OPEN ACCESS

2nd World Sustainability Forum
1-30 November 2012

www. wsforum.org

Article

Sustainability indicators supporting Strategic Environmental Assessment for urban planning

Valentina Castellani[1,]*, Serenella Sala[1]

[1] University of Milano-Bicocca, Department of Environmental Science, Piazza della Scienza 1, 20126 Milano, Italy;

E-Mails: valentina.castellani1@unimib.it, serenella.sala@unimib.it

* Author to whom correspondence should be addressed; Tel.: +39(0)264482824; Fax: +39(0)264482839

Received: / Accepted: / Published:

Abstract: Strategic Environmental Assessment has been introduced by EU legislation recognizing that spatial planning processes need to be supported by the evaluation of medium and long term effects of policies, plans or programs under investigation. The last two decades of Strategic Environmental Assessment (SEA) practices highlighted some lack in comprehensiveness, especially in assessing drivers of different nature (infrastructure, industrial development, household consumption) and related impacts. In fact, household consumption plays a relevant role in the total share of local impacts in a given region or city. This requires to enlarge the perspective of the assessment in order to make it really useful for decision making and resolving possible conflicts between environmental protection and social and economic development objectives in a proficient way. The methodology presented in this paper is an attempt to enlarge the traditional perspective of SEA, centred on the environmental assessment as a picture of current and future situation: the assessment made by a set of single environmental indicators is combined with the evaluation made through the composite indicators Ecological Footprint & Biocapacity and Carbon balance. This evaluation methodology can help: i) to understand if the level of consumption of the local community exceeds the limits of natural resources of the area (in a perspective of self-sustainment at the local scale) or if there is an overshoot between the footprint and the biocapacity, i.e. if the local consumption the cause of excessive land use in other areas; ii) to identify the role of spatial planning choices in determining the sustainability of the entire system. The case study presented in this paper is the implementation of this approach in the Strategic Environmental Assessment of the Urban Master Plans of four municipalities in Northern Italy.

Keywords: Strategic Environmental Assessment, Sustainability Indicators, Ecological Footprint, Carbon balance.

1. Introduction

Strategic Environmental Assessment (SEA) has been introduced by EU legislation (Directive 42/2001 EC) recognizing that spatial planning processes need to be supported by the evaluation of medium and long term effects of policies, plans or programs under development. The main aim of an SEA should be to support decision-making in the planning process and to help policy makers to identify possible alternatives for the actions that can generate environmental impacts on the area of implementation.

The experience made during the last two decades of SEA practice raised some concerns about the real effectiveness of SEA implementation procedures in fulfilling this aim [1]. One of the main issues debated is the necessity to enlarge the perspective of the assessment in order to make it really useful for decision making and resolving possible conflicts between environmental protection and social and economic development objectives in a proficient way.

According to [2] many times SEA fails influencing the decisions and there are very few successful experiences documented at policy-level, mainly because it usually follows environmental Impact Assessment (EIA) approach, structured for projects, trying to adapt it to policies, programmes and plans (PPPs). However, there is one main difference between projects and PPPs which lies in the fact that PPPs entail political decision, that are necessarily influenced by non rational aspects, such as the economic and social conditions of the community where the planning takes place [3]. In this perspective policy makers may have to take decisions based not only on data about the environmental conditions but also on the possible influence of external factors and trends [4] as, for instance, the lifestyle, i.e. consumption behaviour, of the citizens living in the area under investigation.

Household consumption plays a relevant role in the total share of impacts caused by human activities in a given region [5], so it is not useful to set the planning only towards public or industry sectors but it should be important to consider the effects of household lifestyles during the planning process. It is therefore necessary to include in the assessment procedure some decision support tools that take into account also the private consumption component and relative effects [6].

The methodology presented in this paper is an attempt to enlarge the traditional perspective of SEA, centred on the environmental assessment as a picture of current and future situation: the assessment made by a set of single environmental indicators is combined with the evaluation made through the composite indicators Ecological Footprint & Biocapacity and Carbon balance.

The idea is to consider a more comprehensive range of aspects in the evaluation, listed below.

- To evaluate the effects with reference to the existing limits of resources [7] and testing the self-sustainment of the area (in term of resource provision and emissions uptake).

- To quantify the effects generated by the actions of the plans: trying to calculate quantitative variation in the sustainability state of the area under investigation (not only a class of state, e.g. overshoot or credit of resources and positive or negative carbon balance, but a quantitative measure of effects in term of increase or decrease of EF, BC, emissions and uptake capacity).
- To include in the evaluation not only the direct macro effects (e.g. degradation of natural land or building materials consumption due to the construction of new dwelling areas) but also indirect ones, as for instance the increase of electricity and other household consumption following the increase in the number of residents in a given area.
- To evaluate sustainability in a broader perspective, evaluating the contribution from the area under investigation to global environmental problems such as climate change and resource depletion.

2. Methodology

As indicated by the EU directive and National legislation, SEA process has to include quantitative evaluation about the current situation and the foreseen effects of the PPPs under investigation. For this reason, SEA is usually performed trough a set of environmental indicators which give a picture of environmental conditions in the area.

However, if we consider that the main objective of the planning process should be to ensure sustainable development for the area, i.e. an improvement of the quality of life and of services for local community, respecting the quality of environment, it becomes clear that SEA need to balance the three components of sustainable development and cannot be only an environmental impact assessment applied to plans and policies [1]. Some authors (see, for instance, [2]) suggested moving from a rationalist approach to a decision-centred approach for the evaluation that takes into account also the non-deterministic aspects of decisions in policy-making. In this perspective, an environmental assessment which is based only on environmental indicators can be useful for identifying areas of concerns but could be not sufficient to support decision making.

Another important aspect to be considered in the evaluation of PPPs is that, in order to be really sustainable, the planning has to take into account the limits of local resources. Therefore, the concept of limit is the base upon which all the indicators considered should be developed.

