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An integrated information system to support research on soil erosion mitigation techniques after forest fires

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Resumo: O RECOVER almeja desenvolver técnicas mitigadoras e estratégias para a redução da degradação do solo e da água imediatamente após os incêndios florestais. A frequência dos referidos incêndios florestais tem vindo a aumentar, fruto das mudanças climáticas e do deficiente planeamento florestal, com severos impactes ao nível da fertilidade e estrutura dos solos. Como consequência aumenta a erosão da camada superior dos solos, onde se localizam, na maioria dos solos portugueses, os únicos nutrientes existentes. Esta mobilização de nutrientes ocorre nos primeiros eventos chuvosos outonais, e, como tal, a exportação dos sedimentos e dos nutrientes acontece normalmente nos primeiros 4/6 meses após os incêndios. A velocidade a que a perda de cada nutriente ocorre e a extensão dos incêndios florestais é uma condicionante em termos de custos e baliza as soluções que se podem implementar para a redução da degradação do solo e da água. O RECOVER testará um conjunto de soluções praticáveis de forma a reduzir a lavagem das cinzas. A metodologia proposta apresenta uma integração inovadora de técnicas quantitativas de campo e irá proceder a análises de percepção junto de todos os intervenientes no planeamento florestal. Tal abordagem é essencial para a produção de soluções passíveis de se colocar em prática que poderão ser facilmente adoptadas pelos planeadores florestais bem como pelos proprietários florestais. Este projecto apresenta uma abordagem inovadora baseada em levantamentos de campo das propriedades do solo e da vegetação após a ocorrência de incêndios florestais, cujos resultados serão usados para a construção de uma base de dados em ambiente SIG, que servirá para identificar os locais críticos. A implementação de um sistema de informação integrado (conjugando uma base de dados espacial, um servidor de mapas e software SIG) permitir-nos-á armazenar os dados recolhidos no campo bem como a informação produzida através da análise espacial desenvolvida. Esta informação estará disponível através de um portal Web-SIG, complementado com informações para os produtores e todos os outros agentes envolvidos na gestão florestal.

Abstract: The project RECOVER aims to develop mitigation techniques to reduce soil and water degradation immediately after forest fires. Forest fires are becoming increasingly frequent as a result of climate change and poor forest planning, with deleterious impacts on soil fertility and structure. It erodes the top soil layers, where is located the only nutrient pool of the majority of Portuguese soils. This nutrient mobilization happens during the first autumn rainfall events, and therefore sediment and nutrient exportation typically occurs in the first 4/6 months after fire. The speed at which nutrient loss occurs and the extension of forest fires, limits in terms of costs and logistics the solutions that can be taken to reduce soil and water degradation. RECOVER will test a set of feasible solutions to reduce ash flush. This is essential to produce feasible solutions that will be easily adopted by forest managers and forest owners. RECOVER presents an innovative approach based on field surveys of soil and vegetation properties following forest fires, which will be used to perform a GIS database from which the critical spots will be identified. The implementation of an Integrated Information System (integrating a spatial database, a map server and GIS software) will allow us to store the data collected in the field as well as the information produced through the spatial analysis. This information will be available in a web-GIS portal, complemented with information to producers and all other agents evolved in the forestry management.

Palavras-Chave: Incêndios florestais, Degradação e recuperação do solo, IDE, Base de dados espacial, Modelação SIG.

Keywords: Forest fires, Soil degradation and recovery, SDI, GIS database, GIS modeling.

1. Introduction

The RECOVER (Immediate Soil Management Strategy for Recovery after Forest Fires) project aims to develop mitigation techniques and strategies to reduce soil and water degradation immediately after forest fires. Forest fires are becoming increasingly frequent as a result of climate change, socio-economic change and unsuitable forest planning, with adverse impacts on soil fertility and structure. One of the most important is the erosion of the top soil layers, where is located the 'nutrient pool' of the majority of Portuguese soils (Bento-Gonçalves *et al.*, 2008). This nutrient mobilization happens during the first autumn rainfall events, and therefore sediment and nutrient exportation typically occurs in the first 4/6 months after fire. The speed at which nutrient loss occurs and the extension of forest fires, tend to limit, in terms of costs and logistics, the

solutions that can be taken to reduce soil and water degradation.
RECOVER will test a set of feasible solutions to reduce ash flush. The proposed approach presents an innovative integration of field measurement techniques and will perform a perception analysis to all those with responsibilities in forest management. This is essential to produce effective solutions that will be easily adopted by forest managers and forest owners.
To manage all data produced during the project (fieldwork and data analysis) will be implemented an Integrated Information System (that includes a spatial database, a map server and other geographical data management tools) that will allow us develop several spatial analysis and to disseminate the results of this project. This is the task that will be developed by the NIGP (University of Minho).

