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Original
Urban Greenery as a Resource for Urban Environment / Pollo, Riccardo; Giovanardi, Matteo; Mariani, Andreina - In: Advanced Studies in Efficient Environmental Design and City Planning / Trapani F., Mohareb N., Rosso F., Kolokotsa D., Maruthaveeran S., Ghoneem M.. - [s.l] : Springer, 2021. - ISBN 978-3-030-65181-7. - pp. 307-315 [10.1007/978-3-030-65181-7_25]

Publisher:
Springer

Published
DOI:10.1007/978-3-030-65181-7_25

Urban Greenery as a Resource for Urban Environment

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Abstract

In many suburban districts, urban greenery is an impor- tant component in terms of quantity and quality in the urban landscape. The benefits on the environment on the quality of human life and the economic impact on the surrounding built heritage make the natural environ- ment a collective asset for the entire ecosystem. However, the lack of human and economic resources on which today's public administrations can rely makes the man- agement of such spaces problematic, often transforming them into poorly cured and unused places. In this regard, maintenance activities, such as mowing and pruning, as well as a series of continuous operations produce a significant amount of material to be disposed, constituting a monetary and environmental cost for the community. In order to compare different scenarios of reuse of green waste from an economic, environmental, and social point of view, the case study of the "Le Vallette" district in Turin was analyzed. On the basis of the concepts on which the material flow analysis (MFA) is based, the flows that can be produced each year from the mainte- nance activities of the green areas were evaluated. The qualitative and quantitative analysis carried out opened a series of reflections on the current green waste treatment chain. In this way, the concept of urban green is reinterpreted from a landscape element to an economic and environmental resource.

Green urban management; Urban metabolism; Material flow analysis

Introduction

Urban greenery, especially in suburban districts, represents a significant share of the territory with obvious ecosystemic benefits. However, the green system requires a significant organizational and economic effort for management and maintenance, which must be planned over the years. At a national level, official reports (ISPRA, 2016) show that the use of plans and planning tools such as the "Piano del Verde" is only present in one out of ten chief towns. The management of urban greenery, where not carefully planned, is carried out by guaranteeing the minimum activities for the safety of the sites. In this regard, Law 10/13 "Regulations for the development of urban green areas" does not require public administrations to use such instruments. Therefore, the issue of the enhancement and planning of the management of public green heritage is necessary in order to allow a more sustainable use of the resources available to us. In this context, the management and main- tenance of urban greenery is combined with the themes of the contemporary debate on the sustainability of cities, such as urban agriculture, the promotion of the circular economy and the smart city. The proposals for urban habitat and self-sufficient city of Vicente Guallart, a city made of interconnected units at different scales, local and global, represent the ideological synthesis of a possible approach to a circular economy on an urban scale (Lo Sasso, 2011). A city that is careful to pro- duce without waste and to re-insert as much matter and energy as possible into the production cycles necessary for its life (Guallart, 2014). The objective of the study is to compare alternative sce- narios for the reuse of urban green waste. Different approaches and technologies have been evaluated in order to enhance the green waste in terms of material and energy flows generated by the management and maintenance pro- cess (EU, 2010). Normative and logistical aspects enter forcefully into the topics, introducing the theme of the scale and length of the supply chain. Urban green maintenance activities, both horizontal and vertical, such as mowing lawns and pruning trees, produce a considerable amount of organic material that can be recov- ered and reintroduced into production cycles such as soil improver (Tong et al., 2018), biogas or fuel.

