Geomatics in the Assessment and Sustainable Management of Mediterranean Rangelands – The GeoRange approach

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Abstract

After a long history of utilisation, large areas of Mediterranean rangelands are today affected from transitional processes that cause conflicts between past and present land uses or economic and ecological priorities. Heavy overgrazing or the accumulation of woody biomass triggered by the abandonment and undergrazing, are causing substantial management problems. Often aggravated by physical factors, the depletion of range resources, or the increasing frequency and severity of wildfires have become a major concern in the environmental policies all over the European Mediterranean countries.

The GeoRange project pursues an integrated approach of experts in range ecology and management, ecosystem conservation and restoration, remote sensing and spatial information systems (Geomatics). With the direct involvement of responsible land managers, it aims at formalising concepts and strategies for multi-functional range assessments and the design and implementation of management plans, based on a dedicated software environment that includes range-specific remote sensing and GIS-related processing modules for end-users.

The project results in the implementation of techniques and tools to evaluate the current condition of rangelands and define scenarios under consideration of the multi-functional use of Mediterranean rangelands. Here, the integration of inter- and intranet-based information technology is a major step towards providing non-experts with a fast and efficient means to update their spatial databases with processed datasets.

Ultimately, a sustainable use of Mediterranean lands is expected to lead to a unique mosaic of land-uses, thus ensuring maximum landscape diversity, and allowing for the production of a wide range of goods and services such as forage, timber, fuelwood, agriculture, recreation etc., while at the same time preserving biodiversity and wildlife habitats.

Keywords: Mediterranean Rangelands, geomatics, management, ecology, restoration.

1. Introduction – Problems to be solved

Since historical times, the lands of the European Mediterranean have been strongly utilised. The history of livestock grazing of cattle, sheep and goats began in early Holocene, when it replaced the precedent wild herbivores to a large extent, and has been a common and traditional practice in the Mediterranean region ever since (Papanastasis 1998). In combination with physical factors this utilisation frequently caused degradation processes, which in some areas coincided with a substantial loss of

biodiversity. Beside grazing, fire is and has always been a major factor in shaping rural landscapes in the Mediterranean area. Again, the fire phenomenon is closely related to land use and other human activities.

Large areas of Mediterranean rangelands are now affected from transitional processes that cause conflicts between past and present land uses or economic and ecological priorities, i.e. between optimised productivity and ecosystem conservation. Heavy overgrazing or the accumulation of woody biomass triggered by the abandonment and undergrazing, are causing substantial management problems. Often aggravated by physical factors, the depletion of range resources, or the increasing frequency and severity of wildfires have become a major concern in the environmental policies all over the European Mediterranean countries, as well as in other parts of the world. In addition, new qualities are demanded from rangelands, such as preserving their ecological value, biodiversity, recreational and esthetical values. Furthermore, policies affecting rangeland management are often oriented towards specific targets, thereby causing problems to other functions. So have policies to promote grazing sometimes provoked land degradation by overgrazing, fire prevention measures (i.e., clearing) may be in conflict with ecosystem conservation, massive afforestation may negatively affect biodiversity, or even counteract fire prevention measures. Given their spatial extension, their economic and ecological importance as well as their vulnerability to various disturbance regimes, it becomes clear that an improved management of rangeland resources, where both development and conservation/restoration objectives are considered, becomes increasingly important. It is our hypothesis that these problems require an integrated approach that adequately considers the multi-functionality of Mediterranean rangelands that in the Mediterranean Basin, the majority of the land surface be considered as rangelands. In contrast to other parts of the world, Mediterranean rangelands are much more interwoven with cultivated areas, and there are a variety of highly heterogeneous ecosystem types.

Such an approach must refer to spatially differentiated and up-to-date environmental data (biomass and vegetation structure, soil characteristics, socio-economic, legal and political boundary conditions) to efficiently support the design and implementation of multi-functional range management concepts that meet the requirements of local administrative bodies. Obviously, such massive amounts of spatial information (geo-data) require adequate processing and analysis capacities. While the only way to obtain environmental information on a European scale is to employ remote sensing satellites, the only way to achieve their integration with other base data, to analyse and present the information derived therefrom, is by using Geographic Information Systems (Star et al. 1997).

