

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].

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

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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.

ACKNOWLEDGMENT

This work is part of the project entitled "Management and Prevention of Soil Erosion through an Integrated Information System" with the acronym "MaP-Erosion" that is funded by the Hellenic General Secretariat for Research and Technology under the Programme "Aristeia II."

REFERENCES

- [1] Acheson, P.E. (1997) Does the 'economic explanation' work? Settlement, agriculture and erosion in the territory of Halieis in the Late Classical-Early Hellenistic period. *Journal of Mediterranean Archaeology*, 10 (2), pp. 165-190.
- [2] Allen, H.D., Randall, R.E., Amable, G.S., Devereux, B.J. (2006) The impact of changing olive cultivation practices on the ground flora of olive groves in the Messara and Psiloritis regions, Crete, Greece. *Land Degradation and Development*, 17 (3), pp. 249-273.
- [3] Anthopoulou, B., Panagopoulos, A., Karyotis, Th. (2006) The impact of land degradation on landscape in Northern Greece. *Landslides*, 3 (4), pp. 289-294.
- [4] Arhonditsis, G., Giourga, C., Loumou, A., Koulouri, M. (2002) Quantitative assessment of agricultural runoff and soil erosion using mathematical modeling: Applications in the Mediterranean region. *Environmental Management*, 30 (3), pp. 434-453.
- [5] Arhonditsis, G., Giourga, C., Loumou, A. (2000) Ecological patterns and comparative nutrient dynamics of natural and agricultural Mediterranean-type ecosystems. *Environmental Management*, 26 (5), pp. 527-537.
- [6] Arianoutsou-Faraggitaki, M. (1985) Desertification by overgrazing in Greece: the case of Lesbos island. *Journal of Arid Environments*, 9 (3), pp. 237-242.
- [7] Astaras, T., Lambrinos, N. (1988) Land classification of part of Thrace (East Rhodope) by visual interpretation of MSS images of first and second generation landsat images. *GeoJournal*, 17 (3), pp. 357-363
- [8] Astaras, T. (1984) Drainage basins as process-response systems: an example from central Macedonia, north Greece. *Earth Surface Processes & Landforms*, 9 (4), pp. 333-341.
- [9] Athanasopoulou, E., Tombrou, M., Russell, A.G., Karanasiou, A., Eleftheriadis, K., Dandou, A. (2010) Implementation of road and soil dust emission parameterizations in the aerosol model CAMx: Applications over the greater Athens urban area affected by natural

- sources. *Journal of Geophysical Research: Atmospheres*, 115 (17), D17301.
- [10] Aufgebauer, A., Panagiotopoulos, K., Wagner, B., Schaebitz, F., Viehberg, F.A., Vogel, H., Zanchetta, G., Sulpizio, R., Leng, M.J., Damaschke, M. (2012) Climate and environmental change in the Balkans over the last 17 ka recorded in sediments from Lake Prespa (Albania / FYR of Macedonia / Greece). *Quaternary International*, 274, pp. 122-135.
- [11] Bakker, M.M., Govers, G., Kosmas, C., Vanacker, V., van Oost, K., Rounsevell, M. (2005) Soil erosion as a driver of land-use change. *Agriculture, Ecosystems and Environment*, 105 (3), pp. 467-481.
- [12] Barbayiannis, N., Panayotopoulos, K., Psaltopoulos, D., Skuras, D. (2011) The influence of policy on soil conservation: A case study from Greece. *Land Degradation and Development*, 22 (1), pp. 47-57.
- [13] Barbero, M., Quezel, P. (1983) La vegetation de la Grece et l'action de l'homme. (The vegetation of Greece and human action) *Mediterranee*, 48 (2), pp. 65-71.
- [14] Bevan, A., Conolly, J. (2011) Terraced fields and Mediterranean landscape structure: An analytical case study from Antikythera, Greece. *Ecological Modelling*, 222 (7), pp. 1303-1314.