2. Objectives

The aim of this work is to present the methodology applied in the implementation of an Integrated Information System with GIS technology, wich will allow the share of information between the research teams and the development of a geomorphologic process model using GIS tools for determine soil loss critical areas.
The ultimate goal is to produce a tool that allows, to those with responsibilities in managing burned areas, the identification of the critical areas where interventions must be made to obtain the best conservation results at the lowest price, which will have a significant impact on soil conservation, vegetation recover, and therefore on ecosystem functioning. It will also reduce significantly the downstream impacts of ash wash.

3. Methodology

Since the start of the project (2007) and during the years of 2007 and 2008, there were no large or high intensity forest fires in central Portugal, condition for the normal development of this project. To overcome this problem, the solution was to choose an area in monitorization for a long time: Vale Torto catchment (Penedos de Góis) in Açor Mountain. It's a small (8,9 ha) schist and quartzite catchment, covered by shrubs and located in the municipality of Góis, Coimbra.
The project includes an initial phase of collecting and processing information related to the variables identified for the study and defining the data model to implement and organize the spatial database.
The survey (Fig. 1) of the study area (Fig. 2) allowed its three-dimensional modeling and the establishment of a surface runoff/flow modeling.
Also the land use and soil components (structure, texture, moisture, porosity, etc.) characterization, at the slope scale, as well as forest fires factors analysis (intensity, recurrence…), will be used and integrated in the geographic database, allowing the definition of the variables required in the model.
The modeling process of environmental variables has been developed following the need to make explicit its spatial component. Thus, it has been preferred the integration of GIS technology, due to its ability to integrate such models, as well as its efficiency in managing and analyze large amounts of information and, above all, for their capacity to relate this information based on their spatial expression.
Given the intimate relationship between geomorphological processes and the area in which they trigger, we consider it appropriate to apply the methodologies of modeling provided by GIS spatial analysis of erosion processes operated in the aftermath of forest fires.

Figure 1 - Study area survey.

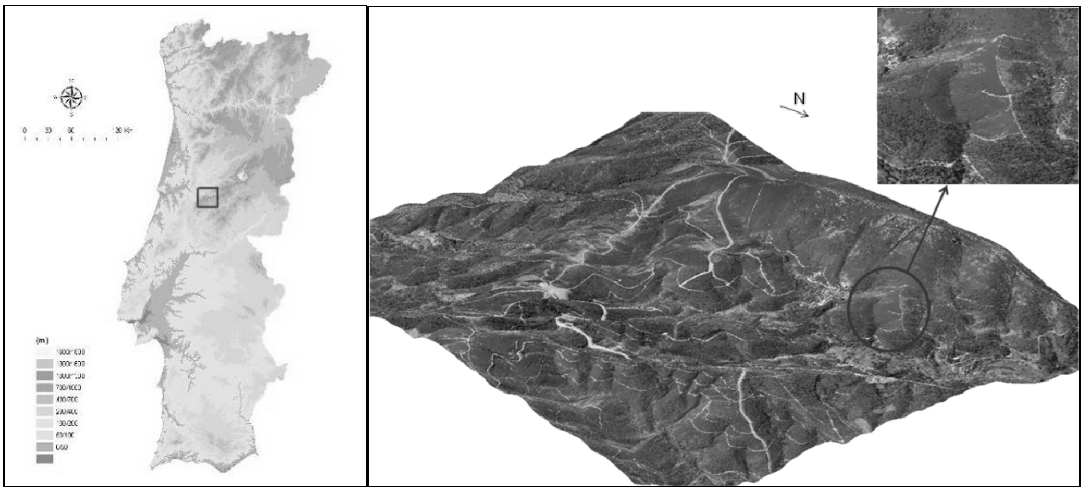

Figure 2 - Study area – Vale Torto (Penedos de Góis) in Açor Mountain.

