Ecosystem services and urban planning. Tools, methods and experiences for an integrated and sustainable territorial government

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Abstract

Urban planning and design for post-carbon sustainable city requires a major connection between the new scientific paradigms of environmental disciplines and useful/communicative indicators to steer local policies.
Nowadays the spatially explicit assessment of Ecosystem Services (ES) and their flows can effectively support the decision making process for sustainable development. Thus the methodology of considering environmental sustainability during planning phases should be hold in plan's construction and integrated during the decision making process at urban scale, also using Co-planning method.
The paper experienced the recent research innovations made by DIST for LIFE program SAM4CP, where preliminary output of ES mapping were used as proxy for the identification of high value areas to be planned.
Inside it is presented a methodology of integration betweenmapsofbiophysical/economical ES values using InVEST software as a tool for geographic, economic and ecological accounting. The mapping activity, related to Land Cover/ Land Use information for a context based case of was used to supportthe preliminary approach to co- planning activityfor multilevel governance, especially .among consensus building approach and the Co-planning Conference.
Innovations are discussed both by processual andtechnical sides: (i) the urban planning activity founded upon the Co-planning method and supported by such analysis, allowed policy makers to go into the substance for reconsider their strategies for sustainable territorial government and (ii)the scientific contribution of the research on mapping ES demonstrates that approach is today fully incorporated on local tools for land management.

1_Introduction

The integration of urban planning and ecology is recently increased and nowadays it is considered a foundation of the discipline: it sets new fields of competence of the municipal/local plan, new disciplinary partnerships and emerges as a result of the introduction of new laws, both national and regional.
Since it is necessary to overcome the "protection/defense" approach of territory, environment and landscape, the plan is able to be the instrument of a new strategy for the unified government of city, territory and environment that integrates urban planning and ecology (Campos Venuti, 1994).
Therefore it is necessary to redefine the overall strategy of the plan,and its contents,renewing and extending their knowledge that underpin its implementation, using new skills and methods of analysis.
Within this premises, the approach of mapping and modelling ES has rapidly increased (Hayha& Franzese, 2014). The ES approach can help to evaluate the effect of a project or policy on soil ecosystems,thus it canhelp to better communicate and visualize planningoutcomes to policy makers, supporting environmental planning decisions,and designing sustainableland uses (Maes, et al., 2012). In terms of energy efficiency, a deep ES modelling should support a better balance of sustainable use of land: the monitoring of flows in terms of ES is a basilar energy related information to better achieve sustainability in planning.

ECOSYSTEM SERVICES AND URBAN PLANNING

Tools, methods and experiences for an integrated and sustainable territorial government

Authors
Carolina GIAIMO
carolina.giaimo@polito.it

Dafne REGIS

Stefano SALATA

DIST - Interuniversity Department of Regional and Urban Studies and Planning
Politecnico di Torino
Viale Mattioli 39
10125 Torino

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The LIFE project SAM4CP[1] aims to connect the scientific knowledge on ES allowing a better territorial decision mechanism. The project leads to include the ecological assessmentof soil within itseconomic valuealso accountingalternativeland-use scenario. This require a high degree "mapping" ESknowledge, using accurate and precise dataset to support traditionalenvironmental analysis for land use planning(Benini, et al., 2010). This is why a group of DIST-Politecnico di Torino expertise[2] is working to develop the technical actions to support planning decision. Such methodology require also technical innovations: a new software for ES mapping has been used for construct land use scenariosanda new participatory planning process has been supported by an ES biophysical and economic assessment.

The project aims to capture the "flows of value" that a land use variation produce to the initial stock, going beyondthe traditional approach of Land Use Change Analysis (Keller, et al., 2015). It is the "quality", rather than the "quantity" of consumed soil to be analysed by the lens of the project. Such information is crucial for a better integration of sustainable/resilient strategy of land use managementin terms of energy systems: only if the knowledge on flows of ES is deep than strategies of mitigation and compensation measures for land transformation can be activated (European Commission, 2012).

As introduced, the mapping process is fundamental to estimate the current (baseline scenario) and expected trends in ES values and their economic assessment. The economic evaluation of ES is going to became crucial for raising environmental policy awareness (de Groot, et al., 2002; Tol, 2005; Gomes Lopes & al., 2015; Baral & al, 2014), but still requires a better connection to the biophysical assessment of ES(Costanza & al., 1997; Tol, 2005). Measuring ES in monetary terms can help make them "visible" and ensure that the benefits of biodiversity are effectively taken into account forplanning processes.

