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Environmental Assessment of Local Food Policies through a Territorial Life Cycle Approach

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Abstract: Sub-national governments play a vital role in achieving food-related sustainability goals through the re-territorialization of agriculture. While the environmental impact of such policies cannot be reduced to decreased food miles, multiple methodological bottlenecks prevent seizing their entire potential. In this paper, a territorial life cycle analysis is adapted and used to comprehend the cradle-to-grave impact of local food policies. This is conducted by assessing the impact of a territory's food-producing and consuming activities before and after the local food policies implementation. To evaluate the feasibility of the methodology, the municipality of Mouans-Sartoux (southeast France), engaged in local food policies for twenty years, is chosen. Four impact categories are modeled: global warming, fossil resource depletion, water consumption, and land use. The findings show that local food policies drive direct and indirect changes in farming and retail practices, but a more significant transformation is achieved by inhabitants, mostly by decreasing meat and ultra-processed product consumption. All actions summed up decrease the local food system's impact by between 7 and 19%. These results demonstrate the efficiency of the method to provide a holistic environmental assessment at a mesoscale as well as the environmental efficacity of the local authority's intervention in food-related matters.

Keywords: sustainable assessment methodology; local food systems; food policy analysis; environmental impact; short supply chain

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1. Introduction

The conditions used to produce, transport, and process our food have important consequences on the environment. Agriculture and the food industry are major contributors to anthropogenic pressures such as climate change, biodiversity loss, and water and soil quality deterioration [1–6].

In response to the consequent environmental degradation, governments worldwide are trying to build policies to curb this current trend. The European Union in particular set multiple regulations such as the European Green Deal, its recent Farm to fork and Biodiversity strategies, the Circular Economy action plan, and more ancient Nitrate Directive. Those aim to cut food-related greenhouse gas emissions, improve the quality of aquatic and terrestrial biodiversity, or reduce the impact of food waste.

Yet the environmental outcome of these policies is difficult to seize on the European or national scale. Each country's indicators are highly variable to regional differences due to diverse pedoclimatic profiles, infrastructure, agriculture, local culture, or social welfare levels [7].

Many authors thereby believe that a local level is a more appropriate scale to rectify and assess the negative externalities of the globalized food system [8,9], and thus, contribute to achieving sustainable development goals [10,11].

In practice, hundreds of municipalities have already signed collective international agreements such Milan Urban Food Policy Pact or Glasgow Food and Climate Declaration aiming to put local sustainable food policies at the heart of their ecological transition [12,13].

In the case of France, the largest agricultural producer in the EU, the recent political ambitions aim to redirect food production closer to consumers and cut agricultural-related greenhouse gas emissions by 50% by 2050 [14]. National policies encourage cities to relocate agriculture and promote sustainable territorial food organization through regulatory tools such as the Food territorial project (Projet Alimentaire Territorial PAT) created in 2014 by the French Ministry of Agriculture [15]. These projects enlarge the strategies undertaken by sub-national governments and regroup the globality of local agri-food policies. Administered by municipalities, food territorial projects aim to anchor the sustainable food economy into local tissue through public procurement, sustainable land policies, support to local farmers, implementation of urban agriculture, awareness-raising about sustainable diets, and other actions [16]. Such projects, thereby, surpass simple relocation policies based solely on developing a short supply chain by including both producer and consumer-based initiatives.