For this reason, we chose to perform the assessment through a traditional set of environmental indicators combined with composite sustainability indicators , able to take into account consumption behaviour and limit of resources. The chosen composite indicators are the Carbon Balance (CB) and the Ecological Footprint (EF). CB and EF take into account a sustainability threshold (limit of resources) and are more focused on the consumption perspective and on the role of responsible behaviours from all the stakeholders of the community.

The present work illustrates an attempt to perform SEA integrating the evaluation made through a set of environmental performance indicators with other indicators derived from sustainability assessment methodologies. Hence, the analysis combines more traditional indicators with the EF assessment of citizens’ consumption and a CB of the area under investigation.

The EF assessment, and its comparison with local biocapacity, helps decision makers to understand if the level of consumption of the local community exceeds the limits of natural resources of the area (in a perspective of self-sustainment at the local scale) or if there is an overshoot between the footprint and the biocapacity, i.e. if the local consumption the cause of excessive land use in other areas.

The evaluation of CO_2 balance is aimed to focus the attention on the climate issue (which is relevant both at the local and the global scale), in order to highlight disequilibrium between direct and indirect emissions of greenhouse gases due to local activities and the uptake capacity of the area. This evaluation can help to identify the role of spatial planning choices in determining the sustainability of the entire system both in the CO_2 reduction strategy and in conservation of the uptake capacity of the territory.

The idea is to include in the evaluation some issues of global concern, such as resource depletion and climate change and to reinforce the use of the carrying capacity concept within the local planning. Apart from legislative thresholds, a focus on the ratio between consumption and impact at local scale is really crucial [6].

Three type of carrying capacity can be defined and applied in defining policies at local scale: quantitative, qualitative and operational carrying capacity (Table 1).

This approach support a vision of “sustainabilities”: a univocal solution for planning sustainability actions is not feasible. Each country, region, municipalities have to define a pathway to sustainability according to: local socio-economic condition, local environmental quality and quantity of resources, culture and stakeholders’ behaviour in production and consumption of goods and services

Table 1. The three levels of carrying capacity and examples of related tools.

Carrying capacity	Tool
Quantitative Carrying Capacity (how much can be consumed in a perspective of self sustainability and as a way to reduce the overall impact on environment and resources).	Carbon Balance (how far we are from a balance between emission and absorption of CO_2) Ecological footprint (how the local pattern of consumption affect the availability of resources)
Qualitative Carrying Capacity (how, where and when a new action may affect quality of an environmental system).	Set of indicators, evaluated against sustainability thresholds, to compare intervention at local scale with actual condition
Operational Carrying Capacity (who may carry on a specific project, in which socio-economic context, at which efficiency level?).	Cost benefit analysis Technology assessment

This methodology has been applied both for the preliminary assessment of the current situation, aimed to identify critical issues to be considered carefully during the planning and, subsequently, for the evaluation of possible effects of the planned actions. Due to the fact that SEA has to be performed during the definition of the UMP, some actions are not yet specifically planned at the stage of the evaluation, and this affects the possibility to quantify the predicted effects in terms of change in the carbon balance of EF; nevertheless, we tried to develop possible scenarios based on the available data, aimed to predict a range of variation and to explore the magnitude of the effects with respect to the previous condition (see section 3.2 for details).

2.1. Environmental indicators

The set of environmental indicators is inspired to the core sets of environmental indicators developed by [8] and [9]; the issue evaluated through indicators have been selected according to the results of the phase of scoping, aimed to the identification of the most relevant themes with reference to the contents of the UMPs under consideration [10].

In order for indicators to be really effective for policy making and for giving information about the sustainability state of a given area, there is the necessity to have reference values against which evaluate the results of the assessment. According to [11], "a given indicator does not say anything about sustainability, unless a reference value such as thresholds is given to it". The identification of reference standards allows decision makers to evaluate the results of the indicator in comparison with a threshold (i.e. to verify if the value measured is below or beyond a determined thresholds of sustainability) or with reference to a target (i.e. the value measured enable to verify if a define target has been reached totally or partially, or if it is not been reached).

Recognising that, even if the definition of thresholds is necessarily a choice that implies a certain level of subjectivity, the evaluation of indicators becomes meaningless in absence of reference targets and standards, the indicators selected for the assessment is evaluated against a threshold or a reference value, upon which classes are defined.

The methodology presented in this study considers some alternatives for defining reference values when law constraints' standards are not available:

- policy targets;
- objective physical limits (giving as a prerequisite the self-sustainment of the area in term of availability of resources and possibility to absorb emissions and wastes);
- benchmark values coming from data at national or regional level and values derived from literature.

The set of indicators and relative classes used to assign scores are illustrated in Table 2.

Table 2. The set of environmental indicators selected and related classes based on thresholds.

Issue	Indicator of state	Score
AIR AND CLIMATE	Concentration of: SO_2,NO_2, Ozone, PM_{10}, CO	Concentration ≥ law limit **0**, Concentration = 0.5-1 * law limit **1**, Concentration < 0.5* law limit 2
	Days of overrun of the daily limit	Overruns ≥ law limit **0**, Overruns 0.5-1* law limit **1**, Overruns of < 0.5 * law limit **2**
WATER	LIM (index for lakes from Water Framework Directive)	LIM = 4-5 **0**, LIM = 3 **1**, LIM 1-2 **2**
	EBI (Extended Biotic Index)	Class IBE = 4-5 **0**, Class IBE = 3 **1**, Class IBE 1-2 **2**
	FFI (index of fluvial functionality)	Class IFF = 4-5 **0**, Class IFF = 3 **1**, Class IFF 1-2 **2**
	I average rate of flow = anthr average rate flow/nat rate flow	I anthr average rate flow/≤ 20% **0**, I anthr average rate flow/=20-35% **1**, I anthr average rate flow/>35% **2**
	I anthr[1] = anthr minimum rate flow /natural average rate flow.	I anthr minimum rate flow ≤ 10% **0**, I anthr minimum rate flow = 10-20% **1**, anthr minimum rate flow >20% **2**
	% of collection and treatment of waste	IE[2] purified 0-50% **0**, AE purified 50-75%