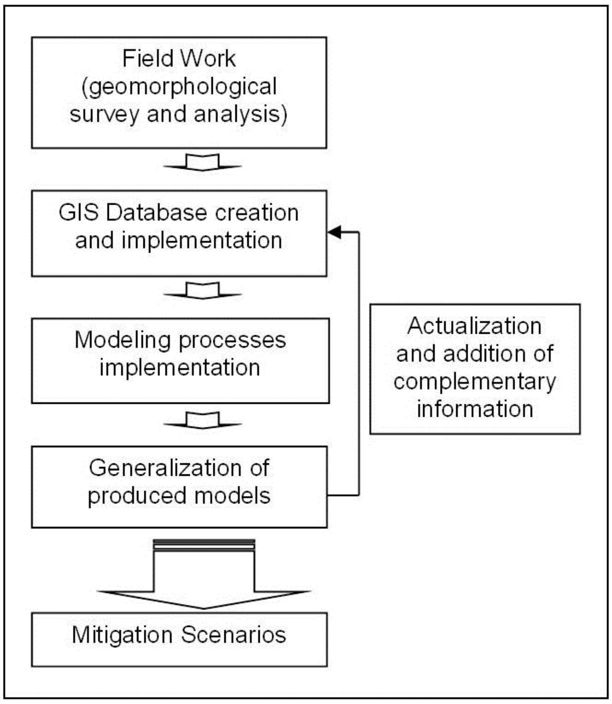

Figure 3 – Scheme for modelation process implementation (Vieira *et al.*, 2009).

Thus, following the installation and monitoring of erosion plots in various sectors of the slope in mountain areas occupied with production forest in central Portugal, will be produced a wide range of information concerning several parameters which combine to the genesis of the erosive geomorphological dynamic mentioned above.

In this sense, the development process of modeling these same variables will allow the measurement of possible interrelationships between them and the definition of behavior standards that can lead us to a predictability of those processes, in order to determine the validity and effectiveness of remediation techniques, however, implemented during the project.

The implementation of the modeling process, conducted with the use of technology in geographic information systems (GIS), will be based on information gathered, its validity and reliability, which is stored and structured in a database integrated in the GIS.

Information included in the geographical database (Fig. 3) will allow the development of a variety of modeling operations, initially targeting the study-plots, allowing the drawing of predictive scenarios.

Modeling results are then generalized to the slope in order to ascertain the validity of extrapolating data and the ability to produce useful trend indicators for decision-making, in terms of appropriate techniques to mitigate erosion on burned areas.

