

Sensitivity Maps in Environmental Impact Studies

Virgilio NAAez¹

¹ Salta National University

Received: 15 December 2013 Accepted: 3 January 2014 Published: 15 January 2014

Abstract

Environmental Sensitivity is closely linked to the concepts of reception or absorption (recovery) that have environmental components, such capabilities must be addressed in a holistic and integrated for analysis of constructive alternatives to incorporate infrastructure. Environmental Sensitivity Maps are undoubtedly important to define a priori the contingency plans, corrective actions, mitigation or compensation to the occurrence of damage to the environment. A case study is presents for the installation of production infrastructure; environmental sensitivity is analyzed through physical, biological and socioeconomic factors (landscapes): surface runoff, topography, soil type, flora -wildlife and land uses. For the generation of environmental sensitivity maps a weighted polynomial was used whose weights were defined on the basis of consultations with experts. Four alternatives for an aqueduct were compared, which are analyzed according to the environmental sensitivity of the areas traversed. The alternative path was defined by the engineers, in charge of the hydraulic project aspects, and the application of the optimal path algorithm, using the environmental sensitivity map as friction, to determine traces of each alternative with less sensitivity. Environmental Sensitivity Maps showed consistency in the analysis of alternatives for the location of new infrastructure.

Index terms— environmental sensitivity maps, environmental impact studies, landscapes, gis, optimal path.

1 Introduction

Environmental Sensitivity (ES) is defined as the susceptibility showed by the different components of natural and built environment for the purpose of further action of man or the influence of climatic factors on the system.

'Landscape sensitivity relates to the stability of character, the degree to which that character is robust enough to continue and to be able to recuperate from loss or damage. A landscape with a character of high sensitivity is one that once lost would be difficult to restore, and, must be afforded particular care and consideration in order for it to survive'. ??Bray, 2003 cited in Tartaglia ??ershaw L, et al., 2005, p.7).

The new sustainable development paradigm, provides the necessary balance between productive activities, social welfare and environmental conservation.

Author: Institute of Natural Resources and Eco Development (IRNED), Natural Sciences School, Salta National University, Bolivia Avenue 5150, A4408FV Salta, Argentina. e-mail: nunezv@unsa.edu.ar ES models are the first step in finding this harmony. (Rebolledo, 2009).

Thomas and Allison (1993), consider landscape sensitivity as the potential and magnitude of change likely to occur within a physical system, and its ability to resist it, in response to external effects. These may be natural or man induced.

The environmental components present unequal levels of prior alterations and different capacities to absorb or assimilate new impacts to which they are subjected. Is now accepted that man has some influence over climatic factors.

4 A) FACTOR 1 -SURFACE HYDROLOGY

From the ecology perspective, ES is defined as the ability of an ecosystem to withstand alterations or changes caused by human actions, without suffering drastic alterations that prevent you from achieving a dynamic balance that maintains an acceptable level in structure and function; their identification and measurement depend on the scale of observation (Meentemeyer and Box, 1987).

The level of Sensitivity depends on the degree of environmental and ecosystem conservation, especially, of the presence of external actions (anthropogenic).

ES is closely linked to the concept of reception capacity (Environmental Tolerance) that the environment (Landscapes), these capabilities must be addressed in a holistic and integrated perspective for the analysis of constructive alternatives to be incorporate in the infrastructure. Quantification landscape reduces the complexity of a set of numerical values or index (Matteucci, 1998).

All of the above requires a combination of tangible and intangible aspects in a valid scale for decision-making, according to a new rationality (Saaty, 1996 cited in Moreno Jiménez et al., 2001, p.6). (esm) on Environmental Impact Studies (eis) Within the general framework of the EIS, the Environmental Sensitivity analysis (ES) is incorporated in the Effects Prevention Stage, hand in hand, as the prospective process, with the members of the working group for further evaluation of EI. Moreover, the ESM are instrumental simulation models (Moldes, 1995) itself, which can be the base for a preliminary assessment of the current conditions of the environment against the actions foreseen in the project's idea stage. ESM also represent an input to perform reports on Environmental Impact Statement (EIS), as required by the relevant public authorities for smaller projects. A case study is presented for the implementation of an ESM for the construction and operation of a aqueduct for the provision of water for an ammonium nitrate production plant, located nearby the town El Tunal, Metán Department, Salta Province, Argentina (Figure ??). Four alternatives were analyzed for mentioned aqueduct traces, depending on the environment sensitivity.

