LONG-TERM ECOSYSTEM RESEARCH AT THE KOILIARIS CRITICAL ZONE OBSERVATORY

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ABSTRACT

The Koiliaris River watershed, located in Western Crete, Greece, is a Critical Zone Observatory (CZO) that represents severely degraded soils due to heavy agricultural impact such as grazing, over many centuries (www.koiliaris-czo.tuc.gr). Mediterranean soils are under imminent threat of desertification (carbon loss) due to climate change that is predicted by the UN IPCC for the region over the next century. The main type of soil degradation in the basin is water erosion, mainly due to the clearing of forests and natural vegetation for cropping and livestock grazing. De-vegetation and inappropriate cultivation practices induce soil organic matter losses, making soils susceptible to erosion and desertification with global consequences for food security, climate change, biodiversity, water quality, and agricultural economy.

A characteristic of the Koiliaris River watershed is the existence of karstic formation, which in common in the Mediterranean geomorphology. The large underwater reservoirs formed, regulate water discharge through karstic springs throughout the year. Specifically for the Koiliaris CZO, the outflow is a combination of permanent flow supplied by the karstic springs and ephemeral flow from the surface runoff. Karst systems in the Mediterranean region have the special feature that a spring could receive contributions from the karst that is extended outside the watershed boundaries to which the spring belongs or karst situated one on top of another with different hydraulic characteristics and thus different transmissivities. This fact underlies the importance of the identification of the extended karst area that contributes to the flow of a spring for the acquisition of accurate hydrologic and geochemical balances of the system, increasing the need for continuously obtaining large datasets.

The discharge of temporary and episodic tributaries in the Koiliaris CZO, and Mediterranean basins in general, which flow abruptly after long periods of drought, contribute to extreme flash flood events. The recorded extreme flash floods have caused severe and extended damages in properties and constructions. The estimation of patterns leading to flash flood and the capability of properly predicting and intercepting social and environmental impacts from these events, makes the need for continuous data collection imperative. The Koiliaris CZO infrastructure is equipped with fully instrumented gauging stations, meteorological stations, precipitation stations as well as demonstration sites for technologies that reduce environmental pollution. Stream and ground water chemistry is monitored on a monthly basis for over a decade. The site is equipped with a high frequency environmental monitoring station measuring physico-chemical parameters. The Koiliaris CZO is managed by the Technical University of Crete. Key research at Koiliaris CZO focuses on water resources management, sustainable management of soils and hydrologic and geochemical modelling of complex terrains.

Water resources management research focus on the identification of hydrologic pathways, the quantification of available surface and groundwater and the sustainable use of water resources in the region. The aim is to understand and model the hydrology of the watershed, the response of the karstic reservoir, the area outside of the watershed that contributes to the karst as well the response times for each of the different hydrologic processes operating at the basin. The Karst-SWAT model has been specifically developed to simulate the behavior of the karst as part of the watershed hydrology. Figure 1 presents an analysis of flush floods of a temporary tributary of Koilairis and how their frequencies have changed over the past 50 years. Climate change simulations of the basin (Figure 2) suggest that the available water resources is expected to be reduced by 15-20% in 2030-2050 and by 40-50% in the 2050-2070 period compared to the current averages. Adaptation of water resource management will be necessary in order the water demand to be satisfied in the future. Regional data and observed and modelled processes from Koiliaris CZO have been used to assess hydrologic conditions on a larger scale,

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the whole island of Crete, where similar hydrologic systems exist, providing insight on the management of water resources in the Mediterranean island.

Sustainable management of soils research focuses on conducting soil surveys to characterize the spatial variability of soil physico-chemical and biological parameters as well as plot experiments focusing on improving soil fertility and soil ecosystem functions. The Greek land has lost its fertility due to its semi-climate and land management practices (agriculture, over-grazing). Soil fertility is directly related to the concentrations of carbon and the nutrients it contains. Based on climatic conditions, fertile soils in Greece can provide up to twice as much production and dramatically contribute to rural development. Restoring soil fertility using organic waste and good agro-ecological practices is essential if Greece is to meet its food needs and to re-establish a major export force for agricultural products. Field studies of using organic amendments (compost and manure) to grow tomatoes have shown increase in biomass production, improvements in soil structure and hydraulic properties, improvement in water filtration and transformation and enhanced biological activity.