At a national level, data on the treatment of municipal green waste is often difficult to assess. A local assessment of urban green wastes production is even harder. It is possible to identify two different approaches to estimate the produc- tion of green waste from maintenance activities. The first, based on the frequency of maintenance activities and the specific growth of different tree species, associates a para- metric quantitative value based on the extent of the land area. These parameters are used on a daily basis to draw up contracts for maintenance activities between the public and private sectors. The second approach, on the other hand, counts the production of greenery that reaches the end of the supply chain. In this way the quantified material is the one that is really treated every year by the specialized plants. This method, although useful to compare the real impact on the likes to other forms of waste, does not allow to evaluate the potential quantity that can be produced by an optimization of maintenance activities. Starting from this last approach we can define some aspects. According to the estimates of the Italian Composting Consortium (CIC), in Italy, out of 4.7 million tons of total organic waste sent for aerobic digestion, 1.5 million tons comes from mowing and pruning and rep- resent about 40% of Italian separate waste collection (CIC, 2017). In addition to the analysis of the amount of green waste, the issue requires reflection on how to treat it. As underlined by several authors (Drechsel et al., 2015; Viljoen & Bohn, 2014), schemes for the collection and treatment of urban organic waste, green maintenance residues and household organic waste have until recently been based exclusively on large plants and services. Only recently, following European and national legislation have forms of recovery with small plants been encouraged. In particular, in Italy, with the legislation on community composting, MATTM Decree no. 266 of December 29, 2016 and Dgls 152/06, the aim was to encourage small-scale activities managed for the benefit of individual members who carry out agricultural activities, including urban ones. This scenario could also be considered interesting for the effects on the involvement of local com- munities in the cycles of the circular economy and in the management and enjoyment of greenery.

Urban Metabolism and Material Flow Analysis

Cities operate according to metabolic processes that absorb, transform, and release forms of energy and matter (Pincetl et al., 2012; Zhang et al., 2013). To evaluate any process, it is necessary to identify the inputs and outputs associated with them (Wolman, 1965; Liang et al., 2012). The term "urban metabolism" represents the quantitative accounts of the overall inputs and outputs of energy, materials, and substances into and out of cities (Shahrokni et al., 2015). Such concept has been widely adopted in the field of urban studies with the goal of environmental mitigation. Moreover, it has a deep interdisciplinary nature and encompasses a wide range of methods and disciplines such as the materials flows analysis (MFA), life-cycle analysis, energy analysis, and ecological footprint. With the aim of encouraging circular processes in the use and management of green spaces, the quantification of material flows inevitably becomes a primary aspect to be investigated. These material and energy flows, from public or private bodies, represent a significant part of the urban metabolism. In this regard, it is possible to analyze indi- vidual processes using the principles of MFA. Such a method is necessary to handle data from observation, accounting to statistical analysis, simulation, and decision support (Dijst et al., 2018). The MFA approach, developed in the industrial sector and then applied to different sectors, allows to evaluate the quantity and direction of material flows within the boundaries of a given system (Baccini & Baader, 1996; Allesch & Brunner, 2015). The evaluation of the different material and energy resources that interact with each other is necessary to better understand the environmental and economic impacts of long and complex processes. Today, municipal green waste from the maintenance of green areas is reused, according to the EU rules, to produce biogas or soil improver compost, allocating to municipal solid waste incineration (MSWI) only the not recyclable fraction of solid municipal waste (SMW). In both processes, although different in terms of methods, the organic material from greenery is mixed with other organic wastes from households and commercial activities to allow the optimal transformation (Lebersorger, 2011). The processing capacity of the material makes veg- etable waste a by-product that can be easily reintroduced into the closed process of a circular economy. However, the virtuous closure of the cycle still finds some regulatory and economic obstacles. The survey carried out among the main companies of the sector in the city has shown that the circular process is hampered by economic issues. For example, the amount of greenery treated each year is much smaller than the actual production capacity. Many greenery maintenance companies' reasons prefer to adopt mowing methods that do not involve waste collection such as mulching to avoid disposal costs. At the same time, the use and sale of natural compost does not find the same appreciation on the market, again for economic reasons, as syn- thetic fertilizers. The UM investigations are often carried out at a regional or urban scale not allowing the evaluation of specific policies and project at a neighborhood scale. Nevertheless the shift at a more granular spatial scale of the UM analysis would allow to support the decision making in the urban planning and design at the neighborhood scale. Such a shift has been underlined by literature as a promising development of UM research and urban planning practices in the field (Kennet, 2013). In order to compare and evaluate in a comprehensive way alternatives policy strategies for urban green management and design, we consider necessary, firstly to quantify the associated flows of matter. Such evaluation takes into account the production of waste from the green areas and the relationship with inhabitants and with locally based as well as regional models of reuse and treatment, composting, biogas production, etc. In this regard, we have chosen a case study that could support, compared to the current manage- ment model and due to the high presence of green spaces, different planning scenarios. The analysis has been made on a neighborhood of nearly 8.000 people and can be applied to any other urban district. The quite reliable and updated input data used in the analysis is mainly from municipal statistics referred to the neighborhood. Where not explicitly stated, quantities have been estimated on the basis of data available in the literature, compared with municipal, regional, and national reports on organic waste treatment in Italy. The greenery surfaces and the number and species of trees have been calculated by a GIS model.