The overall target of the project is to connect the assessment results with the real planning processes in defined case studies. Nonetheless, the project will guarantee a high degree of shared knowledge between stakeholders and public administration at different level. Such approach, which is called "co-planning", allows to steer policies at different level, modify the existent strategies for environmental sustainable land use planning ad to define new ones, starting from the acquired knowledge on soil properties and its ecological and economic values.

At the stage the project is in the middle of its implementation. This limitation should not guarantee that results of interaction between different actions will be fully achieved. In particular, the integration between evaluation and planning activity is not tested yet trough practical experiences. Nevertheless, the project has already defined the methodology regarding the support of planning activity by the integration with ES evaluation: it means that the way how the stakeholders and the public administrations make decision process has to be supported by the ES analytical framework. Moreover, such kind of framework needs to be constructed with a bottom-up approach where local stakeholders and citizens have an importantrole in the definition of ecosystem's value. Finally, according to the Project, the above mentioned activities will be supported by actions of consensus-building also aimed to inform local actors and to spread the importance of considering ES into planning disciplines.

[1] *Title of the Project: Soil Administration Model for Community Profit.*
Project leader: Città Metropolitana di Torinoresponsible for the actions 3, 4 as well as a management and administrative management of the project;
Partner (1): Politecnico di Torino, Interuniversity Department of Regional and Urban Studies and Planning;
Partner (2): ISPRA, Istituto Superiore per la Protezione e la Ricerca Ambientale;
Partner (3): CREA, Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria.

[2] *The DIST research group is composed by:*
Prof Carlo Alberto Barbieri (Scientific Responsable),
Prof. Giuseppe Cinà,
Prof. Angioletta Voghera;
with an operative team of research fellows composed by Dr. Carolina Giaimo, Dr. Dafne Regis and Dr. Stefano Salata.

2_The government of land use change

The territorial government is a wide concept composed both by technical and political skill and expertise that can't be addressed to a "discipline" in the traditional sense: therefore it can't be limited to the regulation of land use and building. It represents an integrated system of theories and practicesmade by knowledge and experiences with a properhorizontal and multiscalar"functional role", which exceeds the typical skills fragmentation of urban planning disciplines. Indeed, the territorial government includes a huge amount of expertise: environment, landscape, soil conservation, ecosystems protection, enhancement of cultural and environmental heritage, socio-economic development, mobility and territorial infrastructure (Barbieri, 2015).

Therefore, it's necessary to adopt rules and procedures for innovative urban and territorial planning, to support policies for the protection, enhancement and qualification of settlement, for urban regeneration and reduction of land take as well as governing climate change. But innovations for sustainability requiresto assume the principle of subsidiary and to recognize that territorial government is an integrated "horizontal" process rather than an"hierarchic system" composed byseparated plans drawn up by different and separated institutions.

By the way, there is a widespread awareness that the hierarchical planning model (and related procedures) based on the approval through dirigisme and indicator-based approach, is now obsolete and inadequate (Barbieri, Giaimo, 2015). Therefore, the sustainability challenge is a matter of institutional relations, rather than a matter of technology for planning: relations must become more horizontal and based at all on methods and procedures for cooperation between local authorities and consultation/participation of public and private stakeholders.

2.1_The planning process governance

It should be noted that the innovative transition from urban planning to local governance is intimately connected with a multi-level system of shared knowledge and methods.When decision making and public deliberation processes are characterized by a multiplicity of public subjects with relevant and differentiated tasks, it is essential to practice the multi-level governance. The multi-level governance is of particular significance in the field of urban and territorial transformations because it deals with the uniqueness of the physical space and the natural interdependence between the various components of the environment (air, water, topsoil, subsoil, biotic communities, etc.) which characterize any human activity and conditions for its operability. Such environmental organic unity and integration contradicts the separation and segmentation of tasks and functions that characterize the administrative action.

Practicing multi-level governance means to implement actions, behaviors and attitudes that favor a process of decision-making avoiding the deliberations of authority, which in turns, imply that decision makers, primarily public, may, as a consequence, don't adopt attitudes that determine the block of each operability.