- [15] Blake, W.H., Theocharopoulos, S.P., Skoulikidis, N., Clark, P., Tountas, P., Hartley, R., Amaxidis, Y. (2010) Wildfire impacts on hillslope sediment and phosphorus yields. *Journal of Soils and Sediments*, 10 (4), pp. 671-682.
- [16] Bohling, N., Gerold, G. (1995) Post-fire regeneration patterns and variations of soil properties in Mediterranean phrygana-areas of Naxos / Greece. *Geokodynamik*, 16 (3-4), pp. 333-345.
- [17] Boix, C., Calvo, A., Imeson, A.C., Schoorl, J.M., Soto, S., Tiemessen, I.R. (1995) Properties and erosional response of soils in a degraded ecosystem in Crete (Greece). *Environmental Monitoring & Assessment*, 37 (1-3), pp. 79-92.
- [18] Cerdà, A. (1998) Relationships between climate and soil hydrological and erosional characteristics along climatic gradients in Mediterranean limestone areas. *Geomorphology*, 25 (1-2), pp. 123-134.
- [19] Cerdan, O., Desprats, J.-F., Fouché, J., Le Bissonnais, Y., Cheviron, B., Simonneaux, V., Raclot, D., Mouillot, F. (2011) Impact of global changes on soil vulnerability in the Mediterranean Basin. *ASABE - International Symposium on Erosion and Landscape Evolution*, pp. 495-503.
- [20] Christodoulou, M., Nakos, G. (1990) An approach to comprehensive land use planning. *Journal of Environmental Management*, 31 (1), pp. 39-46.
- [21] Christopoulou, O., Polyzos, S., Minetos, D. (2007) Peri-urban and urban forests in Greece: Obstacle or advantage to urban development? *Management of Environmental Quality*, 18 (4), pp. 382-395.
- [22] Dalaris, M., Psilovikos, A., Sapountzis, M., Mourtzi, P., Mourtzi, P. (2013) Water erosion assessment in skiathos island using the gavrilovic method. *Fresenius Environmental Bulletin*, 22 (10), pp. 2943-2952.
- [23] Davidson, D.A., Wilson, C.A., Lemos, I.S., Theocharopoulos, S.P. (2010) Tell formation processes as indicated from geoarchaeological and geochemical investigations at Xeropolis, Euboea, Greece. *Journal of Archaeological Science*, 37 (7), pp. 1564-1571.
- [24] Davidson A.D. (1991) Soil erosion in the Mediterranean Basin. *Geography*, 76 (1), pp. 71-73.
- [25] Dekker, L.W., Oostindie, K., Ritsema, C.J. (2005) Exponential increase of publications related to soil water repellency. *Australian Journal of Soil Research*, 43 (3), pp. 403-441.
- [26] Dimoyiannis, D., Valmis, S., Danalatos, N.G. (2006) Interrill erosion on cultivated Greek soils: Modelling sediment delivery. *Earth Surface Processes and Landforms*, 31 (8), pp. 940-949.
- [27] Emmanouloudis, D.A., Christou, O.P., Filippidis, E.I. (2003) Quantitative estimation of degradation in the Aliakmon River basin using GIS. *IAHS-AISH Publication*, (279), pp. 234-240.
- [28] Efstratiou, N., Biagi, P., Elefanti, P., Karkanis, P., Ntinou, M. (2006) Prehistoric exploitation of Grevena highland zones: Hunters and herders along the Pindus chain of western Macedonia (Greece). *World Archaeology*, 38 (3), pp. 415-435.
- [29] European Commission (EC) 2002 Towards a strategy for soil protection. pp. 179.
- [30] European Commission (EC) 2006 Thematic strategy for soil protection. pp. 231.
- [31] Fleskens, L. (2008) A typology of sloping and mountainous olive plantation systems to address natural resources management. *Annals of Applied Biology*, 153 (3), pp. 283-297.
