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III Encuentro PRECOM³OS
DESAFÍOS de la CONSERVACIÓN PREVENTIVA
Seminario para estudiantes doctorales, expertos y gestores de sitios patrimoniales.

UNIVERSIDAD DE CUENCA
desde 1867

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A view on GIS-supported Preventive Conservation of World Heritage

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ABSTRACT:

Monitoring and planning processes related to land use management in a spatial context, considering spatial interaction over time, always necessitate complex human decisions. Spatio-temporal decisions are about evaluating alternative answers to a variety of questions that can be categorized as "how?", "when?", "how long?", "what?" and "what if?" questions. A decision in whatever planning process is a commitment to action, is goal specific and has to do with prediction of the future effects of the choices made. Some of the questions that guide spatial intervention planning can be answered using the analytical functionalities of standard GIS-software. However, when optimisation in the presence of multiple goals and criteria are at stake, spatial analysis needs to be complemented with adapted ranking and multicriteria evaluation techniques. In the last decades, worldwide efforts have contributed to a common language in spatiotemporal decision support. From the development of spatiotemporal decision support systems for forestry planning in South American and European context, a theoretical framework and a generic spatiotemporal Decision Support System (stDSS) generator tool were proposed. From this shared experience, the present short paper offers a view on the monitoring and planning needs as raised by the World Heritage City Preservation Management project vlir*CPM*, for human settlements in the Southern Andes of Ecuador. The main conclusion is that in order to define the requirements of decision support, practical goals and temporal scope must be very clear. Decision support system design, data management and complexity depend on proper formulation and stakeholder

consensus on the questions, values and criteria to be handled by planning support tools. No computerized decision support tool will replace multi-actor decision making and has to be complemented and integrated with expert knowledge, multidirectional communication flows and documentation in order to offer a flexible "toolkit" to those involved with planning goals and action.

1. INTRODUCTION

Antecedents

All around the world tools have been developed in the last decades in order to address the multiple challenges that present the spatial planning of land use changes or land allocation. Previous research has stressed the non homogeneity in space and time of land characteristics and land performance aspects, the diversity in user preferences and decision uncertainty as well as the existence of multiple, interdependent decision objectives (Chakroun & Bernie, 2005). Several studies describe the difficulties that rise when land use policies are elaborated, trying to take into consideration multiple objectives and spatio-temporal variability in an adequate way, as effective tools are lacking to address the decision questions involved (Matthews et al., 1999; Jakeman & Letcher, 2003; Roetter et al., 2005).

With the aim of contributing to the advancement of science dealing with spatiotemporal data modeling and decision support for land use planning, Wijffels et al. (2010) showed that Geographic Information Systems (GIS) can be expanded towards spatio-temporal Decision Support Systems (stDSS) for land use planning by incorporating (i) a knowledge and model base (KMB) for assessing the temporal evolution of land attributes under actual and potential conditions and (ii) a module for dealing with multi-criteria optimization questions. The conceptual framework proposed by Wijffels et al. (2010) is derived from research experiences dealing with sound decision making in forestry planning in the Southern Andes of Ecuador. A spatial decision support system was developed through the improvement of knowledge and assessment methods of the multiple impacts of forestation and through the integration of geographic information technology and Multiple Criteria Decision Making-techniques.

From the point of view that a GIS can be considered to be a spatio-temporal decision support system sui generis (Wijffels et al., 2010), it is obvious that standard GIS-technology can deal with quite some of the questions that rise in a land use planning process, in order to support spatiotemporal decisions. Most GIS packages have the capabilities for the generation of a set of decision alternatives, based on its query, spatial proximity and overlay analysis functions. Nevertheless, when conflicting criteria or objectives are evaluated, standard GIS softwares do not provide the analysis tools for choosing the "best compromise", nor provide functionality to rank alternatives, especially when there exist interdependency among multiple decision criteria.

