Editorial

Geoecology in Mediterranean mountain areas: a tribute to Prof. José María García-Ruiz

1. Introduction

The origin of this special issue arose from a scientific meeting held in Logroño (Spain) in October 2014, under the theme *Geoecology in extreme environments: mountains and semiarid areas* (Arnáez et al., 2014). The main motivation of the event was to recognise, on the occasion of his retirement, the outstanding contribution of Prof. José María García-Ruiz to the progress of Geoecology in Mediterranean mountain areas. Prof. García-Ruiz (Zaragoza, 1949) was lecturer, between 1974 and 1987, at the University of Cáceres, La Rioja and Zaragoza. As staff Scientist and later Professor at the Spanish National Research Council (CSIC), he was Head of the Pyrenean Institute of Ecology (IPE-CSIC) (1987-1990) and Head of the Department of Global Change at the same institute, President of the Spanish Society of Geomorphology (1994-1996), besides a productive and tireless researcher. He has published more than 300 scientific articles, one third of them in international journals, and more than 35 books. He has participated in 40 research projects funded by the European Commission, Spanish and regional governments. With his enthusiasm and dedication he has inspired and encouraged a wide number of geographers and geomorphologists, including 10 PhD students and a great number of collaborators, most of them now working at different Universities and Research Centres around the world.

2. Geoecology in Mediterranean mountain areas

The term Mountain Geoecology and the early principles that helped to establish it as a sub-discipline of Geography are inevitably associated with the life and work of Carl Troll (1899-1975), who drew much of his inspiration from Alexander von Humboldt. Troll was a geographer that devoted much of his life to the study of the mountain areas of the world. In 1968, he developed the idea of “Landschaftsökologie” (landscape ecology), by which he meant a comprehensive physical geography. He later coined the word “Geoecology” as a synonym for “Landschaftsökologie”, and defined it as a discipline embracing the different branches of geology, climatology, pedology, physical

geography, hydrology and biology (Troll, 1968). Troll was the first to define Geoecology as the science of the total and complex interactions between organisms and their environmental factors (Troll, 1972). This perspective includes landscape dynamics and its spatial organization, which above all involves physical geography, but also takes into account the influence of human activities on landscape dynamics and organization.

Later in the 1980's Jack D. Ives, one of the main protagonists in the development of Geoecological studies in mountain areas, stressed that frequently, in the practice of Ecology, the abiotic aspects had received only secondary attention. Thus, the term Geoecology will help to redress this imbalance. Mountain Geoecology can best be described as a late-twentieth century product of convenience to solve practical and environmental problems in the mountain regions of the world. The main attributes of Mediterranean mountain Geoecology are: (i) the development of the concepts of high-land / low-land interactions; (ii) the transformation of mountain economies; (iii) the identification of mountain regions as "water towers" of the world, as well as some of the most important sanctuaries of cultural and biological diversity; and (iv) the recognition of the importance of mountain recreational values (Ives, 1980). Mountain Geoecology achieved international recognition in 1968 when the Commission on High-Altitude Geoecology was founded within the International Geographical Union (IGU). Moreover some scientific journals have emphasized the treatment of mountains areas as special territories; *Mountain Research and Development* was founded in 1981 by Professor Jack D. Ives, and has played a marked role in consolidating a particular perception of Geoecology of mountain areas. Many other journals frequently published papers on hydrology, geomorphology, soil erosion and land use changes in mountain areas, and an increasing number of researchers published noticeable contributions related to Geoecolgy of mountain areas. In 1990 Prof. José María García-Ruiz edited the book "Geocología de las áreas de montaña" (Geoecology of Mountain areas), that was the first review of Geoecology in Spanish and helped spreading his particular view of this trans-disciplinary scientific area. So, a long history of geoecological mountain research can be traced now, and an important part of it was developed by Prof. José María García-Ruiz. In that sense, a special issue about Geoecology in Mediterranean mountain areas was necessary, and Catena was the appropriate journal due to its emphasis on interdisciplinary aspects of soil science, hydrology and geomorphology.

