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Special Issue 2.2023

Burn or sink
Planning and managing the land

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Cover photo by Giuseppe Mazzeo. Rising wheat fields on the hills of Conza della Campania, Irpinia. January 31, 2023.

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Circular and metabolic perspectives in urban contexts. Integrated flows analysis for an ecological transition

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Abstract
Recent European directives, including the "European Circular Economy Package" (2020), the "Farm to Fork" Strategy (2020), and the "Fit for 55" package (2022), focus attention on the issues of circular economy, security and sustainability of food production and reduction of emissions from anthropogenic activities. From this perspective, the study of urban metabolism is a useful approach to make local systems more resilient. In this regard, the intention is to emphasise the embedded commitment of territorial and urban planning to consider the current systemic components related to the flows that cross urban, peri-urban and rural territories, fostering the development of sustainable and circular supply chains capable of supporting an ecological, energetic and climatic transition. Therefore, this paper explores a methodology for the spatial analysis of urban contexts that take into account the main flows (water, energy, agri-food, and waste) that circulate and influence the transformation of the territory. In particular, thanks to the experience of the drafting process of the Territorial Plan of the Metropolitan Area (PTAV) of the Province of Rimini, it was possible to identify some methodological aspects useful for a trend shift towards effective actions aimed at the sustainable and circular management of local resources.

Keywords
Urban flows; Integrated flows analysis; Urban resilience; Ecological transition; Circular resources management.

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1. Introduction

Lifestyle and dynamics that characterise the current age require the adoption of a more efficient and sustainable use of natural resources, characterised by the minimization of waste production and environmental pollutants. Two complementary concepts stand among the main directions for sustainable territorial and city development: urban metabolism and circular economy.

Urban metabolism is an approach that compares urban agglomerations to organisms that, to live and support their functions, need resource flows as inputs, while producing, waste and pollutant emissions as outputs, in a typically linear logic and consistent with the principle of thermodynamics (Rocca, 2020; Lucertini et al., 2020). The analysis of the metabolism of urban systems enables decision-makers to manage the flows involved in a more responsible way to maximise benefits and minimise resource waste, thus promoting a transition from linear to circular and more sustainable systems.

At the same time, the circular economy model promotes a set of principles that guide companies, corporations and services, toward innovative development and business models according to which matter should be cyclically reused and regenerated, remaining within production cycles for as long as possible, minimising the outflows. The model not only generates tangible benefits and reduces raw material requirements and waste generation through eco-innovative solutions, synergies and symbiosis, new technologies and management agreements, but also encourages the recovery and reuse of new supply chains of secondary raw materials as an alternative to traditional ones (Amenta et al.; 2019; Ellen MacArthur Foundation, 2017).

The analysis and monitoring of cause-effect relationships between different urban flows has recently emerged as an innovative strategy for increasing synergy between urban cores and their surrounding areas, fostering processes of ecological transition and climate resilience (Colucci, 2015; Lucertini et al., 2022).

The need for urgent measures and actions to reduce emissions and face the effects of climate change, supporting the transition to circular approaches, is recognized and pursued at the community level, by tha main strategic plans and programs (Franco, 2023). The "Fit for 55" package, which aims to translate the ambitions of the Green Deal (EC - COM/2019/640) into legislation, proposes, in this regard, a series of climate, energy and transport measures. Meanwhile, the "European Action Plan for the Circular Economy" (CEAP - COM/2020/98) includes a wide range of initiatives to strengthen resource efficiency and long-term competitiveness, contributing significantly to achieving climate neutrality by 2050. It aims to modernise and make the EU economy suitable to support a green and inclusive future and protect the environment. It provides legislative and non-legislative measures for the entire product cycle, from design to recycling, to reduce the EU's overall production and consumption footprint and thereby contribute to the achievement of the Green Deal goals. The measures introduced under the Action Plan, in addition to aiming to improve the European regulatory part of sustainable products, aim to empower consumers and public stakeholders, enhance circularity and reduce waste in the sectors that use the most resources, such as electronics and ICT, batteries and vehicles, packaging, plastics, textiles, building and construction, in addition, the supply chains considered are also those of food, water and nutrients.

In this perspective, the research aims to identify a methodological process that can serve as a support to governments for future socio-economic and environmental development processes, through the integration of urban flow issues and the definition of innovative strategies aimed at pursuing the ecological transition and fostering circular approaches. This paper investigates a systematic approach to conducting spatial analysis of urban contexts that can be easily replicated and applied in urban planning. Such analysis takes into consideration key flows, such as water, energy, food, and waste, that circulate within urban areas and have a significant impact on the transformation of the territory (section 2), and then to move on to the experience conducted for the drafting of the Territorial Plan of the Metropolitan Area of the Province of Rimini (section 3). The last section provides an integrated reading of the main urban flows analysed to define a planning and management strategy that can evaluate and consider the entire cycle from a single metabolism perspective.

2. Materials and methods

The study of the interaction of urban flows, through the approach of urban metabolism and circular economy, helps the planning and development of strategies, plans and policies suitable to facilitate the ecological transition, thanks to a better knowledge of the processes in place and their negative externalities towards the environment (Longato et al., 2019; Bolger et al., 2019).

The main objective of both approaches is represented by the transition from a linear and unsustainable model, which generates waste according to the take-make-dispose logic, to a circular and regenerative model, capable of facilitating up-cycling processes and product life extension. In this system, biological flows should be reintroduced into the biosphere, while technical material flows should be valorized, reused, or recycled without causing environmental damage while minimising waste and increasing the efficient use of resources (Gusmerotti et al., 2020).

Requirements for urban metabolism studies, in fact, refer to inflows (water, construction materials, fossil fuels, electricity etc.) production (food, wood etc.), stocks (minerals, nutrients etc.) and outflows (air emissions, wastewater and solid waste) (Conke et al., 2015). The four major urban activities – to nourish and recover; to clean; to reside and work; and to transport and communicate – as identified by Baccini and Brunner (1991), are assessed in terms of four major components that are at core of urban metabolism: water, food (biomass), construction materials, and energy (Kennedy, 2010). This represents a basic accounting effort that can provide scientifically valid and representative data for urban planning.