2 II. Environmental Sensitivity Maps

The area under analysis is presented in Figure ??, showing the site where the ammonium nitrate production plant will be installed, which requires a permanent water supply.

3 Methodology

For Environmental Sensitivity analysis an index has been designed, in which three components of Environmental System Matrix Importance (physical, biological and socioeconomic) were considerate.

To evaluate Physical Environment sensitivity, these factors were established: hidrology -surface runoff (lotic) and surface water (lentic) -, topographythrough the slope -and finally, soils (Soil Groups and Suitability Classes).

To construct the factor for Biological Environment a combination of conservation value index, obtained for plant communities and birds, was used.

The Social-economic Environment was assessed in terms of the different land uses in the area and its related infrastructure, reflecting also on the degree of involvement that economic activities may suffer.

Factors (criteria) were selected by specialists from an initial hierarchical list, according to the relevance defined for the project objectives.

Environmental Sensitivity map (Figure 16) was obtained by the weighted sum of the sensitivity maps for each factor, as shown in Figure 4. Maps of sensitivity for each factor were standardized on a scale of 0 -10, 10 being the maximum value. Analytical Hierarchy Process copes with using original data, experience and intuition in the same model in a logical and through way (Forman, 1999 cited in Büyükyazici, Sucu, 2003).

Then, a set of weights for each of the factors was established. The analyst worked in group with specialists to complete the comparison matrix in pairs. Wondered to each specialist individually to estimate a rating and the group if it was agreed to start the debate. The consensus was not difficult to achieve with this procedure.

4 a) Factor 1 -Surface Hydrology

The drainage network was derived from a Digital Terrain Modeling (ASTER satellite, resolutions 30 m -Figure 5) and interpreted from high spatial resolution images (CBERS 2B HRC, resolutions 2.5 m Figure ??).

Comparisons are made in pairs and concern the relative importance of the two criteria involved in determining suitability for the stated objective. Ratings are provided on a nine-point continuous scale (Eastman et al., op. cit.). The equation was developed to mitigate the sensitivity to drainage networks environment and to achieve a gradual reduction in sensitivity as a function of distance from the axis of each drainage (talweg). The exponent allows to adjust the spatial scope of sensitivity according to the importance of the hydrology factor in the environmental context (Figure 5). The environmental sensitivity for the physical environment, was directly related to the environmental susceptibility to erosion, capable of generating economic or social involvement and in whose prediction, prevention or correction geomorphologic criteria should be used. For the orderly classification of slopes an exponential function was used $y = 0.1749 e^{0.6409x}$. Then S factor (steepness: Revised Universal Soil Loss Equation -RUSLE -) was calculated (Foster et al., 2003). Finally, the following linear equation was used: $y = 0.882x + 0.745$, with an $R^2 = 0.942$, for assigning values of topography sensitivity by the S factor.

5 c) Factor 3 -Soils

Considering the characteristics of Soil Associations (Nadir and Chafatinos, 1995) present in the area under analysis the Soils Sensitivity map was generated (Figure 13). In this case, the Soils Group, the Suitability Class and the type of landform that corresponds to each unit were considerate (Table 3).

6 (B)

7 d) Factor 4 -Flora and Wildlife

Considering both, the importance and the conservation status of different flora and wildlife represented mainly by birds as indicators of environmental condition-, the fourth factor was built (Table ??). A good environmental quality has a greater number of animal populations.

8 (B)

Table ?? : Values assigned to the categories of factor 3: Sensitivity for Flora and Wildlife Units.

9 Flora and

10 f) Alternatives Trace

As it has already been said, four alternatives of the aqueduct trace were compared, such alternatives are analyzed according to environmental sensitivity of the areas traversed. The alternative path was defined by the engineers in charge of the hydraulic aspects project, taking into consideration the possible water taking sites (Figure 10).

11 (B)

e) Factor 5 -Land Use Considering Land Use, the fifth sensitivity factor was created that includes the categories listed and valued in Table 5. As part of alternatives analysis, the optimal path algorithm (PATHWAY: IDRISI Taiga V. 16.05) was applied, using the Environmental Sensitivity map as friction (Figure 16).
IV.