From afforestation planning towards cultural heritage conservation management

In the Ecuadorian Andes and other tropical mountain areas, deforestation, related soil erosion and river sedimentation and loss of soil fertility are considered among the main environmental problems. Controlled afforestation has already shown to be able to contribute to the reversal of the trend of increasing land degradation (Bruynzeel, 2004). In this respect, spatial planners and managers and other stakeholders of afforestation projects require to a larger or lesser extent, support for selecting sites and choosing among alternative options for afforestation management with the idea of optimizing the effects of afforestation.

Tracing parallels between two apparently so different domains of decision making in time and space on the use, monitoring and management of "land units (sites)", aiming at the best "performance" possible, taking multiple evaluation (valorisation) criteria into account, we can observe that the Ecuadorian governmental instances that deal with world cultural heritage conservation face similar challenges to those confronted by decision makers in forestry planning processes. Heading at preventive conservation, monitoring and policy making, decision makers deal with choosing among alternative options for world cultural heritage management with the idea of optimizing the return of preventive monitoring and intervention in sites, building blocks, neighbourhoods, settlements or cities.

It is clear that a Preventive Conservation and Management Plan for World Cultural Heritage deals with complex spatial questions, such as "Which heritage sites (Where?) have the priority for preventive conservation, taking into account the present state of the sites and their heritage values as evaluated from an architectonical, archaeological, anthropological, historical, socio-economic evaluation perspective?" "On which heritages sites (Where?) direct conservation intervention is required, considering deterioration threats and vulnerability?" Also spatial interaction plays an important role, for example answering questions such as "How to intervene in world heritage sites within a certain distance of an emergent building and with a high horizontal visibility, in order to prevent a deterioration of the heritage and socio-cultural values of the emergent building".
Also various time aspects are tangled, such as "When to pass from preventive conservation to reactionary (or direct) conservation interventions, taking into account heritage values and deterioration risks?", "How long a preventive conservation measure must be maintained in order to maximize the conservation objective as well as to increase the economic benefits of the land use on the site?" Moreover, temporal decisions always have to do with the capability of modelling processes and predicting the effects of an intervention, such as "risks" and "damages" in the case of world cultural heritage conservation.
The issue at stake is how to balance between the complexity of the questions to be answered together with their technological consequences, and the immediate, concrete needs for planning and decision making on "urgent", "preventive" or "future" intervention, based on intrinsic heritage values as well as multiple stakeholder valorisation.

2. MATERIALS / METHODS

Three methodological approaches of the multicriteria decision making challenges described above are combined in order to evaluate the potential of GIS-based decision support for world cultural heritage conservation and management:

GIS-based stDSS technology

The present evaluation of the needs and approaches for spatiotemporal decision support is rooted in former experiences in the field of forestry planning. Two stDSS were developed to support afforestation planning in north-western Europe and the southern Andes of Ecuador respectivily. The AFFOREST-stDSS was developed in north-western Europe, with the aim of strengthening the capacity to use knowledge regarding environmental effects of afforestation of former agricultural land (Heil et al., 2007) in afforestation projects. The FORANDEST-stDSS is meant to support decisions aiming at the enhancement of the physical and socio-economical land performance through forestation, in the Southern Andes of Ecuador. Alike the AFFOREST-stDSS, the FORANDEST-stDSS addresses questions related to the future environmental performance of forested agricultural land. In addition, the FORANDEST-stDSS encompasses non-agricultural land en socio-economic performance. In this context Geographical Information Technology is considered as an "adaptive generator of spatio-temporal decision support systems", specifically in the context of land use planning (Wijffels et al., 2010; Van Orshoven et al., 2010). While the AFFOREST and FORANDEST spatial decision support systems are based on a "filled" database and an adapted toolbox, the OSMOSE software, developed with funding of the Flemish regional government in Belgium, offers a development framework for specific sDSS for sustainable spatial development, as it consists of a data model, i.e. an "empty" database, and an extended toolbox that permit to develop new stDSS in different thematic contexts. OSMOSE stands for a conceptual generator of specific decision support systems for spatial allocation of land use types.