- [32] Floras, S.A., Sgouras, I.D. (1999) Use of geoinformation techniques in identifying and mapping areas of erosion in a hilly landscape of central Greece. *International Journal of Applied Earth Observation and Geoinformation*, 1 (1), pp. 68-77.
- [33] Flum, D., Salzmann, H., Züger, M. (2005) Replacement of failed shotcrete facing by a flexible slope stabilisation system. *Polish Geological Institute Special Papers*, 20, pp. 40-45.
- [34] Foteinis, S., Mpizoura, K., Panagopoulos, G., Chatzisyneon, E., Kallithrakas-Kontos, N., Manutsoglu, E. (2014) A novel use of the caesium-137 technique to estimate human interference and historical water level in a Mediterranean Temporary Pond. *Journal of Environmental Radioactivity*, 127, pp. 75-81.
- [35] French, C.A.I., Whitelaw, T.M. (1999) Soil Erosion, Agricultural Terracing and Site Formation Processes at Markiani, Amorgos, Greece: The Micromorphological Perspective. *Geoarchaeology - An International Journal*, 14 (2), pp. 151-189.
- [36] Fuchs, M. (2007) An assessment of human versus climatic impacts on Holocene soil erosion in NE Peloponnese, Greece. *Quaternary Research*, 67 (3), pp. 349-356.
- [37] Fuchs, M. (2006) Mensch und Umwelt in der Antike Süd Griechenlands: Ergebnisse geoarchäologischer Forschung im Becken von Phlious, Nordost-Peloponnes (Man and environment in antique Greece: Geoarchaeological investigations in the basin of Phlious, Northeast-Peloponnese). *Geographische Rundschau*, 58 (4), pp. 4-11.
- [38] Fuchs, M., Wagner, G.A. (2005) The chronostratigraphy and geoarchaeological significance of an alluvial geochronology: Comparative OSI and AMS 14C dating from Greece. *Archaeometry*, 47 (4), pp. 849-860.
- [39] Fuchs, M., Lang, A., Wagner, G.A. (2004) The history of Holocene soil erosion in the Phlious Basin, NE Peloponnese, Greece, based on optical dating. *Holocene*, 14 (3), pp. 334-345.
- [40] Fuchs, M., Wagner, G.A. (2003) Recognition of insufficient bleaching by small aliquots of quartz for reconstructing soil erosion in Greece. *Quaternary Science Reviews*, 22 (10-13), pp. 1161-1167.
- [41] Fytrolakis, N., Peterek, A., Schröder, B. (2005) Initial geoarchaeologic investigations on the Holocene coastal configuration near Phaistos / Agia Triada (Messara plain central Crete, Greece). *Zeitschrift für Geomorphologie, Supplementband*, 137, pp. 111-123.
- [42] Gatsis I., Pavlopoulos A. (2001) Geomorphological observations and related natural hazards using merged remotely sensed data: A case study in the corinthos area (NE Peloponnese, S. Greece). *Geografiska Annaler, Series A: Physical Geography*, 83 (4), pp. 217-228.
- [43] Giakoumakis, S.G., Tsakiris, G.P. (1997) Meteorological Drought Effect on Sediment Yield. *Water Resources Management*, 11 (5), pp. 365-376.
- [44] Giupponi C. and M Shechter (eds.) (2003) Climate Change in the Mediterranean: Socio-Economic Perspectives of Impacts, Vulnerability and Adaptation. Edward Elgar Publications, Glos, UK.
- [45] Gomez, J.A., Amato, M., Celano, G., Koubouris, G.C. (2008) Organic olive orchards on sloping land: More than a specialty niche production system? *Journal of Environmental Management*, 89 (2), pp. 99-109.
- [46] Gouma, M., van Wijngaarden, G.J., Soetens, S. (2011) Assessing the effects of geomorphological processes on archaeological densities: A GIS case study on Zakynthos Island, Greece. *Journal of Archaeological Science*, 38 (10), pp. 2714-2725.