The evaluation of these components shows the efficiency in resource use, its future need, the existence of any environmental burden, the contribution of recycling and the capacity of waste treatment, enabling a better awareness of how much impact human activity (social, economic and political) is causing in the natural environment (Brunner, 2007; Holmes & Pincetl, 2012). Furthermore, the scientific literature investigating these concepts at the spatial scale recognizes the importance of the WEF Nexus - Water, Energy & Food (Orimoloye, 2021), on which part of this research approach is based. The three sectors – water, energy, and food security nexus – are considered necessary to design inherent and interconnected future systems from the perspective of holistic spatial planning, which is also capable of considering potential synergies and critical conflicts to be addressed (Ahmadi et al., 2020; Varriale, 2018).

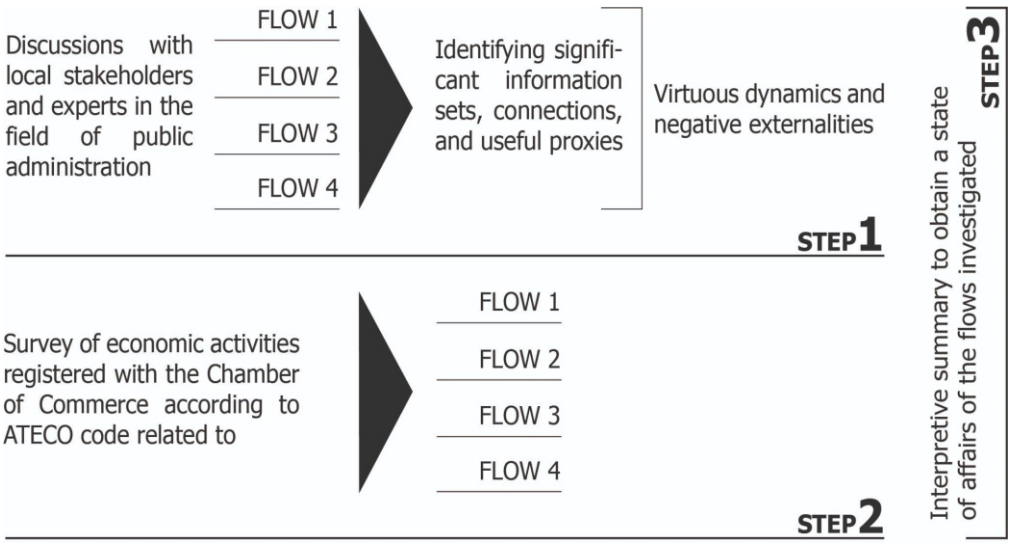

Fig.1 Work flow of the proposed methodology divided into 3 steps

Similarly, the objective of this work is aimed at building the foundational cognitive level for a future replicable methodology that can define how urban metabolism can be considered within planning processes. This study also places its focus on water, energy, agri-food, and waste flows to comprehend current local production

processes and practices and to direct virtuous transition processes. The decision to restrict the analysis to these four primary flows was a direct request from the involved public administration, partly due to practical considerations related to managing data and information, thus ensuring a streamlined and reproducible process in analogous contexts. The study's execution is, therefore, structured into three steps designed to guide the process and ensure enhanced replicability.

2.1 Step 1

Discussions with local stakeholders and experts in the field of public administration involved allowed the initial study of usable spatial information to be contextualised, highlighting capitalizations and potential synergies with existing survey initiatives. For each flow, some significant sets of information are identified for connections and useful proxies to identify virtuous dynamics and negative externalities on the territory. Furthermore, the vector format of the spatial database chosen for evaluation is capable of collecting and processing different attributes useful for the spatial analyses under consideration.

Flows	Elements	Attributes
Water	Wells and springs	Withdrawals, extractions, ...
	Water consumption	Quantity by municipality, use, civil sector, ...
	Sewage treatment plants	Quantity/quality in terms of pollutants ...
	Distribution/disposal infrastructure network	Linear kilometres, white/grey/black network, ...
	Hydrographic network	Linear metres, monthly average level, ...
	Land-based water storage (reservoirs/natural reservoirs, dams, etc.)	Storage capacity, average monthly level, area, gross volume, ...
	(…)	(…)
Energy	Non-renewable energy systems	Type, amount of energy produced/year, plant emissions, ...
	Renewable energy systems	Type, amount of energy produced/year, ...
	Energy consumption	Quantity by municipality, use, sector, ...
	Non-renewable civil heating systems	Type, amount of energy/year, plant emissions, ...
	(…)	(…)
Agrifood	Livestock farming	Type, no. of cattle, ...
	Farmhouses, restaurants, bars	Type, no. beds, no. covers/day, services, ...
	Food and beverage processing, preservation and production industries	Economic activities, no. of employees, economic capital, ...
	Farms	Crop type, organic/non-organic, marketable production, ...
	(…)	(…)
Waste	Waste facilities	Type (EWC), quantity of waste treated, ...
	Waste production	Type, amount of waste (by municipality and/or per capita), ...
	Sorted/differentiated waste	Type, quantity of waste output by municipality, ...
	Local composting activities	Utilities, ...
	(…)	(…)

Tab.1 Potential components for each flow considered

2.2 Step 2

At the same time, a survey was conducted for the (4) urban flows of related economic activities registered with the Chamber of Commerce according to ATECO code. This step required a prior matching matrix with the grouping of consistent activity codes by flow.

