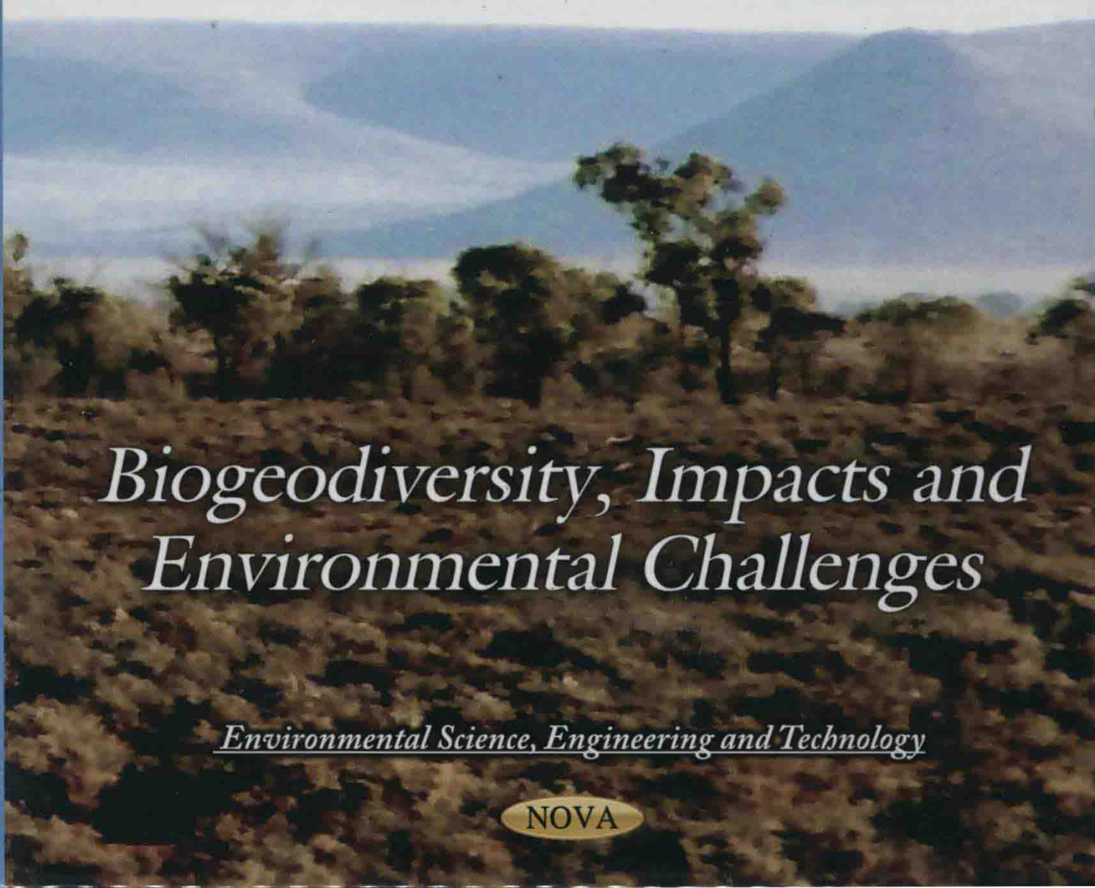
Gabriel Ferguson
Editor

Arid and Semi-Arid Environments



Biogeodiversity, Impacts and Environmental Challenges

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ENVIRONMENTAL SCIENCE, ENGINEERING AND TECHNOLOGY

ARID AND SEMI-ARID ENVIRONMENTS

BIOGEODIVERSITY, IMPACTS AND ENVIRONMENTAL CHALLENGES

GABRIEL FERGUSON
EDITOR

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PREFACE

Water is the most limiting factor for irrigated agriculture in arid and semi-arid areas of European Mediterranean countries. In this book, the authors' explore the different mechanisms and robust tools to monitor plant-water status, with the aim of keeping crops within a certain threshold of moderate-to-mild water stress. Other chapters include research on agricultural techniques in semi-arid environments that would benefit the surrounding environment and impact soil management. The third chapter includes site-specific documentation of landforms developed in the Ejina Basin in Central Asia and its implications for late quaternary landscape evolution and palaeoenvironmental change. The fourth chapter focuses on the links between economic value addition, demographics, personal income and entrepreneurship in selected South African towns. The last chapter reviews thirty years of ecological monitoring in Algerian arid rangelands.

