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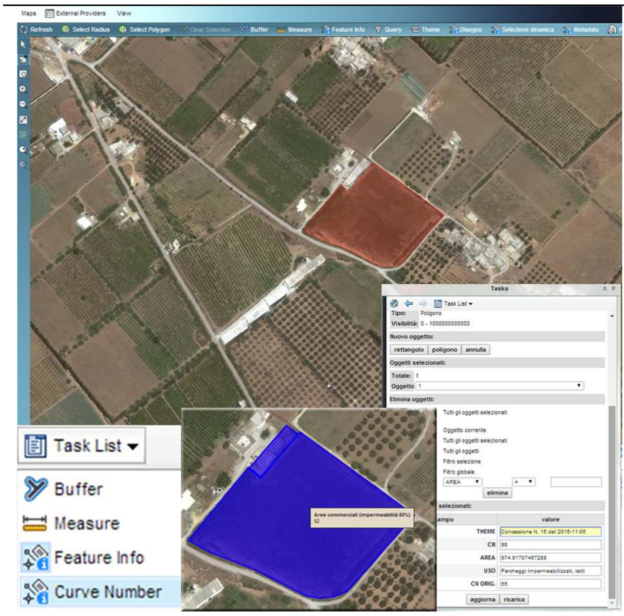

IMPLEMENTING GIS TECHNOLOGY: A SPATIAL DECISION SUPPORT SYSTEM TOOL TO STUDY THE IMPACTS OF LAND USES

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ABSTRACT
The need of soil consumption control and of the conservation of eco-systemic values of existing resources are the basis of this attempt to implement the GIS technology as a web-based Decision Support System. Following the European Community guidelines, an instrument for limiting, mitigating and compensating soil sealing is set in place, ensuring that the hydrological response of a given area during precipitation must remain constant before and after transformation. It is presented a practical approach with a technological improvement through a GIS evolution in the field of anthropic impact analysis. The web application makes use of the SCS-CN Soil Conservation Service-Curve Number method developed by the USDA in 1972 to study the phenomenon of the run-off. The web application, built as a webGIS service, based on the online interoperability of multiple users, defines a tool for the control of man-made impact and for a BMP-Best Management Practice driven policy for boosting eco-systemic values in Regional Planning. The challenge is to bring together GIS tools and evaluation models in a networked environment by implementing them towards online interoperability. Public officials, in charge of evaluating new projects, can be guided by the tool in the ex ante and ex post simulation of the land transformation. The effects that the land transformation causes are reflected in the CN as shown trough the web application therefore BMP to improve the hydrological solicitation response can be promoted. The tool is able to help the decision-making actors to cope with the complexity of reality and can help the planner towards strategic decisions based on spatial data.

KEYWORDS:
Spatial Decision Support Systems, Curve Number, Best Management Practice, web GIS, land use changes

1 INTRODUCTION

In September 2015 n.17 Sustainable Development Goals (SDGs) were adopted by world leaders whose countries will mobilize efforts to end all forms of poverty, fight inequalities and tackle climate change over the next fifteen years. They recognize that ending poverty must go hand-in-hand with strategies that build economic growth and addresses a range of social needs including education, health, social protection, and job opportunities, while tackling climate change and environmental protection.
Environmental threats are experienced mainly in agricultural, natural and semi-natural areas where there is more economic potential associated with a land use transformation. The increase of artificial covering, at the expense of these areas, causes a deep biophysics soil alteration (ISPRA, 2016) virtually irreversible.
The main impacts that soil sealing produces, according to the European Commission (2012), are:

- On water resources
- On biodiversity of underground and surface soil
- On food safety
- On the carbon cycle
- On the reduction in evapotranspiration
- On air quality
- On the link between chemical and biological cycles
- On the quality of life worsening.

One of the major source of degradation of rivers and lakes is the phenomenon of the flow of surface water (run-off). The effective control and management of the flow of water is therefore an evident need and the conservation of soil as non-renewable resource push towards finding solutions to strategic planning for future scenarios of management and regeneration. The removal of the agricultural or natural land associated with urbanization alters the hydrological system with increase in volumes and surface runoff peaks resulting in the release and transport of pollutants in the area in addition to erosion phenomena shortly afterwards.