- [47] Grabner, S., Heiselmayr, P. (2000) Vegetation dynamics of phrygana in erosion rills on Mykonos (Greece). *Acta Botanica Croatica*, 59 (1), pp. 111-134.
- [48] Grove, A.T., Rackham, O. (1993) Threatened landscapes in the Mediterranean: examples from Crete. *Landscape and Urban Planning*, 24 (1-4), pp. 279-292.
- [49] Haidouti, C., Karyotis, T., Massas, I., Haroulis, A. (2001) Red soils of Thrace (Greece): Properties, development, and productivity. *Communications in Soil Science and Plant Analysis*, 32 (5-6), pp. 617-632.
- [50] Hagýó, A., Tóth, T., Bloem, E., Van Der Zee, S.E.A.T.M., Horváth, E. (2008) Soil-plant interrelations: The significance of soil degradation and the risk assessment methodology for salinization. *Cereal Research Communications*.
- [51] Hasiotis, T., Charalampakis, M., Stafatos, A., Papatheodorou, G., Ferentinos, G. (2006) Fan delta development and processes offshore a seasonal river in a seismically active region, NW Gulf of Corinth. *Geomarine Letters*, 26 (4), pp. 199-211.
- [52] Hill, J., Hostert, P., Tsiourlis, G., Kasapidis, P., Udelhoven, T., Diemer, C. (1998) Monitoring 20 years of increased grazing impact on the Greek

- island of Crete with earth observation satellites. *Journal of Arid Environments*, 39 (2), pp. 165-178.
- [53] Hill, J., Megier, J., Mehl, W. (1995) Land degradation, soil erosion and desertification monitoring in Mediterranean ecosystems. *Remote Sensing Reviews*, 12 (1-2), pp. 107-130.
- [54] Hill, J. (1993) Monitoring land degradation and soil erosion in Mediterranean environments. *ITC Journal*, 1993-4, pp. 323-331.
- [55] Hrissanthou, V., Delimani, P., Xeidakis, G. (2010) Estimate of sediment inflow into Vistonis Lake, Greece. *International Journal of Sediment Research*, 25 (2), pp. 161-174.
- [56] Hrissanthou, V. (2005) Estimate of sediment yield in a basin without sediment data. *Catena*, 64 (2-3), pp. 333-347.
- [57] Hrissanthou, V., Mylopoulos, N., Tolikas, D., Mylopoulos, Y. (2003) Simulation modeling of runoff, groundwater flow and sediment transport into Kastoria Lake, Greece. *Water Resources Management*, 17 (3), pp. 223-242.
- [58] Hrissanthou, V. (2002) Comparative application of two erosion models to a basin. *Hydrological Sciences Journal*, 47 (2), pp. 279-292.
- [59] Hrissanthou, V. (1998) Comparison between two mathematical models for the computation of sediment yield from a basin. *AHS-AISH Publication*, 249, pp. 137-142.
- [60] Ibañez, J., Valderrama, JM, Papanastasis, V., Evangelou, C., Puigdefabregas, J. (2014) A multidisciplinary model for assessing degradation in Mediterranean rangelands. *Land Degradation and Development*, 25 (5), pp. 468-482.
- [61] Kairis, O., Karavitis, C., Salvati, L., Kounalaki, A., Kosmas, K. (2015) Exploring the Impact of Overgrazing on Soil Erosion and Land Degradation in a Dry Mediterranean Agro-Forest Landscape (Crete, Greece). *Arid Land Research and Management*, 29 (3), pp. 360-374.
- [62] Kairis, O., Karavitis, C., Kounalaki, A., Salvati, L., Kosmas, C. (2013) The effect of land management practices on soil erosion and land desertification in an olive grove. *Soil Use and Management*, 29 (4), pp. 597-606.