12 Results

Below are the sensitivity maps obtained for each factor. For Environmental Sensitivity analysis a sample at random points 100 was extracted, probability distribution is shown in Figure 17, while the descriptive statistics are presented in Table ??.

13 Frecuency

14 Class

15 Environmental Sensitivity

The average of environmental sensitivity is within the interval ± 0.22 respect to the average of the sample with a probability of 95%.

16 a) Alternatives Trace Analysis

All alternatives trace run through areas with medium to low environmentally sensitivity. The greater environmental sensitivity is present in the trace for Alternative 3, followed by 4, then 2 and finally 1. It should be taken into account that: Alternatives 1, 2 and 4 have values close to environmental sensitivity and did not differ between them in more than 23.7%. (Table 7 and Figure 18). To the traces defined by Optimal Path, Environmental Sensitivity decreases for all alternatives, although that increases the length of the trace 3p and 4p. (Table 7 and Table 8). Comparing the alternatives 1 and 1p, the second reduced 29% environmental sensitivity respect to the first. Finally we conclude that the trace 1 and 1p presents the lowest environmental sensitivity. Managers must be decide what is the final trace, taking into consideration other criteria such as the costs of construction and operation.

V.

17 Discussion

Environmental Sensitivity is a concept closely linked to landscape as a complex system. Quantifying the landscape through indexes, reduces system complexity allowing spatial pattern analysis, and process alterations under study.

Environmental Sensitivity Maps are an instrumental model that provides adequate and sufficient information for understanding current conditions and the ability of the landscape to absorb new actions.

Environmental Sensitivity analysis can be incorporated into the forecast stage of Effects on Environmental Impact Studies. Environmental Sensitivity Maps represent an input for carrying reports on Environmental Impact Statement.

Hydrological Sensitivity equation allowed to integrate spatially the hydrologic factor as a decreasing continuous variable from drainage networks and water bodies. This function solves the problem of localized effect of the valuation of discrete entities.

Environmental Sensitivity Maps showed consistency in the analysis of alternatives for the location of new infrastructure. The combined use of environmental sensitivity map and the Pathway method allowed to define alternatives of trace for the aqueduct more efficiently from environment perspective.

VI.



Figure 1: Figure 1 :

23

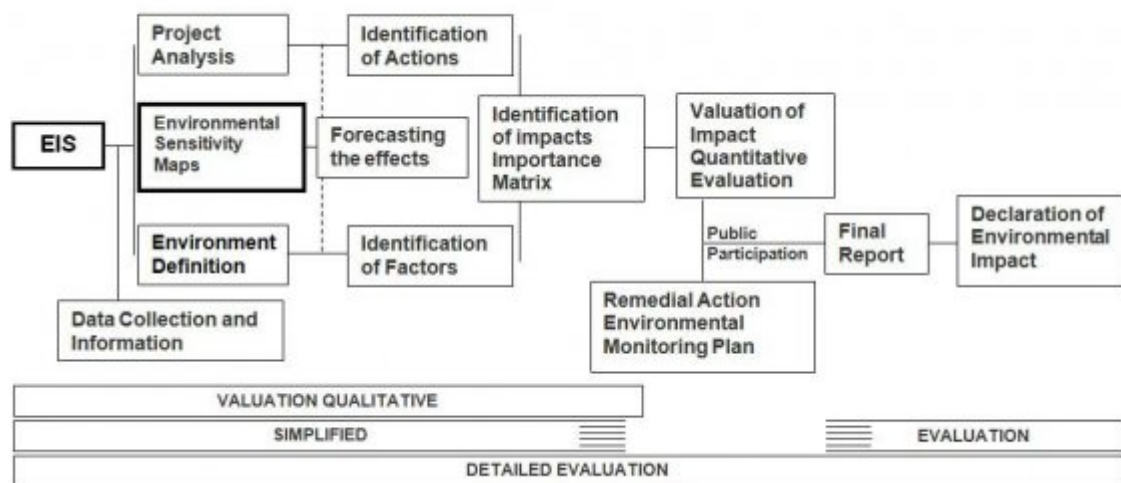


Figure 2: Figure 2 :Figure 3 :

4



Figure 3: Figure 4 :

5



Figure 4: Figure 5 :