2 STATE OF THE ART

The Sustainable Development, introduced for the first time by the World Commission on Environment and Development – WCED in 1987 in the Brundtland Report (Our Common Future), is meant as the process aimed at achieving environmental, economic, social and institutional improvements. The process of sustainable development, in line with EU laws, connects the protection and enhancement of natural resources with the economic, social and institutional promotion, in order to meet the needs of current generations without compromising the ability of future generations to meet their own. These objectives are linked in an interdependent relationship and are opposed to the heritage and natural resources, specially water and soil, deterioration. The consequences of the land artificialisation process are the significant loss of ecosystem services and the increase in "hidden costs" defined by the European Union (European Union, 2013), due to the increasing soil sealing. Ecosystem services are defined as all the benefits that are obtained, directly or indirectly, by ecosystems (Romano, Di Giacomo, Mattogno, 2015). In recent years a decisive signal to environmental sustainability is represented by the European Union Directives which transpose the requirements to counter the degradation of aquatic and terrestrial ecosystems. The degradation of aquatic and terrestrial ecosystems is associated with risks on human health, decreased quality of life and the loss of human lives and economic losses caused by disasters (Romano, Di Giacomo, Mattogno, 2015). The CICES Common International Classification of Ecosystem Services classification (Haines-Young and Potschin, 2013; ISPRA, 2016), in Table 1, divides ecosystem services in the following categories:

- Provisioning (food and biomass, raw materials, etc.);
- Regulation & Maintenance (climate regulation, carbon capture and storage, erosion control and nutrient, water quality control, protection and mitigation of extreme hydrological events, genetic reserves, conservation of biodiversity, etc.);
- Cultural (recreational, cultural and spiritual functions, landscape, natural heritage, etc.).

Section	**Division**
Provisioning	Nutrition
	Materials
	Energy
Regulation & Maintenance	Mediation of waste, toxics and other nuisances
	Mediation of flows
	Maintenance of physical, chemical, biological conditions
Cultural	Physical and intellectual interactions with ecosystems and land/seascapes
	Spiritual, symbolic and other interactions with ecosystems and land-/seascapes

Tab. 1 The CICES Common International Classification of Ecosystem Services classification (Haines-Young and Potschin, 2013)

In relation to ecosystem services capability of mediation of flows, the new settlement developments should be designed to minimize impacts on the quality and quantity of water that can possibly cause flooding downstream. The authorization control process of new interventions becomes a way to push the designer to define, on the basis of the outflow assessments, the BMP required size to meet the necessary reduction of the impacts that the proposed intervention could cause. According to Pistocchi (2001) only on the correct

representation and prediction of natural resources and their processes can derive practices and environmental policies rational foundation.
ICT - Information and Communications Technology tools can be effectively adapted to the requirements of the environmental assessment. One of the ICT tools globally used for territorial analysis is the Geographic Information System (GIS) Technology which was born in the United States around 1960. The GIS abilities to inform about location, characteristics, trends of the studied phenomena are increasingly been recognized.

The GIS Technology is configured as a decision support tool, Decision Support System (DSS), for spatial analysis and for human impacts assessment, as it facilitates proper operational decision based on a correct interpretation of reality. The Geographic Information System as DSS allows:

- A shared geodatabase provision,
- A common cartographic base endowment,
- information dissemination between different entities,
- real time data dissemination,
- information continuous updating tools,
- phenomena analysis tools,
- different levels and sectors training,
- procedures potential optimization,
- resources optimization.

The resulting challenge is to bring together GIS tools and assessment models in a network environment implementing them to the online interoperability as described by the OSGeo Consortium. The OSGeo Consortium refers to the term interoperability as the ability to find what you need, to access it, understand and use it for own needs.

3 OBJECTIVES

The general framework of objectives of this research work can be identified in:

- The protection of the quality and quantity of water resources
- The contrast to the uncontrolled sprawl
- The promotion of Best Management Practices (BMP)
- The sensibilization towards efficiency control in the preparation of building permits at the local level
- The support to new approaches to integrated and sustainable design.

It is shown a methodology developed for the implementation of support tools for planning and for evaluating impacts on water and soil resources in marginal areas. The underlying objective of the research is to study a methodology for the application of modeling assessment of human impacts on nature on Decision Support System tools and in particular on the GIS Geographic Information System technology. The interest is for the design of a web based DSS for the mitigation of hydraulic impacts on the landscape and for the eco-systemic functions maintenance. This methodology allows to recover a tool, user-friendly and accessible to novice users, to control the impact of new design contributing to the assessment of soil erosion scenarios based on land use change projections. The resulting effect is, during the validation phase of the project and therefore during the construction permits procedure, an indication of design requirements. In consideration of the surfaces affected by the project it will be necessary, therefore, to perform the mandatory BMP estimation to reduce the transformation impact.