3. Geoecology investigations through Professor José María García-Ruiz

The contribution of Prof. García-Ruiz to the study, knowledge, protection and development of Geoecology in Mediterranean mountain areas is invaluable. José María García-Ruiz generated a bright contribution of the Spanish Geoecology integrating climatic, hydrologic and geomorphologic processes with a variety of socio-economic and cultural aspects at different spatial and temporal scales. During the last four decades, Prof. García-Ruiz explored important human and physical geographical aspects of global mountain environments, as well as the natural history of western European mountains, focussing in the Spanish Pyrenees and the Iberian Range, gathering much of the Ives' Geoecology perspective. When José María García-Ruiz edited in 1990 the previously mentioned book *Geocología de las áreas de montaña* (*Geoecology of Mountain areas*), it included 11 chapters that explored many of the physical and human geographical aspects of the global montane environment.

The work of Prof. García-Ruiz mainly focused in 4 interrelated topics, integrating different temporal and spatial scales:

(i) **Geomorphology and glacial dynamics**, especially in the Pyrenees and in the Iberian Range. The most relevant contribution to glaciations, geomorphology and paleoenvironments in the Pyrenees is devoted to him, including detailed field work, the implementation of new technologies and interdisciplinary strategies, and using a holistic landscape view (García-Ruiz et al., 1990, 2000, 2001). His contribution to the debate about the early deglaciation processes in southern European mountain areas, as well as to the precise dating of the maximum glacier advance, that occurred earlier than the last global glacial maximum (LGM) at around 20 ka BP, has been very relevant. Therefore, Prof. García-Ruiz has contributed to context new information related to regional climate conditions in the Iberian mountain areas during glacial periods (including the most recent ones as the *Little Ice Age-LIA*: García-Ruiz et al., 2014).

(ii) **Environmental hydrology and climatology**. Climate fluctuations and human activities strongly influence the characteristics of hydrological and geomorphological processes in mountain areas. Human activities can act at very short term, representing changes in land management, crops and livestock, the spatial organization and density of plant cover and soil

characteristics, and may result in rapid changes in interception, infiltration, water storage within the soil, overland flow and streamflow generation (García-Ruiz et al., 2011). Prof. García-Ruiz´s team installed experimental plots and catchments to test the different hydrological and erosion responses. From these experiments, they stated that changes in land cover have a direct influence on hydrological geomorphic processes (García-Ruiz et al., 2008, 2010; Nadal-Romero et al., 2013). In the case of the Mediterranean region, runoff generation is particularly important in mountain areas, which behave as "islands of humidity" or "water towers" (Viviroli and Weingartner, 2004), whereas the lowlands are water consumer areas. For all these reasons, both climate and land use/land cover changes in mountain areas can directly affect the quality and quantity of water resources.

(iii) **Soil erosion**. Prof. García-Ruiz started working in the 1980´s in soil erosion (one of his priority research lines), with his article on *Forms of erosion in the south Pyrenean Eocene Flysch* (García-Ruiz and Puigdefábregas-Tomás, 1982). He has analysed the main environmental and human features related to soil erosion processes in the Mediterranean, and the main factors that explain the extreme variability of soil erosion rates, not only closely related to physical factors (lithology, topography and climatology) but also to land use and plant cover changes (García-Ruiz et al., 2013). As a summary of his research course, Prof. García-Ruiz published in 2009 a book (*Soil erosion in Spain*, García-Ruiz and López Bermúdez) and in 2010 the paper *The effects of land uses on soil erosion in Spain: a review*, where he reviewed the long history of human activity in Spain, explaining the development of erosion landscapes and sedimentary structures (García-Ruiz, 2010). In 2013 he published *Erosion in Mediterranean landscapes: Changes and future challenges* (García-Ruiz et al., 2013) analysing the main environmental and human features related to soil erosion processes, and the main factors that explain the extreme variability of factors influencing soil erosion, particularly recent land use change. In 2015 he published *A meta-analysis of soil erosion rates across the world* (García-Ruiz et al., 2015a), concluding that scientists should be more interested in processes, causes,

internal relationships, and the role of stream channels, than in obtaining erosion rates, the interpretation of which can lead to numerous errors.