In the italian public administration, still persist a hierarchical top-down approach, where public subjects express their own formal “veto power” to “influence” local policy. The over simplification of the power expression over municipalities by sovra-local public authority isn’t able to guarantee the effective success of the initiatives, because the complexity of the relationships among different competences and knowledges, require better capacities of co-planning between the involved subjects rather that a vertical approach.
It is therefore necessary that public administrations, at all levels – and private operators too – assume attitudes to co-work together for achieving sustainability, practicing the Co-planning attitude for the territorial government, through the instrument of the Co-planning Conference.
The Co-planning Conference favors feedbacks among different stakeholders positions, offering the opportunity to share communicable targets. However, the creation of a common agreement during decision making phase forces the involved subjects to declare what they really want, and the activities they have to pursuit.
The complexity of Co-planning Conferences is given both by the creation of a common decision making process based on a shared cognitive framework, and by the “formal” expression of power and competences of the subjects which are representatives of institutional bodies (Presidents of Region and Cittàmetropolitana di Torino, Mayors, or their delegates).
In this way, the public administration defines and declares the criteria by which it elaborates the evaluations: this corresponds to the so called “scoping phase” of SEA processes.

2.2_The challenge for LIFE SAM4CP: using ES to evaluate plan options

The complexity of governing urban, territorial and environmental phenomena through the plans require a great amount of analysis, interpretation and also graphic representation. Therefore these three activities are constitutive of the planning process.
LIFE SAM4CP project aims to demonstrate that territorial sustainable development requiresthe application of integrated skills – at all scales – of ecological, economic and socio-political disciplines within a transdisciplinary framework. Therefore, the ES analysis is one that require such integration between different evaluations, because the context based assessment of biophysical and economic valuesis based on integration between theories of environmental economy, geographic information system, mapping and representation of territorial data.
ES assessment for planning purposes is one of the challenges that both academic and administrative sectors have to deal in the next years. Indeed, in areas where good quality of ecosystems is maintained, the territory and its local community became more resilient and less vulnerable (EEA, 2010).
But the incorporation of ES assessment for planning purposesrequires radical re-thinking of the local governance system and in particular the planning activity for plans construction, as an instrument of knowledge both regulatory and strategic.
The role of the ES analysis should enforcethe integrated planning approach, especially joining the Strategic Environmental Assessmentthat produces

planning scenarios and a shared framework for evaluates, by public and private subjects operating at different levels and in different sectors, the spatial trade-offs among different land use functions. The role of ESassessment is to define the fixed and flexible elements of negotiations for land use regulation, therefore it represents the integration between plan and SEA which is essential to define broad strategies of sustainable development overcoming the pure technological enhancement of environmental issues.
Generally, the ES analysis helps institution and local stakeholders to play their choiceswithin a background strategy for sustainable development, which fixes the rules for improve or to restore theidentity characters of the territory. However, it doesn't have an adequate regulatory support in the planning process. For this reason one of the LIFE SAM4CP actions involvesthe realization of a structural variant for the local plan first in the municipality of Bruino and later in other three municipalities.
These variants pursues the goal of reducing land consumption and uses the co-planning procedure between Region, Cittàmetropolitana di Torino and the involved municipality, using ES assessment.
Thus, SAM4CP provides to involved municipalities (through a consensus building process), tools to support planning decisions and accompanies them in the revision of their urban plans.

2.2.1_Ecosystem services and co-planning

Among the activities of Co-planning, the relationships between public institutions andbetween institutions and users, are based on collaboration and participation in the definition of planning contents. In that phase, the involved institutions are forced to share the definition of the knowledge framework (which is complex and multileveled among different scales) and the objectives, methods and projects. Co-planning allows every institution to provides their information, knowledge, skills and specificities, in particular through its plans.
In Piemonte Region, the introduction of this new approach to urban planning dates back to the Regional Law n.1 of 2007 which was a partial modification of the regional planning law in force at time. Then it was confirmed by further partial modification introduced by the Regional Law n. 3 of 2013.
Co-planning is like defined a time-dependent path but open and constantly updated: the local administration share its knowledge and compares the diagnosis with other institutions and stakeholders, seeking incrementally an agreement on the general objectives and guidelines to pursue.
The innovative aspect is that the Conference is convened and chaired by the Mayor of the Municipality that propose the structural urban planning variant. During the Conference such Municipality take part, with voting rights, with the Città metropolitana di Torino and the Region.
A crucial aspect is that, depending on the contents of the structural variant, the mayor of the Municipality may invite at the Conference – without voting rights – other entities or authorities and stakeholders, competent or simply interested in territorial planning.Obviously, behind the decision to invite other actors, there is a political assessment by the Mayor whichselect only those that seems useful to involve. The deliberations of the Conference are valid when shared by the majority of participants with voting rights and the

conclusion of the planning process takes place in the town council, on the base of the Conference results.
The Municipalities that have joined LIFE SAM4CP, including the case of study of Bruino, will take part to the Co-planning Conference with the analysis on ESdeveloped during the project. Such analytical frameworkis developed prior to the final definition of the contents of the plan and commonly with the Strategic Environmental Assessment.