- [63] Kalatha, S., Economou-Eliopoulos, M. (2015) Framboidal pyrite and bacterio-morphic goethite at transitional zones between Fe-Ni-laterites and limestones: Evidence from Lokris, Greece. *Ore Geology Reviews*, 65 (P1), pp. 413-425.
- [64] Karydas, C.G., Sekuloska, T., Silleos, G.N. (2009) Quantification and site-specification of the support practice factor when mapping soil erosion risk associated with olive plantations in the Mediterranean island of Crete. *Environmental Monitoring and Assessment*, 149 (1-4), pp. 19-28.
- [65] Kosmas, C., Gerontidis, St., Marathanou, M., Detsisa, B., Zafiriou, Th., Nan Muysen, W., Govers, G., Quine, T., Vanoost, K. (2001) The effects of tillage displaced soil on soil properties and wheat biomass. *Soil and Tillage Research*, 58 (1-2), pp. 31-44.
- [66] Kosmas, C., Danalatos, NG, Gerontidis, S. (2000) The effect of land parameters on vegetation performance and degree of erosion under Mediterranean conditions. *Catena*, 40 (1), pp. 3-17.
- [67] Kosmas, C., Gerontidis, S., Marathanou, M. (2000) The effect of land use change on soils and vegetation over various lithological formations on Lesvos (Greece). *Catena*, 40 (1), pp. 51-68.
- [68] Kosmas, C.S., Danalatos, N.G., Moustakas, N.K. (1997) The soils. *Hydrobiologia*, 351, pp. 21-33.
- [69] Kosmas, C., Danalatos, N., Cammeraat, L.H., Chabart, M., Diamantopoulos, J., Farand, R., Gutierrez, L., Jacob, A., Marques, H., Martinez-Fernandez, J., Mizara, A., Moustakas, N., Nicolau, J.M., Oliveros, C., Pinna, G., Puddu, R., Puigdefabregas, J., Roxo, M., Simao, A., Stamou, G., Tomasi, N., Usai, D., Vacca, A. (1997) The effect of land use on runoff and soil erosion rates under Mediterranean conditions. *Catena*, 29 (1), pp. 45-59.
- [70] Kouli K. (2012) Vegetation development and human activities in Attiki (SE Greece) during the last 5,000 years. *Vegetation History and Archaeobotany*, 21 (4-5), pp. 267-278.
- [71] Kouli, M., Soupios, P., Vallianatos, F. (2009) Soil erosion prediction using the Revised Universal Soil Loss Equation (RUSLE) in a GIS framework, Chania, Northwestern Crete, Greece. *Environmental Geology*, 57 (3), pp. 483-497.
- [72] Leeder, M.R., Collier, R.E.LI., Abdul Aziz, L.H., Trout, M., Ferentinos, G., Papatheodorou, G., Lyberis, E. (2002) Tectono-sedimentary processes along an active marine / lacustrine half-graben margin: Alkyonides gulf, E. Gulf of Corinth, Greece. *Basin Research*, 14 (1), pp. 25-41.
- [73] Lespez, L. (2003) Geomorphic responses to long-term land use changes in Eastern Macedonia (Greece). *Catena*, 51 (3-4), pp. 181-208.
- [74] Lithourgidis, A.S., Damalas, C.A., Eleftherohorinos, I.G. (2009) Conservation tillage: A promising perspective for sustainable agriculture in Greece. *Journal of Sustainable Agriculture*, 33 (1), pp. 85-95.
- [75] Lykousis, V., Chronis, G. (1989) Mass movements, geotechnical properties, and slope stability in the outer shelf-upper slope, northwestern Aegean Sea. *Marine Geotechnology*, 8 (3), pp. 231-247.
- [76] Marathanou, M., Kosmas, C., Gerontidis, St., Detsis, V. (2000) Land-use evolution and degradation in Lesvos (Greece): A historical approach. *Land Degradation and Development*, 11 (1), pp. 63-73.