Flows	ATECO code	ATECO Denomination
Water	36.00.00	- Water collection, treatment and supply
	37.00.00	- Wastewater collection and purification
Energy	35.11	- Electricity production
	35.12	- Electricity transmission
	35.13	- Electricity distribution
	35.14	- Electricity trading
	35.21	- Gas production
	35.22	- Distribution of gaseous fuels by pipeline
	35.23	- Gas distribution by pipeline
Agrifood	01.4	- Animal husbandry
	01.50	- Agricultural crops associated with animal husbandry: mixed activity
	10.1	- Processing, preservation and production of meat
	10.2	- Processing, preservation and production of fish, shellfish and molluscs
	10.3	- Processing, preservation and production of fruit and vegetables
	10.5	- Processing, preservation and production of dairy products
Waste	38.11.10	- Non-hazardous solid waste collection
	38.12.10	- Hazardous solid and non-solid waste collection
	38.21	- Non-hazardous waste treatment and disposal
	38.22	- Hazardous waste treatment and disposal
	38.32	- Material recovery and sorting
	39.00	- Remediation activities and other waste management services

Tab.2 Analysis of ATECO codes for the analysed flows

2.3 Step 3

The performance of the first steps lay the preconditions for an interpretative synthesis of the (4) cognitive frameworks to obtain a state of the art of the investigated flows.

The comparison and systematisation of the selection of usable spatial information allow a comprehensive picture of the analysed context as well as an interpretive synthesis framework for circular management. In this sense, the integrated reading of the main urban flows, which is useful for the evaluation of management strategies capable of considering the entire cycle from a single metabolism perspective, allows the construction of an interpretative and synthesis framework in which complexity can be translated into perspectives of change to direct and convey sustainable and circular management of the territory.

3. Results

The approach on which the experience conducted within the Province of Rimini is based, for the drafting of the Territorial Plan of Metropolitan Area (PTAV), involves different aspects of the life of cities and territories, to ensure a transversal and innovative contribution. In line with the regional law Emilia Romagna 24/2017, the process of identifying and analysing the (4) main urban flows – water, energy, agri-food and waste – contributes to initiating effective actions compatible with the preservation and recovery of urban and environmental heritage. More in detail, the approach pursued is based on an in-depth knowledge of the territory and the different components related to the 4 flows, closely related to the circular economy paradigm

and urban metabolism, to support the definition of innovative and conscious spatial policies and strategic objectives.

For each flow chosen, as suggested by the methodology identified, significant sets of information were identified, capable of identifying the different attributes useful for the territorial analyses of Rimini Province (Tab. 3). In addition, the different economic activities registered with the Chamber of Commerce according to ATECO code referring to each urban flow analyzed were identified (Fig. 2).

Flows	Elements	Source	Attributes
Water	Wells (119)	ARPAE Emilia-Romagna	Localization
	Springs (44)	ARPAE Emilia-Romagna	Localization
	Sewage treatment plants	ARPAE Emilia-Romagna	Localization, type
	Hydrographic network	PTCP Rimini 2007, Variant 2012	Type
Energy	Energy installations (25)	ARPAE Emilia-Romagna	Location, type, manager
	Electricity consumption	ARPAE Emilia-Romagna	Civilian consumption, industrial consumption, transport sector consumption at municipal scale
Agrifood	Livestock farming (34)	Sustainable Agriculture Sector, Emilia-Romagna Region	Location, type, species raised, number of animals, amount of nitrogen emissions/storage
	Farmhouses (71)	Agritourism Sector, Emilia-Romagna Region	Location, type, number of rooms, number of beds, number of meals/year, type of courses/activities offered
	Food processing, preservation and production industries	ATECO – Chamber of Commerce	Location, type of business, number of employees, economic capital
	Farms (10)	ATECO – Chamber of Commerce	Location, type of business, number of employees, economic capital
Waste	Waste facilities (72)	ARPAE Emilia-Romagna	Localization, type
	Total waste generation	ARPAE Emilia-Romagna	Waste production by CER, quantity of separated, undifferentiated and total waste production at municipal scale

Tab.3 Components analysed for each flow considered

The analysis conducted for the water flow (Fig. 3) shows that the Rimini area has a consistent concentration of wells in the coastal strip (119). At the same time, the inland part is characterised by several springs (44). The lower number of springs is also due to the limited presence in Emilia-Romagna of karst formations, which represent just 1% of regional outcrops. Regarding the withdrawal of the water resource from water bodies, the data for civil use count for the year 2012, 4.32 mm^3/year (ATERSIR, 2018), while water consumption amounts to 31,875,602 m^3/year (ISTAT, 2020) with the prevailing sector being the domestic sector, which contributes more than half of the withdrawals, followed by the industrial, hotel and public establishments sectors.

Spatial planning for sewerage and water purification for the purpose of water protection is based on the agglomeration concept, which is under the responsibility of the Province, which exercises them in close collaboration with the municipalities concerned and ATERSIR. By resolution of the GR no. 201/2016, the Region redefined the delimitation of the agglomerations homogeneously over the territory, identifying in the Rimini area 131 agglomerations, for a total of 877,851 population equivalent served (p.e.), of which five main ones, with a consistency of more than 2,000 p.e. (Novafeltria; Bellaria - Igea Marina; Riccione; Cattolica - Misano -

Val Conca; Rimini - Val Marecchia - San Marino) with a service coverage of about 90%. It appears interesting to note that the remaining part of the resident population lives in isolated nuclei (0.9%) or in scattered houses (9.1%), not served by public sewerage, for a total of about 30,500 equivalent inhabitants.