Chapter 1 – The soil erosion, runoff and nutrient-loss patterns were monitored in a mountainside with olive (*Olea europaea* cv. Picual) plantations under conventional and conservation agricultural systems based in two different soil management: 1) conventional tillage and 2) non-tillage with barley (*Hordeum vulgare*) strips of 4 m width, respectively. The erosion plots, located in Lanjaron on the southern flank of the Sierra Nevada Mountains in SE Spain, had 30% slope at an altitude of 565 m and 192 m^2 (24 m x 8 m) in area. The highest erosion rate of 3.5 t ha^{-1} was registered under conventional system and runoff of 11.4 mm under conservation system, over the entire study period (19 erosive events). The conservation system reduced the soil erosion by 69% with respect to the conventional system, and the runoff under conventional system in relation to conservation system by 54%. The total NPK fluxes by runoff from conventional system amounted to 2.87, 0.09 and 0.93 kg ha^{-1}, and from conservation system 1.57, 0.09 and 0.98 kg ha^{-1}, respectively. In general, the soluble average concentrations of plant nutrients (N-NO_3, N-NH_4, P-H_2PO_4, and K) in the surface runoff were higher than the recommended level for standard water quality for from conventional system. These findings support the recommendation of conservation agricultural techniques for semiarid and sloped agricultural land with rainfed-tree crops for erosion and pollution control.

Chapter 2 – Water is the most limiting factor for irrigated agriculture in arid and semi-arid areas of European Mediterranean countries. The searching of alternative irrigation strategies such as deficit irrigation and the use of different tools to monitor the crop-water status are some options to improve the water management under limiting drought conditions. Infrared thermography is a non-invasive promising technique to monitor the crop-water status based on the relations between the leaf or canopy temperature and the transpiration rate, which is largely related with the stomatal conductance. From an energy balance point of view, as a consequence of stomatal regulation (partial closure) under a mild or moderate water stress, leaf temperature tends to increase because of a decrease in the heat dissipation associated with the transpiration process, which is known as the evaporative cooling process. However, temperature readings are highly dependent on many meteorological variables being very difficult to define threshold values of canopy temperature for the irrigation scheduling or the crop-water status monitoring. For this reason, in spite of many works devoted to the use of infrared thermography, there are many questions and doubts that have to be solved for real optimization, protocolling and standardization of this technique, (such as, when the images should be taken, the best time along the day, the most representative, and relevant water stress index or the image processing). Taking into account these considerations, the aim of this work was to respond to some questions that could help to optimize the use of this technique in some woody crops: i) which are the main advantages and disadvantages of this technique?; ii) which of the actual thermal indices is the most useful and representative?; iii) when is the best moment to assess the crop physiological status using the canopy temperature, focusing the answers in woody crops.