- [77] Margari, V., Gibbard, PL, Bryant, C.L., Tzedakis, P.C. (2009) Character of vegetational and environmental changes in southern Europe during the last glacial period; evidence from Lesvos Island, Greece. *Quaternary Science Reviews*, 28 (13-14), pp. 1317-1339.
- [78] Metzidakis, I., Martinez-Vilela, A., Castro Nieto, G., Basso, B. (2008) Intensive olive orchards on sloping land: Good water and pest management are essential. *Journal of Environmental Management*, 89 (2), pp. 120-128.
- [79] Montgomery D.R., 2007. Soil erosion and agriculture sustainability. *Proceeding of the National Academy of Sciences of the United States of America*. Vol 104(33), pp 13268-13272.
- [80] Morvan, X., Saby, NPA, Arrouays, D., Le Bas, C., Jones, R.J.A., Verheijen, F.G.A., Bellamy, P.H., Stephens, M., Kibblewhite, MG. (2008) Soil monitoring in Europe: A review of existing systems and requirements for harmonization. *Science of the Total Environment*, 391 (1), pp. 1-12.
- [81] Myronidis, D., Ioannou, K., Sapountzis, M., Fotakis, D. (2010) Development of a sustainable plan to combat erosion for an island of the Mediterranean region. *Fresenius Environmental Bulletin*, 19 (8 B), pp. 1694-1702.
- [82] Myronidis, D.I., Emmanoueloudis, D.A., Mitsopoulos, I.A., Riggos, E.E. (2010) Soil Erosion Potential after Fire and Rehabilitation Treatments in Greece. *Environmental Modeling and Assessment*, 15 (4), pp. 239-250.
- [83] Nearing M.A., Pruski F.F., and O'Neal M.R. (2004) Expected climate change impacts on soil erosion rates: A review. *Journal of Soil and Water Conservation* 59(1): 43-50.
- [84] Nektarios, P.A., Ntoulas, N., Zacharopoulou, A., Chronopoulos, I. (2010) Athens concert hall roof garden construction. *Acta Horticulturae*, 881, pp. 683-688.
- [85] Neboit-Guilhot, R. (1990) Les contraintes physiques et la fragilité du milieu méditerranéen (Physical constraints and fragility of the Mediterranean area). *Annales de Géographie*, 551, pp. 1-20.
- [86] Noulas, C., Karyotis, T., Charoulis, A., Massas, I. (2009) Red mediterranean soils: Nature, properties, and management of rhodoxeralfs in northern Greece. *Communications in Soil Science and Plant Analysis*, 40 (1-6), pp. 633-648.
- [87] Oikonomou, N., Eskioglou, P. (2006) Marble treatment waste for slope stabilization. *Fresenius Environmental Bulletin*, 15 (3), pp. 239-241.
- [88] Oostwoud Wijdenes, D.J., Poesen, J., Vandekerckhove, L., Kosmas, C. (2001) Measurements at one-year interval of rock-fragment fluxes by sheep trampling on degraded rocky slopes in the Mediterranean. *Zeitschrift für Geomorphologie*, 45 (4), pp. 477-500.
- [89] Panagos, P., Christos, K., Cristiano, B., Ioannis, G. (2014) Seasonal monitoring of soil erosion at regional scale: An application of the G2 model in Crete focusing on agricultural land uses. *International Journal of Applied Earth Observation and Geoinformation*, 27 (PARTB), pp. 147-155.
- [90] Panagoulia, D, Dimou, G. (1997) Sensitivity of flood events to global climate change. *Journal of Hydrology*, 191 (1-4), pp. 208-222.
- [91] Pearce, F. (1996) Deserts on our doorstep. *New Scientist*, 151 (2037), pp. 12-13.
- [92] Podmanicky, L., Balázs, K., Belényesi, M., Centeri, Cs., Kristóf, D., Kohlheb, N. (2011) Modelling soil quality changes in Europe. An impact assessment of land use change on soil quality in Europe. *Ecological Indicators*, 11 (1), pp. 4-15.