Based on conceptual research and specific field studies, the GeoRange Project aims at creating an efficient documentation, management and decision support environment, dedicated to the specific needs of rangeland ecologists, managers and conservationists. To cope with these objectives, the system must be capable to support a thorough assessment of range conditions (mainly based on data from earth observation satellites), to assist in the identification of physical and socio-economic factors driving ecosystem processes, and to efficiently support the design and implementation of multi-functional range management scenarios that can meet the requirements of local administrative authorities. Beyond the technology aspects, such a data processing and assessment environment must incorporate the expert knowledge of range ecologists and managers, as well as the expertise of specialists in landscape conservation and restoration.

2. The GeoRange Approach

The science and technology of gathering, analysing, interpreting, distributing and use of geographical information is frequently summarised under the term “Geomatics”. It is for this reason that the project, which intends to combine satellite remote sensing, spatial analysis concepts and GIS (Geographic Information Systems) technology, has been paraphrased GeoRange.

The GeoRange approach is explicitly based on an adequate consideration of the multi-functionality of Mediterranean rangelands by integrating specialists from different fields. Based on conceptual research and specific field studies, the project aims at creating an efficient documentation, management and decision support environment, dedicated to the specific needs of rangeland ecologists, managers and conservationists who are also involved in the project.

2.1 Objectives

This approach comprises five major objectives:

•The assessment of the current range condition and range health by establishing a rule-base incorporating state variables and related indicators to be derived in the project.

•Retrospective analyses of range development to understand how ecosystems have responded to previous management efforts or changing determinants.

•The efficient organisation, integration, visualisation and distribution of spatial and non-spatial data through a customised GIS-environment and an Internet-based user interface.

•The synthesis of the accumulated expertise on driving factors and past developments resulting in site-specific scenarios for sustainable management of rangelands aiming at a reconciliation between ecological and economical interests.

•The development of a dedicated *"Data Processing and Analysis Environment"* enabling end-users to monitor the impact of new management strategies and continually revise scheme by updating their spatial databases with recent data.

2.3 Study sites

The respective study sites were chosen having regard to different environmental and socio-economic settings as well as to incorporate areas, where rangelands are of major importance in the European Mediterranean: one pilot area in the Region of Valencia (Spain), one in Sardinia (Italy), and one in Macedonia (Greece).

The Region of Valencia (eastern Spain) is one of the most affected by wildfires in Spain and in the Mediterranean basin (Vallejo and Alloza 1998). Within a context of fire-prone weather, extensive marginal land abandonment, including what we could consider undergrazing, has led to large fuel accumulation and the development of extended and continuous combustible lands over the landscape. In this region, successive management plans have been launched, trying to reduce fire hazard and to restore burned lands. The pilot area is located in the vicinity of Ayora (Valencia), where the fire incidence in 1979 led to an ambitious Fire Management and Reforestation Plan by the Spanish Ministry of Agriculture, that was partially implemented in the following years. The total surface area considered is 360 km2. This area is representative of large marginal lands affected by wildfires in Valencia and neighbouring regions.

Sardinia is among the regions in the Mediterranean where the landscape is predominantly characterised by rangelands (>50% of 2.4 Mio ha), of which approx. 30% are public land. A good deal of them, are being left to common use by rural communities. Fire setting for shrub removal by shepherds is still common practice leading to high fire frequency in semi-natural Macchia and Garrigue. The test site covers an area of approximately 2000 km^2 in NW-Central Sardinia. Pastoral activities are by far the most important land use, imposing heavy grazing pressure on wide areas mainly through sheep (1994: 4.300.000), but also goats and locally pigs. Recent practice to increase forage, including the removal of shrubs on pastures by regular deep ploughing, sowing of herbaceous species and irrigation of pastures, does not appear to be more sustainable than traditional burning.