Chapter 3 – The north-south trending basin of Ejina in Inner Mongolia of northernwestern China, Central Asia is located at the lower reaches of the Heihe River watersheds and is a regional tectonic depression limited to the west part of the Alashan Plateau. Though neotectonic activity is believed to be the major factor in the evolution of the topography, detailed documentation and analysis of climatic landscape features like alluvial fans, desert plains, aeolian dunes and bedrock gorges and their environmental implications are lacking. The present study is a site-specific documentation of landforms developed in the wide part of the Ejina Basin, with the aim to identify the climatic landforms based on the method of climatic geomorphology and to evaluate its landscape evolution and response to palaeoclimate changes. The morphodynamics of older landscapes are recognized by making comparison with the present climate and its corresponding landscapes. Occurrence of desert plains and aeolian dunes in the central basin is inferred to be the products of modern hyper-arid climate. No active geomorphoclimatic dynamics for development of desert bedrock gorges and pediments is observed at the margins in the present day conditions, thus we infer an obvious linkage of these landforms to the humid phases, which provided high energy runoff for the formation of landforms associated erosional features. Clear evidences testifying the basin-scale shifting and transformation of different morphoclimatic zones in the Ejina basin are observed, which prove that the main geomorphic unit is changed from an alluvial-lacustrine plain to a desert plain. Pediments and desert gorges are both relict landforms associated with more humid and colder climate during the last glacial period. However, the coexistence of diverse landscapes and the consequent geomorphodiversity in the basin should be a compound result of surficial processes other than glaciations. Fluvial/alluvial actions, aeolian, abrasion/deflation, aggradation and degradation processes together with climatic changes have conjunctionally played important role. The climate and hydrological conditions of the basin during the last glaciation and during the Early Holocene were much better than at present, possibly having an average annual precipitation ranged between 60~350 mm on the margins of the basin and being characterized in the central basin by high lake levels during ca. 39-23 ka BP but great fluctuations during Holocene. Because the Asian summer monsoon was quite weak during the glacial times, the periods of lower aridity during the late Pleistocene in the Ejina Bain could be induced by an increase of the westerlies and a weakening of the Asian winter monsoon on the arid areas of the central Asia.

Chapter 4 – The landscape of the Karoo, the arid to semi-arid heartland of South Africa, has for millennia been subjected to a conservation/utilization dilemma. At first hunter-gatherer San tribes lived off Karoo plants and animals. Some two thousand years ago Khoikhoi herders and their livestock arrived. In the 18th Century European farmer settlers moved into the Karoo and replaced the San and Khoikhoi. In time they became wool producers and suppliers to Industrial Britain. Wool was a major export staple of the Cape Colony. After World War II wool passed its export pinnacle and by the 1960s some Karoo towns were regressing. Increased poverty was a big concern and numerous government-instigated investigations followed. Since then some Karoo towns have prospered in post-productive fashion. Now the Karoo faces new development challenges. South Africa's part of the Square Kilometre Array, a large radio telescope, is being developed in the western Great Karoo. Some large solar power installations have also been erected. The Karoo was also identified as a likely source of shale gas. The South African government recently decided to allow exploration to proceed, an action that has occasioned vociferous opposition and rekindled the conservation/utilization dilemma. Exploration could last a decade and the period should be used to gather facts needed for wise and transparent decisions. This chapter contributes to this by focusing on the links between economic value addition, demographics, personal income and entrepreneurship in selected Karoo towns. Statistical and other techniques are used to quantify relationships between gross economic value addition, town populations, total personal income and total number of enterprises in Karoo towns. A power law describes the enterprise richness of Karoo towns and an analysis of functional business diversity indicates a tipping point at about 100 enterprises. The ways by which entrepreneurial spaces are used in Karoo towns are elucidated and a predictive capability is developed about the likely responses of populations, entrepreneurs and employment in Karoo towns to economic impacts, be they from the exploitation of shale gas or other developments. A lack of local information forced the use of US information about drilling rig numbers and densities in shale gas and oil extraction. This enables predictions indicating substantial economic and other benefits to some Karoo towns from shale gas extraction. These benefits have to be weighed against potential detrimental impacts of gas extraction in order to seek possible win-win solutions.

Chapter 5 – In 1978, several observatories, aiming ecological monitoring, were settled in the arid high plains of South west Algeria. These observatories are now integrated in an international network called ROSELT (Long Term Ecological Monitoring Observatories Network) administered by the OSS (Observatory of the Sahara and the Sahel). A study area included in one of these observatories was monitored on more than thirty years. It is part of Algerian steppe, the most widespread of the Maghreb. The results showed that this area has undergone profound changes.