The European Union in the Guidelines on best practice to limit, mitigate or compensate soil sealing (2012) aims to promote three types of approaches designed to:

- Limit soil sealing
- Mitigate the negative effects caused by the use transformation soil
- Compensate any inadequacy of mitigation measures

where the waterproofing limitation of the soil, and then the respect of the hydraulic invariance - according to which, in other words, the flow rate at the peak resulting from an area drainage must remain constant before and after the transformation of the use of the soil in that area - remains a priority compared to mitigation or compensation measures. The European Union (2012), in particular, aims to promote an approach to prevent the conversion of green areas and the subsequent sealing of their surface layer or part of it. This approach in fact encourages the re-use activities of already built-up areas such as brownfields.

It is emphasized, moreover, the use of tools, such as the one proposed, able to support the uncontrolled sealing contrast activity. Mitigation measures are intended to be adopted, where there has been a waterproofing transformation, to keep some of the soil functions and to reduce the significant direct or indirect negative effects on the environment and human welfare. Among these measures it is placed the use of suitable permeable materials instead of cement or asphalt and an increasingly greater use of natural systems to collect water taking into account however that it is impossible to completely compensate sealing effects.

4 MATERIALS AND METHODS

In the water sector the numerical modeling is now the basis for all analysis, planning and land management activities. The growing availability of spatial data, observations and calculation tools, enriched by the support of GIS technology allows to conduct more detailed and reliable simulations.

The use of mathematical models that simulate ecological processes is dependent on the availability of a model that adequately represents the case or of a model that is developed ad hoc. The model development, the model implementation in case studies, and the results interpretation are specialized skills whose effect can be applied to the reality influencing the decision-making process.

The Intergovernmental Scientific Program Man and the Biosphere Program (MAB) launched by UNESCO in 1971 was promoted to establish a scientific basis for the improvement of relations between people and their environments emphasizing the need to assist policymakers in understanding the interdependence between urban systems and the environment. Rapid urbanization in order to meet urban needs often occurs with the loss of ecosystems and valuable territories (Shen et al., 2011). For the Italian National Institute for Environmental Protection and Research - ISPRA (2016) specific information should be given to local managers to define and implement measures in order to limit, mitigate or compensate soil sealing behaving undisputed advantages for the natural heritage and at the same time for public spending. Last ISPRA's Report on soil consumption (2016) considers it necessary and urgent to provide municipalities with clear information and useful tools for reviewing even the predictions of new buildings inside the urban and regional plans already approved. The Report confirms that the soil is vital for our environment, our health and our economy itself recognizing the value of natural capital. The modeling of hydrological-hydraulic phenomena triggered by precipitation on a basin and, therefore, the formation of full outflows in peri-urban areas, requires the detailed knowledge of the spatial and temporal distribution of rainfall (Figure 1).

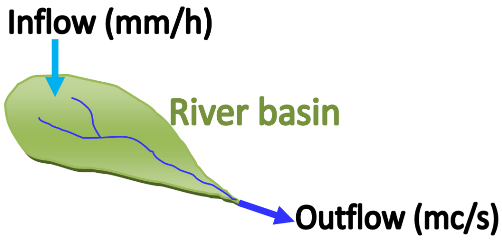

Fig. 1 Schematic representation of surface runoff formation

The volume of water that reaches the closing section as a result of precipitation can be decomposed into four contributions (Greppi, 1999; Moisello 1999):

- direct flow;
- runoff;
- hypodermic flow;
- underground (or deep) flow.

The surface runoff formation phenomena plays a fundamental role in the genesis of flood picks and erosive processes that occur in the catchment areas. The runoff, in fact, is the fastest component of the outflow and it has the flow rate maximum values, this phenomena study is therefore of particular importance in the planning and design activities to safeguard natural resources.
In the field of general simulation of the phenomena, to be used to guide the design, simple mathematical models are able to represent the global behavior of the basin by estimating the flow rate at the peak.