Despite such rising enthusiasm for a more locally organized food system, their environmental efficiency is yet to be proven. The literature has been extensively developed on the impact of a short food supply chain over the past two decades [17–28], but there is a research gap related to the consequences of more comprehensive and integrated local food policies [18]. The most recent meta-analyses and studies demonstrate heterogeneous outcomes concerning shorter supply chains with prevalent findings showing little or no significant environmental advantage if only the transport part is considered [18,19,21,22,29,30]. Yet when the entire life cycle of the supply chain is considered including agricultural practices or consumer habits, such as protecting landscape biodiversity or eating seasonally, the short supply chain and locally organized food system might present considerable environmental benefits [18,31]. Previous research shows that reconnecting production and consumption can positively affect sustainable production and consumption patterns [32,33]. To encourage and amplify such changes, the municipalities engaged in international treaties such as Milan Urban Food Policy Pact increasingly include actions such as encouraging organic agriculture development or changing diet habits in their reterritorialization policies. The academic literature proves that similar actions can have a vast impact-reducing potential [34–38]. Yet studies considering systemic impact, and the indirect consequences of developing local food organizations and integrated food policies are scarce [8,18]. When addressed, the latter is measured by descriptive indicators or frameworks rather than impact assessment [17,39,40]. More systemic and impact assessment studies of local policies exist but there are either action-specific such as improving the sustainability of public procurement in school canteens [41] and developing urban agriculture [42] or they analyze hypothetical transformations such as the environmental potential of changing local diets or reducing transportation distances [43].

While this previous research on agri-food assessment and local food initiatives shows mostly positive environmental impacts, its sectorial approach disregards the impact on the entire territorial system and its complex interdependencies. For instance, for methodological reasons, the existing studies led at the municipal level employ either producer or consumer-based perspectives [44,45]. This is mostly due to the methodological difficulty of assessing territorial policies including a high variety of actions, ranging from urban farming to food waste reduction, and the difficulty of understanding the causal link. Yet it has been proved that local consumption patterns are influenced by the local food supply [46]. Neglecting such connections lead to an underestimation of the interrelations of the processes involved in the whole food systems from farm to fork and hence of their environmental impact. There is, therefore, a need for a territorial, systemic, and longitudinal assessment based on the entire life cycle of food supply chains monitoring farmers' and consumers' practices to better comprehend the impact of local initiatives [18].

Concerning food supply chain, agriculture, and land planning environmental assessment (EA), the most used systemic method including the whole life cycle in the current worldwide research is by far life cycle assessment (LCA) followed by Material Flow Analysis (MFA), Input-Output Analysis (IOA) and Ecological Footprint (EF) [47–52]. The LCA

method [53] has a promising potential for assessing the impact of complex decision-making as its systemic approach avoids burden-shifting between life cycle stages and impact categories [54]. It has also been proven to be an efficient tool for urban planning [55,56].

To be able to use the LCA approach at a territorial scale and consequently include all local activities, the territorial life cycle assessment (TLCA) method was created [57]. TLCA assesses the eco-efficiency of all production and consumption activities located in the territory while defining the functions provided by those activities. The reference flow is defined by the land planning scenario implemented in the studied geographical territory. The upstream processes linked to local activities are included in the scope. The inventory is carried out by collecting the data related to local activities and linking them to existing LCA databases. The territorial hotspot activities are further identified by considering the land-use functions the corresponding territory provides [58].

The TLCA methodology was first developed to assess all territorial activities including every industry sector [57] but was later declined to evaluate an agricultural territory [59–61]. These existing studies reveal that most of the analyzed impact comes from outside of the studied territory. This confirms the advantage of a lifecycle-based methodology that prevents underestimating the local policies' impact by focusing solely on the locally visible indicators. This is particularly true in the case of developed countries or urban food systems environmental assessment as the average food autonomy of the main French cities is estimated to be two percent [62].

Despite its potential, to our knowledge, the use of the TLCA-based method has not been implemented in food policy assessment and requires several adaptations. This is what we propose to do in this study. The main objective is to reply to the research question of whether the LCA method is an efficient methodology to be used for systemic and territorial assessment of food policies. Secondarily, it aims to examine the cradle-to-grave impact of integrated local food policies going far beyond the short supply chain and sectorial actions. It consequently addresses the research question about the impact of systemic food planning and its contribution to sustainability goals. The paper thus fills in a research gap on systemic assessment methods for local policy evaluation, the impact of locally organized food systems, and its contribution to sustainable development.