The OSMOSE-concepts are designed to address four types of questions concerning land use planning (De Meyer et al., 2011):

1. What is the performance of a considered land unit under the current land use type ? This 'What?' question returns for the selected land units the value of one or more specific environmental performance attributes for the current (initial) land use type (iLUT);
2. What would be the performance of a land unit if iLUT is converted into a new 'target' land use type (tLUT) ? This 'What if?' question returns for

the selected land units the value of one or more specific ES-attributes after a particular change from iLUT to a specified tLUT;

3. Where (on which land units) should a tLUT be applied to obtain the specified threshold or the best possible performance? This 'Where?' question turns out those land units which meet the proposed environmental performance attribute values or which are best ranked according to these attributes;

4. Which tLUT should be applied on a selected land unit to obtain the specified threshold or the best possible performance? This 'How?' question identifies for each land unit the tLUT that meets the proposed environmental performance attribute values or that is best ranked according to these attributes.

In all these questions 'performance' is multi-dimensional. According to De Meyer et al. (2011), this means that the performance of the combination of a land unit and land use type (LUT) is determined by one or more environmental performance attributes. Consequently, each question can encompass a multi-criteria analysis in which multi-criteria decision methods must be applied and in which the attributes not necessarily have the same importance and hence are differentially weighted.

As described in the introduction, also in the context of cultural heritage conservation a Preventive Conservation Plan will be elaborated on the basis of complex spatiotemporal decisions, where different qualitative and quantitative criteria are weighted and alternatives ranked. For the Cultural Heritage City of Cuenca, a sequence of inventory, registry, cataloguing, valuing, risk assessment, maintenance and monitoring stages are proposed. Each of these data generating stages is supposed to be supported by a Cultural Heritage Information system, systematizing, analyzing and visualizing the information obtained. Based on a cadastre map, heritage sites with specific characteristics are localized in space, valuated and evaluated over time. Heritage sites will be selected and ranked for intervention, based on its attributes and spatial relationships. A combination of standard spatial analysis tools with adapted tools for multicriteria evaluation seems to be at stake in order to contribute to this complex, spatiotemporal decision making process.

Land Evaluation

Land use changes on sites or land units are the result of decisions based on individual and site specific criteria, considering the spatial context to a limited extend. Land use planning is policy-based, concerns larger areas and is part of a broader, multi-stakeholder process requiring specific concepts and tools.

A land use or management plan aims at the spatial allocation of land management options for a particular geographical extent and for a given time frame. Alternative scenarios for the future are generated on the base of a diagnosis of the actual state (base line) and the assessment of trends, opportunities, limitations, risks and conflicts (Wijffels et al. 2010), all of this being constrained by policy goals and stakeholder preferences and concerns.

Land use planning at different scales typically starts with a land evaluation exercise for one or more types of land use in order to evaluate the suitability of a piece of land for a set of alternative land use types and to predict future land performance. According to FAO (2007), the framework for land evaluation has evolved during the last decades as the scope and the purpose of the land evaluations changed. Whereas initially the purpose was to introduce more profitable and better adapted land use options, nowadays land evaluation deals with solving technical as well as socio-economic and environmental problems in the actual land use, problems which are due to conflicting demands on limited land resources. Land evaluation must consider the productive potential as well as the environmental services and sustainability of land use (FAO, 2007).