The Macedonia study site is representative for the rangeland types, traditionally supporting the rural economy of the mainland of Greece. The grazing system is continuous with additional food in winter and movement of flocks to upper altitudes in summer. During the last years subsidies by the European Community for animal husbandry have favoured an increase in animal numbers and consequently heavier grazing. The degradation of rangelands has also contributed to the problem of reduction of water capacity of two adjacent lakes. The area has been chosen to fit to Lagadas County in order to link up properly with various existing statistical information connected to administrative boundaries. This will allow to keep a close contact with local authorities and potential end-users and to proceed in a better way to specific actions covering the various needs of the region.

2.4 Project Structure and Implementation

The GeoRange Project combines the expert knowledge of range ecologists and managers, as well as the expertise of specialists in landscape conservation and restoration with expert teams in remote sensing, GIS and geostatistics.

The Project is structured into several Project Components, which are closely connected (figure 1).

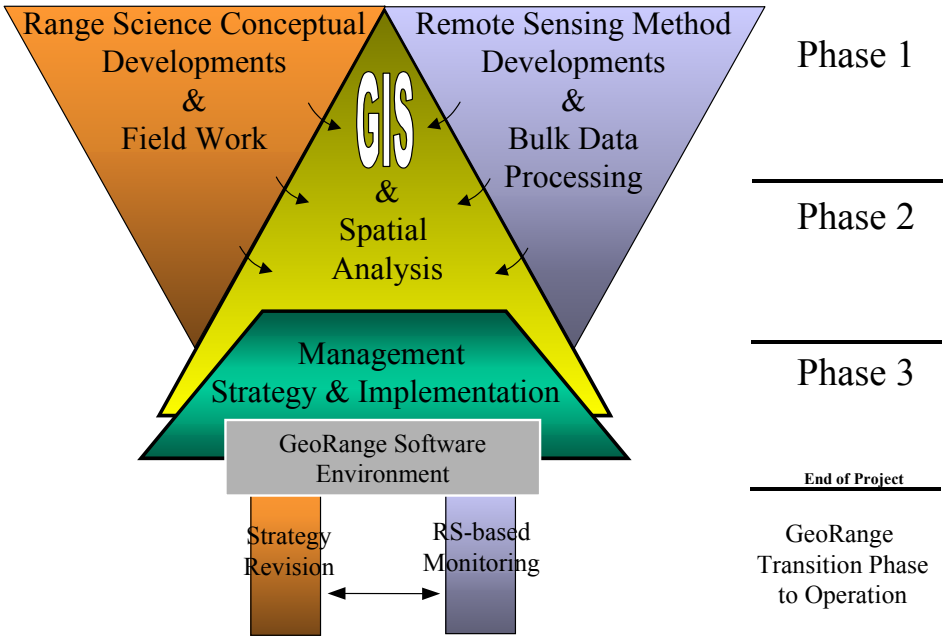

Figure 1. Thematic and temporal structure of the GeoRange Project

Embedded into conceptual-methodological research and the collection of specific field data on one side, and the acquisition, pre-processing and thematic analysis of large remote sensing data sets on the other, the major task will be the establishment of a prototype GIS for each of the three project sites, which are representative of substantially different rangeland problems (grazing optimisation, fire prevention and conservation, integrated watershed management). Figure 1 shows how the proportion of resources allocated to these activities will be changing through this development phase (project phase 1 and 2). In the implementation phase (phase 3), the major part of the work will concentrate on drafting and implementing optimised management concepts for the three site-specific scenarios. This phase will draw from the validation data sets and the conceptual and methodological achievements from phase 1 and 2, and is complemented by specific method developments to optimise the existing processing strategies. Thus, it will provide an ideal test bed for evaluating and finalising the "GeoRange Data Processing and Analysis Environment". This software package, which is then tested and evaluated under participation of the corresponding end-users, will be finalised and fully documented within the project, ready for being launched into a post-project transition phase to operational use.