6

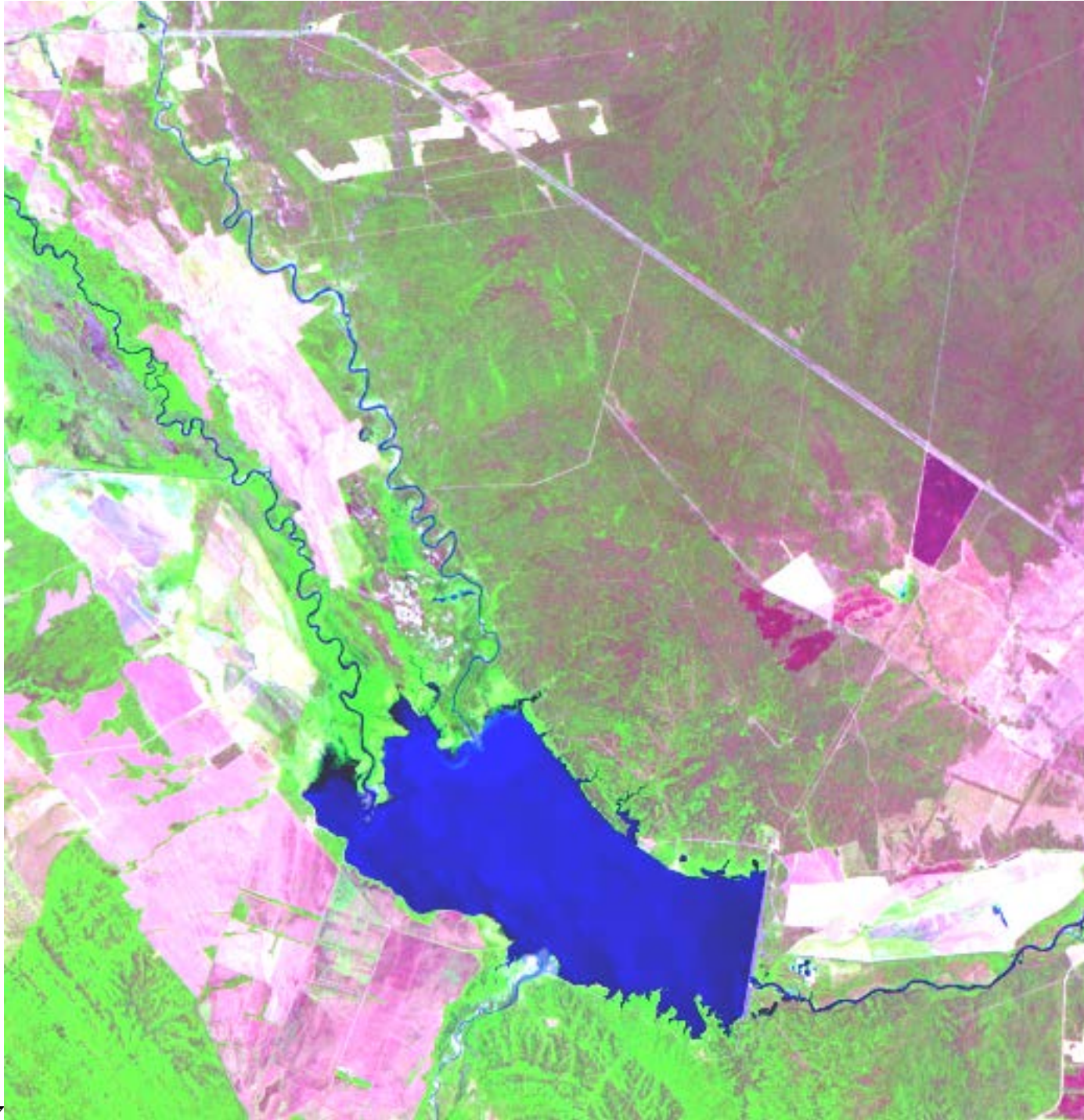


Figure 5: Figure 6 :