Three principal hypotheses are investigated in this research. First, it stipulates that the TLCA-based methodology is an adequate assessment method for understanding the enlarged impact of a more locally organized food system and relevant local food policies. Secondly, it assumes that local food policies emerging in the Global North have significantly positive consequences on the local actors, their practices, and their habits. Finally, the third hypothesis supposes that the positive changes triggered by local policies generate important environmental benefits contributing to the achievement of national and European sustainability targets.

The hypotheses are assessed by applying the adapted TLCA approach to the municipality of Mouans-Sartoux engaged in food policies in the past twenty years. The structure of the paper is as follows: it first describes the study area and the methodology used. This is followed by results chapter describing the findings obtained through questionnaires and interviews conducted in the study area as well as the calculated environmental impact reduction stemming from the local policies and their contribution to international and national targets. Finally, the discussion and conclusion chapters address the added value of the used LCA methodology to the literature on the integrated policies assessment, the impact triggered by local authorities, and its implications for further research and policymakers.

2. Materials and Methods

2.1. Study Area

Mouans-Sartoux is a town of 9500 inhabitants located in the suburban area of the city of Nice in the southeast of France.

For the past 20 years, sustainable food policies have been part of the town's Agenda 21, intending to improve local food self-sufficiency and engage in food transition, from both, the producer, and consumer sides. The elected officials are involved in food challenges, and in 2012, the municipality converted to 100% organic and local food public procurement for municipal schools' canteens [63]. The transition was conducted without any increase in price thanks to the reduction of food waste. The school canteens weighed leftover food and consequently adjust the quantities cooked, which caused a 75% decrease in food waste [64].

The town equally bought four hectares of an agricultural plot to supply the public canteens with organic vegetables. Today the plot was extended to six hectares, employs three farmers (municipal workers), and provides more than 80% of the vegetables served in the canteen. In addition, 50% of the dishes served in the canteen are vegetarian [65]. The impact of this action went beyond the pupils and influenced the surrounding environment. For instance, according to the municipality's survey, 85% of parents of pupils eating in municipal canteens declared changing their eating habits [66]. Moreover, this initiative has been a lever for sustainable food policies that followed. The municipality increased the agricultural protected land from 40 to 112 hectares in urbanism documents and created an association of collective gardens [67]. At the same time, the municipality supports organic grocery stores, such as grocery stores selling in bulk to reduce waste, and helps to supply social grocery stores* (*selling productions with 70–90% reduction for precarious population) with organic products and products from community gardens and set a weekly marketplace for local producers [68].

In 2016, the town implemented the Food territorial project which led to the creation of the House of Sustainable Food Education MEAD (Maison d'éducation à l'alimentation durable) which is a municipal service dedicated to the development of sustainable local food policies [64]. The scope of its actions includes the settlement and assistance to farmers and raising awareness of sustainable food through education for all stakeholders, including families, visitors, elected officials, and pupils (Ibid.). Every year since 2017, the MEAD organizes the Challenge "Families with Positive Diet" FAAP (Famille à l'Alimentation Positive) to engage a dozen households in revisiting their diets and reorienting them to more sustainable, organic, and local food without increasing their food budget [63]. This is carried out through farm visits, cooking classes, gardening, etc. Other events are equally organized by the municipality each year such as "The Honey festival" or the "Marché gourmand" annual market to spread awareness of sustainable diets and give place to local producers (Ibid).

Yet due to its localization, the reconquest for local food sovereignty is hindered by real estate speculation, artificialization pressure, and soaring prices which results in a small proportion of existing farms. Despite this, local production is overwhelmingly sold in local organic shops, which constitute around half of the food stores situated in the municipality (Figure 1).