[1] Anthr= anthropogenic; nat = natural
[2] IE = inhabitants equivalent

	water	**1**, AE purified 75-100% **2**
	Treatment efficiency	Effluent concentrations ≥ current limit **0**, Concentrations = 0.7-1 * current limit **1**, Concentrations < 0.7* current limit **2**
	Quantitative status of groundwater	Class C **0**, Class B **1**, Class A **2**
	Qualitative status of groundwater	Class 4 **0**, Class 3 and 2 **1**, Class 1 **2**
LAND USE	Share of mining areas in total municipal area	>1% **0**, > 0-1% **1**, 0 **2**.
	Share of green areas in total municipal area	< 35% **0**, 35-75% **1**, >75% **2**
AGRICULTURE	Share of utilized agricultural area in total municipal area	< 35% **0**, 35-75% **1**, >75% **2**
	Share of organic agricultural area in total utilized agricultural area	< 35% **0**, 35-75% **1**, >75% 2
	Share of organic farms in total farms	0 **0**, >0-50% **1**, >50% **2**
BIODIVERSITY AND LANDSCAPE	Share of protected areas in total areas with potential natural value	0 **0**, >0-50% **1**, >50% **2**
WASTE	Share of renewable energy in total average yearly consumption	0 **0**, >0-50% **1**, >50% **2**
	m^2 of solar panels	0-5 **0**, 5-50 **1**, >50 **2**
ENERGY	Average per-capita waste production/average provincial per capita production	>100% **0**, 50-100% **1**, <50% **2**
	% of separate waste collection/target from the Provincial Waste Plan	>100% **0**, 50-100% **1**, <50% **2**

2.2. CO_2 balance at the local scale

CO_2 balance is generally based on comparison between emission and uptake of CO_2. In spatial planning, this kind assessment is rarely taken into account. In this paper, a methodology developed by Pennati and colleagues [12] is applied as a basis for estimating and mapping the CO_2 balance at local scale, providing a tool for the investigation of local situation with reference to the achievement of CO_2 emissions reduction objectives. The first step is the assessment of the gap between emission and uptake at local scale. The second step is the decision support for spatial planning towards choices that can assure a reduction of the emission and a higher uptake capacity of the territory. Hence, policy objective at both local and global scale can be reached also considering the gap at local scale and reducing emissions and/or planning land use to increase amount of local uptake of CO_2.

The methodology proposes to compare data of direct and indirect emission with data of uptake referred to specific land uses, which were collected from literature and optimised for local condition.

For the emission, direct emission are the emission related to activities that take place in the area under investigation (source of data is the Italian national inventory of emission[3]), whilst indirect or indirect emission are related to emission that occur outside the area under investigation but caused by production and consumption pattern in the area under investigation (e.g. electric consumption or waste production).

In literature, there are several methodologies for estimating CO_2 emission from different sources, whilst there are only few comprehensive studies about the role of vegetation and soil for CO_2 absorption at local scales.

In this study, the balance is calculated considering various rate of uptake due to several kind of actual land use.

[3] based on EMEP/Corinair (2001)

In [12] the rates of uptake resulting from the literature review are presented. In the calculation of the balance, those values are divided by an average and precautionary factor of two in order to take into account that the data from the review refer only to the CO_2 fixed during the day and not to the plant respiration during the night. This precautionary factor account for potential variability of data also. In fact, experimental studies often present different results, because of the difficulty in measuring uptake and of the influence by meteorological and climatic conditions.

In this paper, an example of application in four municipalities in Northern Italy is presented, where emission and uptake data are mapped with GIS, enabling to highlight the uptake deficit and the role of sustainable land use planning.

2.3. Ecological Footprint and Biocapacity

Ecological footprint (EF) is an aggregated index that correlates the life-style of a population with the amount of natural resources needed to support it (the "life-supporting natural capital") [13]. It is an indicator based on a basic concept, which is highly communicative because this relationship is measured by a quite simple parameter: the extent of the natural bioproductive area (measured in hectares per capita) needed to satisfy the consumption and to absorb the waste of a population. The assessment of EF is based on an evaluation of consumption, clustered in five components: food, housing, transportation, goods and services. Any of these components is responsible of an EF, which is measured in a specific unit that is equal to one hectare of the mean productivity of the earth. To determine if the EF of a community is sustainable or not, it is necessary to compare local extension of bioproductive land (biocapacity, BC) with local demand of land (EF), defining an environmental balance of the local system. Assuming that to be sustainable a system has to be self-sustaining, the amount of deficit or overshoot of natural resources emerging from the environmental balance represents an estimation of the level of sustainability of the area considered.

The Ecological Footprint of the area object of the SEA has been calculated firstly referring to the current state and then trying to predict the foreseen effect of the actions included in the Plans.

The methodology used is the bottom-up approach [14], that allows for sub-national EF assessment and permits to consider the changes in consumption patterns caused by the implementation of the Plans.

The bottom-up method first establishes the amount of activity undertaken by a population in five categories if consumption and one category of emission (transportation, food, goods, services, building and waste). Activities are then converted into energy and direct land use. Finally this amount is converted into global area units to allow comparison with the global biocapacity (amount of ecological supply provided by a given area), assumed as the natural constraint for sustainability of consumption [15].

The evaluation consists in:

1. Assessment of EF based on consumption by local households
2. Assessment of BC of the area.
3. Comparison between EF and BC, to evaluate the sustainability of the area in the present condition.

This evaluation has the aim to identify the more relevant areas of consumption and the types of land that experience the higher pressure from human activities.

To fulfil the aim of the study, which has a local focus, data collection for calculation of EF of the current state has been performed giving priority to sources that can ensure availability of primary data, such as the municipality councils or local statistics offices (e.g. for data about waste and housing) and using provincial or regional data (e.g. for mobility and food consumption) as a proxy only when local data were not available.