3_Ecosystem Services assessment

The above mentioned Conference, which is the pillar of Co-planning approach, is a crucial aspect for achieving the target of SAM4CP project. It is in such Conference that the scientific knowledge of ES, the agreement between stakeholders, and the participatory approach with local community, are discussed together among different administrative levels to find the decisional agreement.
Such agreement is the keystone of project aim: the uses of ES as a proxy for a sustainable development generates abetter planning activity. By the way SAM4CP consider the uses of new ESmapping techniques as a central part of a common knowledge system for governing land use change effects.
The construction of ES values in the case of study has been reached using the software InVEST-Integrated Valuation of Ecosystem Services and Tradeoffs. The software may be useful for informing resource management strategies and quantitative ranking of scenarios that can aid decision making, also because is a powerful tool to explore possible results of scenario between different land use alternatives.
The softwarewas usedto estimate the 7 main ecological functions provided by natural soil (biodiversity, carbon sequestration, water purification, water yield, contrast to soil erosion, provision of habitat for pollinators; food production). Models were builds to have a great deal of accuracy and precision in order to support the management of a planning project with local community: the challenge was not to use InVEST as a tool for accountability of ES, but to use it as a real support in decision making mechanism during the Co-planning phase.The research presented considers the last release available (in 2015) of the InVEST model (version 3.1.0).

3.1_The biophysical evaluation of ES

The need of reliable, precise and accessiblegeographic datasets is increasing, and the request of such data is only partially fitting with the provision of public geospatial datasets (Benini, et al., 2010). This is forcing techniciansto create “ancillary” datasets which are site specific and reliable, but not comparable between similar methodologies.
The organization of the input was crucial for output reliability, especially for those functions that requireda huge amount of data to connect with LULC map. As regard as input collection for InVEST, some limitations weredeterminedby the common dataset offered by the standard models of the software. Normally such modelsare too general, because environmental data (climatic, hydrologic, agronomic) are collected and restituted at macroscale rather than at microscale. For these reasonsit has beendecided to:

- collecthigh detailed environmental data using the web GIS online dataset of the Piemonte Region;
- useInVEST as a tool to support environmental analysis which was refined, articulate, handled with adjustment, even simplified, with adding information, or with a synthesis of results made with subsequent multilayered analysis (Keller, et al., 2015).

Even tested, the experience with the program is so limited. Thereforeit is quite problematic to understand at how changing parameters of each single variables can have significant effect on model's output. Anyway, further advancement of the project will fill such gaps.

3.1.1_Mapping ES using Bruino (TO) as a case of study

The Municipality of Bruino(among other three Municipalities) has been selectedas a key case study in LIFE activities according to the letter of interest. The LIFE activity has to produce avariance of the Local Land Use Plan.
The phase 1 of the project has been dedicated to run the software InVESTfor each ES selected. In particular, actions were dedicated to:

- the construction dataset (using standard and ancillary data);
- the research of sources for input software values;
- the interpretation of output models.

Immediately a question arises from actions development: the necessity of achieve a betterintegration onLand Usedata (repertories as CorineLand Cover) with Land Cover ones (imperviousness of soil). Actually "artificial surfaces"are simply considered,by environmental analysis,as a uniquecategory of "bed values" which generates noise and pollution; while, on theother hand, artificial green areasare a consistent and connective part of primary rural ecological network. A green garden, placed inthe dense city, even private and inaccessible for public uses, can provide ES as a natural widezone. Certainly, if a green zone has artificial boundaries, the habitat quality of some species is neglected; despite this, all other relevant functions are still provided by such open space.
The degree of impervious surfacehas been measuredas the average value for each Land Use class ofBruino, exporting the attribute table of LULC shapefile and creating a pivot table using Microsoft Excel. Such value has been used only for quantify the permeability of artificial surfaces, thusthe index of permeability has been used asanadditionalqualitative indicatorto settle the software'sinput value for environmental quality function.
Than the software was launched for all the main ecological function below described.
Habitat Quality: the map shows the cluster where the quality of habitat (as proxy ofthe overall environmental quality) is high or low. The case shows that on the north east (the Sangona River) and south west (the hill) of the municipality are placed the main "corridors". In the middle of the flat floor of the valley the settlement system is distributed, but leapfrogged clusters of medium environmental quality are spread even close to dense residential and industrial zones.
Carbon Sequestration: the model uses data on wood harvest rates, harvested product degradation rates, and stocks in carbon pools to estimate the

