Geodatabase for the assessment of energetic potential of territory

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ABSTRACT. *Regarding the current necessity to reduce energy consumption, and to redefine energy supply systems, the territorial and urban planning~~,~~ opens up interesting new, development scenarios in GIS based on multi criteria analysis, with particular reference to the modelling and innovative implementation phase. The accurate knowledge of the territory with all its potential makes it possible to start specific and effective interventions to exploit the most part of its characteristics.*

The present paper proposes a first analysis and an interpretative model capable of integrating into the municipal energy planning process the opportunities offered in terms of management and project aid, from the relational geodatabase.

Such an experimental application of a support decision GIS based on multi criteria analysis would allow greater efficiency in the organization and management of spatial information (in relation to energy issues), if enhanced and used by the governmental organism.

RÉSUMÉ. *Compte tenu du besoin actuel de réduire la consommation d'énergie et de redéfinir les systèmes d'approvisionnement en énergie, la planification territoriale et urbaine ouvre de nouveaux SIG (système d'information géographique) intéressant basé sur une analyse multicritère, des scénarios de développement avec une référence particulière à la phase de modélisation et de mise en œuvre innovante. Une connaissance précise du territoire avec tout son potentiel permet de démarrer des interventions spécifiques et efficaces pour exploiter ses caractéristiques majeures.*

Le présent article propose une première analyse et un modèle interprétatif capable d'intégrer les opportunités offertes en termes d'aide à la gestion et à la conception dans le processus de planification énergétique municipal à partir de la géodatabase relationnelle.

Une telle application expérimentale d'un SIG de décision d'appui reposant sur une analyse multicritère, si elle était améliorée et utilisée par un organisme gouvernemental, permettrait une plus grande efficacité dans l'organisation et la gestion de l'information spatiale (en relation avec les questions énergétiques).

KEYWORDS: *GIS, energy, geodatabase.*

MOTS-CLÉS: *SIG, energie, géodatabase.*

DOI:10.3166/ISI.23.6.7-17

1. Introduction

Nowadays, Italy’s tendency towards a more efficient energy system and less dependent on foreign sources, involved that low-carbon sources, especially renewable energy, would play an increasingly important role. The latter came to represent more than a fifth of the primary energy required and the first source of electricity generation.

Led by mechanisms of public support, renewable sources have consolidated in recent years a leading role in the Italian energy system. They are now used widespread both for the production of heat and electricity.

The urgent necessity both to reduce energy consumption and to redefine energy supply systems open interesting disciplinary development scenarios for GIS and territorial/urban planning.

Through the identification of the potentials and energy necessities of the territory, it is possible to define new categories of actions to reorganize the territory.

This paper aims to show how the usage~~:~~ of a GIS supporting decisions model is able to manage problems concerning the energetic installations. (Syed T. Tirmizi and Syed R.U.H. Tirmizi, 2018). The evident lack of operating methods, found during such installations, has as main purposes:

1) being a valid help during the territory designing, processing and fostering stages commonly defined as “strategic” for planning;

2) fostering innovative procedures for management, government and planning territory, through the development of the so called “territory visions”, trying to involve local development and the global economy;

3) fostering a balanced “governance” competition with the government. In substance, if the model is shared and acknowledged, it can help the research stages, together with the doctrine of authority’s ones (public administration-private interests);

4) guaranteeing the comprehension (if shared by people) of subjects involved, and, consequently, fostering the total and real participation of people.

Here, there are brief considerations about the reference outlook of the energy market and the informative helps, for planning eolian and solar parks, and for mini-hydro source (Mutani G., *et al.*, 2018). Subsequently, we will look into the aspects concerning the development, and the description of the same model. The last part of the paper presents the results obtained and the research’s developments.

2. Methodologies

Any system of generation and distribution of energy has an impact on the surrounding landscape, both from an urban and a territorial point of view.

It is, therefore, important to be able to assess in advance the potential and the energy necessities, in order to overcome the problems related to spatial planning; and therefore to define new categories of actions and interventions that are effective and suitable for the definition of a new organization and planning of the urbanized and non-urban territory (Hartmann *et al*., 2014).

To this purpose, an interpretative model was implemented capable of integrating the opportunities offered, in terms of management and design aid, from relational geodatabases into the energy planning process.