Case Study: Neighborhood "Le Vallette," Turin

The case study has been selected following two distinct criteria. The first refers to the urban nature of the neigh- borhood, which can be identified as a distinct part of the city of Turin both for cultural identity and architectural mor- phology. The second has been its size and the large amount of green spaces. The neighborhood and its greenery is, indeed, large enough to generate a material flow to allow the adoption of specific strategies at neighborhood scale and the comparison of different scenarios. Moreover, the provision of such a large green areas would allow the hypothesis to devote a part of it to urban agriculture. In such a way, we can imagine a metabolic flow from green areas management wastes to local agriculture as well as a significant flow contributing to the urban raw material provision to the bio- gas production by the regional industrial system facilities.

The urban agriculture and community composting is rooted on the experiences carried out in the past decades in many countries, wealthy as well in the south of the world (Oberlin & Szántó, 2011). Many successful examples of community composting are described in literature, in urban areas as well as in the countryside (Slater et al., 2010). As we note above, research on urban metabolism at neighborhood scale has been suggested and developed in recent years (Kellett et al., 2013; Shahrokni et al., 2015). Many authors identify the neighborhood scale as the basic level to estimate the urban metabolic flows with the scope to identify the flows and compare the environmental mitigation strategies. The study area is the district of Turin called Lucento- Vallette, built as an iconic complex of Public Residential Building of the sixties. The 800,000 m^2 district on the northwest outskirts of Turin has been designed between the 1950s and 1960s looking at the Scandinavian examples of self-sufficient urban areas, equipped with all facilities and surrounded by greenery. The project was contributed by the major exponents of the Turin architectural scene of the time: Gino Levi Montalcini, Ottorino Aloisio, Roberto Gabetti and Aimaro Isola and many others. This part of the city, iden- tified with the name “Le Vallette,” is still today a peripheral area characterized not only by the quality of the architecture, but also by the presence of significant green areas, even if not fully recognized by the real estate market as an envi- ronmental and economic value (Fig. 1). The neighborhood is inhabited by about 8300 people with a large share of the elderly, slightly higher than the average number of Turin, and with a fair presence of population of recent immigration. The per capita green area is about 42 m^2, twice as the average for the city. The green character of the district can become a precious element and a resource for its enhancement.