Applying the logic of land evaluation to the planning process for preventive conservation of cultural heritage sites, "land use and management" can be translated into conservation terms, such as "considering heritage as a resource" and "preventive maintenance practices". Literally land use is taken into account as a factor affecting heritage conservation, while at the same time the classification of a site as culture heritage, can be understood as a land characteristic, which includes and excludes certain land use management options. The concept of land management is implicitly included in a Preventive

Conservation Plan, as spatial location and interaction are important factors in the assignment to land units of preventive maintenance practices, risk assessment and curative intervention. The objective of a Preventive Conservation Plan is to accomplish and optimize the conservation objective, equally considering socio-economic and environmental problems, due to conflicting demands "on and off site", within the limitations of the world cultural heritage status. While the term "suitability" at first sight seems to be inappropriate, the iterative evaluation of heritage value and deterioration risks, qualifying the heritage site for different therapy alternatives, is similar to a classic land evaluation, searching for the best heritage site performance through the selection of the most adequate land use and management alternatives.

UNESCO Preventive Conservation Cycle

The ICOMOS charter of 2003 offers a set of principles for the analysis, conservation and structural restoration of architectural heritage, such as: *"The peculiarity of heritage structures, with their complex history, requires the organisation of studies and proposals in precise steps that are similar to those used in medicine. Anamnesis, diagnosis, therapy and controls, corresponding respectively to the searches for significant data and information, individuation of the causes of damage and decay, choice of the remedial measures and control of the efficiency of the interventions. In order to achieve cost effectiveness and minimal impact on architectural heritage using funds available in a rational way; it is usually necessary that the study repeats these steps in an iterative process."*

The charter states moreover that the best therapy is preventive maintenance and when any change of use or function is proposed, *"all the conservation requirements and safety conditions have to be carefully taken into account."* From the above it can be understood that during the diagnostic phase, processing the available information from anamnesis and deciding on the adequate therapy, multiple criteria must be considered and weighted. Based on combined criteria, such as values, damage, risk, functionality, experts and stakeholders define how and when to intervene in the cultural heritage site.

According to Van Balen (2012), preventive conservation refers to *"actions and procedures that aim at preventing damage or at reducing them through control of the environmental factors and at creating the best conditions for its preservation."* The author stresses that early detection of deterioration can prevent major damage and reparation cost. In order to timely identify and correct defects on historic buildings, a monitoring system can generate the necessary alerts at time, while maintenance practices on a regular basis will reduce intervention costs. Three levels of preventive conservation are distinguished, depending on the stage of damage: (i) prior to its origin, intervening in the causes of damage, (i) after the damage can be recognized (early detection) and (iii) avoiding that the damage extends once it is present. The monitoring system mentioned must be able to provide the arguments for a sound decision during the reiterative diagnostic phase. Therefore the system will detect changes in values, damages, risks, functionality etc. compared to the base line resulting from anamnesis. The previous allows for evaluating the effectiveness of preventive or curative interventions on preserving the conservation state of the cultural heritage site.

The elaboration of a Preventive Conservation and Management Plan in the context of the World Heritage City of Cuenca is based on the iterative cycle of monitoring steps as described above and elaborated by the UNESCO. Each of these stages requires specific information, from different sources, such as field survey, laboratory analysis, expert reports and analogue documents. When mentioning a monitoring system that archives and organizes the information obtained from monitoring in the field, at the same time it is suggested that it consists of an instrument for sustaining the decisions taken along the iterative cycle. During anamnesis all existent information related to the heritage sites is gathered together with the information available from Inventory and Registry of cultural heritage units. Moreover it is foreseen to realize an additional field survey, inside the buildings, in order to establish a base line (catalogue), identifying key features or indicator phenomenon that permit to evaluate the present state in terms of heritage values, risk assessment and the potential of heritage as a resource.

In the *diagnosis* stage, important decisions are taken, based on the base line information, establishing heritage value and deterioration risk, determining the type of therapy that should be assigned to each of the heritage sites. Moreover, at this stage, heritage sites and interventions are compared, ranked in priority and scheduled over time.
Then in the *therapy* stage, additional information is generated that adds to the evaluation of the heritage site, as well as various parameters will change through intervention. Finally at the moment of control, through timely monitoring, new values will be established, evaluating the effectiveness of the intervention as well as taking in to account the additional information generated, in order to return to and aliment the previous stages.