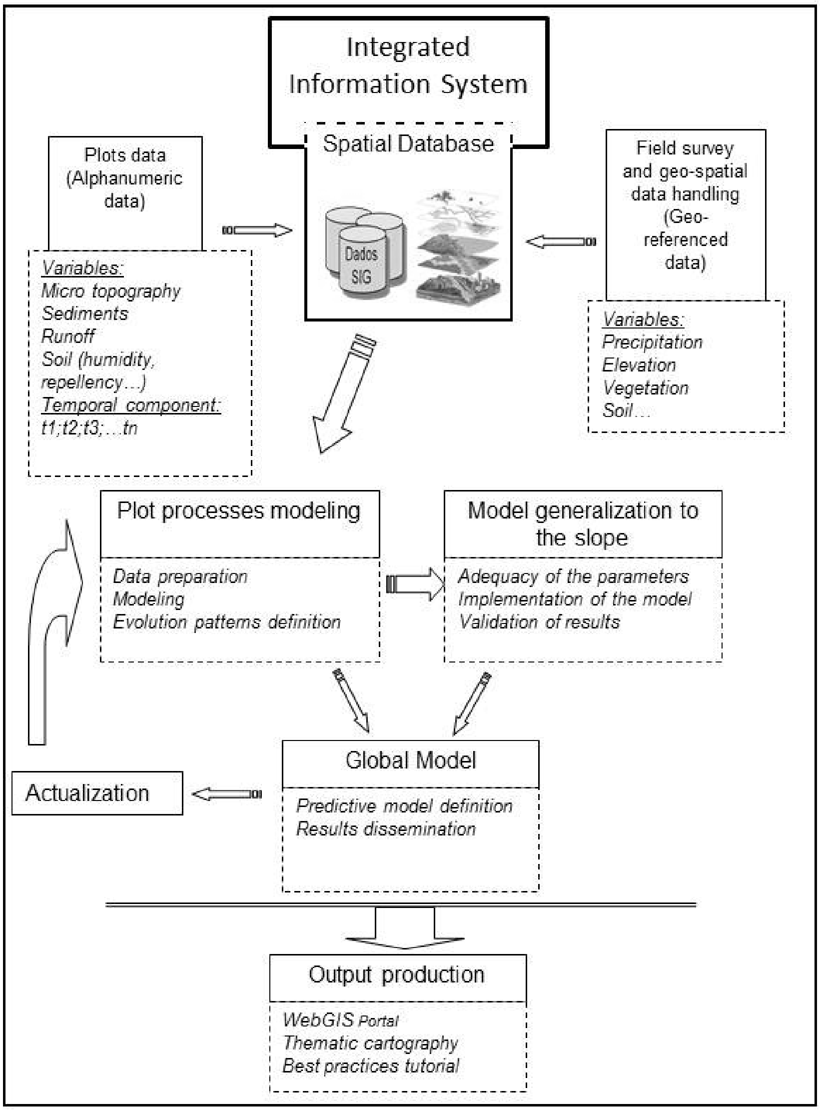

Figure 4 – Conceptual scheme supporting the implementation of the geomorphological modeling process (Vieira *et al.*, 2009).

The modeling process (Fig. 4) incorporates an early phase of collecting and processing information concerning the variables identified for the study, as well as the definition of the data model to implement and the structuring of the geographic database that will store data, framed in the terms of SDI (Spatial Data Infrastructure) that will support it.
SDI implementation should allow easy sharing of geographical data and resources (services), in order to tackle poor access to data. Adequate implementation and coordination with other SDI should allow, likewise, to address the problem of excessive amount of data often duplicated by various SDI.
An SDI creation process must take into consideration some assumptions in terms of objectives, nature and principles, so that a structured and sustained implementation of the SDI can be carried out (Afonso, 2008).
An effective SDI RECOVER implementation is supported by a set of components consistent with the objectives established: institutional structure, regulatory framework, technology, data policy, data, metadata, services, and people. In this paper, we will emphasize the technology component.

3. Results

The implementation of a SDI is a key factor for the development of RECOVER project, because it will allow greater interaction between project research teams, and the consequent sharing of data, making it available for the spatial modeling processes required to identify critical areas of risk of soil loss.

Hence this SDI incorporates a set of technological articulation, of which stand out those related to Geographic Information Systems.

RECOVER SDI features a set of technologies involving different areas:

- in terms of storage, physical infrastructure and software used are considered. Data produced within the project will be fully stored on LASICS GIS servers; servers of institutions where relevant spatial information or reference data is stored are also considered.

Regarding storing and data management software, an DBMS-OO was implemented. This database incorporates a spatial extension (PostgreSQL / PostGIS), which is essential for storing and managing data with spatial components (elevation data, lithologic maps, land use maps, among other), alphanumeric data relating to elements monitored in the study areas and other information produced within the project;

- regarding geographic information processing technology, in addition to the peripheral devices for capturing data, integration, manipulation and data analysis tasks will be performed by GIS applications, mainly opensource.

Despite the diversity of available options, preference was given to QuantumGIS software, for its friendly interface, its robustness and the large number of spatial analysis tools available. It also displays high degree of integration with other software used in SDI, particularly with DBMS-OO PostgreSQL/PostGIS and MapServer;

- in terms of metadata production and management, an high reputable performance application was used, also opensource. The Geonetwork is a data catalog with links to the Web, so those interested in information, can view data on the Web and at the same time, query components, which are essential for its correct metadata. It's a software with a Web link that contains information / metadata about the database. This software allows information producers to edit, enter and share their metadata and users to view it on internet (posted online through Web Services), enabling various entities to share information concerning the subjects geo-referenced online;

- technologies for providing 'Web Services' also used opensource softwares, widely disseminated and ensuring high operability.