- [93] Pope, R.J.J., Wilkinson, K.N. (2005) Reconciling the roles of climate and tectonics in Late Quaternary fan development on the Spartan piedmont, Greece. *Geological Society Special Publication*, 251, pp. 133-152.
- [94] Pope, K.O., van Andel, T.H. (1984) Late quaternary alluviation and soil formation in the southern Argolid: its history, causes and archaeological implications. *Journal of Archaeological Science*, 11 (4), pp. 281-306.
- [95] Psilovikos, A., Margoni, S. (2010) An empirical model of sediment deposition processes in Lake Kerkini, Central Macedonia Greece. *Environmental Monitoring and Assessment*, 164 (1-4), pp. 573-592.

- [96] Rozos, D., Skilodimou, H.D., Loupasakis, C., Bathrellos, G.D. (2013) Application of the revised universal soil loss equation model on landslide prevention. An example from N. Euboea (Evia) Island, Greece. *Environmental Earth Sciences*, 70 (7), pp. 3255-3266.
- [97] Samaras, A.G., Koutitas, C.G. (2014) Modeling the impact of climate change on sediment transport and morphology in coupled watershed-coast systems: A case study using an integrated approach. *International Journal of Sediment Research*, 29 (3), pp. 304-315.
- [98] Schrader, K. (1995) Die griechische Insel Naxos - eine bedrohte Landschaft (The Greek island of Naxos - a threatened landscape). *Erde*, 126 (1), pp. 73-86.
- [99] Shakesby R.A.. 2011. Post-wildfire soil erosion in the Mediterranean: Review and future research directions. *Earth-Science Reviews* 105, pp. 71-100.
- [100] Smith, G.W., Nance, R.D., Genes, A.N. (1997) Quaternary glacial history of Mount Olympus, Greece. *Bulletin of the Geological Society of America*, 109 (7), pp. 809-824.
- [101] Stamati, F.E., Nikolaidis, N.P., Venieri, D., Psillakis, E., Kalogerakis, N. (2011) Dissolved organic nitrogen as an indicator of livestock impacts on soil biochemical quality. *Applied Geochemistry*, 26 (SUPPL.), pp. S340-S343.
- [102] Stefanidis, S. (2011) Estimation of the mean annual sediment discharge in fire affected watersheds. *Silva Balcanica*, 12 (1), pp. 91-96.
- [103] Stefanidis, P., Sapountzis, M., Stathis, D. (2002) Sheet erosion after fire at the urban forest of Thessaloniki (Northern Greece). *Silva Balcanica*, (2), pp. 65-77.
- [104] Symeonakis, E., Karathanasis, N., Koukoulas, S., Panagopoulos, G. (2014) Monitoring sensitivity to land degradation and desertification with the environmentally sensitive area index: The case of Lesbos island. *Land Degradation and Development*, (Article in Press).
- [105] Tal, A. (2010) Desertification (Book Chapter) *Turning Points of Environmental History* pp. 146-161.
- [106] Tampakis, S., Karanikola, P., Koutroumanidis, T., Tsitouridou, Ch. (2010) Protecting the productivity of cultivated land. The viewpoints of farmers in Northern Evros. *Journal of Environmental Protection and Ecology*, 11 (2), pp. 601-613.
- [107] Terzoudi, Chr.B., Gemtos, T.A., Danalatos, N.G., Argyrokastritis, I. (2007) Applicability of an empirical runoff estimation method in central Greece. *Soil and Tillage Research*, 92 (1-2), pp. 198-212.
- [108] Theocharopoulos, S.P., Florou, H., Walling, D.E., Kalantzakos, H., Christou, M., Tountas, P., Nikolaou, T. (2003) Soil erosion and deposition rates in a cultivated catchment area in central Greece, estimated using the ^{137}Cs technique. *Soil and Tillage Research*, 69 (1-2), pp. 153-162.