3. CONCLUSION

While the heritage monitoring system until now consists of a GIS-based information system, consulted and interpreted by experts in the field, the system should also allow for ranking of the alternative sites and constructions and types of intervention based on multiple, multidisciplinary, and weighted criteria. As mentioned above, the generic GIS technology is capable of treating multicriteria questions through multicriteria evaluation techniques, such as *"Where are located the units of interest?"*, considering multiple positional criteria or attributes, according to thresholds previously established. Nevertheless, the generic GIS technology is not able to rank the alternatives generated. In order to do so, GIS technology can be extended with additional algorithms as applied in other contexts of multicriteria decision making. Then the system will be able to handle questions such as *"Where are the units of interest in order to accomplish a maximized results for criteria 1 and a minimized result for criteria 2, taking into account that criteria 1 has a mayor weight?"*.

The design and content of the information system depends on the available or mobilisable data and on definition of objectives and of the criteria required to sustain decisions that accomplish these objectives. In the first place it is observed that a variety of information sources are brought together, eventually within one information system that has to answer various types of queries, based on multiple criteria of different nature. In order to have this huge database properly providing the needed information, analysis and

Expectation	Representative question
To register	Which are the heritage values and the present state of risk of the heritage units considered?
To monitor	In view of its historical evolution, which heritage units have a major deterioration risk within the following x years? How do values, states, attributes and risks evolve over time?
To alert	In which heritage units intervention is most urgent? Which heritage units are exposed to major deterioration risk?
To stratify	Where are the zones with major concentration of heritage units that are well conserved? Which building blocks are situated near to an "emergent" (refers to public function or social importance) building? Which zones of the city contain a major number of heritage units?
To ordinate	Which heritage units show a high, medium or low conservation value? According to the established criteria, which heritage units should be handled/treated in a first, second and third phase?
To rank	Where (in which site) it is most urgent to intervene? Where (in which site) it is most important to intervene? Where (in which site) it is most efficient to intervene? Where (in which site) should be intervened first?
To predict	Where do we have to intervene now in order to avoid that intervention in x years will be major, impossible or expensive? How do we have to intervene in order to minimize the deterioration in the following x years?
To select	Which are the heritage units to deal with, taking into account established threshold values for the cultural value of the heritage sites? Which are the heritage units to deal with in the first place, taking into account established threshold values for the environmental value of the heritage sites?
To combine multiple criteria	Which heritage units should be dealt with in a first stage, considering the cultural, environmental and emergent values as well as the damages and risks observed? Which heritage units should be dealt with in a first stage, assigning a weight of 60% to the conservation state, 30% to the eminent risk and 10% to the "emergence" (refers to public function or social importance) value of the sites?
To contest complex questions	If a budget of A USD is available and the time scope is B years, which heritage units within a distance C from an "emergent" (refers to public function or social importance) building and/or a visibility at a distance D, should be intervened preferentially and in which order, taking into account E criteria, each with their respective weight?

Table 1: Possible expectations towards the monitoring system for preventive conservation management

alerts, it must be very clear what is expected from the system. A brief, basic analysis of the possible expectations of the system in preventive conservation context is presented in Table 1. For each activity expected from the system, an example of a question to be answered by the system is given.

From the above it can be concluded that the elaboration of an "information system" is not just about monitoring, but about supporting decisions for preventive conservation on the base of comparing base line values of heritage sites with monitored values over time. The stakeholder group should clearly define their expectations from the system, being aware of the fact that a decision support system does not replace the formulation of alternatives and the decision making process as such, but enables to pinpoint the data required for defining alternatives and achieve a ranking of the alternatives in the presence of multiple criteria of differential importance, be it for awareness rising of the consequences of decisions or be it to solve complex questions that are difficult to answer without the support of a computerized information system.

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