1

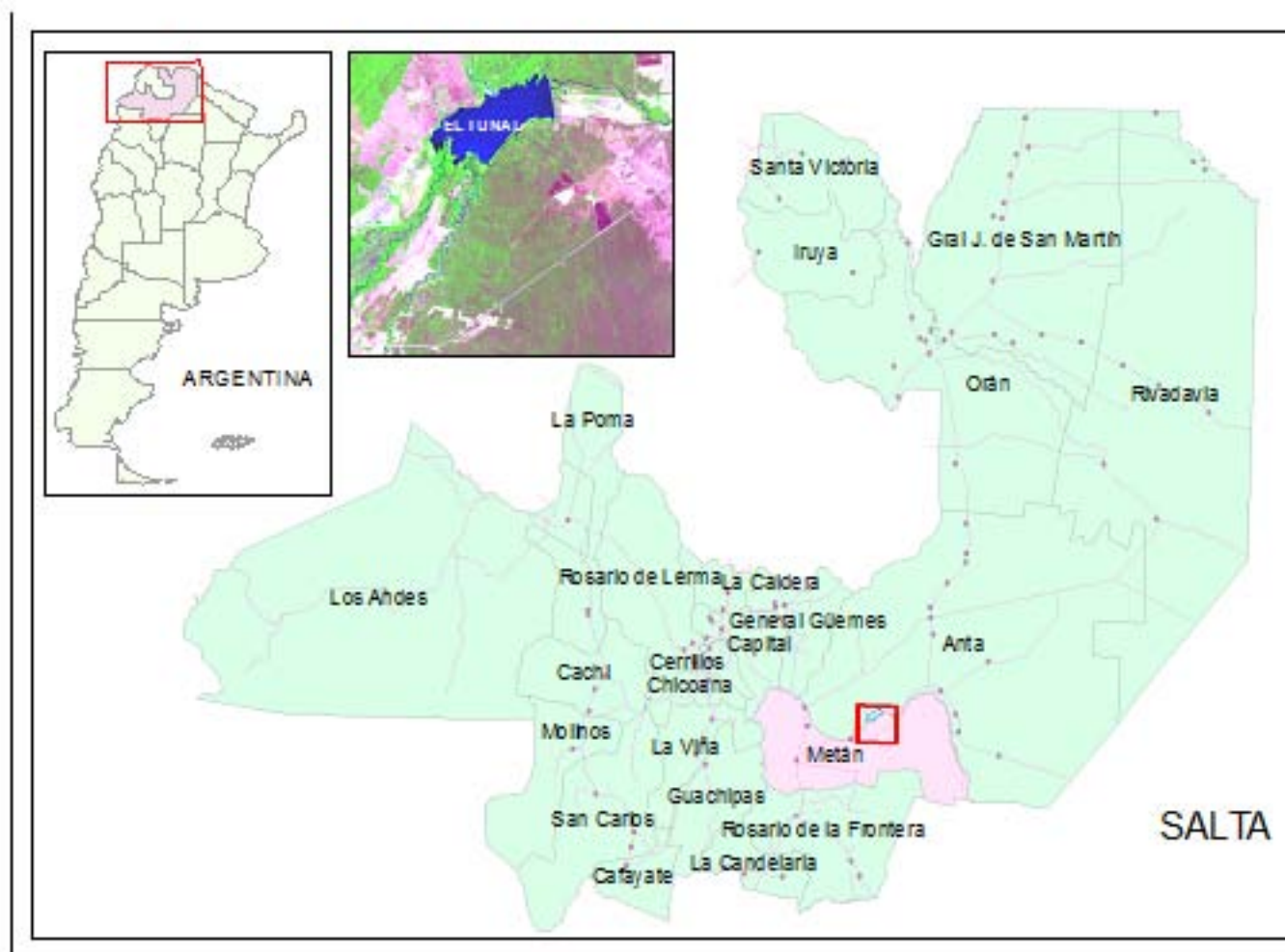


Figure 6: Table 1 :