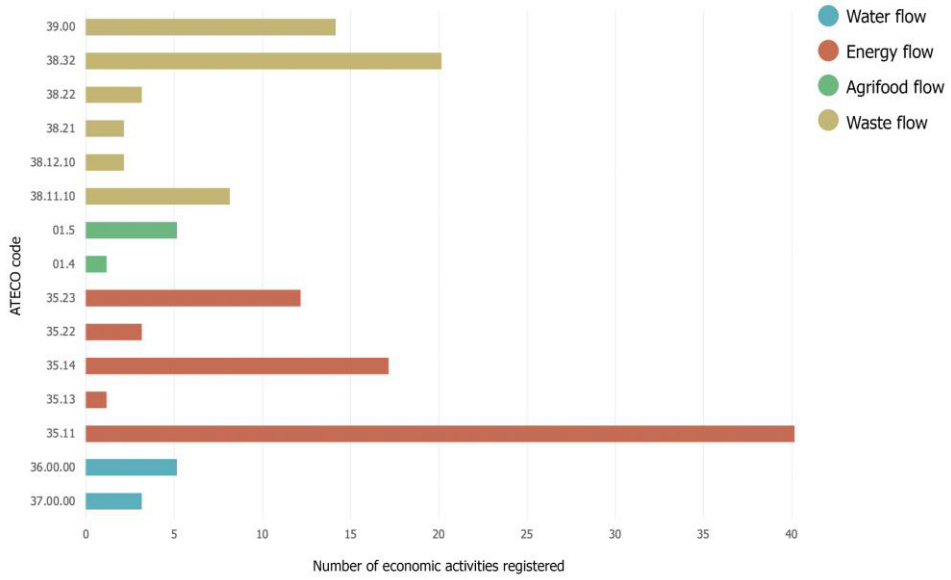

Fig.2 Histogram of economic activities registered with the Chamber of Commerce for the analysed flows. Identification of different economic activities registered with the Chamber of Commerce according to ATECO code referring to each urban stream analyzed. It emerges that the largest number of economic activities registered are those related to the energy and waste sector

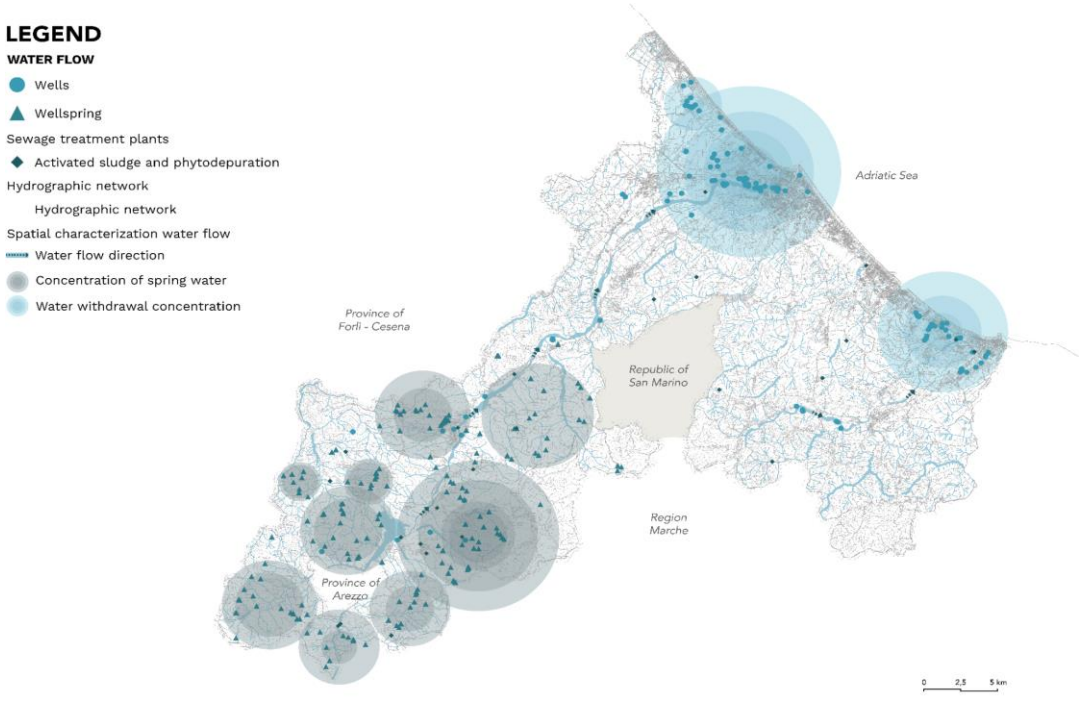

Fig.3 Metabolic flow of water system. In the figure there are point and linear elements and also interpretive elements, namely those falling under the category of "spatial flow characterization"

About the distribution of the collection network, the total extension of the sewerage network of the Rimini sub-area, in the year 2012, is about 2,324 km, divided into white network: 722 km, black network: 856 km, mixed network: 746 km. As for wastewater treatment systems, five main agglomerations are found to have more than 10,000 AE distributed along the coastal strip, while one is between 2,000 and 10,000 AE. There are

also agglomerations below 2,000 AE, distributed mainly inland, which deliver urban wastewater to centralised sewage treatment plants equipped with Level 3 treatment. Almost all of the public sewage system conveys wastewater to such plants, while minimal fractions are served by small 2nd-level or phytoremediation plants. Level 1 treatments (Imhoff pits) also serve a marginal portion of the population (0.5%). Isolated cores and scattered houses outside agglomerations and served by individual sewage systems remain excluded from purification, with an incidence of about 30,500 inhabitants.

The territory under study has a good endowment of infrastructure in the area, which allows for the assumption of additions aimed at pursuing greater environmental sustainability (ATERSIR, 2018). In addition, the total number of economic activities registered with the Chamber of Commerce according to ATECO code for water flow amounts to 4 activities.

Regarding the energy issue, energy consumption related to the year 2021 was 295,702.9 GWh, split between industry (46% of total consumption), domestic sector (23%), services (29%) and agriculture (2%) (Fig.4a). The availability of energy sources is largely derived from imports: total energy production amounts to 291 GWh (Fig.4b), with about 191.9 GWh produced from renewable sources, including photovoltaics (56.8% of total provincial renewable production) and bioenergy (39.8%). In contrast, thermoelectric production amounted to 175.4 GWh, with 48.6% of the total from non-cogenerative plants, i.e., plants that do not jointly produce electricity and heat for technological uses or district heating.