In line with the latest guidelines on the planning of energy resources, we made a methodological jump that was to catalyze the approach towards the construction of a "widespread" production and distribution system for electricity (Jones, 2015); for this purpose, a structuring of the GEODB was conceived as a priority based on the energy potential of each individual sector: - environmental system - urban system (Fthenakis and Kim, 2009).

The intention of the project is to experiment a support decision GIS, that is based on multi criteria analysis through the integration of geomatical methodologies (remote sensing and dem) aimed to make plugins that allow us to identify the areas potentially suitable for the creation of projects of clean energy. (Toolkit *et al*., 2007).

2.1. Formulation of the multi-criteria GIS-Based decision support methodology

We have developed a GIS-based decision-making methodology that prioritizes suitable sites and assesses their capacity. The purpose of the application was therefore to seek a compromise between a new form of decentralized management of distributed energy (for Distributed Generation (DG) we mean the use of a large number of small generation systems and average size, generally less than 10 MW peak) and the environmental impact that this creates through the construction of an open GIS that is an excellent tool for decision support, making available, through the use of geodatabases , a "rigorous" procedure for the "choices" hypothesized on the territory (Torres-Sibille and Ramírez, 2009).

The GIS supports the use of territories with advantageous characteristics for the production of clean energy (i.e. large non-shaded areas, hydrogeological conditions, soil stability, current land cover and proximity of the transmission infrastructure).

An appropriate selection leads to a reduction in investment costs, using the existing infrastructure and reducing network connection costs.

The criteria and methods used to select the location site are presented in detail in the flowchart of Figure 1.

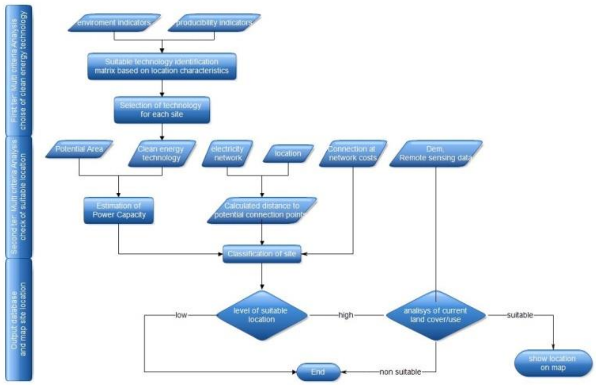

Figure 1. Flow chart multi-criteria analysis

2.1.1. First tier of multi-criteria analysis: suitable clean energy technology

For this purpose, it was necessary to consider the relationship between what we want to project with the surrounding landscape, not intended it as a category of items such as, for example, physical, natural, biological and historical, but as the totality (a complex of categories) (Evans *et al*., 2009).

Regarding the removable energy applications in particular urban areas, the visual impact is the main item to be considered, and at the same time the most complex, because it involves individuals with a different perception, aesthetic taste and visual understanding (its evaluation is subjective).

The first indicators taken into consideration in the present study for the assessment of the impact of the proposed energy plants were of two types: environmental and economic. The environmental indicators were those of visual type (for the mini wind plants the height of the wind tower, for the micro-hydroelectric ones the height of the building in which the turbine resides, for the solar ones the surface of the buildings covered by collectors), those relating to land use (for mini wind farms the size of the wind turbine, for micro-hydroelectric plants the area occupied by the construction in which the turbine resides), those relating to the influence on the water regime (parameter considered for mini-hydroelectric plants and calculated on the basis of litres per second) and finally those related to noise (parameter considered for mini-wind plants and measured on the basis of the decibels issued).

The economic indicators evaluated, on the other hand, were the yield (parameters assessed by the kWh produced by the plant) and the cost of the plant.

2.1.2. Second tier of multi-criteria analysis: Location suitability

Once the technology has been selected for each site (first multi criteria-analysis level), the second multi-criteria analysis level classifies the locations based on two decisive parameters: the estimated power capacity that the area can potentially host, and the distance from the network or to substation existing electricity. At the same time, remote sensing data are evaluated to know about the land use of the location, and DEM to know the morphologic characteristic of the site.