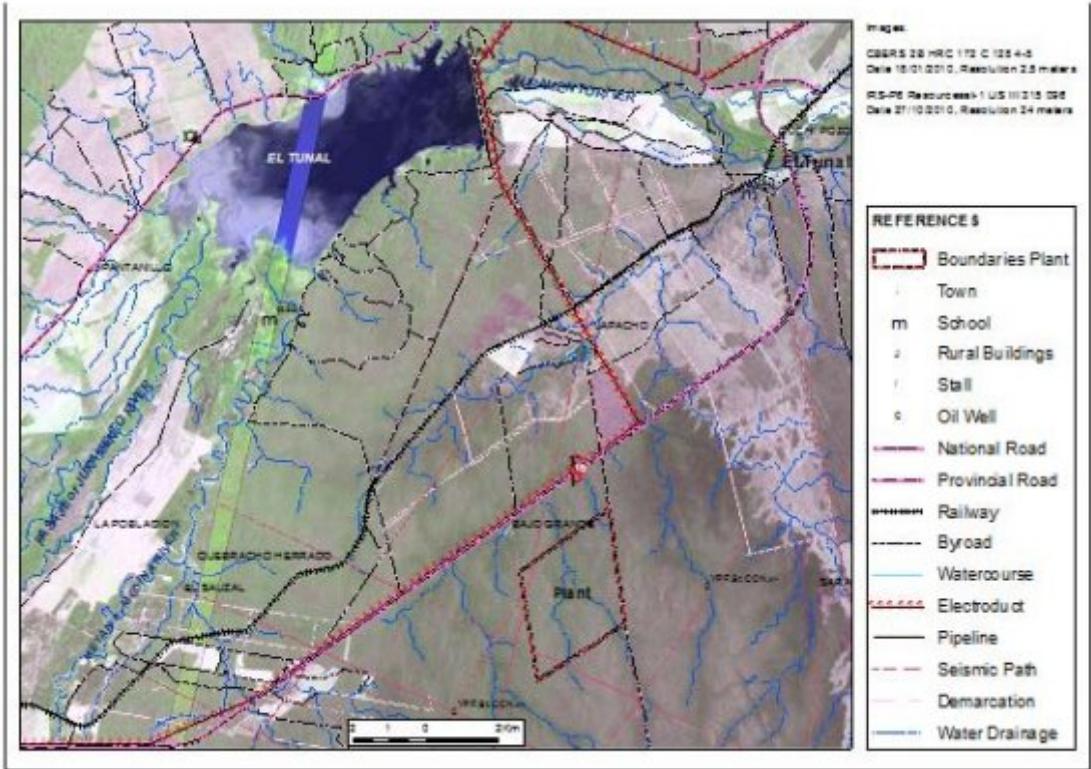
7

Figure 7: Figure 7 :



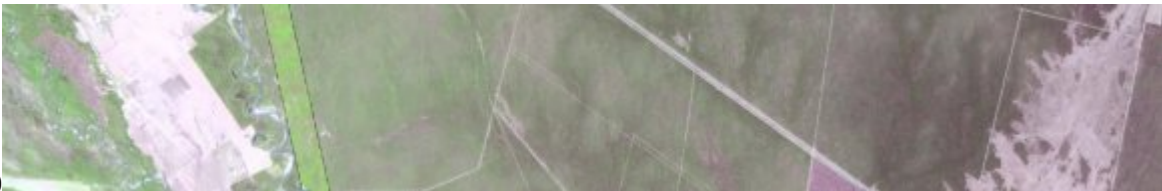
8

Figure 8: Figure 8 :



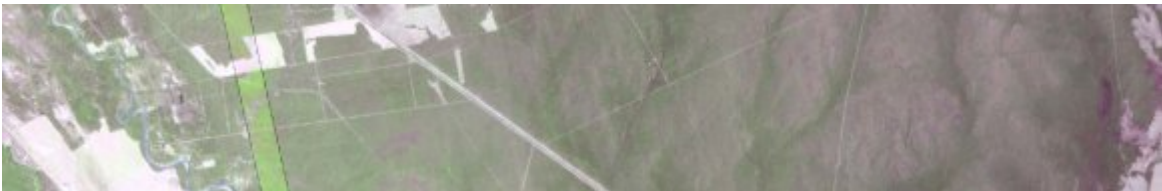
9

Figure 9: Figure 9 :



10

Figure 10: Figure 10 :



11

Figure 11: Figure 11



1314

Figure 12: Figure 13 :Figure 14 :