The SCS-CN method, developed by the Department of Agriculture of the United States of America USDA, the Soil Conservation Service (Soil Conservation Service) in 1972, of the CN Curve Number, estimates the cumulative net precipitation (mm) as a function of cumulative gross antecedent precipitation, coverage and use of the soil and of the initial conditions of soil moisture. According to the United States Department of Agriculture (USDA 1986), there are various factors taken into account in determining the runoff CN. The main factors that determine the CN are the hydrologic soil group (hydrologic soil group HSG), the type of coverage, the treatment, the hydrological condition, and the runoff antecedent condition (ARC). Another factor considered is whether the impervious areas discharge directly into the drainage system (connected) or if the flow extends over the permeable areas before entering the system (not connected).
The basic relationship of the CN Curve Number method is as follows:

$$Q(t) = \frac{[P(t) - I]^2}{[P(t) - I + S]} \tag{1}$$

Where:
Q (t) [mm]: net rain height up to the instant t
P (t) [mm]: Rain height precipitated up to the instant t
S [mm]: maximum storable water height in saturated soil
I [mm]: purification or initial loss = 0.2 * S

This relationship is only valid for P (t) greater than or equal to I, while in the case in which the total height of cumulative precipitation has been less than I, Q (t) = 0 and therefore the outflow is null.
The term I takes into account also the complex phenomena such as the interception by the vegetation and the accumulation in terrain surface depressions which delay the occurrence of surface runoff.
From the analysis of the results obtained by the SCS into numerous small experimental basins, it has been proposed the empirical relation that binds I to the S and which allows to estimate I as I = 0.2S. The value of S is normally attributed through the use of an intermediate parameter, the Curve Number (CN), according to the relation:

$$S = \frac{25400}{CN} - 254 \tag{2}$$

Therefore it follows that the outflow height up to the instant t is equal to:

$$Q(t) = \frac{[P(t)-(0{,}2*S)]^2}{[P(t)-(0{,}2*S)+(\frac{25400}{CN}-254)]} = \frac{\{P(t)-\left[0{,}2*\left(\frac{25400}{CN}-254\right)\right]\}^2}{\{P(t)-\left[0{,}2*\left(\frac{25400}{CN}-254\right)\right]+\left(\frac{25400}{CN}-254\right)\}} \tag{3}$$

The CN parameter is a dimensionless number and varies from 100 (for water bodies) to about 30 for permeable soils with high infiltration rates. The CN is therefore essentially linked to the nature of the soil, the type of vegetation coverage and the soil moisture conditions prior to the precipitation.
As regards the nature of the soil, the Soil Conservation Service (SCS, 1972) has classified the types of soil into four groups on the basis of the different characteristics of permeability, from group A with very high infiltration capacity to group D with little infiltration capacity. The operational procedure proposed for the effects of the land use changes assessment provides several phases defined as follows:

I. identification of the total area of the subdivision being evaluated;
II. identification of the surfaces of the individual specific use of the soil components (roof, parking, green area, ...);
III. classification of individual surfaces with the appropriate CN;
IV. obtaining (automatically) the weighted average CN for the total surface area;
V. set a return time and apply the formula (3)to obtain SCS CN Q output from the sub-basin.

The application allows to identify the total area of the subdivision being evaluated and the surfaces of the individual specific use of soil (roof, parking, green zone).
Once the areas are identified, the classification of individual surfaces is possible with adequate CN to obtain automatically the weighted average CN for the total surface area that is equal to:

$$CN_M = \sum \frac{Ai*CNi}{Atot} \tag{4}$$

Where:
CN_M : average weighted CN for the total area
CN_i : single surface CN
A_{tot} : total surface area (automatically obtained)
A_i : single surface (automatically obtained)

As a consequence of this evaluation there is the need to simplify the possible application of BMP to mitigate the impact. The "Service Level Method" (LS) is a BMP selection method designed by the American Public Works Association & MID-America Regional Council for the macro region of Kansas City, USA, which is based on applied hydrology research of the Soil Conservation Service and practice studies recognized in USA.
The LS requirement for the development is determined by the change in runoff as measured by the change in curve number from the predevelopment condition to the postdevelopment condition (Figure 2).