3. Project hypotheses

The methodology proposed has been applied to a case study in the province of Reggio Calabria (Italy), through the use of partial and non-exportable data in order to test the functioning of the proposed methodology (Marino C. *et al*., 2017).

3.1. Eolic project hypothesis

Wind turbines (horizontal axis), despite not large, have not been considered suitable for urban areas. The main reasons are the visual impact, noise pollution and land use. For this a minimum distance from population centers has been proposed, as well as an "impact assessment" (the presence of areas of particular environmental value may limit the possibility of installing systems). The main parameters for the location of wind farms were wind speed and the specific producibility of the wind (understood as the amount of energy that the wind, in a particular area, can produce) (Table 1, Table 2, Table 3) (Monforti *et al*., 2014). Built the different themes (the urban areas map, the map of the constraints, the wind speed map, the producibility of the wind map), and modelled the environmental and economic indicators and the main parameters mentioned above, the areas compatible with the location of the mini-wind plants were obtained (figure 2).

Table 1. Eolic environment indicators

environment indicators	Parameters	Value	Im-pact
Visual	Height (m)	h < 5	1
		5 < h < 10	2
		h >10	3
Land use	Aerogenerator width (m)	a < 3	1
		3 < a < 5	2
		a > 5	3
Noise	Decibel (Db)	R < 20	1
		20 < R < 45	2
		R> 45	3

Table 2. Eolic economic indicators

Economic Indicators	Parameters	Value	Im-pact
producibility	producibility (kwh)	Rend > 10	1
		5 <Rend< 10	2
		Rend < 5	3
Cost	Cost (€)	c < 1000	1
		1000< c < 5000	2
		c > 5000	3

Table 3. Parameters for the location of the proposed plants

Parameters for the localization of wind power plants	
Distance from the centers	Distance from the centers
Wind speed	Wind speed
Wind producibiliity	Wind producibiliity
SIC area	SIC area

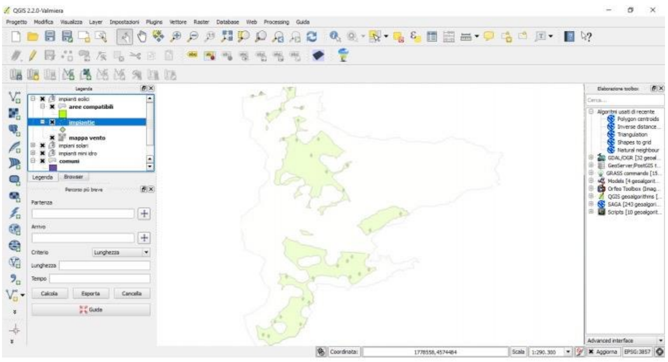

Figure 2. Derivative location of the proposed wind farms

3.2. Micro-hydroelectric project hypothesis

As well as for micro-hydroelectric plants, once the proximity to a watercourse has been established, the hydrographic network has been hierarchized by dividing it into river rods of 5 different orders (being torrential rivers, it is necessary to establish areas where a minimum flow of water is always assured) acquiring useful information on the composition of the soil and on the permeability (it was considered useful to understand which areas are more willing to filter the water inside them reducing the flow on the surface) (table 4, table 5).

Table 4. Mini-hydro environment indicators.

Environment Indicators	Parameters	Value	Im-pact
Visual	Height (m)	h < 5	1
		5 < h < 10	2
		h >10	3
Land use	area (m)	a < 50	1
		50 < a < 100	2
		a > 100	3
Flow rate	flow rate (l/s)	R < 5	1
		5 < R < 50	2
		R> 50	3

Table 5. Mini-hydro economic indicators.

Economic Indicators	Parameters	Value	Im-pact
Producibility	Producibility (kwh)	Rend = 10	1
		5 <Rend< 10	2
		Rend =5	3
Cost	Cost (€)	c < 1000	1
		1000< c < 5000	2
		c > 5000	3

Constructed the different themes (hydrological map, lithological map, permeability map), and modelled environmental and economic indicators and the main parameters mentioned above, the areas compatible with the location of micro-hydroelectric plants were obtained (Figure 3).

