erosion studies in Greece and help enhance the sustainability of soil management in the future.

***Keywords*—**Climate change, agricultural sustainability, environmental sustainability, soil management.

I. Introduction

Soil erosion is a natural geomorphologic phenomenon that describes the removal and transportation of the soil particles by forces such as water and wind [79]. Erosional anthropogenic induced factors primary include human activities and interventions to the physical environment (land-use coverage, roads, dams, urban settings, etc.) that typically exacerbated the natural erosional factors and can increase soil erosion exponentially [79].

These anthropogenic activities and interventions have led to soil erosion being one of the most serious environmental problems worldwide. This exacerbated soil erosion can be observed through historical time scales by monitoring changes in geomorphologic characteristics [19], [92]. In Europe, the most susceptible areas to land degradation and desertification appear to be found in the Mediterranean region [19]. The semi-arid Mediterranean region is an area extremely prone to erosion due to its climate, frequent wildfires and the fact the region has been inhabited by humans for thousands of years [91], [99], [105].

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Global warming is also expected to substantially impact soil erosion. It will impact erosion in a number of different processes necessary to accommodate a new climatic regime such as rainfall amounts and intensities, number of days of precipitation, ratio of rain to snow, plant biomass production, plant residue decomposition rates, soil microbial activity, evapotranspiration rates and shifts in land use [83]. These many changes in all these processes make it difficult to predict the exact impacts of climate change on soil erosion although erosion and runoff is expected to increase at an even greater rate compared to rainfall intensity that has been forecasted [44].

This clearly indicates the need to understand the future conditions regarding soil erosion in the region. Numerous methodologies have been used to assess the threat of erosion and official frameworks for soil monitoring have established for most European countries [80] although there is not yet a European Union common policy to assess the erosion risk except some steps of proposals that are still under discussion [29], [30].

In Greece, minimal systematic and holistic efforts have been done to reduce this significant environmental problem but an important step was the compilation of a soil erosion risk map [80]. Also, due to technological evolution new soil erosion assessment tools and modeling methodologies have developed [50]. Finally, during the last decades, there was an exponential increase of the publication related to the soil erosion because it is a special risk issue that has a direct relationship with humans [25].

The first objective of the paper was to conduct a representative review of scientific publications that have studied soil erosion in Greece. Afterwards, a systematic analysis of the publications was conducted chronologically and thematically. The analysis was important in order to identify the scientific gaps regarding the study of soil erosion risk in Greece.

II. Literature Review and Analysis

The electronic database of Scopus was used in order to locate scientific publications that concern soil erosion. The keywords "soil", "erosion" and "Greece" were inputted in the search engine of Scopus. The initial results of the search were 186 scientific papers. After reviewing, a lot of publications were not added because neither applied on the Greek region nor concerned the soil erosion. The final selection included 110 papers that have been published in scientific journals. There are probably more publications in other search engines and especially in the Greek language (e.g. proceedings, thesis and books). Also, publications such as hardcopies were not included in this literature review because they are not readily available as are publications in electronic form. The analysis of the publications was done at two levels. The first level described the chronological display while the second was the thematic.

III. Results and Discussion

A. Chronicle of Publications

There were only six publications in the eighties. In the nineties the publications were tripled compared to the eighties (21 articles). After the year 2000 the scientific publications continuing to increase their number and were more than a double (51 articles) compared to the nineties. For the period 2010 to February 2015 there were 32 publications, but considering that this period includes only four years and two months of 2015, it seems that the publications will continue to increase in number. The greatest number of publications can be found in two years: both years 2006 and 2010 had 9 publications. Overall these findings indicate that the interest and awareness on the importance of soil erosion in the scientific community of Greece has increased.

B. Thematic Categorization

After reviewing all the publications, 28 general subject matters were identified. Based on these subject matters, the publications of the review were further grouped into five broad thematic categories. The five thematic categories were the following: a) type of studied land, b) physical phenomena, c) anthropogenic impacts, d) assessment tools and e) management, with each category having three to seven subject matters. It must be noted that most publications covered multiple subject matters and more than one category.