Change in CN	Impact	LS
17 or greater	High water quality impact	8
7 to 16	Moderate water quality impact	7
4 to 6	Low water quality impact	6
1 to 3	Minimal water quality impact	5

Fig. 2 The relation between the CN change and the impact evaluation and the Level of Service needed

The LS provided by the stormwater management system is determined by applying the Value Rating (VR) provided by each BMP (bioretention swales, bioretention basins, constructed wetlands, ponds, swale/buffer systems, etc.) to the area of the site from which the BMP treats runoff. If the development or project does not meet the definition of development or is otherwise excluded, BMPs are still recommended.
In particular the steps of the procedure proposed by the American Public Works Association and the MID-America Regional Council (APWA / MARC, 2012) for selecting a BMP are:

1. Calculate the weighted curve number for pre-development conditions using the SCS-CN method reference.
2. Calculate the weighted curve number for the proposed development.
3. Determine water quality measurements, or Level of Service (LS), which compensates for the difference between CN Pre and post-development.
4. Calculate the weighted Value Rating (VR) provided by the proposed development, including waterproof surfaces, vegetative cover and preserved or replanted vegetation.
5. If the weighted VR of the proposed intervention does not meet the LS, a mitigation system can be assumed by applying BMP
6. Calculate the weighted VR for the mitigation package
7. Realize the actual sizing design of the BMP system.

5 RESULTS AND DISCUSSION

Geographic Information Systems provide the ability to perform spatial analysis and allow to graphically highlight the results of queries on the data related to the map.
This technology allows the capture, storage, analysis, visualization, and the return of information from geographic data. In other words, an interactive mapping system is a tool that allows to analyze the relationships between objects located on the territory.

The added value of this technology is that the data, stored properly, systemized and localized cartographically, can be viewed simultaneously by multiple technicians on the network even from different places (Figure 3).

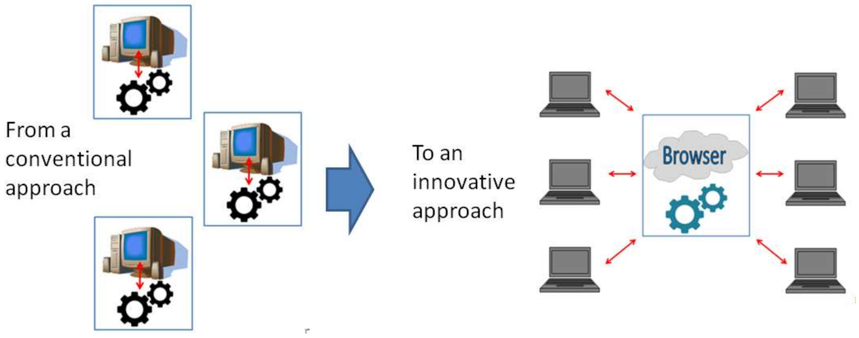

Fig. 3 The shift from a conventional approach Client based to an innovative approach of cloud interoperability

The Geographic Information Systems schematize information in a structure with several layers each containing a single theme and enabling knowledge integration through a multi-sectorial and multi-scale approach. Implementing GIS technology towards online interoperability through Web-GIS permits to answer the challenge to bring together GIS tools and assessment models in a network environment. The Web-GIS was established, precisely to connect all public servers and the information available to manage the map information on the web. The Web-GIS solutions improved with specialized tools help make information available anytime and anywhere to the different stakeholders in the network building a common and accessible tool able to guide decision-making power on a science-based approach. The control of the effects of changes in land use in environmental quality, particularly in the management of water resources, can thus become operational on the network through the application of innovative tools.

The application includes the development of a database linked to the designed object to have information about the area, CN, land use, surfaces description of the part of land subjected to change. In this data structure values can be inserted, directly from the Client, with the underlying cartography, and these values will be stored in the map server to constitute the database of the transformation. Therefore, it is possible to create a working layer "Editing" (Figure 4) on which to edit the new design situation.

Fig. 4 The drawing layer on which new objects are stored

Having identified a project area, new surfaces can be designed representing the different kind of land uses. For each type of land use, and therefore for each surface, in the CN value attribution, new characteristics of permeability can be assigned according to what will be built in those areas (Figure 5). Each saved characteristics will directly be visible from every stakeholder involved in the assessment.