The choice fell on MapServer, an opensource software used as a development platform for building spatial applications.

When data possess the appropriate conditions to be displayed on the Web, the web map viewer allows online users to access to spatial data (thematic maps, satellite pictures), to its vector data and corresponding metadata.

This service allows the management of map elements (such as displayed elements, scale, legend), the production of thematic maps based on logical or regular expressions (eg by running 'Queries' in rasters, vector layers and databases), identification of information layers, development of information layers, amongst other, allowing work on various platforms (such as Linux, Windows, etc.) and with information in various matrix and vector formats (such as: TIFF / GeoTIFF, EPPL7, and others through ESRI Shapefiles, PostGIS, ESRI ArcSDE, etc.).

The diagram below provides a simplified way to check the structure (in technology terms) designed for the SDI RECOVER.

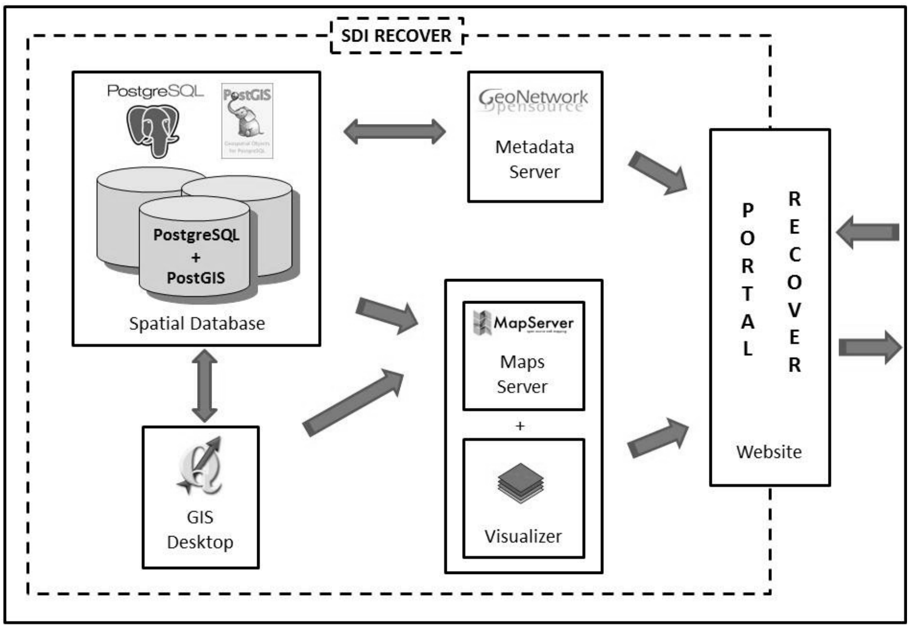

Figure 5 - SDI RECOVER structure (Vieira *et al.*, 2009).

4. Conclusions

The RECOVER (Immediate Soil Management Strategy for Recovery after Forest Fires) project, carried out in cooperation between research units of University Aveiro, University of Minho and Escola Superior Agraria de Coimbra, considered essential to implement a Integrated Information System whose main objective is the development of mitigation techniques and strategies to reduce soil and water degradation immediately after forest fires occurrences.

High data production, the need of its adequate structuring and analysis as well as the sharing process between the various RECOVER project teams, led to the implementation, previously identified, of an Integrated Information System (an SDI) allowing an efficient management of geographic or non-geographic information.

The main objective of SDI is the integration of a wide range of information concerning soil and other factors and processes monitored in terms of erosive geomorphological dynamics and make them available for analysis in a GIS environment in order to contribute to better decision making processes namely in what concerns choosing the type of mitigation measures to be applied in post-fire, to reduce, at the lowest price and the most effective way, soil degradation caused by the early rainfall events after the fire.

Based on the information produced by the RECOVER research teams and with the physical support provided by LASICS infrastructure, SDI RECOVER was structured, observing a set of structural, normative and technological assumptions, indispensable for its effective implementation.

The SDI physical structure was assured by the integration of a spatial database, in which PostgreSQL 8.4 software and a PostGIS 1.1 extension were used, granting increased spatial data management skills.