The calculation of EF for the foreseen evolution of local conditions following the implementation of the Plans is not always possible, because of the detailed amount of information needed to perform the evaluation: due to the fact that SEA takes place during the definition of the Plans, it follows that some of the action included in the planning are not sufficiently detailed to provide adequate data for calculating the exact increase or decrease of the EF after the implementation of the Plans. Nevertheless it can be useful to predict possible variations of the EF through the development of scenarios that take into account the evolution of consumption due to the set of actions included in the Plans. This approach, even if represents a rough outline of the evaluation, can constitute an early warning for decision makers and provide information useful to address more detailed analysis before and during the implementation phase. Moreover, it offers the possibility to evaluate the situation in a comprehensive manner, considering the effects of the actions as contributing in a cumulative way to the final sustainability conditions of the area.

To evaluate the result of EF assessment of a specific area, it is necessary to compare this value, representing the human demand of nature for that area, with the amount of natural capital stock that the area can supply. In this perspective, local BC represents the reference value to determine if human consumption is in a condition of deficit or overshoot in comparison with natural resources availability.

BC of the area is evaluated assigning factors of bioproductivity (equivalence factors) to each type of land considered in the EF method (Energy land and forests, pasture, cropland, built-up land and fisheries). The first step in the evaluation of BC at local scale is, then, the comparison between the classes of soil use available in local classification (in this case, the DUSAF database by Lombardy Region, based on Corine land cover classes, [16]) with the six classes of land of EF method. The result of this comparison is summarized in Table 3.

Table 3 - Comparison between land classes in EF model and in DUSAF database.

Land in Ecological Footprint model		DUSAF classes of land use	Equivalence factor
Energy land and forest		Natural vegetation, woodland, woody plants	1.34
Pasture		Pasture and meadows	0.49
Cropland	Primary	land under cultivation (arable crops, orchards, vineyards, horticultural land)	2.21
	Marginal	Uncultivated land	1.79
Built up land		serviced and built up land, urban decay, mining land	2.21
Fisheries		Lakes, basins, river beds and artificial watercourse	0.36
		Infertile soils, sandy lands, gravelly	0.00

	soil, beaches, deposits of detritus, rocky outcrop without plant cover	

The class “non productive land” integrated the model developed by Redefining Progress: some classes of land use in DUSAF database have no correspondence with land classification in EF model and, moreover, they have productivity equal to 0. For this reason, this new class was created, with an equivalence factor equal to 0. Assigning equivalence factors to the areas included in the respective DUSAF classes associated in the table, it is possible to estimate total biocapacity (expressed in global hectares or global square meters[4]) of the area considered.

Following the same approach, it is possible to calculate variation in BC that can follow the implementation of the Plans, considering the transformation in land use, i.e. land cover illustrated in the Plans (e.g. transformation from agricultural land to urban areas due to the expansion of dwelling areas in the municipalities). This kind of calculation can be more precise than the prediction of EF variation, because data needed for the assessment are less complex and regards only land use, which is one of the core issues in spatial plans (i.e. are well detailed in the plan).

3. Area of study

The area of study chosen for the implementation of the methodology is a cluster of four municipalities (Novate Mezzola, Samolaco, Verceia and Gordona) in Lombardy Region, in Northern Italy. It is an interesting area from the SEA perspective because it allows for evaluation at sub-regional scale but not limited to one single municipality (i.e. it has a wider range of interventions).

In 2008, the average population per municipality was between 1103 (in Verceia) and 2941 (in Samolaco). Only in the municipality of Verceia there has been a slight decline in population between 2000 and 2008, while in the remaining municipalities there has been an upward trend, with a maximum of 11% in Novate Mezzola.

Land use shows absolute prevalence of forests, which cover percentages ranging from 51.4% to Novate Mezzola and 68.9% of Verceia, while the areas designated for urban settlements, residential and production are very limited in all four municipalities. Moreover, there are some protected areas, belonging to the Natura 2000 network, whose area falls within two or more municipalities boundaries.

Indeed the area and the UMPs of the four municipalities have interesting characteristics for testing the approach presented in this paper because it is a rather natural territory and actions of the Plans don’t imply significant interventions in term of new infrastructures or industrial activities.

Therefore in the evaluation of current and future conditions it becomes relevant to include the contribution of the actions to household consumption and services for the local community (e.g. mobility) rather than to assess only the environmental impacts of the main actions (e.g. construction of new buildings or infrastructures) from an Environmental Impact Assessment (EIA) point of view.

The SEA regards the Urban Master Plans (UMP) of the four municipalities that are developed jointly, starting from common development objectives for the entire area. The choice of the four municipalities to work together relies on substantial homogeneity of the areas and arise from the willingness to build up a common strategy for the development of the territory and to overcome the

4 Every kind of land has a different bioproductivity. To have EF results expressed in a unique measure – the global hectare – the model normalizes the values of bioproductivity of the areas in different nations and of different kind of land.

economic difficulties related to the realization of a detailed SEA (as highlighted also by Laniado and colleagues [17]).

The main objectives of the UMPs are:

1) Recovery of a former industrial area (Falk industries)
2) Valorisation of natural and cultural heritage
3) Promotion of sustainable tourism in guest accommodation solutions (e.g. agritourism and B&B)
4) Development of pedestrian and cycle routes
5) Improvement of services
6) Identification of areas for new residential dwellings trying to avoid urban sprawl.

4. Results

The results of the methodology's implementation are related to:

- Set of environmental indicators applied to the local context
- Carbon Balance and Ecological Footprint at local scale

4.1. Environmental indicators

Table 4 illustrates the scores of environmental indicators about the current condition and the foreseen condition after implementation.

The evaluation made through the environmental indicators selected highlights some areas of concern: the more severe problems regard air quality and the availability of water resources. There are also some low scores about agriculture and energy issues.

As it is shown in table 5, there is no change in the scores between and after the implementation of the Plans.

On the one hand, this means that the actions included in the Plans are not going to cause significant damage or change to the current conditions; on the other hand, the absence of changes means also that the actions are not relevant enough to contribute to the improvement of the current condition in the critical areas.

Table 4 - Scores of environmental indicators in the area of study.