15

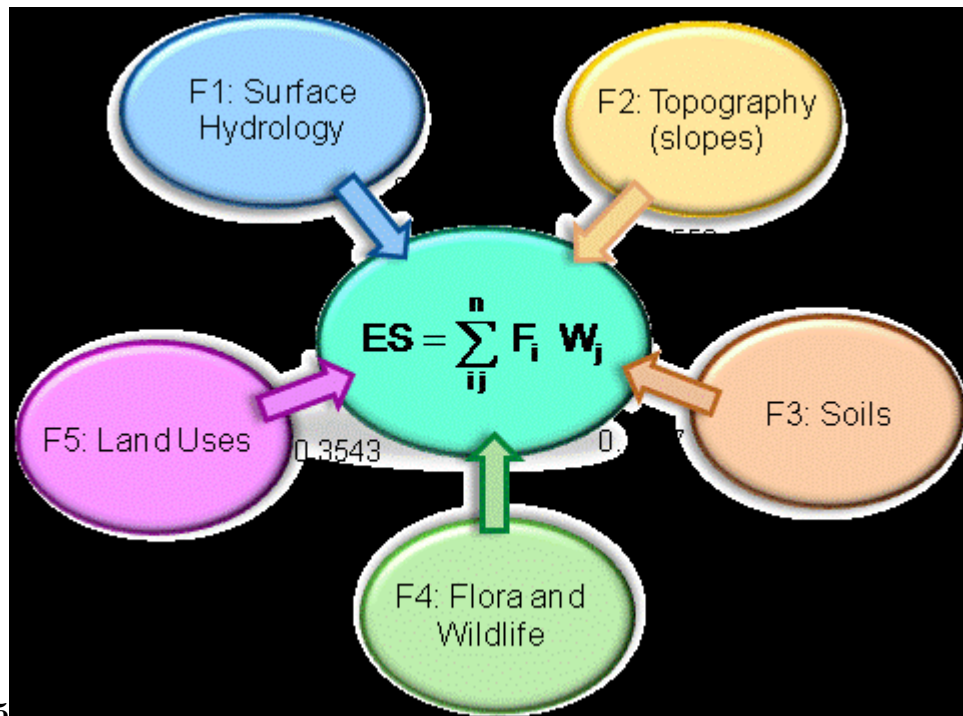


Figure 13: Figure 15 :

19



Figure 14: Figure 19 :

20

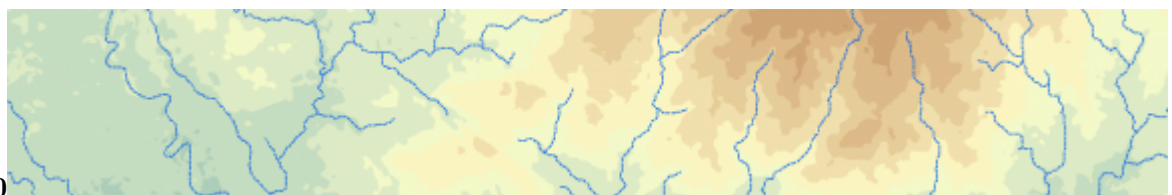


Figure 15: Figure 20 :

2

Class	Topographic sensitivity (slope).	S RUSLE	Factor	Sensitivity
	Slope (%)			
1	0.0 -0.3 %	0.06		0.01
2	0.3 -0.6 %	0.09		0.08
3	0.6 -1.2 %	0.16		0.27
4	1.2 -3.0 %	0.35		0.64
5	3.0 -6.0 %	0.68		1.25
6	6.0 -9.0 %	1.01		2.16
7	9.0 -12.0 % 1.50			3.43
8	12.0 -25.0 % 3.57			5.12
9	25.0 -50.0 % 7.01			7.29
10	> 50.0 %	11.38		10.00

Figure 16: Table 2 :

3

Code	Soils Associations	Soils Group	Sensitivity
Ao-Lpb	Arrocera -La Población	C	3.92
Cho	Chorroarín	C	3.92
Lvi	Las Víboras	E	1.68
Oll-Etu	Olleros -El Tunal	B-C	5.28
Sig	San Ignacio	B	7.22
Sma	Santa María	C	3.92
Ts-Sun	Tuscal -Sunchal	C	3.92

Figure 17: Table 3 :

5

Land Use	Sensitivity
----------	-------------

[Note: 4 8 Intensive and extensive farming, intensive livestock: patch, dams, paddocks, stockyards, drinking trough, electric herdsman, ponds: FARMING. 39 Purpose without: exploration path, demarcations and badlands: BADLANDS. 1]