- [109] Theocharopoulos, S.P., Florou, H., Kritidis, P., Belis, D., Tsouloucha, F., Christou, M., Kouloumbis, P., Nikolaou, T. (2000) Use of ^{137}Cs isotopic technique in soil erosion studies in Central Greece. *Acta Geologica Hispanica*, 35 (3-4), pp. 301-310.
- [110] Tolikas, D., Hrissanthou, V., Mylopoulos, Y., Koudoumakis, P. (2001) Sediment control in the basin of Kastoria Lake. *Progress in Water Resources*, pp. 385-393.
- [111] Tourloukis, V., Karkanias, P. (2012) Geoarchaeology in Greece: A review. *Journal of the Virtual Explorer*, 42, pp. 4.
- [112] Triantakoustantis, D.P., Kalivas, D.P., Kollias, V.J. (2013) Autologistic regression and multicriteria evaluation models for the prediction of forest expansion. *New Forests*, 44 (2), pp. 163-181.
- [113] Tsara, M., Gerontidis, S., Marathanou, M., Kosmas, C. (2001) The long-term effect of tillage on soil displacement of hilly areas used for growing wheat in Greece. *Soil Use and Management*, 17 (2), pp. 113-120.
- [114] Tsimi, C., Ganas, A., Dimoyiannis, D., Valmis, S., Lekkas, E. (2012) Catchment-wide estimate of single storm interrill soil erosion using an aggregate instability index: A model based on geographic information systems. *Natural Hazards*, 62 (3), pp. 863-875.
- [115] Vafeidis, AT, Drake, NA, Wainwright, J. (2007) A proposed method for modelling the hydrologic response of catchments to burning with the use of remote sensing and GIS. *Catena*, 70 (3), pp. 396-409.
- [116] Valmis, S., Dimoyiannis, D., Danalatos, N.G. (2005) Assessing interrill erosion rate from soil aggregate instability index, rainfall intensity and slope angle on cultivated soils in central Greece. *Soil and Tillage Research*, 80 (1-2), pp. 139-147.
- [117] Vött, A., Brückner, H., Handl, M., Schriever, A. (2006) Holocene palaeogeographies of the Astakos coastal plain (Akarnania, NW Greece). *Palaeogeography, Palaeoclimatology, Palaeoecology*, 239 (1-2), pp. 126-146.
- [118] Weingartner, H., Karnassioti, A., Vavliakis, E. (2001) Landschaftsdegradation in Nord- und Zentralgriechenland - Regionale Beispiele (Land degradation in Northern and Central Greece - Regional examples). *Petermanns Geographische Mitteilungen*, 145 (4), pp. 56-67.
- [119] Xeidakis, G., Delimani, P., Skias, S. (2006) Sea cliff erosion in the eastern part of the North Aegean coastline, Northern Greece. *Journal of Environmental Science and Health - Part A Toxic / Hazardous Substances and Environmental Engineering*, 41 (9), pp. 1989-2011.
- [120] Yassoglou, N., Kosmas, C., Moustakas, N. (1997) The red soils, their origin, properties, use and management in Greece. *Catena*, 28 (3-4), pp. 261-278.
- [121] Zagas, T.D., Raptis, D.I., Zagas, D.T. (2011) Identifying and mapping the protective forests of southeast Mt. Olympus as a tool for sustainable ecological and silvicultural planning, in a multi-purpose forest management framework. *Ecological Engineering*, 37 (2), pp. 286-293.
- [122] Zaimis, G.N., Emmanouloudis, D., Iakovoglou, V. (2012) Estimating soil erosion in Natura 2000 areas located on three semi-arid Mediterranean islands. *Journal of Environmental Biology*, 33 (2), pp. 277-282.
- [123] Zarris, D., Vlastara, M., Panagoulia, D. (2011) Sediment Delivery Assessment for a Transboundary Mediterranean Catchment: The Example of Nestos River Catchment. *Water Resources Management*, 25 (14), pp. 3785-3803.