(iv) **Land use changes and land management.** During the 20th century many changes occurred in land use in Mediterranean mountain areas. Dramatic shifts that affected the sustainability, quantity, quality and management of water resources, soil resources and other ecosystem functions and services (García-Ruiz and Lasanta-Martínez, 1993; García-Ruiz et al., 1996). Prof. García-Ruiz has mainly studied land use changes on the Pyrenees and the Iberian Range (García-Ruiz and Lasanta-Martínez, 1990) and land abandonment and revegetation processes in Mediterranean mountain areas (Molinillo et al., 1997). Due to the out-migration that has taken place in many Mediterranean mountain areas, including the Spanish Pyrenees since the 1950s, a great reduction in the rural population and the abandonment of extensive land activities such as agriculture or grazing occurred. Land abandonment of old cultivated fields led to plant colonization in a process conditioned by highly complex interrelations among land use prior to abandonment, the state of the soil at the time of abandonment, and climatic and topographic conditions (García-Ruiz and Lana-Renault, 2011). Prof. García-Ruiz also studied the recent history of reforestation practices in the Pyrenees, the environmental factors involved, and its hydro-geomorphic consequences (Ortigosa et al., 1990). Moreover, land use changes in Mediterranean mountain areas caused important *ex-situ* consequences in the lowlands, including the availability and quality of water resources for irrigation (Jlassi et al., 2016), the occurrence of floods and intensity of siltation processes in the reservoirs, which reduce their lifespan (García-Ruiz et al., 2015b). Future land management has to be characterized by forest and shrubs expansion in most Mediterranean mountain areas. Specific land policies are necessary to remediate the consequences of land use change, and especially land abandonment processes (García-Ruiz et al., 2011).

Finally, after this relevant scientific research career, and despite his retirement, in 2015 Prof. García-Ruiz has published two other noticeable manuscripts that should be highlighted.

(i) *Why geomorphology is a global science* (García-Ruiz, 2015), which emphasized the global importance of geomorphology, stating that landforms are the result of the activity of geomorphic processes on geological structures, occurring over varying time scales. Each landform is the consequence of a complex interaction between bedrock, changing climate, biological activity, geomorphic processes, and human activity and time. Prof. García-Ruiz remarked that the collaboration of geomorphologists with ecologists has contributed to enhance the role of geomorphologists in environmental studies. Finally, he proposed a personal definition of geography as "*the scientific study of the spatial organization of structures, processes and facts that shape the (visible and invisible) landscapes of the earth*", and concluded that at some scale, "*everything is geography. All that is needed is a particular (or special) point of view"*.

(ii) *Geo-ecological effects of global change in the Central Spanish Pyrenees: A review at different spatial and temporal scales* (García-Ruiz et al., 2015b). Prof. García-Ruiz´s team reviewed the effects of climate variability and land use/land cover changes in the Central Spanish Pyrenees through time. They concluded that climate variability has been the most important factor of landscape evolution until the intensification of anthropogenic activity, focusing the maximum human pressure on the territory not in the mid-Holocene or Roman period (as it is usually established in Iberia), but in Medieval Ages and, specially, during the mid-19th century. It was in this moment when the cultivation of most south-facing slopes up to approximately 1650 m a.s.l. occurred, as well as the recurrent use of fire to control shrub colonization, resulting in intense soil erosion and degradation, as well as the development of braided rivers with a high torrential behaviour. Since the beginning of the 20th century, and particularly in the 1950's and 1960´s, farmland abandoned occurred in the northern part of the Mediterranean favouring plant recolonization and a treeline upward migration in the subalpine belt. They concluded that natural systems are characterized by an extreme complexity of interactions, and that a quick response of plant cover, runoff generation and soil erosion can occur on mountain areas as a consequence of climatic and land use change.