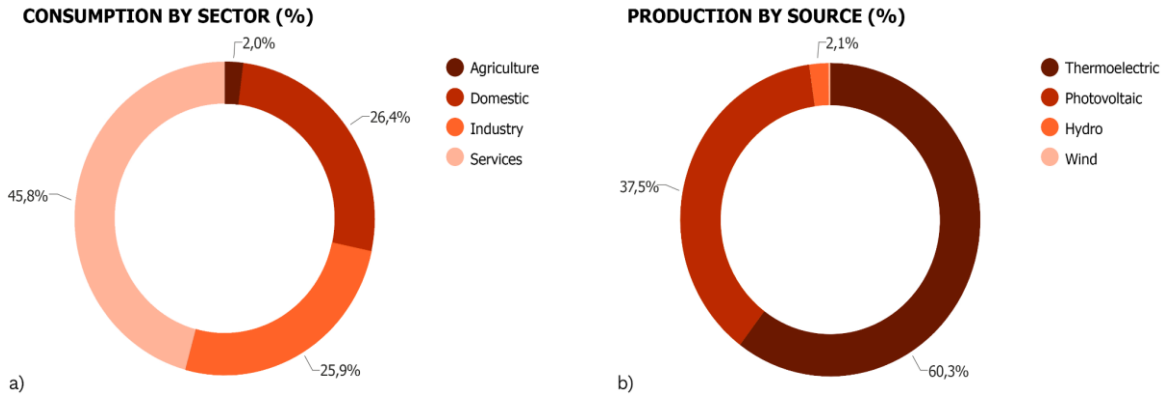

Fig.4 Electricity consumption by sector (a) and electricity production by source (b) of Rimini Province

Among thermoelectric power plants with cogeneration, as of 2021, there were 85.2 GWh produced by condensing plants, 61.8 GWh produced by internal combustion plants with cogeneration, and 28.5 GWh produced by gas turbines. In the province of Rimini, production from renewable sources (RES) relative to 2021 was 191.9 GWh; among these, production from bioenergy (76.3 GWh) and photovoltaic plants (109.0 GWh) stand out. In particular, for the gross output of installed photovoltaic systems, there is an increase in the two-year period 19-20 of 5.8%, which is higher than the regional average of 3.9% and equal to about 5 GWh. Regarding the number of systems present, as of 2020, there are 7,138 photovoltaic systems in the province (+7.8% compared to 2019) with a total installed capacity of 98.7 MW, (+4.3 MW) (TERNA, 2021). The provincial capital is the leading municipality in terms of total thermal and electrical energy consumption, followed by the municipalities of Riccione and Bellaria-Igea Marina. The municipal contexts of the coastal axis show higher total consumption than the inland areas, consistent with the different distribution of seasonal populations in the province. Regarding Rimini's energy infrastructure system, there are 25 power generation plants (ARPAE, 2021), discretely distributed throughout the territory (Fig. 5). In particular, (1) a wind power plant in the municipality of Casteldelci; (1) a geothermal plant in the municipality of Cattolica; (12) hydroelectric plants (>50 kW); (6) biomass thermoelectric plants; (4) fossil fuel thermoelectric plants; and (1) waste-to-energy plant in the municipality of Coriano.

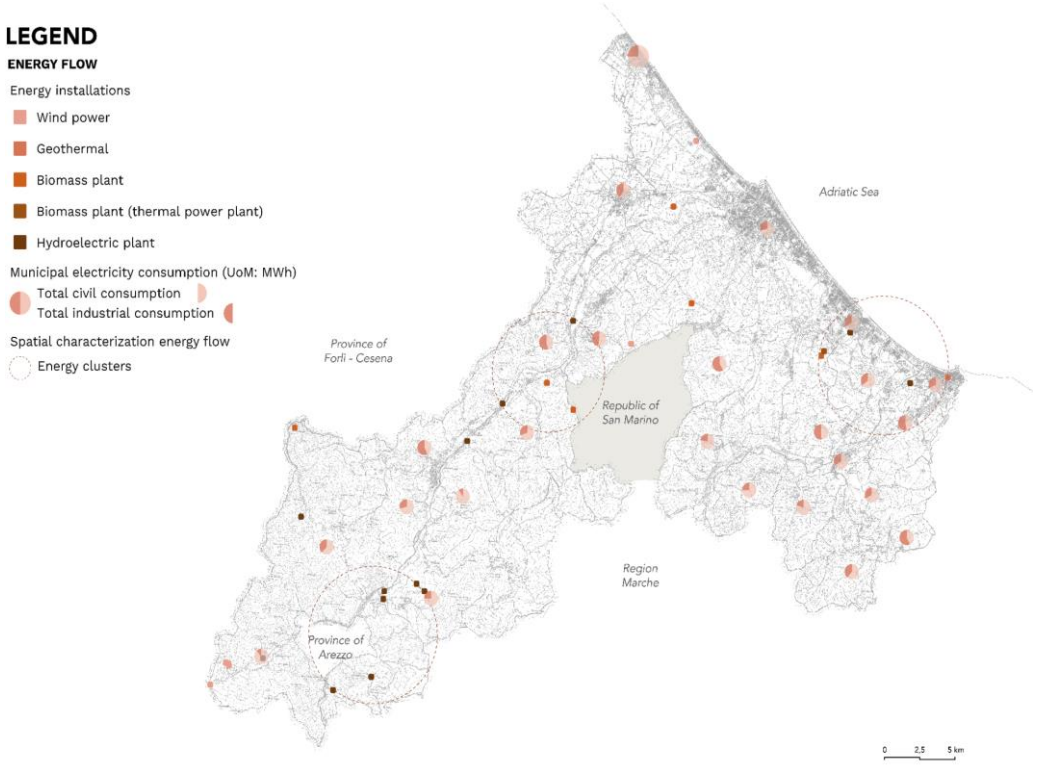

Fig.5 Metabolic flow of energy system. In the figure there are point and areal elements and also interpretive elements, namely those falling under the category of "spatial flow characterization"

The agri-food system is characterised by a balanced distribution over the territory (Fig.6), except for the coastal strip where economic and environmental dynamics strongly reduce the presence of agro-rural land uses. In a context characterised by a vocation for tourism, the presence of agri-tourism is distributed throughout the territory (71 total), with the greatest concentrations in the peri-urban areas, more accessible to the coastal system.