Development of Analysis

The analysis has been carried out starting from the identifi- cation of green areas capable of “producing” green waste. Consistent with the MFA methodology, the first phases of the research were used to define the system's inputs. Data on the consistency of existing green areas was obtained from the geographic information system (GIS) of the municipality of Turin. The GIS methods have been underlined by litera- ture as an important tool for the UM and MFA, above all in the field of energy supply and demand models, as well as transport of goods and people models (Dijst et al., 2018). The cartographic data that has been made available by the municipality for a wide range of purposes allows to make, in fact, a series of qualitative and quantitative analyses on urban green areas (www.geoportale.it). By using the GIS software, it has been possible to estimate the extension for each type of green area identified by a quite an accurate database. The area analyzed counts about 350,000 m^2, divided into different categories: generic green areas, green areas with trees, sports green areas, green areas for traffic distribution, and green areas that cannot be used (Fig. 2). Urban green areas have been classified with the scope of associating the maintenance activity and green wastes pro- duced every year to each class. The open data from the municipality of Turin allows to evaluate not only the hori- zontal green areas, but also the trees present. In the area analyzed, there are about 800 tall and medium-stem trees, divided by type as shown in Table 1. Also, with regard to vertical green areas, standard maintenance activities for the calculation of waste quantities was considered on an annual basis. The data reported in Table 1 with reference to the type of maintenance activities and annual frequency has been estimated on the basis of specialized literature (Baldan, 2015; Blengini & Fanti, 2009; Saer et al., 2013) and inter- views with operators involved in the maintenance of public green areas and the reuse of waste for energy purposes within the study (ACEA). Each maintenance activity is associated with a quantity of waste material produced as shown in Table 2. As it is well known, these quantities are related to the vegetative cycle of the plants and are therefore variable according to the climate, the specific site, and the weather conditions of the year. However, it was considered accept- able, in the first instance, to use average data provided by a recent study by the Laboratory of Environmental Systems Analysis & Management (LASA) of the University of Padua (Baldan, 2015). Once the input data was defined, the research shifted to green waste treatment methods. As already mentioned, there are two main types of treatment of green waste: the “anaerobic” one, aimed mainly at the production of biogas and the “aerobic” one useful to produce soil improver compost. Starting from Scenario A, which represents the business as usual scenario in the context analyzed, the consequences generated by favoring one treatment over the other were assessed in terms of energy and compost pro- duced. The energy production has been evaluated in terms of thermal energy and electricity by biogas through current technologies. The three scenarios are thus defined: Scenario A. Which corresponds to the current management model, estimated on the basis of the percentages of waste treatments by the published regional government reports, where a portion of the vegetables collected is sent to composting, a part conveyed to the process of anaerobic digestion and a residual percentage incinerated (Città Metropolitana di Torino, 2017; ISPRA, 2019);

Scenario B. An “Anaerobic” model in which it is proposed to increase the share of green waste collected and sent for anaer- obic digestion treatment for the production of biogas and the composting of residual sludge; Scenario C. A scenario of collection and treatment on a local basis with the start of recovery and community composting processes with reuse in urban agriculture at a local scale. For the setting of the three scenarios, the quantities of waste collection from mowing and pruning have been cal- culated on the basis of the maintenance programs by the municipality of Turin and by agronomic literature (Baldan, 2015) The split of the portion sent to aerobic as well as anaerobic treatment has been done according to the figures by the aggregated regional government data published (Città Metropolitana di Torino, 2017) (Table 3). As shown in Fig. 3, the scenario A is characterized by a slightly long and complex chain, which involves part of the waste treatment in sites located outside the metropolitan city and, in some cases, outside the region. The Scenario B has a more rational industrial character of the treatments, while the Scenario C adopts a community-based approach to the urban agriculture (De Zeeuw, 2015; Mougeot, 2000), involving in an active way the inhabitants (Viljoen et al., 2014, Caputo, 2012). It should be noted that the waste, sludge, from biogas production (Scenario B) is in part reused for compost soil improver production. In the Scenario C, we adopt the hypothesis of imple- menting a local waste collection from the maintenance of the green area in order to implement an aerobic treatment plant located at the edge of the area devoted to the reuse of bio- waste, green waste plus household organic waste (the whole biowaste). The compost produced would be used to feed the community's horticultural crops. On the basis of the average figures by the literature, relating to the production of both compost and energy that can be activated by the treatment of organic waste, the estimate products for each scenario have been calculated. In particular, the reference has been made to: the figures from the study of the University of Padua (Baldan, 2015), the data provided by Italian biogas producer associations (Frances- cato, 2007) and the data provided by the municipal waste collection company of Turin (AMIAT) for the year 2015 regarding the biodegradable solid urban waste. For the production of compost, reference was made to the values presented by the study Sustainable Compost Application in Agriculture (ECN, 2008). To calculate the horticulture gar- den surface feeder by the compost, we adopted the index by ECN (2008). The output of the three alternative scenarios has been estimated in terms of material obtained, biogas and com- postable soil improver, energy from biogas, thermal and electrical kWh, and arable land supported by the use of compost.