With reference to this, there are two main considerations that can be made. Firstly, some of the critical problems identified depends from drivers and pressure that act not only at local scale as it is, for instance, for air quality (it has to be considered that the four municipalities are located in Lombardy Region, which is one of the most critical areas in Europe), so it is difficult to obtain measurable results from local actions, even if every single action is fundamental for the final result. Secondly, even if the Plans do not include highly significant interventions (e.g. construction of highways) that can cause significant environmental impacts, it is impossible to assume that the actions of the Plans won't have any impact at all.

Therefore it can be interesting and useful for decision makers to have instruments able to track these small effects, in order to provide useful information for decision making process of the Plans and to make SEA really effective. Our proposal for composite sustainability indicators to be integrated with environmental indicators presented before is illustrated in the following paragraphs.

4.2. Carbon balance

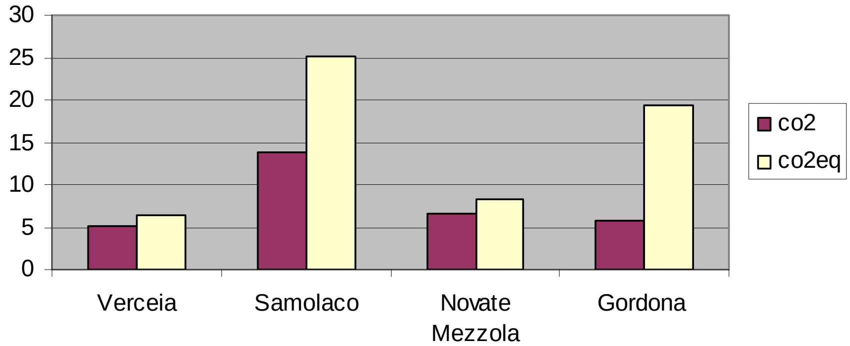
The assessment of the CB at local scale is performed in three steps: assessment of direct emission, assessment of indirect emission, assessment of the local uptake capacity related to land use.

Direct emissions of CO_2

The regional inventory of CO_{2eq} emissions was used to calculate direct emissions [18]. The main source of emission in the area of the 4 municipalities under investigation are: agriculture (especially cattle for Gordona and Samolaco), transport (especially for a main road along the lake), the domestic heating. For heating, it is worth of consideration that the emission is mainly related to the use of wood as an energy fuel in Novate Mezzola e Samolaco. In Figure 1 the contribution of CO_2 on the total CO_{2eq} value is shown.

The total amount of direct emission of CO_{2eq} is 58.88kton CO_{2eq} per year.

Figure 1. Direct emission for the four municipalities, in kton of CO_2 and CO_{2eq} per year (reference year 2005).



Indirect emissions of CO_2

Indirect emissions were calculated attributing emissions to local electric consumption and waste production. In Table 5, an overview of the indirect emissions from electric consumption and waste production is shown.

Table 5. Indirect emission due to local electric consumption and waste production.

Municipality	Inhabitants	Electric consumption (MWh)	Indirect emissions (kt CO_2)[5]	Waste production in 2008 (kg)	Indirect emission (kt CO_2)[6]
Gordona	1812	2058.43	1.093	628092	1.381
Novate Mezzola	1846	2097.06	1.113	656246	1.443

[5] Indirect emissions are calculated multiplying electricity consumption for a factor of 0.351 kg CO_2/KWh related to the production of 1 Kwh according to the national energy mix.

[6] Indirect emissions for waste are calculated multiplying waste production for a factor of 2.2 kg CO_2/kg of waste according to the composition of wastes in Italy

Samolaco	2941	3340.98	1.774	751112	1.652
Verceia	1103	1253.01	0.665	379828	0.835

The overall indirect emissions related to electric consumption are 4.46 kton CO_{2eq}/year and the overall indirect emission related to waste production are 5.3 kton CO_{2eq}. Indeed, this two emission source are strongly related with household consumption patterns and not only with local policies.

CO_2 uptake

CO_2 uptake was calculated mapping the actual land use (DUSAF) and applying the values reported in [12]. In Figure 2, all the areas in green contribute to the uptake whilst the area in grey and orange contribute to the emission (urban areas, agricultural areas, industrial areas, infrastructures).

The overall uptake of the area is 292.78 kton/year. Applying the precautionary principle mentioned before to take into account the CO_2 exchange of vegetation and the variability of the data, the final estimated values equal to 145 kton CO_2 /year.

CO_2 balance

To assess the CO_2 balance and the impact of the actions in the SEA, total emissions were considered. The analysis of that emission represents also a basis for setting further strategic policies for CO_2 reduction at local scale. The total emissions (68.63 kton CO_2eq /year) are the result of the direct emissions (58.88 kton CO_2eq), the indirect emissions related to electric consumption (4.46 kton CO_2eq) and the indirect emission related to waste production (5.3 kton CO_2eq). Accounting for the local uptake, the balance is positive. In fact, the area uptake every year is equal to 145 kton CO_2 and emit 68.63 kton CO_2eq with a balance of 76.36. This result is mainly due to the presence of a dense forested area. In a study applied to areas more densely populated, the balance is negative and the overall emissions are one order of magnitude more than the uptake (see [12]).

Nevertheless, even if the balance in this area is positive, the emission per capita are quite high (17 ton/year per capita). Hence, the SEA has to take into account policies focused on the reduction of CO_2 within the main drivers of emission (cattle, transport, heating system) and policies for natural capital conservation, especially referring to forested areas (to maintain the uptake capability of the area).

4.3. Ecological Footprint and Biocapacity

The biocapacity of the area of study is 39.090 gha and it is higher than the real extent of the area (20.570 ha). This result reflects the distribution of land cover types in the area and the abundance of green areas (more productive) with respect to urban ones (unproductive). The detailed distribution of land cover, which represents the basis for BC calculation, is illustrated in Figure 3 and the results of EF and BC for each municipality are illustrated in Table 6.

Figure 2. Land use in the area of study, according to cluster of uses to assign a biocapacity value. The green areas are also those for which the CO_2 uptake is more than zero.