In general, the Rimini area is based mainly on several economic activities dedicated to livestock breeding (34) registered with the Chamber of Commerce according to ATECO code. Given the total number of livestock raised, poultry farms appear to be the most substantial (with about 342,627 heads), located especially in the belt in front of the hilly foothills, followed by pig farms (5,444 heads) and rabbit farms (4,500 heads). The few large farms (10) are mainly located in the belt facing the hilly first fifth while, near the coastal belt, a large presence of small farms characterises the area. Even in the mountainous area, the business categories are still similar, with a prevalence of small to medium-sized farms in the area, a positive feature of the entire territory that ensures a closer and more direct relationship between the rural and urban worlds. Moreover, regarding the agricultural context, it was noted that the back-coastal belt has predominantly traditional farming, while in the mountainous areas a much larger presence of organic farms.

This difference in production systems between the mountainous hinterland and the lowland agricultural territory can be explained taking into consideration two factors in particular: on one hand, a greater vulnerability of hilly areas to the phenomena of erosion and mineralization of soils related to the use of chemical synthetic fertilisers instead of the use of organic fertilisers capable of increasing the physical and mechanical properties of the soils; on the other hand, an insufficient conventional production in the most inaccessible areas to guarantee the income of farmers, who must necessarily opt for new management trajectories capable of guaranteeing a sustainable income for their activity.

Also very significant is the conversion of farmland to organic farming techniques, and the municipalities with a greater presence of organic practices are concentrated in inland areas, along valleys characterised by lower

tourist attraction and strong agricultural vocation. The municipalities of the province tend to show processes of organic growth to the detriment of traditional practices that deplete local resources such as soil, except for urban contexts such as Cattolica, Bellaria – Igea Marina, Misano Adriatico and Morciano di Romagna, which are found to have a reduced presence of organic cultivation practices.

Fig.6 Metabolic flow of agri-food system. In the figure there are point elements and also interpretive elements, namely those falling under the category of "spatial flow characterization"

In the context of territorial policies aimed increasingly toward a circular and sustainable economy aimed at the more efficient use of resources, sustainable waste management plays a key role as it reintroduces resources into the local market. With this in mind, it becomes essential to respond to the needs emerging from sector planning, through an adequate infrastructure system based on recovery facilities capable not only of supporting the growing flow of separate waste collections but also of withstanding dependencies on foreign markets, with the support of local disposal facilities.

The province of Rimini has (72) waste management facilities, contributing in 5% to the regional system (ATERSIR, 2020a). The infrastructure system (Fig.7) consists of plants capable of meeting the treatment/disposal needs of undifferentiated waste and special waste, making the area self-sufficient (ATERSIR, 2020b).

Among the types of treatment plants present are treatment plants (70), divided into mechanical treatment (TM) plants, by which waste is screened to separate its different commodity fractions and/or conditioned to achieve process objectives, or, in the case of secondary solid fuel production, product performance; biological treatment (TB) plants, aimed at achieving mineralization of the most degradable organic components (stabilisation) and sanitization of the output waste; and mechanical biological treatment (TMB) plants. There is also a composting plant (1), for the management of the selected organic fraction, and a municipal solid waste incinerator (1) (WTE), operated by Hera S.p.A. In addition to being subjected to continuous supervision, the plant is included in the Region's environmental monitoring program named "*Moniter*".

The coastal zone shows a higher production of sorted municipal waste than the backcountry context, consistent with the higher population density and tourist attractiveness. The strong tourist attractiveness concentrated

on the coast greatly accentuates the pressure on natural resources and waste generation, which is higher in the coastal zone than in the backcountry context. The study shows that waste is sorted more in the coastal areas than in the hilly areas, so much so that some inland municipalities (9) do not carry out separate collection services due to the fragmented management of the collection service, which implies different collection modes depending on economic feasibility. It can be seen that in such contexts the production of the undifferentiated fraction is significantly higher in absolute values, despite the clear disparity in resident population. On the contrary, it is evident that some urban waste flows, which have long been initiated to separate collection, such as paper, glass and wet waste, are more widespread and consolidated than others.