Results and Perspectives

The evaluations carried out on the three scenarios have shown the achievable potential of each chain. Within the common goal of limiting direct landfill material as much as possible, the analysis shows in principle the results of two different approaches. The analysis carried out allows a quantitative comparison only between the Scenarios A and B being not possible to directly measure against the Scenario C. Such a comparison would be too complex and not meaningful due to the wide range of the variables in different context. The quantitative analysis car- ried through the method described in the paragraph 4 allows the following considerations, although is mandatory to remind the need of reliable figures on average production of biogas as well as compost to allow such material flow analysis. The Scenario A, “business as usual”, shows quite a high performance of the waste management system driven by the fulfillment of the EU Directives goals relating the urban waste sorting threshold and the minimization of landfilled or incinerated fraction. Nevertheless, the chain is quite long and complex and it is difficult to trace the wastes from the production to the treatment plant. The duty for the traceability is in charge to the firm managing the maintenance. The chain is fully top-down and there is no involvement of the inhabi- tants in the wastes production by the reuse of harvesting, mowing and pruning activities. In the hypothesis to consider in our accounting also the household biowaste, the citizen has only charges without any direct benefit, real, or per- ceived (Manfredi et al., 2011; Lang et al., 2006). The output of the Scenario B is more relevant for the energy production and is based on the development of the biogas by waste industry. This sector has had in the past years a massive development in Italy and a technological shift. Nevertheless it represents a market driven solution pushed by tax tariffs and by rules. The production of energy is quantity relevant, and the technology is more and more efficient but not competitive with other forms of energy generation. The Scenario C is an alternative bottom-up approach linking the waste by the greenery maintenance to the pro- duction of compost feeding the urban gardening. Above all if combined with the collection of household biowaste this process would allow a large provision of amendment and fertilizer. Due to the extension of green areas and the number of residents, such production would exceed the demand to satisfy the local needs. Nevertheless, such an approach, although the technological advances in community com- posting plants and quality of the compost, requires additional resources to be implemented and an awareness and partici- pation of the community itself. In both the improvement scenarios, B and C, we can measure the benefits in terms of reducing the use of fossil fuels, for energy production replacing natural gas with bio- gas or for the avoided production of synthetic fertilizers replaced by compost (Bordoni, 2009; Francescati et al., 2007; Piccini, 2007). The energy production by anaerobic digestion plants is significant but certainly not comparable to that obtained with traditional or renewable energy produc- tion plants. At the same time, the wide spreading of compost from organic waste is still not comparable to synthetic fer- tilizer, although the first one is at the center of continuous developments and improvements in the field of agriculture (Cofie et al. 2006) (Table 4). Moreover, the balance between the three scenarios' evaluations from an economic and environmental point of view requires the comparison of the two methods with respect to the technologies and types of installations used, and it is possible to make a number of considerations about the length of the supply chain and its effects on the social issues. As far as the social impacts on the study area are concerned, the results of the evaluations carried out con- siderably differentiate the two improvement models (B and C). In the case of the anaerobic digestion chain, the current collection and sorting mechanisms do not change from the Scenario A, except in the potential shortening of the chain, while composting at local level, Scenario C, shows a strong potential for the production of soil improvers and fertilizer that can be reused on site by leveraging the availability of public and private green spaces. The evaluation of the cultivable space potentially supported by the production of soil improver, therefore, seems to indicate a scenario of local development with the creation of oppor- tunities for work and participatory economy (Lahec, 2019). Even if a minority in urban context, community com- posting practices are wide spreading. On the other hand, the industrial sector of the production of installations for the decentralized production of quality compost is growing in quality and quantity. The link with the development of urban agriculture initiatives can lead to social benefits through the mechanisms of participation both in the collection of waste, and in the improvement of its quality, and in the develop- ment of cultivation for self-consumption. In the case of the Le Vallette district, the potential for the production of soil improvers and fertilizer would exceed the needs of the area. This circumstance may suggest the adoption of mixed solutions between the improvement sce- narios. Moreover, the strong dependence of both product quality and emissions on the technological performance of installations, both large scale and local, requires consider- able attention to the engineering and management aspects of the digestion plants, both anaerobic, for the production of biogas, and aerobic, to obtain compost.