amount of carbon currently stored in a landscape or the amount of carbon sequestered over time. The map shows were soils are capable to "hold" a high degree of carbon, and provide a "carbon pool" function which is fundamental also for climate change mitigation policy.

Water Yield: the map represent the relative contributions of each land use cell to the yield of water per each watershed. The value ofevapotranspiration has been used to map those areas that better filter the stream via evapotranspiration.

Nutrient Retention: the map indicates the contribution of vegetation and soil to purifying water through the removal of nutrient pollutants from runoff. In particular the map shows at pixel level how much load from each pixel eventually reaches the stream.

Sediment Retention: the map indicates the total potential soil loss per pixel in the original land cover. High values correspond to places where loss ofsediment is higher than in other parts. This vulnerability is crucial especially for territories where erosivity is high (hills or mountains).

Pollinator Abundance: The map represents an index of the likely abundance of pollinator species nesting on each cell in the landscape. It provides information on sites where suitability for nesting is high or low, this give adequate information especially for planning agricultural uses.

Crop Production: this services has been mapped using the Land Capability Classification modelprovided by the Regional database of Soil, and not InVEST. This inventory was sufficiently accurate to estimate which was the productive capacity of each pixel of land, according with the definition of suitability of soil for agricultural purposes.

3.2_The economic evaluation of ES

To assign an economic value to specificES provides the possibility to develop better environmentalplanning practices and toincrease the knowledge of the stakeholders and decision makerstowards the economic values of natural, non-reproducible, resources.

A pioneer study of Costanza et al. (1997) classified the global land use into 16 primary categories and grouped ES into 17 type; using this approach it waspossible to extract equivalent ES weight factor per hectare in different areas. The total ES of each land use category was obtained through multiplying the area of each land category by the value coefficient.

Related to this, when ES values is associated to a land use transition matrices, notable changes on ecosystem values can be observed and the economic loss of specific transitions can be noted and explained. New indicators (as the percent decrease of the total ES value) can enforce the evidence of economical long term effect of land use change and urbanization. Sometimes the rate of increase or decrease of a specific land use does not correspond to the rate of variation on ES. This is why it is so important to exactly quantify ES values.

Nevertheless, many economists criticized the valuation method because different approaches may produce significantly different results. Moreover, some studies have pointed out that the valuation method is less meaningful to estimate the total value of an ecosystem, and may be more appropriate for marginal change analysis (Shuying et al. 2011). So the ES analysis is useful to analyze the rate of increments or decrement of values rather than the total-value of a land use scenario (Bateman & al., 2013).

3.2.1_The methodology in Life SAM4CP: a multi-criteria approach for the economic evaluation

One of SAM4CPoutput is the estimation of economic values of soils on the base of their biophysical values.

Many authors discuss the possibility of reaching economic values ofES, but few of them explains how to link the biophysical side of evaluation with its economic value. Nevertheless,the project presents a first simulator of land use scenario, which keeps togetherspecific biophysical performance of land with a corresponding monetary value. Using the ES mapping as the base for biophysicalquantification, the challenge wasto adopt and found methodologies to associate parametric"prices" of ES provided by soil. A typical example isthe carbon sequestration service, which is the natural storing service offered by soil acting as carbon pool.

Starting from LIFE+MGN (Making Good Natura)[3] research models, the biophysical maps where used to associate economic values.

Firstly, it was assumed that all measured values are "potential" rather than "definitive",and they derived from market price of substitution/artificial production of asimilarservicewhich normally is provided by soil. The word "potential" is referred to the condition of arbitrariness of such quantification, and the challenge is to estimate the trend between one, or more, alternative land use scenarios. This approach gives the possibility to understand which is the trade-off among different "potential" function that soil can provide.