4. The articles in this Special Issue

The 15 articles of this special issue cover a broad range of topics on Geoecology in Mediterranean mountain areas. The contributions collected are only a small part of what has been published during the last four decades and provide insight into the broad field of research in which Prof. García-Ruiz worked. The papers have been organized into four main topics integrating different temporal and spatial scales.

The first group of articles is related to **glaciers, geomorphology and paleoenvironments**. González-Sampériz et al. (2016) compile and summarize the available paleo-environmental multiproxy lacustrine data from the last 20,000 years from the southern Central Pyrenees. They identify large changes in vegetation and hydrology that occurred during last glacial and Holocene periods. They present the long-term Central Pyrenees environmental history, showing a relatively high degree of internal spatial coherence which can help to evaluate the possible impact of current and future global change. González-García et al. (2016) reveal the present-day activity of a protalus lobe in a mountain permafrost environment. They describe a periglaciar landform with low activity and rapid interannual variations and they conclude that the location of a protalus lobe in marginal periglaciar environments can be used as an effective morphoclimatic geo-indicator. Manzano et al. (2016) aim at identifying the spatial patterns related to woody angiosperm fossil glacial survival, the structural and functional characteristic of montane refugia, and gaps in knowledge on the woody angiosperm patterns of survival in Mediterranean mountains. They conclude that floristic, geobotanical, paleobotanical, ethnographical and genetic evidence should be merged to gain a deeper understanding on the role played by Mediterranean mountain as glacial refugia in order to explain present situations, and to consider efficient conservation and management practices. The last paper of the first group, by Fletcher and Hughes (2016), examines the sedimentological and paleoecological records of a small infilled basin located adjacent to a Late Pleistocene moraine and close to the rock avalanche in the High Atlas (Morocco). They highlight (i) the challenges of paleoenvironmental research on non-water logged deposits in semiarid mountain landscapes, and (ii) the potential for "widening the paleoecological net" to include a wider range of geomorphological settings in pursuit of new information of the Geoecology of mountain regions.

The next three papers deal with **climatological, environmental and hydrological** issues in Mediterranean mountain areas. Vicente-Serrano et al. (2016) study the effects

of reservoir and water demand on streamflow and river regimes in a heavily regulated river basin of Northeast Spain. They show that the progressive increase of water capacity increased the disassociation between climate and runoff, evidencing that reservoirs can cause a significant decline in downstream runoff and significant alterations of natural river regimes. Lallias-Tacon et al. (2016) use airbone LiDAR and historical aerial photos for characterising the history of floodplain morphology and vegetation responses of braided rivers in South-eastern France (French Alps). The study underlines that: (i) there were two major periods of incision; (ii) flood intensity controls smooth or abrupt channel incision; (iii) large and medium floods induce channel widening; (iv) long-term changes play a significant role in explaining vegetation mosaics with a well-developed vegetated flood plain; (v) the presence of shrub patches seems to be a good indicator of incision periods; and (vi) the photointerpretation classes are fully validated by LiDAR techniques. Picco et al. (2016) aim at analysing the medium- and short-term evolution of vegetation cover, fluvial islands and main channel characteristics along a gravel-bed reach of the North-eastern Italy. They indicate that changes in river morphological evolution depended on variations in human activities. They suggest that after a slight recovery phase subsequent to the cessation of gravel extraction activities in the late 1990´s and some remarkable flood events, the Piave River entered an equilibrium phase. They observe an increase of stable and mature forest along the riparian zone, which is probably connected to the abandonment of farm activities and to the lack of significant flood events.