The first three months of the GeoRange Project represented a mobilisation phase. Among the most important issues was the joint evaluation of the theme-oriented researchers, to develop the conceptual model for assessing rangelands (figure 2). Here, target rangeland functions and the related management activities were identified, and indicators of range condition that allow the evaluation of these activities were chosen.

Within GeoRange Phase 1, much of the work is devoted to primary data acquisition, the compilation of spatial data bases and the standardised processing of large volumes of remote sensing data.

The theme-oriented research teams will launch specific field data collection and mapping exercises for the different sites, needed for verifying some of the criteria and indicators. The additional fieldwork will be the basis upon which existing information is updated and complemented. Special emphasis will be placed on establishing a close link between field measurements and satellite data, where the field teams will be supported by the RS/GIS-oriented research teams who will collect spectral information on the predominant surfaces, that can complement information, already available in spectral libraries such as MedSpec.

In the second phase of the GeoRange project the level of integration is further increasing: a central data server will be installed to support the collection, management and distribution of geo-information layers. On top of this informatics structure an Internet Map Server will be implemented to allow for interactive browsing of remote sensing and map data from all GeoRange sites. This front-end capability will be based on standard GIS-packages with a customised graphical user interface to support easy access to the information and associated meta-data. It serves two major issues: first, through the online-

evaluation of data sets, project partners will be able to efficiently retrieve any data set needed for use in their local GIS environment, without necessary multiplying all data for all partners. In a second step, nodes will be created at the theme-oriented research teams in the GeoRange sites to provide data access for the end-users.

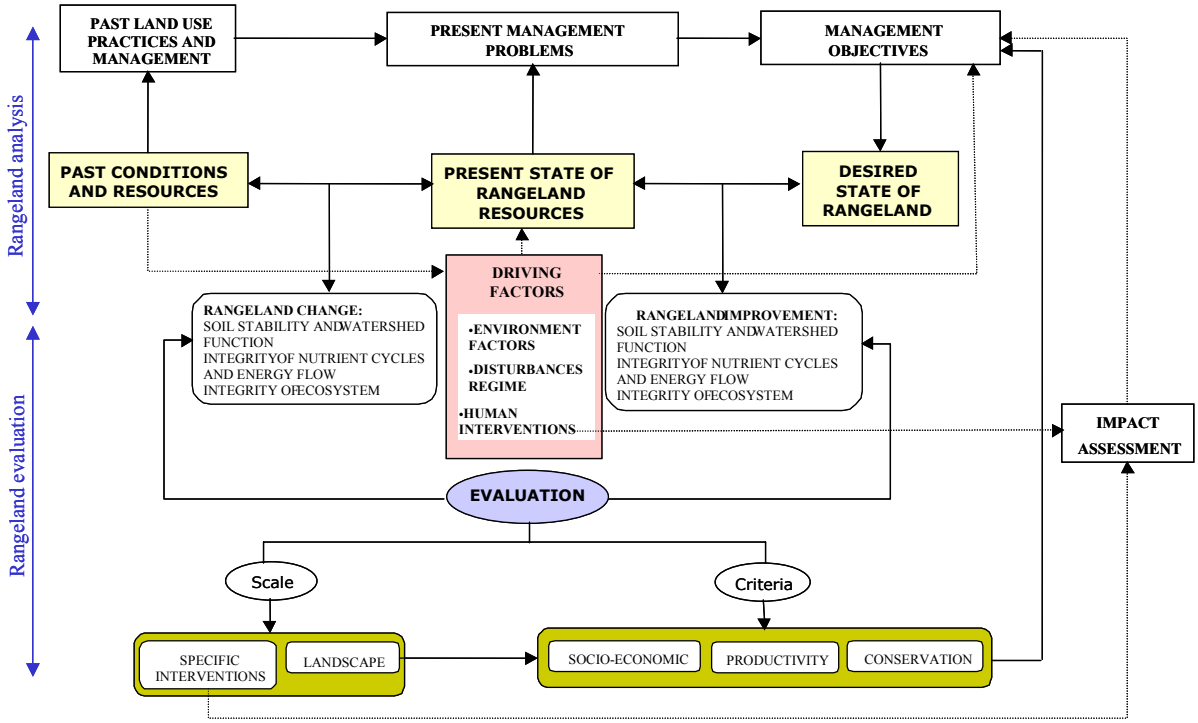

Figure 2: GeoRange conceptual framework.