Biophysical evaluation produces output per pixel expressed by (i) indexes or (ii) absolute quantities. The seven functions defined by projectare estimated using such units:

- index from 0 to 1 for Habitat Quality and Crop Pollinator;
- tons/pixel for Carbon Sequestration and Sediment Retention; mm/pixel for Water Yield; kg/pixel for Nutrient Retention;
- values form 0 to 8 for Land Capability Classification (Crop Production).

While for ES with absolute values it is possible to definea price per unit (according with scientific study, 1 tons of sequestered carbon is equal to 120 euro), mistake arises when the economic value is associated to indexes. Such limitation is declared also by the huge bibliography whichremarks the impossibility to allocate a final price to ES (e.g. biodiversity).Anyway, even though with declared limitations, a "derived" value was applied, using the classical approach to economy of quantify the "production value" of a goodrather than its "willingness to pay" value.

An example is given by two important functions expressed with biophysical indexes: Habitat Quality (which measure the biodiversity value) and Crop Production (which measure the productivity capacity). The economic evaluation of biodiversity index was estimated from the price of "reproduction" of land uses that provides biodiversity in urban areas.For example the cost of planting a forest, rather thanthe cost of a public garden for urban green areas. This price of "substitution" (how does it cost to reproduce such goods?)

[3] *Project "Making Public Good Provision the Core Business of Nature 2000" (LIFE+11 ENV/IT/000168) coordinated by University Consortium (CURSA). For more information: http://www.cursa.it/ecms/uk/research/making_good_natura.*

was distributedusing a linear function to all the land use categories. The same approach was used for potential productivity of soil. Starting from the market values (per hectares) of specific cultivation it waspossible to estimate which wasthe average economic value per hectare of agricultural landscape on-specific sites. Thus the "potential" agriculture productivity for each land use class was calculated using a linear equation.
The relationship between the biophysical and economicmodels of evaluation allows,at the time of land use changes (potential or defined), toget a continuous variation between values both environmental and socio-economic, and estimates the overall impacts led by the potential transformation of land use.

4_Conclusions

SAM4CP is one of the EU project which is aimed by pragmatism in the use of new concepts as ES for sustainable territorial government. The project tries to introduce new procedures and technologies among stakeholders to achieve a better land use planning for local communities. By the way, its applications in research is dependent to the local planning needs with a detailed, abundant, system of knowledge and, moreover, to use the great theoretical amount of information related on ES for planning purposes, considering all the typical problems of planning activity (e.g. assigned building rights, constrains, incongruence between planned and existent land uses).
Procedural and technical innovations were discussed in the paper and both are characterized by uncertainties and limitations. Even if Co-planning Conference is traditionally embedded by planning culture of Piemonte because it has been introduced by Regional Laws since 2007, the way in which public authorities express their opinion often continues to be characterized by a hierarchical attitude, particularly from the Region, instead of consider-local needs and knowledge. The Co-planning Conference should be used as a place to determine goals, plans and actions through shared, horizontal and collaborative activities of public authorities at all levels.
Secondly, a high degree of uncertainty arises for ES assessment when variable's input is discussed. And such uncertainty doesn't enforce the position on local Administration among Co-planning Conference. Thus it is soon to understand if SAM4CP project can really reach the possibility to "increase the power" of the Municipalities using a defined scientific approach to valuate different land use scenario.
The risk is to be much oriented on a pure theoretical advancement of research on ES rather than to be operative for introducing real planning innovation over the traditional framework of systems and powers.
Anyway, the consensus building approach based on a deep knowledge of ES trends and dynamics is shading lights on some planning issues related to sustainability of land uses: only a qualitative knowledge, rather than quantitative, supports practices of mitigations or compensations for urbanization. It is widely demonstrated that there is not a direct relation between the quantity of urbanized land and its quality.
If the prior strategy at EU level for 2050 is to reduce (limitation) the amount of land take, it is equally important understand how to manage next

transformations of land using mitigation and compensation measures. Far away from being the most important target of the project, if this simple concept is agreed by sovra-local authorities than a better predisposition to share a common system of knowledge on sustainable land uses will be reached.

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Direttore responsabile
Patrizia Lombardi

Redazione
Costanzo Mercugliano, Luisa Montobbio
E-mail: costanzo.mercugliano@polito.it

Editore
DIST, Politecnico e Università di Torino
Viale Mattioli, 39 – 10125 Torino
Tel.: (+39) 011 090 7456 – Fax: (+39) 011 090 7499

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