The following three papers deal with relevant approaches on **present soil erosion studies**. Borrelli et al. (2016) assess the impact of clear-cutting on soil erosion in Italian forests and evaluate the effects of logging activities in soil erosion by means of comprehensive remote sensing and GIS modelling techniques. They identify erosion hotspots that represent a serious threat for the soil-related forest ecosystem and are in sharp contrast with the EC Thematic Strategy for Soil Protection and with the EC Water Framework directive. Barreiro et al. (2016) propose a novel methodology based on multi-proxy analyses of lake sediments aimed at quantifying sediment delivery and erosion dynamics and a combination with soil erosion data recorded in experimental monitored catchments to validate the main factors of erosion dynamics. Comparing the reconstruction from the Iberian Lakes with data from experimental catchments in the Central Pyrenees, they show that the size of the study area (spatial scale), the land cover and the erodibility of the geological formations and soils are key factors to control the

sediment fluxes from Mediterranean mountain areas. Boix-Fayos et al. (2016) explore the redistribution of organic carbon by lateral flows at the catchment scale in an arid Mediterranean area from a geomorphological perspective. The study carried out in the Cárcavo catchment (SE Spain) indicate that sediments mobilized by erosion are poor in organic carbon compared to the soils of the catchment. The total organic carbon erosion rates are comparable to other data reported in sub-humid Mediterranean catchments and to the ones modelled worldwide for pasture lands. They conclude that lithology, soils and geomorphology seem to exert an important control on the organic carbon redistribution in this catchment with quite extreme and fragile environmental conditions, more than land use and vegetation cover.

The last 5 papers deal with **land management and land use change**. Lasanta et al. (2016) review the extent of land abandonment in Europe, the stages of abandonment and its driving causes. The largest abandonment took place in the mid-20th century in Mediterranean mountain areas, although during the last decades of the 20th century abandonment has taken place due to the CAP policies and the end of communist regimes in the East of Europe. They highlight that among the drivers, external factors act as enhancers that emphasize land abandonment and internal causes control the dynamic and the extent of this phenomenon. Romero-Díaz et al. (2016) synthetize the contrasted response of the soil system to land abandonment in three ecosystems in Western Mediterranean Mountains of Spain. In Murcia (SE Spain), with the exception of some terraced in marls, land abandonment improved the vegetation cover and some soil properties, and reduced runoff and erosion. In Valencia (E Spain), the recovery of vegetation after land abandonment and the consequent increase in organic matter, infiltration capacity and aggregate stability resulted in much lower erosion rates. The research carried out in Andalucia showed the relationship between vegetation patterns and soil moisture. van Hall et al. (2016) aim at getting insight on the effects of natural vegetation succession on the development of soil quality in the sub-Mediterranean Dragonja catchment in SW Slovenia. They select four stages of vegetation succession on north- and south-facing slopes. Stage of vegetation succession (age of abandonment) significantly influenced the organic carbon, total nitrogen, aggregate stability, biodiversity, and vegetation cover. Aspect significantly influenced the soil´s quality but did not have a significant influence on the biodiversity. Redondo-Vega et al. (2016) evaluate the changes in land use due to mining activities during the last 50 years in the

north-western Spanish mountains. Due to mining activities highly degraded areas have been created, sometimes accompanied by the disappearance of heritage sites and geodiversity. Finally, Keesstra et al. (2016) study the influence of fire history, plant species and post-fire management on soil water repellency (SWR) in Israel (Carmel Mountains). SWR was highest in un-burnt *Pinus halepensis* areas. They suggest that the dynamics and fluctuations in SWR differ in magnitude under different plant species. From the results, a conceptual model of the reaction of SWR on multiple fires was developed.

We present this volume in honour of Professor García-Ruiz's immense achievements and contributions to Geoecology of Mediterranean mountain areas. He is an outstanding scholar, a gifted researcher and an exceptional teacher, mentor, scientific and promoter of Geography and Geoecology in mountain areas. However, his most important contribution has been the example he has set for other many young scientist as a teacher, researcher and leader. Spanish Geography is highly indebted with Prof. García-Ruiz. We thank him sincerely for his distinctive contribution and encouragement over many decades.

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