A metadata server was also integrated, using Geonetwork software, to provide information about the data produced and published in the SDI, thus fulfilling the ISO requirements and OGC relating metadata.

Another important component of this infrastructure is the map server: Mapserver software was the one selected. By providing a range of services related with the dissemination of spatial data, the RECOVER requirement related with the dissemination of results to society, particularly for those involved in forest and soil management, is fulfilled.

The integration of a GIS Desktop is an essential element in the structuring and linkage of the various components, making a decisive contribution to the management of geographic data and its interconnection with the map server. GIS Desktop is particularly crucial in spatial modeling and thematic map production processes.

Thus, one can draw a reliable structure to store, analyze and disseminate spatial and alphanumeric data, available from RECOVER web portal, where GIS technologies are a key element for an effective presentation of the geographical information produced.

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References

Afonso, C. S. P. V. 2008. Infra-estruturas de Dados Espaciais nos Municípios – Contributo para a definição de um modelo de implementação. Dissertação de Mestrado em Ciência e Sistemas de Informação Geográfica, Instituto Superior de Estatística e Gestão de Informação da Universidade Nova de Lisboa, 125 p.

Benavides-Solorio J & Macdonald LH, 2005. Measurement and prediction of post-fire erosion at the hillslope scale, Colorado Front Range. International Journal of Wildland Fire, 14, 457-474.

Bento-Gonçalves A. J., Vieira, A. A., Ferreira, A. D. & Coelho, C., 2008. Caracterização geomorfológica e implementação de um sistema integrado de informação, em ambiente SIG, no âmbito do projecto RECOVER (Estratégias de remediação de solos imediatamente após incêndios florestais". Revista Geografia Ensino & Pesquisa, V. 12, nº 1, Santa Maria, Rio Grande do Sul, Brasil, 3721-3735.

Bento-Gonçalves, A. J. & Vieira, A. e Ferreira-Leite, F. 2010. Mitigation of erosion after forest fires: a geomorphological approach based in GIS modeling. Actas das Jornadas Internacionales – Investigación y gestión para la proteccion del suelo y restauración de los ecossistemas forestales affectados por incêndios forestales, Santiago de Compostela, 111-114.

Coelho, C. O. A., Ferreira, A. J. D., Boulet, A. K. & Keizer, J. J., 2004. Overland flow generation processes, erosion yields and solute loss following different intensity fires. Quarterly Journal of Engineering Geology and Hydrogeology, 37, 3, 233-240.

Goodchild, M.F. *et al.* (Ed.), 1996. GIS and environment modeling. John Wiley & Sons, England. 504 p.

Loenen, B. 2006. Developing geographic information infrastructures. The role of information policies. DUP Science, Delft University Press, 390 p.

Longley, P., Goodchild, M., Maguire, D. & Rhind, D. 2004. Geographic Information Systems and Science. Wiley, 519 p.

Longley, P. & Batty, M. (Ed.), 1997. Spatial analysis: modeling in a GIS environment. John Wiley & Sons, England. 392 p.

Moffet, Correy *et al.* 2007. Modeling soil erosion on steep sagebrush rangeland before and after prescribed fire. Catena, 71, 218-228.

Shakesby, R., Ferreira, A. J. D., Ferreira, C. S. S., Stoof, C. R., Urbanek, E. & Walsh, R. P. D.. Wildfires in Portugal: characteristics, soil degradational impacts and mitigation measures. Desire.

Shekhar, S. & Chawla, S. 2003. Spatial databases. A tour. Prentice Hall. 262 p.

Thomas, A. D., Walsh, R. P. D. & Shakesby, R. A. 2000. Post-fire forestry management and nutrient losses in eucalyptus and pine plantations, northern Portugal. Land Degradation & Development, 11, 257-271.

Vieira, A. A. B., Bento-Gonçalves, A. J., Martins, C. O. & Loureiro, E. 2009. Sistema integrado de informação, em ambiente SIG, aplicado à erosão de solos na sequência de incêndios florestais. Geo-Working Paper, Série de Investigação 2009/20, Núcleo de Investigação em Geografia e Planeamento, Universidade do Minho.