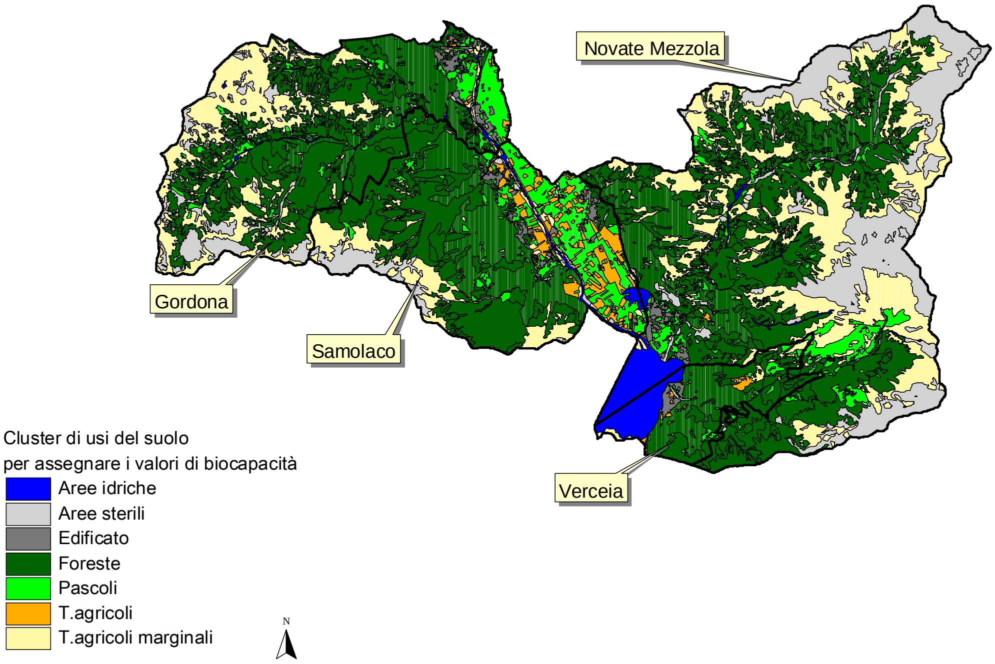
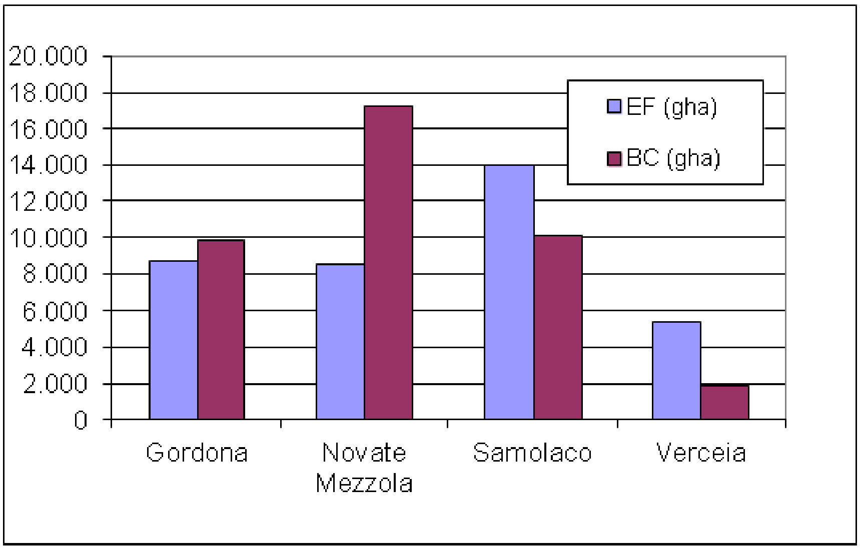


Table 6. EF and BC of the four municipalities in the area of study.

Municipality	EF per-capita	Residents	Total EF	BC (gha)
Gordona	4.8	1,810	8,688	9,872
Novate Mezzola	4.9	1,732	8,487	17,222
Samolaco	4.8	2,913	13,982	10,132
Verceia	4.9	1,104	5,410	1,865
Total			36,567	39,090

EF from household consumption is 4.8 gha/person in Gordona and Samolaco and 4.9 gha/person in Novate Mezzola and Verceia. The result is in line with the average Italian EF (4.8 gha/person in 2008) and represents a high level of consumption that, if extended to the entire world, cannot be sustained by the Earth capacity. However at the local scale this result can be considered quite good, because almost in all municipalities the EF doesn't overshoot the local BC (Figure 3).

Figure 3. Comparison of EF and BC in the area of study (current condition, before the implementation of the UMPs).



The most significant categories of consumption which determine the total amount of EF are “food” and “transport”. As a general indication for the planning, it can be said that EF from food consumption is mainly related with transportation of food from foreign countries, i.e. can be reduced increasing the share of local products consumed; EF from transport is related to CO_2 emission, so it can be reduced through sustainable mobility solutions in alternative to the use of private car by citizens.

As mentioned in section 2.3, it is not possible to forecast the exact variation in EF that should follow the implementation of the Plans because the UMPs will be followed by a detailed planning of single interventions. Nevertheless, it can be useful to make some considerations about the possible effects of the actions on the total EF of the area under investigation, based on the data available from the plans.

The main lines of intervention of the Plans do not include actions that are supposed to cause significant variations in the EF: sustainability criteria as to prefer the use of existing buildings instead of building new ones to fulfil the need of new dwelling areas, the valorisation of the natural and cultural heritage for tourism purposes and the conservation of agricultural areas should help to prevent the conversion from more productive lands (e.g. croplands) to less productive ones (e.g. built up lands).

However, there are some specific actions that need to be further investigated to predict their effective contribution to EF; these issues are discussed in the following paragraph.

Firstly, the identification of possible new dwelling areas, even if it is planned in a way that tries to avoid urban sprawl and to limit the construction of new buildings, necessarily implies an increase in the number of people that live in the area, i.e. an increase of the total household consumption affecting all the categories of EF (food, energy, transportation, waste, etc.). The foreseen raise in population foreseen by the UMPs in the four municipalities (due to the expansion of residential areas) is 2,271 new inhabitants (+30%). Therefore in case the new dwelling capacity would be totally exploited, the total EF would increase of 11,014 gha, overshooting biocapacity by 8,491 gha.