The Integrated Critical Zone model was developed in order to simulate the geochemistry of the critical zone as well as the dynamics of soil structure, hydraulic properties and carbon and nutrient sequestration. The model can quantify the basic soil function (biomass production, nutrient sequestration, water transformation and a proxy for soil biodiversity) as well as the stocks and fluxes of all major elements that participate in the geochemical cycling of the watershed. The model is developed in the 1D-ICZ form to simulate plots and fields and it is coupled with SWAT (SWAT-ICZ) to simulate the geochemical processes at the watershed level. The ICZ model can be used to assess, understand, and quantify the complex interactions between the different processes in the soil-plant-water system and can be applied as a tool to design sustainable agricultural management practices, taking into consideration synergy and trade-offs among soil functions.

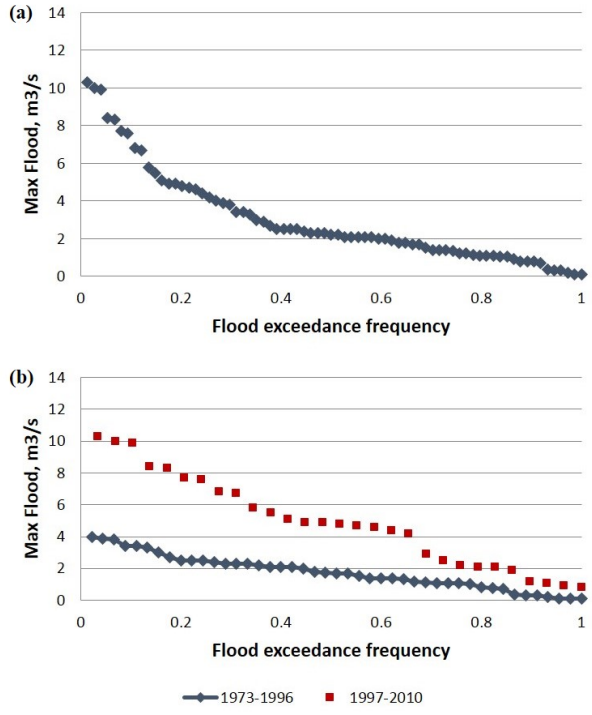

Figure 1. Flash flood analysis of Keramianos Tributary. (a) maximum flow – flood exceedance frequency using all floods (1973–2010), and (b) maximum flow – flood exceedance frequencies for 1973–1996 and 1997–2010

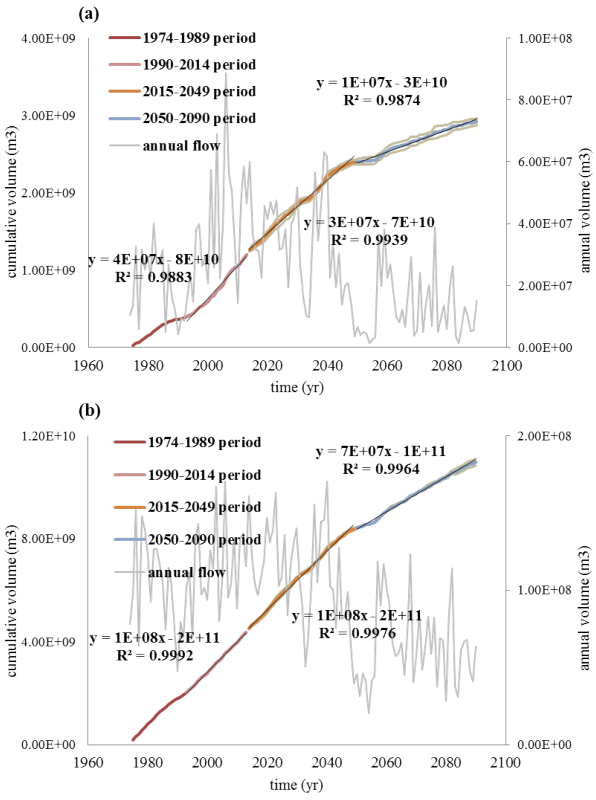

Figure 2. (a) Cumulative distribution of surface water volume at the watershed exit over the years (b) Cumulative distribution of Stylos springs water volume over the years

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