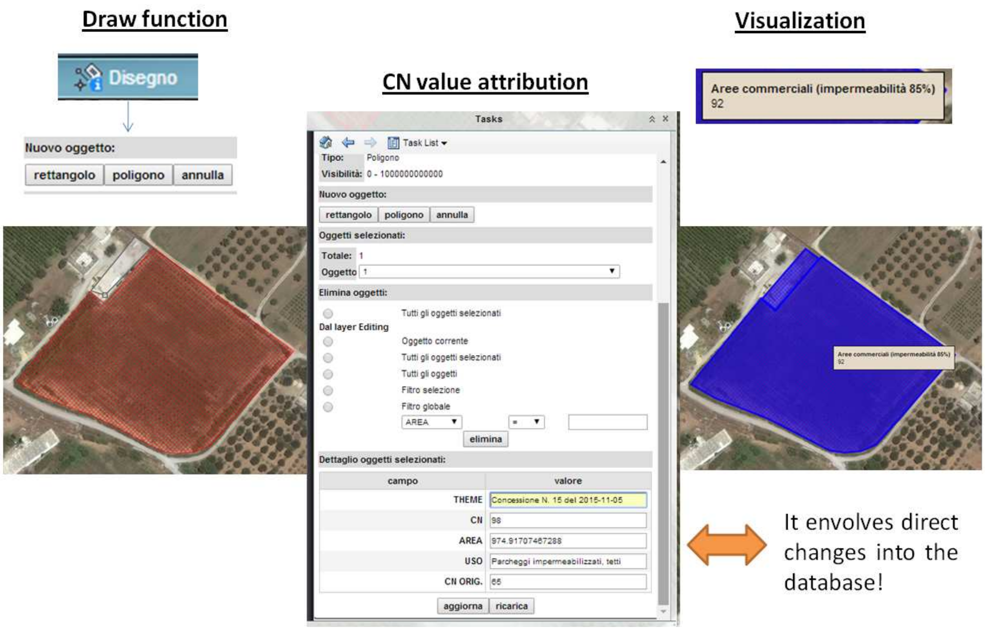

Fig. 5 The flow of procedures provided by the developed web application

The application takes into account the total area and makes it possible to recover the value of the percentage increase of CN that describes the impact that the territorial transformation induces (Figure 6).

At Community level, among the solutions that exist to compensate the loss of soil and its functions is the proposal to establish eco-accounts. It is also hypothesized a soil sealing fee to be collected to be used for soil protection or other environmental purposes (European Union, 2012).

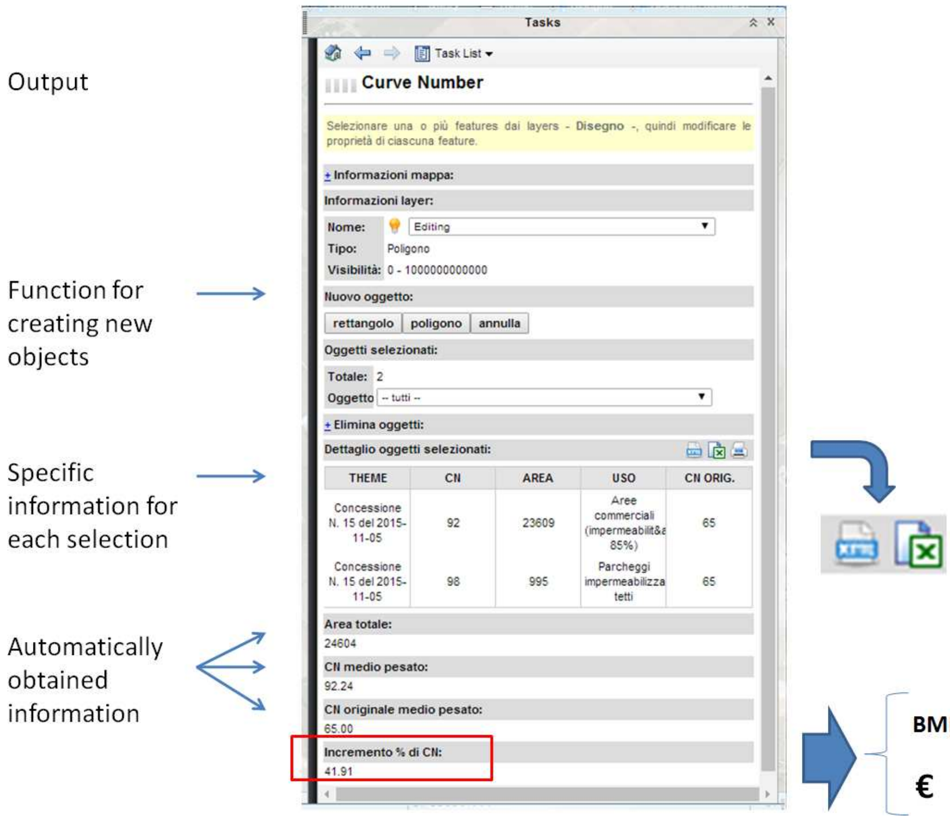

Fig. 6 The output of the application: the results of the evaluation can be used to provide environment taxation or BMP design