A. The type of land: The category refers to the geographic form and usage of the studied areas. 61 publications were counted and divided in seven subjects: i) basins/ catchments, ii) rivers/streams, iii) lakes/wetlands/ponds, iv) coastal areas, v) natural landscapes, vi) agricultural landscapes and vii) protected areas. 17 publications described greater basins or smaller catchments [4], [27], [32], [37]-[39], [43], [56]-[59], [69], [73], [77], [101], [108], [110], while few articles focused on transported sediment from rivers/streams [55], [90], [114], [123]. Ten studies represented the bodies of water such as lakes [10], [55], [57], [67], [68], [95], [110], [118], wetlands [5] and ponds [34]. Seven coastal areas were counted [23], [41], [70], [72], [97], [111], [117] and three fan deltas [24], [51], [93] that constitute a mixed environment of both rivers and coasts. Fifteen publications covered natural landscapes that included forests, grasslands, pastures, rangelands, phrygana and terraces [11], [13]-[16], [21], [47], [60], [61], [63], [66], [69], [89], [112], [122]. In addition, seventeen agricultural lands were mentioned; most of them concerned olives [2], [4], [31], [45], [48], [62], [64], [66], [78], vineyards [67], [122], cereals [67] and others [11], [65], [106], [107], [108], [113]. Finally, nine of the studied areas were protected under the Natura 2000 or Ramsar networks [10], [55], [57], [58], [67], [68], [95], [118], [122].

B. Physical phenomena: Physical phenomena include the abiotic natural processes that trigger the soil erosion and were divided in five subject's matters: i) hydrology, ii) geology, iii) geochemistry, iv) wildfires and v) climate. There were 78 publications that covered 71% of the total reviewed database. A vast number of publications was related to hydrology as water and soil erosion have a strong relationship [4], [8], [10], [15], [16], [18], [22], [26], [31], [34], [42], [47], [48], [51], [55]-[59], [62], [68], [69], [90], [95], [97], [101]-[103], [107], [110], [114]-[116], [120], [123]. As soil erosion is a geologic phenomenon, there were many publications referred to geologic matters such as geomorphology [1], [8], [18], [22]-[24], [35], [38], [39], [41], [42], [46], [51], [66], [72], [73], [75], [85], [94], [97], [100], [111], [117], [119], hydrogeology [57], [68], [104], [120], mineralogy [40], [49], [63], [86], [121], landslides [33], [61], [75], [87], [88], tectonics and geophysics [42], [51], [63], [72], [85], [93], [111]. Many publications discussed the subject of geochemistry [4], [15], [23], [49], [63], [67], [68], [78], [86], [101], [108], [109], [117], [120] that included the physicochemical parameters and the pedogenesis of soils. A factor that increases the erosion process is wildfires [15]-[17], [31], [48], [82], [103], [115], [118], [122]. As was mentioned, climate (paleo-climate and climate change) is a sector that affects erosion and it was represented by several publications [9], [10], [17], [18], [36], [43], [48], [70], [77], [90], [93], [94], [97], [100], [117].

C. Anthropogenic impacts: This category refers to the negative effects of the human's activities to the environment. 65 publications were found and divided in the following subjects: i) agricultural activities, ii) forest activities, iii) livestock, iv) urban, v) socio-economic and vi) archaeology. The majority of publication referred to agricultural activities and their relationship to the soil erosion processes [2], [8], [11], [12], [20], [31], [42], [45], [48], [60], [62], [64], [65], [69], [74], [78], [86], [89], [98], [106], [107], [109], [112], [113], [120], [122]. Forest activities concerned logging [121] and skidding [118]. Livestock is an agricultural activity but primarily focused on grazing impacts [6], [11], [13], [17], [20], [52], [60], [61], [68], [89], [101], [118]. Urban areas included settlements [3], [21], [84], [103], [111], [112], [119] and engineering constructions such as slope stabilization [3], [84], roads [9], [33], [87], [112] and dams-reservoirs [58], [95], [123]. A great number of publications concerned socio-economic impacts [1], [12], [14], [20], [33], [45], [60], [68], [74], [78], [87], [98], [104], [106], [118] and finally, archaeology included historical settlements and historical human activities that affected the soil erosion [1], [10], [23], [24], [28], [35]-[38], [41], [46], [70], [73], [76], [94], [111], [117].