These modifications concerned both physical and biological components. The parameters considered include vegetation, flora, and soil surface properties. It appears that land cover has changed and former vegetation dominated by *Stipa tenacissima, Lygeum spartum* and *Artemisia herba alba* has disappeared. New species, like *Atractyis serratuloides, Salsola* *vermiculata* and *Noaea mucronata*, rare in 1978 are now dominant, in relation with a dynamic of degradation. The largest decline is observed for *Stipa tenacissima* vegetation units constituting 2/3 of the landscape in 1978 and occupying just 1/10 in 2010. The vegetation cover has also significantly declined. In 1978, the average coverage was over 34%, whereas now it is less than 19% of the total. The biodiversity has also changed. The floristic richness has decreased. In 1978, 234 species were inventoried in the study area, for 134 in 2005 and only 94 in 2011. On the other side, the family composition and phytogeographical spectra have also changed, in the sense of an adaptation to xeric conditions. This can be explained by severe spells of drought combined by an exponential rise of livestock during the last 30 years. Finally, even if the last years were wetter and a slight improvement in vegetation cover was observed, there is no evidence for a desertification in reverse, as it is considered for the Sahel. On the contrary, we are still in a degradation process on the long term.

CONTENTS

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Chapter 1

LINKING SEMIARID-MOUNTAIN AGRICULTURE TO ENVIRONMENTAL BENEFITS AND ADVERSE IMPACT

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ABSTRACT

The soil erosion, runoff and nutrient-loss patterns were monitored in a mountainside with olive (*Olea europaea* cv. Picual) plantations under conventional and conservation agricultural systems based in two different soil management: 1) conventional tillage and 2) non-tillage with barley (*Hordeum vulgare*) strips of 4 m width, respectively. The erosion plots, located in Lanjaron on the southern flank of the Sierra Nevada Mountains in SE Spain, had 30% slope at an altitude of 565 m and 192 m^2 (24 m x 8 m) in area. The highest erosion rate of 3.5 t ha^{-1} was registered under conventional system and runoff of 11.4 mm under conservation system,

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over the entire study period (19 erosive events). The conservation system reduced the soil erosion by 69% with respect to the conventional system, and the runoff under conventional system in relation to conservation system by 54%. The total NPK fluxes by runoff from conventional system amounted to 2.87, 0.09 and 0.93 kg ha^{-1}, and from conservation system 1.57, 0.09 and 0.98 kg ha^{-1}, respectively. In general, the soluble average concentrations of plant nutrients (N-NO_3, N-NH_4, P-H_2PO_4, and K) in the surface runoff were higher than the recommended level for standard water quality for from conventional system. These findings support the recommendation of conservation agricultural techniques for semiarid and sloped agricultural land with rainfed-tree crops for erosion and pollution control.

Keywords: Semiarid agriculture, runoff; erosion; olive orchards, mountainous land; non-point source pollution

1. INTRODUCTION

Since ancient times the olive tree (*Olea europaea* L.) is the most widespread crop of the Mediterranean area, growing under rainfed conditions on marginal lands, due to its ability to adapt to drought that is mainly cultivated in shallow, stony, and steep soils.

According to the FAOSTAT (2015), the olive tree covers a surface area of about 9.5 Mha in the world, of which more than 2 Mha of olives are grown in Spain. Concretely more than 75% of olive area is located in Andalusia (S Spain), where many orchards are confined to slopes or rugged land, and under different production systems (de Graaff et al. 2008).

The widely spaced olive trees on slopes combined with poor vegetation cover of the soil increases the vulnerability of the orchards to soil erosion (Panagos et al. 2015; Taguas and Goméz, 2015). Also, in this areas water is the most limiting resource, where the climate is typically characterized by high potential evaporation and low and highly variable rainfall during the growing season. Consequently, measures to control the soil erosion and runoff are crucial in order to mitigate these negative effects produced during the rainfall storms (Durán et al. 2011).

The traditional tillage can induce roughness and may have serious impact on runoff and erosion patterns, many olive orchards have used this technique in order to reduce the competition between trees and weeds for water uptake. There are various reports concerning the impact of soil management on soil erosion in olive orchards in Mediterranean zones (Hernandez et al., 2005; Gómez et al. 2009a, Palese et al. 2014), however, the results are contradictory due to the diverse set of environmental conditions considered.

Conservation agricultural techniques include: non-tillage combined with mechanical weed control; reduced tillage with or without weed control; and a cover crop sown in the autumn and killed with herbicides in the spring (Maetens et al. 2012). In such an environment, cultivating plants in strips running across the slope can lessen the erosion by reducing runoff and breaking up its trajectory over sloping lands, thus, unnecessary runoff losses are minimised by promoting its infiltration in the soil matrix (Durán et al. 2009).