Moreover the construction of new buildings has a relevant impact on EF in terms of material and energy consumption (from about 6,000 gm^2 for a detached house to about 9,000m^2 for a condominium; [19]. It is not possible to predict the EF of new buildings since it would require to have detailed data about the main features of these buildings, such as total volume, type of construction materials and energy performance. Therefore these are parameters that need to be carefully taken into account in the phase of detailed planning of the new construction, in order to reduce the potential increase in EF.

The same concept applies to the actions regarding the expected increase in the number of tourists: it is important that, as mentioned in the Plans, the actions are oriented to the promotion of guest accommodation structures, that help to prevent the construction of new buildings and can ensure a lower footprint during the use phase. Tourism represents an issue that has to be take carefully into account because the footprint from this kind of activities can be a relevant share of the total footprint insisting on the area [20] [21]; moreover, there can be a significant difference between the EF of a night spent in a B&B (about 60 gm^2*person-1*night-1) and in a 3 or 4 stars hotel (about 140 gm^2*person-1*night-1) [22].

Regarding the effects of the Plans on the BC of the area, it is possible to quantify the variation on the basis of the detailed information about the area interested by the transformations foreseen by the UMPs. The variation in BC can be calculated multiplying the extent of the area interested by the transformation for the correspondent equivalent factor. For instance, if there is an agricultural land of 1 ha that will be transformed into built up land (e.g. in the case of the construction of new residential district), the BC will be reduced from 2.21 gha to 0 gha.

In the area of study there is only one municipality that will benefit from an increase in BC due to the restoration of a former industrial area that will be transformed from built up land to meadows. All the other actions imply a reduction in BC due to the transformation from productive land to unproductive one, even if the variation is not significant if compared to the total BC of the area (reduction of 19 gha out of 39,000 gha). The detail of the variation is illustrated in Table 7.

Table 7. Prediction of BC variation due to the actions of the Plans.

Municipality	Action (code)	Transformation		Area (ha)	BC Variation
		Before	After		
Gordona	M-AT1	Pasture	Built up	329	-16.21
Novate Mezzola	N-AT1a	Built up	Pasture	38,5	1.88
	N-AT1b	Pasture	Built up	1	-0.49
	N-AT2	Pasture	Built up	0.79	-0.38
	N-AT4	Pasture	Built up	0.80	-0.39
	N-AT5	Pasture	Built up	0.53	-0.25
	N-AT6	Pasture	Built up	0.42	-0.20
Samolaco	S-AT1	Cropland	Built up	0.85	-1.87
Verceia	V-AT1	Pasture	Built up	0.70	-0.34
	V-AT2	Pasture	Built up	1.31	-0.64
	V-AT3	Pasture	Built up	0,78	-0.38

5. Discussion

The use of composite indicators in the context of spatial planning could be leverage for supporting decision making at local scale. Nevertheless, it is important to evaluate weakness and strengthens of applying such indicators.

First of all, both the balance of CO_2 and the ecological footprint are composite indicators developed for assessing the impact of local consumption pattern considering:

- Different drivers: energy consumption, transport, dwellings etc

- Different perspectives (for example the energy consumption: in the case of the CO_2 balance, energy consumption affects both the direct and the indirect emissions. Indeed, energy consumption for heating implies direct emission of CO_2 whereas energy consumption for electricity may imply indirect emission related to where the energy production occurs; energy in the context of Ecological Footprint is considered mainly in order to assess carbon emission and the necessity of forest to absorb it).

Table 8. Strengths and weaknesses of the methodology proposed.

Weakness	Strengths
Availability of data at local scale, with a temporal and spatial consistency	Ability to capture drivers of impact that generally are not taken into account in local planning. In many case, two third of the total amount of CO_2emission at local scale are due to transport and domestic combustion (in Italy the household and services sector accounts for 34.4% of consumption, followed by the transportation and industrial sectors, at 34.2% e 29% respectively; ISPRA, 2009). It is important to support local decision making assessing the influence of citizen behaviour with respect of the overall emission.
Direct link with local policy at the level of the assessment	Creating scenarios of sustainable production and consumption pattern
Necessity to have detailed description of each action to derive reliable input data for the calculation (or at least to develop possible scenarios).	Focus on land use, which is a central theme in urban planning.
The balance at local scale in some case is driven by factors that cannot be planned by local authorities (e.g.: Considering a municipality, the presence of a power plant that provide energy for a certain region affects negatively the balance. In this case, the regional strategic planning plays a role in smoothing the hot spots of emissions)	Indicators easy to be presented to decision makers and local stakeholders. Being based on a balance, those indicators allow to a synthetic assessment of the performance of production and consumption pattern in a specific context

6. Conclusion

Researcher and practitioners highlighted the necessity to identify ways of making SEA more effective as a decision supporting tool, evolving from an EIA perspective, oriented to impact prediction, to a more comprehensive sustainability evaluation, that allows for the comparison of alternatives and that takes into account a wider range of issues.

In the case of Urban Master Plans, especially if they refer to small areas without significant industrial activities or infrastructures, household lifestyles can play a relevant role in determining the environmental impacts of the local community, i.e. the effects of the actions included in the UMP. In many cases when the plans object of SEA don’t include significant infrastructure constructions or industrial activities establishment, the evaluation can appear as not useful and made only for legal compliance. Nevertheless, the absence of big actions doesn’t entail necessary the absence of any environmental impact, especially if considered in the long-term, and consequently the impossibility for SEA to provide useful information for sustainability improvement to decision makers.

Therefore it is important to include in the SEA process suitable tools for this purpose, able to consider a wider range of aspects. Following this perspective, the methodology presented in the paper is composed by a set of environmental indicators, evaluated against sustainability thresholds, aimed to provide a detailed picture of the current and future state of the environmental compartments. In addition, the evaluation is performed also through composite indicators, EF and BC and the carbon balance, aimed to provide a more comprehensive picture that considers also the effects of “non traditional” SEA issues (e.g. household lifestyles as drivers for consumption and related environmental impacts) and allows for the creation of scenarios based on direct and indirect effects of the actions of the plan.