D. Assessment tools: This category included 78 publications that were divided in: i) field measurements/observations, ii) laboratory analysis, iii) equations/formulas/indices, iv) remote sensing, v) GIS and vi) modeling. Field measurements/observations included field plots and experiments [4], [5], [15], [18], [26], [32], [35], [49], [61], [62], [65], [67], [76], [88], [94], [95], [107], [113], [121], [122], boreholes/wells/cores sampling [10], [36], [41], [63], [70], [74], [77], [98], [109], [117], [123], geophysical surveys [51], information acquired by documents [76], [94], [98] and questionnaires [106]. Laboratory analysis was represented by radio chronology; specifically by dating gamma radiation of isotopes such as Cesium-137 [34], [65], [108], [109], Carbon-14 [77], [117], [119] and other isotopes by optical stimulated luminescence dating [37]-[40]. In addition, laboratory analysis includes geotechnical techniques [23], [33], [65], [66], [75], [84], [87], [109], geophysical analysis [51] and other physicochemical techniques [4], [5], [10], [49], [67], [117]. The next subject matter was equations such as Universal Soil Loss Equation (USLE) [4], [46], [56], [59], [82], [89], [123], Revised Soil Loss Equation (RUSLE) [64], [71], [96], Gavrilovic [22], [27], [89], [102], Runoff Curve Number [4], [107], indices [43], [104], [114], [116] and other algorithmic equations-formulas [4], [26], [56], [58], [59], [95], [113], [114], [116]. There were many studies that used new technologies in order to manage and depict the erosion risk. These technologies included remote sensing techniques using satellite images [7], [32], [42], [52], [53], [54], [64], [71], [115], Geographic Information Systems (GIS) [7], [22], [27], [32], [42], [46], [52], [53]-[55], [64], [71], [82], [96], [102], [104], [108], [112], [114], [115], [121], [123] and modeling tools [2], [9], [11], [27], [34], [46], [55], [56], [58]-[60], [89], [90], [97], [108]-[110], [121].

C. Management

The category management was divided in: i) policies, ii) risk assessment, iii) construction techniques and iv) land management techniques. This category had 67 publications. The policies took into consideration agricultural policies such as the Common Agricultural Policy [12], [31] and [52]. The risk assessment was represented by studies that produce soil erosion risk maps [7], [20], [22], [27], [32], [42], [52], [53], [57], [64], [71], [81], [82], [89], [96], [97], [104], [114], [115], [122] and estimations of soil erosion [4], [26], [43], [55], [56], [58], [59], [69], [95], [103], [108], [109], [116] that could be considered guides for researchers and authorities. Construction techniques included plans that could reduce the erosion by using techniques such as slope stabilization and other control measures [3], [8], [33], [57], [75], [81], [84], [87], [88], [96], [110]. The last category was land management techniques that referred to conservation and mitigation agricultural plans that preserve and protect the physical environment from soil erosion threats [2], [3], [4], [6], [8], [11], [13], [14], [16], [17], [21], [31], [45], [47]-[49], [52], [54], [57], [60]-[62], [64]-[69], [74], [76], [81], [86], [98], [107], [110], [112], [113], [120], [121], [122]. It is observed that most studies were related with agricultural land management plans and studies that produced erosion risk maps.

IV. Conclusion

Soil erosion is a worldwide environmental threat and serious and systematic measures need to be taken to mitigate this threat. Many European countries have established policies in order to mitigate this threat and protect the environment. In Greece a lot of researchers and responsible authorities have focused on soil erosion but further study and a strategic management plan is needed due to climate change impacts. The analysis of the review recognized an increase of the publications over the year. The publications covered a wide range of subject matters from type of studied land area, physical phenomena, anthropogenic impacts, assessment tools and management. A strong common policy and a monitoring system are needed in order to mitigate the soil erosion risk in Europe, especially in Mediterranean countries such as Greece. Also, farmers must be better informed about the soil erosion processes, the factors that trigger them and finally, awareness of proper agriculture management must be adopted in order to reduce the erosion risk.

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