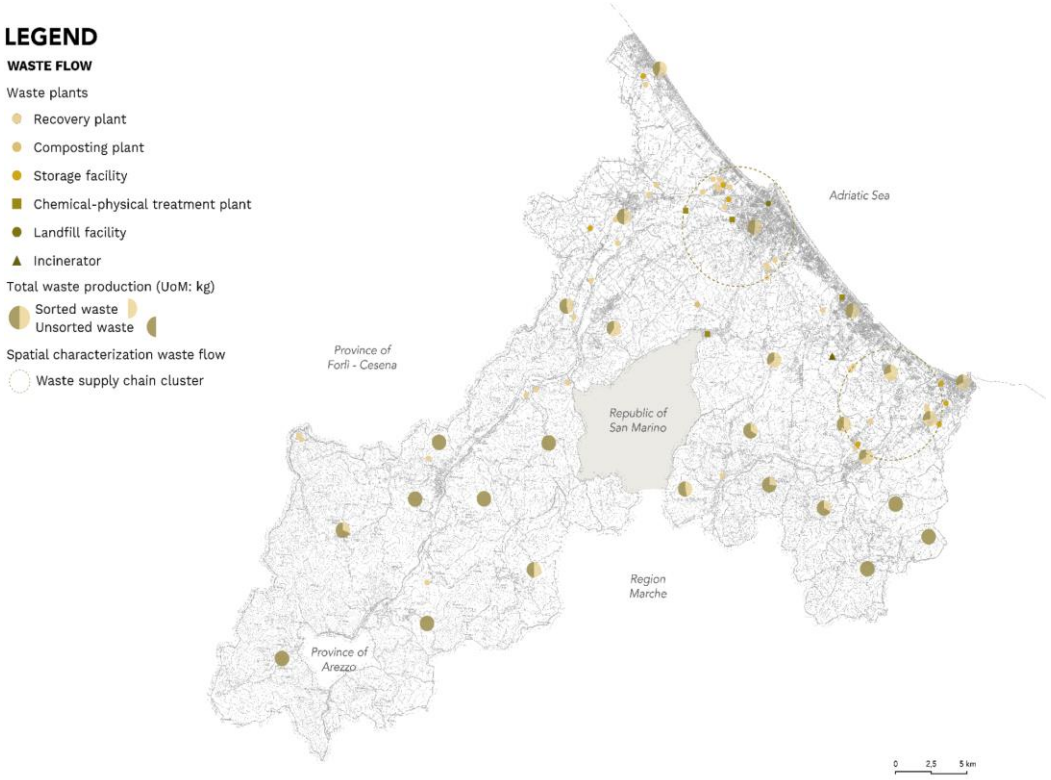

Fig.7 Metabolic flow of the waste system. In the figure there are point and areal elements and also interpretive elements, namely those falling under the category of "spatial flow characterization"

In general, the system is characterised by a network of flows sufficiently distributed throughout the Rimini area (Fig.8). In the coastal strip, where the economic dynamics are characterised by a high vocation for tourism, a higher concentration of water withdrawal is denoted, to the detriment of the concentration of spring water present in the hilly first-fifths. Concerning the spatial characterization of energy flow, civilian consumption is found to be greater than industrial consumption, while clusters related to the agribusiness chain are found to be distributed throughout the territory, with a greater presence in peri-urban areas. In addition, areas near the coast are characterised by higher waste production, consistent with higher population density and tourist influx.

4. Discussion and conclusions

The objective of this paper was to test a replicable methodology for spatial analysis of contexts that would take into account the investigated flows such as water, agri-food, energy and waste, which affect land transformation. The experimentation allowed the identification of the system and areas for flow management, preparing a cognitive framework useful for urban management strategies. The intention was to assess the

local supply chain from a circular perspective capable of answering questions concerning "*how*," "*where*" and "*to what extent*" to act to enhance resources and undertake virtuous paths of sustainability, in the province of Rimini.

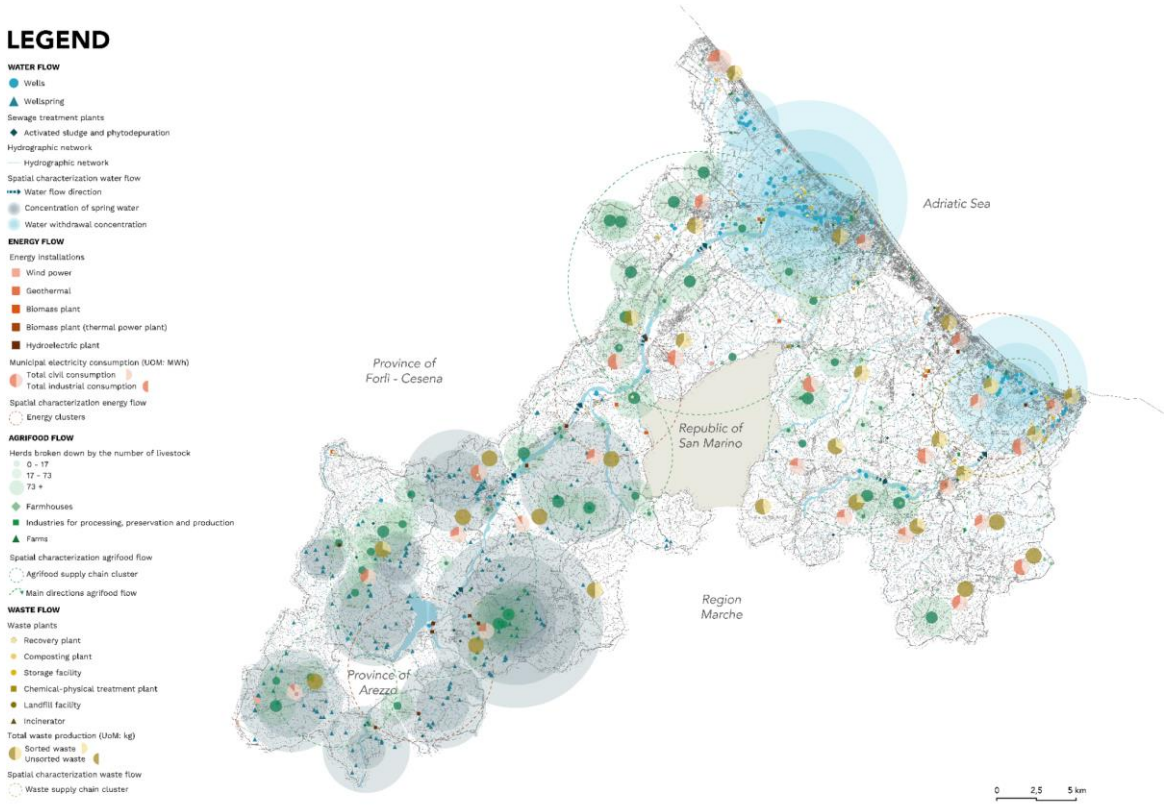

Fig.8 Overall analysis of urban metabolism related to the (4) flows analysed. The overall analysis of urban metabolism related to the four flows analyzed refers to a detailed examination of how a city functions in terms of the use and exchange of key resources, namely water, energy, food and waste. This type of analysis focuses on a comprehensive understanding and visualization of how these flows affect the urban environment as a whole

This contribution highlights some gaps and critical issues in the flows analysed, which are incomplete or partial and therefore do not allow an exhaustive and in-depth analysis. Despite the close collaboration with local government, the approach shows the need to provide itself with recent and detailed information data capable of rendering a static process into a dynamic system.