Conclusion

In regard to the methodological issues we can observe that a more granular evaluation of the material flows by tech- nologies and tools like the GIS, big data sources or sensors appears to be useful to foster environmentally conscious choices. A neighborhood scale like in the case study can be adopted as a field of investigation and evaluation of alter- native management scenarios. Making explicit the outputs of the scenarios, quantitative as well as qualitative, can help in the decision making in urban planning. The literature in urban metabolic studies underlines (Broto, 2012; Lehec, 2019; Bahers & Giacché, 2019; Passaro et al., 2015) the nonlinear character of the processes described and the complexity of urban systems requiring mixed strategies and responses to the inhabitants needs. Moreover, the availability from agricultural and industrial disciplines of data and information is needed to define indicators enforcing such analysis. This issue underlines the interdisciplinary nature of such investigations of the urban system. The data obtained shows that the share of waste material from mowing and pruning, especially in the case study presented, may represent a significant share of urban meta- bolism. From a circular economy point of view, now at the center of European research actions and policies, the analysis of urban organic waste treatment chains stimulates envi- ronmental, social, and economic considerations. The current measures, aimed at achieving the objectives of separate waste collection, do not yet make it possible to accurately measure the origin and quality of the raw material. The evaluations carried out highlight the potential of both improvement scenarios for the energy and agricultural val- orization of waste, whose supply chains have seen a sig- nificant development of application models, legislation, and technology in recent years. In particular, scenarios mainly aimed at decentralized compost production allow to support large urban cultivable portions. With regard to the analysis of environmental impacts, it is necessary to refer to a detailed analysis able to quantify, with respect to the specific plant adopted, the means used for transport and the characteristics of the materials delivered. In this way a life-cycle assessment (LCA) analysis (Leber- sorger et al., 2011) would be necessary to assess the relative emissions and the quality of the material produced. Moreover, the studies conducted (Blengini & Fanti, 2009) have shown a strong dependence, in terms of harmful emissions (GWP), on the efficiency of the equipment and the effectiveness of filtration devices. With the exception of incineration, which is not only environmentally critical but also unsuitable for this type of waste, the emission-related effects of both aerobic and anaerobic digestion are balanced by the production of energy and material that can be reused in crops. The industrial biogas chain may require higher economic costs related to collection, storage, treatment, and transport than the short composting chain on a local scale. In addition, the use of large areas, as in the case study, horticultural crops, would reduce the burden of green maintenance, now borne by local government and condominiums. A further element for the valorization of the green resource is the application of traceability technologies also in the part of the organic waste chain upstream of anaerobic treatment and composting, contributing to an evaluation of urban metabolism flows and the benefits achievable in terms of energy, materials, and food production. In other words, through the detection of green maintenance activities it is possible to both make evident the economic importance of waste and optimize its management. In this sense, and with the support of advanced technologies, even in scenarios of integration between industrial supply chains and local pro- duction, it is possible to think of a new form of self-sufficiency of some parts of the city. The refunctionalization of urban greenery, from a simple and indistinct green area to an area destined for other uses, such as agriculture, seems feasible, especially in reality as in the case study. On a social and urbanistic level, these sce- narios suggest new urban “landscapes” characterized by productive functions integrated with recreational and envi- ronmental mitigation functions in which the destination to forms of cultivation, supported by closed waste recovery cycles, can flourish and give a new meaning to areas cur- rently underutilized and devoid of character. As clearly stated by the literature in the field, the adoption of a model treatment of the greenery wastes, also in asso- ciation with household food waste, is strongly dependent from the local conditions, in the supply side, the waste, as well as the demand side, the material to be converted in energy, through the biogas production installations, or in nutrients for crops, through the composting practices (Broto, 2012). Future developments in the research about UM at the neighborhood scale will require an interdisciplinary coop- eration between architects and environmental engineers, botanist, and agronomist providing a sound basis for standards and planning at a territorial scale in a circular economy perspective.

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