Table 6. Parameters for the location of the proposed plants

Parameters for the localization of wind power plants	
Proximity to the waterway	Proximity to the waterway
fluvial Order	fluvial Order
Gradients	Gradients
Lithology	Lithology
Permeability	Permeability

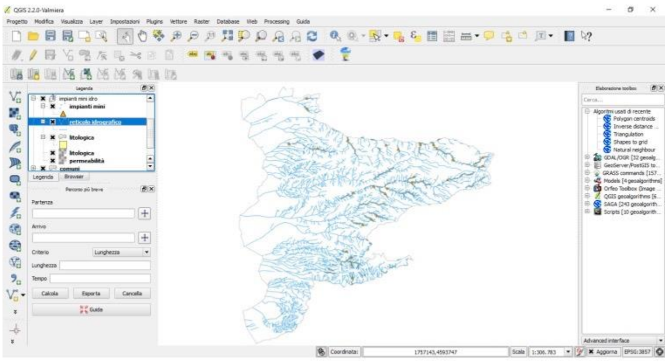

Figure 3. Derivative location of the proposed hydroelectric plants

3.3. Solar project hypothesis

For the solar potential, in order to incentivize its use, it has been proposed ~~an~~ integration of the Building Regulations (BR)with the rules on energy.

It has therefore been hypothesized that according to the BR area in which the building is located, this will have to produce at least a percentage of energy from renewable sources, imposing at the same time that the building itself has a percentage of area covered by collectors as much as possible limited (the surface has been calculated according to the BR area) in order to minimize the visual impact (figure 4, figure 5) (Ralston, 2002).

Once the various themes have been constructed and the proposed indicators modelled, the advantages in terms of energy would be evident for the community ~~in~~ when all the buildings comply with this standard and the proposed energy saving strategies have been implemented (Chiaradia *et al*., 2008).

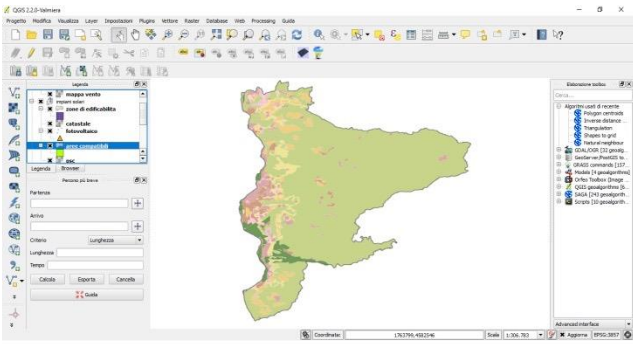

Figure 4. Minimum area of installable solar plant

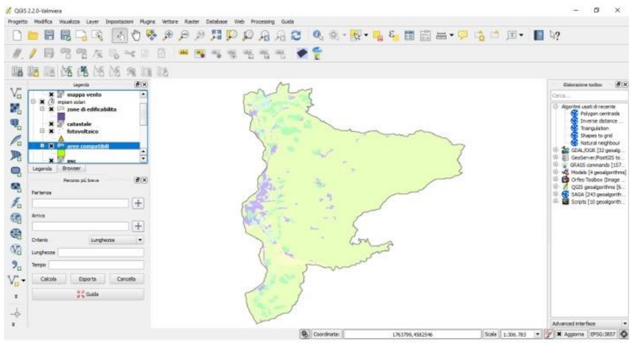

Figure 5. Maximum area of installable solar plant

4. Conclusion

The first tests carried out with the available data led to the localization of 182 mini-wind power plants and 29 micro-hydroelectric plants, and an optimization of area for solar plant installation (Figure 5) (Chiaradia *et al*., 2012).

The present application was obtained using partial and non-exhaustive data, and the multi-criteria parameter above-mentioned.

The aim of the application was to experiment the working principles of multi-criteria GIS-Based decision support methodology.

It can be considered as a starting point for further future developments (Turner, 2007).

Clearly, the system can be improved, however in this first step it gave a good results in terms of spatial and alphanumeric data management.

Once the proposed system has been completed, it can constitute an useful support for municipal activities with particular reference to urban, energy and environmental planning.

The system is still under construction and verification of its various components and its geodatabase structuring and it must be tested in its entirety with updated and complete data in order to provide results that can actually be used.

Further improvements can regard the implementation part, through the creation of special functions.

However, in relation to the objectives set, with the available data, an appreciable result was obtained.

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