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Consistent with this, the (4) flows investigated show data and information bases that could have more detail and be more useful in providing a circular approach, in terms of quality and quantity of extracted resources.

In a condition of uncertainty, there is an increasing need to prepare integrated management that provides for the active participation of stakeholders and ensures technical-specialist support for policy decisions, especially in critical emergencies resulting from climate change.

It seems interesting to note for the flow of water a fragmentation in the management of the service with repercussions in the balance between surface water and groundwater: the reclamation consortia manage the surface water withdrawal phases while the control and management of groundwater withdrawal is assigned to other entities. This subdivision causes conflicts to the qualitative and quantitative aspects, in view of climate change that sees a negative alteration of rainfall and the degree of groundwater recharge.

What has been illustrated helps to recognize the need for adaptive resource management, based on detailed knowledge of the availability and usability of local resources over time and space. Another aspect is being proactive and thus based on the ability to act consciously and responsibly with preventive actions in the presence of events that could affect availability and quality. This underscores the importance of proceeding with an integration of the metabolic approach into the decision-making and implementation tools in terms of policy and instruments, arriving earlier than decisions. Indeed, the collection of information, which underlies and is a prerogative aspect, requires that there be coordination in the form of both typological and temporal collection. This is to allow the complexity of studying metabolism, which involves the simultaneous integration of different information bases, to facilitate governance tools and local policies to act in a preventive and circular form. Especially in a scenario of ecological, climate and energy transition, it is important to be able to provide usable indications consistent with the principle of anticipation.

Very useful is the presence of a supra-local coordinating body capable of bringing together the collection of available data and information, much of it of a point type, then providing for their integration. In this sense, the PTAV is a favoured effort as it can hold together various data at the territorial level. In section 2 of our study, we emphasized that the choice to limit the analysis to the four main streams-water, energy, food, and waste-was made in response to an explicit request from the government involved. This choice was also motivated by practical considerations related to the management of the data and information needed for the analysis. The goal was to ensure a streamlined and replicable process that would also be suitable for use in similar contexts. Reducing the number of streams considered greatly simplifies data collection, processing and interpretation, enabling a more manageable approach to urban planning. This limitation has proven to be extremely useful in providing clear and easily interpretable results for public administration.

However, it is important to note that urban metabolism can involve a wide range of flows and sectors, in addition to those previously mentioned. Therefore, a future perspective might be to extend the proposed methodology to support the analysis of these other flows. This would provide a more comprehensive and detailed understanding of how the city functions and could be particularly valuable in situations where the complexity of the system requires a broader view. The flexibility of the methodology allows the interaction of the analysis with other flows, thus contributing to even more sophisticated and integrated urban planning.

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Image Sources

Fig.1: Author's elaboration;

Fig.2: Author's elaboration based on data provided by the Chamber of Commerce, 2022;

Fig.3: Author's elaboration for the Rimini Province PTAV drafting process;

Fig.4: Author's elaboraion based on data provided by TERNA Driving Energy, 2021;

Fig.5 to 8: Author's elaboration for the Rimini Province PTAV drafting process.

Table Sources

Tab.1: Author's elaboration for the Rimini Province PTAV drafting process;

Tab.2: Author's elaboration based on data provided by the Chamber of Commerce, 2022;

Tab.3: Author's elaboration for the Rimini Province PTAV drafting process.

Author's profile

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Katia Federico, Urban and spatial Planner. Research fellow at the Iuav University of Venice. From June 2021 she starts her research and urban planning support activities within the Planning and Climate Change LAB of the Iuav University of Venice, on issues related to climate change and circular economy. In particular, he carries out in-depth studies on the mapping of the vulnerability of rural territories to the impacts of climate change related to the Emilia-Romagna Region; technical support in the drafting of the Metropolitan Plan of the Province of Rimini, through the processing and metadata of spatial data, development of graphic designs and particular support in the drafting of contents and elaborations inherent to urban metabolism and circular economy, studying and planning the territory through the approach of the circularity of metabolic flows. She is currently carrying out research activities with a research grant developed in collaboration between Iuav and ENEA, entitled: "Circular economy and resource governance in the urban-periurban relationship," which aims to study how the circular economy approach can be translated and applied to the territory, to the flows of resources necessary for urban and peri-urban management.

Gianmarco Di Giustino

Gianmarco Di Giustino, Urban planner and PhD student in urban and territorial planning at the Iuav University of Venice and part of the Iuav Planning Climate Change LAB. Since 2019 he has been collaborating on different national and international research projects on spatial planning with a particular focus on the topics of circular economy, NbS and sustainable development with attention on socioeconomic impacts. In his current research activity, he is involved in projects and working groups, for which he deals with spatial planning and public policy programming about resilience challenges and environmental vulnerability. His PhD research project aims at deepening the knowledge relating to how planning and public policies can facilitate the process of ecological transition, and more generally the conservation of the ecosystem and biodiversity; the reduction of the impacts on the economic chains of climate change and the promotion of sustainable development.

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Giulia Lucertini, assistant professor in rural and agricultural appraisal, PhD in valuation and local economics (University of Padua) and in "aide à la decision" (Université Paris Dauphine). From 2021 she became an assistant professor at the Iuav University of Venice, at the Department of Architecture and Arts. In this period she deals mainly with evaluation and analysis of projects and public policies aimed at climate change adaptation, and resilient spatial planning between urban and rural environments. In recent years, she has also worked on the circular economy and urban metabolism linked to land use and rural activities for a more sustainable and regenerative exploitation and consumption of natural resources, with particular attention to local food policies and more generally local agriculture.