The third phase of the project mainly tends to consolidate and further integrate intermediate results and products achieved or made available so far. Parallel, the RS/GIS-oriented research teams jointly develop an additional research component which aims at further improving and optimising remote sensing inputs to range condition assessments. At the community level, range condition is evaluated with regard to conservation criteria such as biodiversity, cover, Leaf Area Index (LAI), litter and soil factors, as well as to productivity criteria such as amount, distribution, availability and forage quality of biomass. At the landscape level, it may be evaluated with diversity, dominance and patchiness including number, area, perimeter, regularity and complexity of patches (Farina 1998).

While it was decided to build the operational satellite assessments of range conditions (in phase 2) largely on semi-empirical, i.e. operational, approaches, it is considered important to more closely investigate the potential of deriving vegetation parameters directly from the inversion of applicable canopy reflectance models. Here, close collaboration between all partners (including end-users and institutional partners) is foreseen to ensure that alternative options are also evaluated and suggested to the respective decision-makers. With regard to the time that has already elapsed since the acquisition of satellite data, it is planned to complement the existing data bases with up-to-date satellite imagery and the derived variables.

3. Conclusion

The **GeoRange** Project identifies changes that may lead to, or already have resulted in, loss of biodiversity, loss of habitats and of fertile lands. By assessing the factors that are responsible for these changes, and by finding ways to assess lands under investigation with respect to different potential uses,

the project also lays the basis for mitigating effects of land degradation or loss of biological value, for restoring disturbed lands, or the conservation of precious eco-topes or habitats.

The integration of the knowledge of specialists in different fields of science with the demands of land managers and policy makers puts a focus on the European dimension of rangeland management, and supports the competitiveness of European research in this field. It will help respond to obligations arising from the ratification of international treaties and agreements aiming at the restoration and preservation of a healthy environment for future generations, such as the U.N.-CCD, the Convention on Biodiversity, and various other conventions related to the U.N. Conference on Environment and Development.

The project will result in the implementation of techniques and tools to evaluate the current condition of rangelands and define scenarios under consideration of the multi-functional use of Mediterranean rangelands. Here, the integration of inter- and intranet-based information technology is a major step towards providing non-experts with a fast and efficient means to update their spatial databases with processed datasets.

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References

Farina, A. 1998. Principles and Methods in Landscape Ecology. Chapman & Hall LTD: Cambridge.

Papanastasis, V.P. 1998. Livestock grazing in Mediterreanean ecosystems: αn historical and policy perspective. *In* Ecological basis of livestock grazing in Mediterranean ecosystems, pp.5-9. Proceedings of the International Workshop held in Thessaloniki (Greece) on October 23-25, 1997. Edited by Papanastasis, V.P. and Peter, D. Office for Official Publications of the European Communities: Luxembourg.

Star, J.L. Estes, J.E. and McGwire, K.C. 1997. Integration of geographic information systems and remote sensing. Topics in Remote Sensing 5. Cambridge University Press: Cambridge.

Smith, M.O. Ustin, S.L. Adams, J.B. and Gillespie, A.R. 1990. Vegetation in deserts: I. A regional measure of abundance from multispectral images. Remote Sensing of Environment 31: 1-26.

Vallejo, V.R. and Alloza, J.A. 1998. The restoration of burned lands: The case of eastern Spain. *In* Large forest fires, pp.91-108. Edited by J.M. Moreno. Backhuys, Leiden.