Figure 18: Table 5 :

1

Average	3.36037583
Standard error	0.11033639
Median	3.44382751
Mode	1.46900749
Standard Deviation	1.10336387
Sample variance	1.21741184
Kurtosis	-0.41780406
Asymmetry coefficient	0.17337022
Rank	4.21480226
Minimum	1.37450743
Maximum	5.58930969
Sum	336.037583
Account	100
Confidence level (95.0%)	0.21893137

Figure 19: Table 1 :

7

Environmental
Sensitivity

Figure 20: Table 7 :

.1 Acknowledgements

To María Laura Núñez and Claudia Rodas for her collaboration in the translation review of the manuscript. To the Salta National University Research Council for the financial support. To the National Institute for Space Research (Brazil) for the satellite image provision. To Adolfo Colina, Nestor Ilvento and Gabriel Guillén, who were in charge of delineation of aqueduct traces. To Juan Sauad, Miguel Menéndez, Héctor Regidor and Alejandro Núñez for their participation in the assessment of factors.

.2 Defined by Engineers

Alternative Trace: Area (ha) * Sensitivity

[Hacettepe Journal of Mathematics and Statistics] , *Hacettepe Journal of Mathematics and Statistics* 32 p. .

[Thomas DSG, Allison RJ ()] , *Landscape Sensitivity. Environmental Conservation. England, UK* Thomas DSG, Allison RJ (ed.) 1993. 20 p. .

[Eastman et al. ()] , J R Eastman , Jin W Kyem , Pak Toledano , J . 1995.

[Calatayud (2009)] , Spain Calatayud . September 2009. p. .

[Saaty ()] ‘A Scaling Method for Priorities in Hierarchical Structures’. T L Saaty . *J. Math. Psychology* 1977. 15 (3) p. .

[Matteucci (ed.) ()] *Complex environmental systems: spatial analysis tools*, S D Matteucci . Matteucci SD, Buzai GD (ed.) 1998. p. . University of Buenos Aires (Quantifying landscape structure)

[Forman ()] *Decision by Objectives*, E H Forman . 1999. Text Books. George Washington University (unpublished)

[Saaty ()] *Decision Making with Feedback: The Analytical Network Process*, T L Saaty . 1996. Pittsburg, PA: RWS Publications.

[Kershaw ()] ‘Developing the Approach to Strategic Landscape Sensitivity’. Tartaglia Kershaw , L . *Hampshire County Council. UK* 2005. 54.

[Meentemeyer and Box (ed.) ()] *Landscape Heterogeneity and Disturbance*, V Meentemeyer , E O Box . Monica GT (ed.) 1987. New York: Springer -Verlag. p. . (Scale effects in landscape studies)

[Fernández Vitoria ()] *Methodological Guidelines for Environmental Impact Assessment*, Conesa Fernández Vitoria , V . 1997. Bilbao, Spain: Mundi Prensa. p. 338.

[Raster Procedures for Multi-Criteria/Multi-Objective Decisions Photogrammetric Engineering and Remote Sensing] ‘Raster Procedures for Multi-Criteria/Multi-Objective Decisions’. *Photogrammetric Engineering and Remote Sensing* 61 (5) p. .

[Rebolledo ()] *Remote Sensing: Water and sustainable development. XIII Congress of the Spanish Association of Remote Sensing*, R Rebolledo . 2009.

[Foster ()] *Revised Universal Soil Loss Equation, Version 2. User´s Guide. USDA-Agricultural Research Service*, G R Foster . 2003. Washington, D.C. 77.

[Moreno Jiménez ()] ‘Scientific method in environmental assessment and selection’. J M Moreno Jiménez . *Operational Research* 2001. 1 (1) p. . (Zaragoza, Spain.)

[Nadir and Chafatinos (ed.) ()] *Soils of the NOA*, A Nadir , T Chafatinos . Nadir, Chafatinos (ed.) 1995. Salta y Jujuy; Salta, Argentina. 3 p. .

[Moldes ()] *Technology of Geographic Information Systems*, Fj ; Ra-Ma Moldes . 1995. Madrid, Spain. p. 146.

[Büyükyazici and Sucu ()] *The analytic hierarchy and analytic network processes*, M Büyükyazici , M Sucu . 2003.