6 CONCLUSIONS

The methodology specializes the particular approach established in previous projects extending and implementing GIS technology Geographic Information System towards online interoperability. The target of the methodology and technology implementation is represented by stakeholders who act directly on land such as: public authorities and private professionals.

The implementation of GIS technology Geographic Information System would allow the planner to use the environmental tool to study the impacts of land uses on the project area when performing environment control of supposed land use changes.

The development of ICT solutions integrated with spatial data knowledge must guide the planner towards strategic, reliable and shared decisions in the water sector.

The application of innovative ICT tools in the field of peri-urban regeneration can become a powerful tool, particularly in the water resources management, to guarantee environmental quality control and to avoid land use consumption as suggested by the European Union.

Implementing GIS technology to enhance the comprehension of interactions between the existing multiple aspects, the environmental processes simulation and the impacts analysis of land management activities on water resources can permit the definition of scenarios as key components underlying the political decisions (Di Giacomo, 2016).

REFERENCES

Di Giacomo T.V., (2016), *Tools and Methods to Reclaim the Value of Water Resources in Peripheral Areas*, UNISCAPE En-Route I QUADERNI DI CAREGGI, UNISCAPE'S ONLINE PUBLICATION - a. I - n. 3 - 2016, pp. 289-293, UNISCAPE EN-ROUTE International Seminar Recovering River Landscapes 28-30/09/2015, University of Naples Federico II, print ISSN 2281-3195

European Union (2012), *Guidelines on best practice to limit, mitigate or compensate soil sealing*. Bruxelles, 15.5.2012, SWD (2012) 101, ISBN 978-92-79-26216-6, doi: 10.2779/81286

European Union (2013), *Hard surfaces, hidden costs. Searching for alternatives to land take and soil sealing*, Luxembourg: Publications Office of the European Union, ISBN 978-92-79-30550-4, doi:10.2779/16427

Greppi M., (1999), *Idrologia. Il ciclo dell'acqua e i suoi effetti*, Ed. Hoepli, Milano

Haines-Young R. and Potschin M. (2013): *Common International Classification of Ecosystem Services* (CICES): Consultation on Version 4, August-December 2012. EEA Framework Contract No EEA/IEA/09/003

ISPRA (2016), *Consumo di suolo, dinamiche territoriali e servizi ecosistemici*, Rapporti 248/2016, ISBN 978-88-448-0776-4

Moisello U., (1999), *Idrologia tecnica*, Ed. La Goliardica Pavese, Pavia

Pistocchi, A. (2001), *Il ruolo della modellistica delle georisorse nei processi di pianificazione territoriale*, [Dissertation thesis], Alma Mater Studiorum Università di Bologna. Dottorato di ricerca in Georisorse e geotecnologie, 13 Ciclo. DOI 10.6092/unibo/amsdottorato/12, ISSN: 2038-7946

Romano R., Di Giacomo T.V., Mattogno C., (2015), Paper "*Agricoltura periurbana e cura del territorio*" in XXII Conferenza Internazionale VIVERE E CAMMINARE IN CITTÀ. NUOVI PARADIGMI Brescia, 5 giugno 2015

SCS (Soil Conservation Service), (1972), *SCS National Engineering Handbook*, Sec. 4, *Hydrology*, USDA, USA

Shen L., Ochoa J. J., Shah M.N., Zhang X. (2011). *The application of urban sustainability indicators - A comparison between various practices*, Habitat International 35, Elsevier, pp.17-29.

USDA, *Urban Hydrology for Small Watersheds* 210-VI-TR-55 (1986). United States Department of Agriculture, Natural Resources Conservation Service, Conservation Engineering Division, Second Ed., June 1986

WEB SITES

Retrieved from http://cices.eu/ Last access June 2018

Retrieved from www.osgeo.org Last access June 2018

Retrieved from http://www.millenniumassessment.org/en/Index-2.html Last access June 2018

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