As discussed in section 5, this approach presents some strengths but also some weaknesses. The main features are the reference to the physical limits of the resources and the inclusion of both public and private stakeholders as responsible of consumption patterns and related impacts. Moreover, the methodology is deeply oriented to land use evaluation, which is a focal point in urban planning.

Finally, being based on a balance, those indicators allow to a synthetic assessment of the performance of consumption patterns in a specific context (and to develop scenarios when only not detailed information is available from the Plan) and can be easily presented to policy makers and local stakeholders to support decision making.

The direction for SEA further development should aim to a shift from integrated assessment methodologies towards sustainability assessment methodologies able: to assess the policy but also the consumption patterns influencing the local environmental quality; and to capture the different dimensions of the local carrying capacity, being quantitative, qualitative and operational.

Acknowledgments

The Authors acknowledge the contribution of Valeria Mezzanotte and Alessandro Bisceglie, involved in the development of the technical environmental reports for SEA of Gordona, Novate Mezzola, Samolaco and Verceia municipalities.

Conflict of Interest

The authors declare no conflict of interest.

References and Notes

1. Bina, O. A critical review of the dominant lines of argumentation on the need for strategic environmental assessment. *Environmental Impact Assessment Review* **2007**, *27*, 585–606.

2. Nilsson, M.; Dalkmann, H. Decision making and Strategic Environmental Assessment. In *Tools, Techniques & Approaches for Sustainability: Collected Writings in Environmental Assessment Policy and Management*; Sheate, W. R., Ed.; World Scientific, 2009; p. 410.

3. Pintér, L.; Hardi, P.; Bartelmus, P. Sustainable Development Indicators: Proposals for the Way Forward. **2005**.

4. Brown, A. L.; Thérivel, R. Principles to guide the development of strategic environmental assessment methodology. *Impact Assessment and Project Appraisal* **2000**, *18*, 183–189.

5. Nijdam, D. S.; Wilting, H. C.; Goedkoop, M. J.; Madsen, J. Environmental Load from Dutch Private Consumption: How Much Damage Takes Place Abroad? *Journal of Industrial Ecology* **2008**, *9*, 147–168.

6. Scott, K. *A Literature Review on Sustainable Lifestyles and Recommendations for Further Research*; Stockolm, Sweden, 2009; p. 42.

7. Meadows, D. H.; Randers, J.; Meadows, D. L. *Limits to Growth: The 30-Year Update*; Earthscan: London, 2004; p. 338.

8. OECD *OECD key environmental indicators*; OECD Environment Directorate, Ed.; Paris, France, 2004; p. 38.

9. European Environmental Agency *EEA core set of indicators - Technical report 1/2005*; Copenhagen, 2005; p. 38.

10. Donnelly, A.; Jones, M.; O' Mahony, T.; Byrne, G. Selecting environmental indicator for use in strategic environmental assessment. *Environmental Impact Assessment Review* **2007**, *27*, 161–175.

11. Lancker, E.; Nijkamp, P. Sustainable Agriculture in the Developing World and the Tropical Context. *Impact Assessment and Project Appraisal* **2000**, *18*, 111–124.

12. Pennati, S.; Castellani, V.; Sala, S. CO2 budget estimation and mapping at a local scale. In *Ecosystems and sustainable development VII*; CA Brebbia, M Neophytu, E Beriatos, I ioannu, A. K., Ed.; WIT Press: Sothampton, 2009; Vol. 122, pp. 21–32.

13. Wackernagel, M.; Rees, W. *Our Ecological Footprint: reducing human impact on the Earth*; New Society Publishers: Canada, 1996; p. 176.

14. Simmons, C.; Lewis, K.; Barrett, J. FORUM : THE ECOLOGICAL FOOTPRINT Two feet — two approaches : a component-based model of ecological footprinting. *Ecological Economics* **2000**, *32*, 375 – 380.

15. Ecotec *Ecological footprinting - final study. Working document for the STOA panel - European Parliament, Directorate General for Research, Division Industry, Research and Energy*; Luxemburg, March 2001, 2001.

16. ERSAF *Uso del suolo in Regione Lombardia. I dati DUSAF. Regione Lombardia*; Grafiche Tirredi, Cologno Monzese (MI), 2010.

17. Laniado, E., Ricci, A., Zanchi, M. La valutazione ambientale dei Fondi strutturali europei nella Regione Lombardia. *Valutazione Ambientale* **2003**, *3*, 50–53.

18. ARPA Lombardia - Regione Lombardia INEMAR, Inventario emissioni in atmosfera. (CO2 eq emissions in atmosphere) www.inemar.eu/xwiki/bin/view/Inemar/WebHome.

19. Bastianoni, S.; Galli, A.; Niccolucci, V.; Pulselli, R. M. The ecological footprint of building construction. In *The Sustainable City IV: Urban Regeneration and Sustainability*; Mander, U.; Brebbia, C.; Tiezzi, E., Eds.; WIT Pres: Southampton, 2006; pp. 345–356.

20. Bagliani, M.; Da Villa, E.; Gattolin, M.; Niccolucci, V.; Patterson, T. M.; Tiezzi, E. The ecological footprint analysis for the province of Venice and the relevance of tourism. In *The Sustainable City III*; Marchettini, N.; Brebbia, C. A.; Tiezzi, E.; Wadhwa, L. C., Eds.; WIT Press: Southampton, 2004; pp. 123–131.

21. Gössling, S.; Borgström Hansson, C.; Hörstmeier, O.; Saggel, S. Ecological footprint analysis as a tool to assess tourism sustainability. *Ecological Economics* **2002**, *43*, 199–211.

22. Castellani, V.; Sala, S. Ecological Footprint and Life Cycle Assessment in the sustainability assessment of tourism activities. *Ecological Indicators* **2012**, *16*, 135–147.