The release of plant nutrients from soil and their transport in runoff, as is the case of agriculturally applied NPK, may affect the quality of the water bodies receiving these effluents, especially in areas that are located in lowlands (Ordoñez et al. 2007; Gómez et al. 2009b). Mountain agriculture for olive production involves fertilization, often applying more nutrients than required by crop; this excess could be contributed to environmental pollution, especially from runoff.

Nitrogen fertilizer is regarded as the main contributor to $N\text{-}NO_3$ losses by runoff that depends on drainage, the relative rate of plant uptake, and several N-transforming processes such as mineralization, immobilization, nitrification and denitrification. In contrast to the high capacity of $N\text{-}NO_3$ to transport, phosphorus $P\text{-}PO_4$ is rapidly retained as insoluble inorganic compounds and sorbed to soil particles, being the losses in surface runoff tend to be quite low. Potassium (K) is an essential plant nutrient in fruit production, and therefore olive growers, tend to apply heavy amounts of this element to encourage good-quality fruit and to boost the foliar content in K-deficient orchards.

The objective of this work was to compare the effects of two agricultural systems in steeply sloping areas on soil erosion, runoff, and plant-nutrient transport under the experimental conditions of Lanjaron (Granada, SE Spain). Concretely, conventional and conservation agricultural strategies in olive orchards based in two soil-management systems: 1) conventional tillage and 2) non-tillage with barley (*Hordeum vulgare*) strips of 4 m width, respectively.

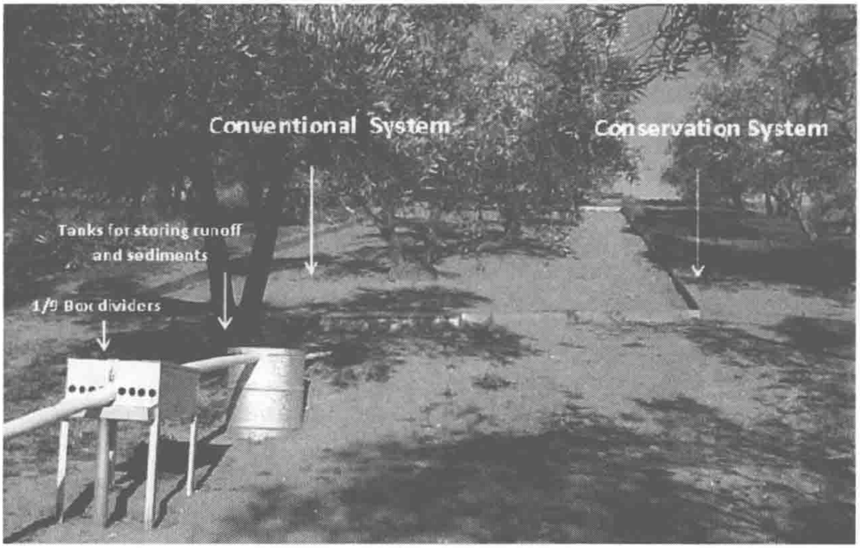

Figure 1. Runoff-erosion plots used for the experiment in Lanjaron (SE Spain).

Table 1. Production systems used in the study

System	Soil management	Cultural operations			
		Winter	**Spring**[1]	**Summer**	**Autumn**[1]
Conservation	Non-tillage with barley strips	Weed control between strips with pre-emergence residual herbicide, diuron (1 kg ha^{-1})	Chemical kill of barley strips (mulch of barley straw)	None	Mouldboard ploughing to 5-cm depth. Sowing of barley in strips of 3 m wide (180 kg ha^{-1})
Conventional	Conventional tillage	None	Mouldboard ploughing to a depth 15 cm	None	Mouldboard ploughing to a depth 15 cm

[1] Fertilizer (N) by broadcasting in spring; [2] Fertilizer (NPK) by broadcasting in autumn. Fertilizer in the form of 15-15-15 NPK at a nominal rate of 453.2 kg ha^{-1} and urea 301.5 kg ha^{-1} yr^{-1}.