As a result of the broad range of actions that have taken place over the past 20 years, the impact of the territorial food policies stays difficult to measure. The municipality already assessed the impact of the local food supply, food waste reduction, and vegetarian menu implemented in the public canteens, which all together lead to the annual economy of 100 tons of CO_2-eq [69]. Yet, it can be assumed that the years of awareness-raising and sustainable territorial initiatives have a direct and indirect impact on the entire local food system, including local farmers and food retailers taking part in the project as well as on the diets of inhabitants. The main assumptions are the following:

- Farmers are encouraged to implement more sustainable farming practices and sell locally
- Industries are encouraged to environmental management practices concerning local supply chain, store waste, and energy management
- Inhabitants are encouraged to modify their diets towards less processed and more organic, local, and plant-based food

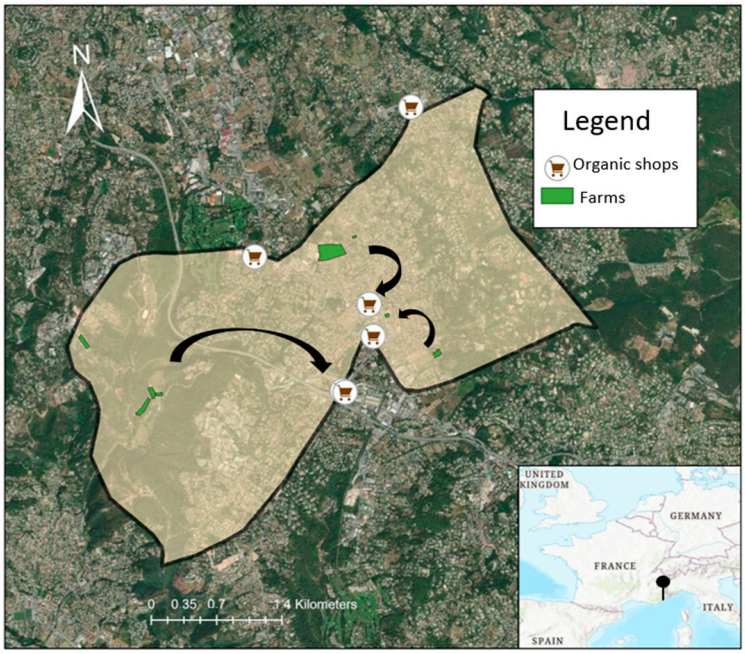

Figure 1. The map of the studied area, its farming surface, and organic stores.

Despite that, such assumptions and their environmental consequences have never been ascertained due to the methodological complexity it presents. In this study, we propose to use local quantitative data collection and statistical analysis to study the changes triggered by local food policies, and the adapted territorial LCA to calculate their environmental impact.

2.2. Territorial LCA-Based Assessment of Local Food Policies

2.2.1. Goal and Scope Definition

The goal of this assessment is to evaluate the impact of a wide range of actions of local planners on the territorial food system including food producer and consumer activities of Mouans-Sartoux municipality. To achieve this ambition, the adapted territorial LCA is used. The employed methodology consists of classic four LCA steps (scope definition, inventory, impact assessment, and interpretation) while considering a territory and its food activities as a product or service to be assessed.

The scope is limited by the geographical and administrative boundaries of the municipality based on Alberti et al. [70]. Compared to conventional LCAs, characterized by a unique functional unit, in the TLCA, the reference flow is the entire food territorial system including major producing or consuming-related activities. This means that the system includes both, food produced and processed locally (that can be either consumed locally or exported) and food imported for local consumption (Figure 2).

The territorial activities assessed are as follows: local agricultural production at the farm gate, processing, and retail industries' energy use, generated local food transport, consumption activities including the entire life cycle of the locally imported food, and finally local waste treatment. The burdens included in each activity type are allocated based on the individual responsibility of each actor, i.e., the local farmers are responsible for the production at the farm gate and the consumers are responsible for the production, processing, and transport of imported goods. Transportation activity type includes only local transportation comprising farmers' transport (not included in the production activity) and the consumer's travel (not included in the consumption activity). Freight transport for imported goods is accounted for in the consumption activity. To avoid double-counting, we precisely retrace the part of the local production consumed within the municipal borders through local interviews conducted.

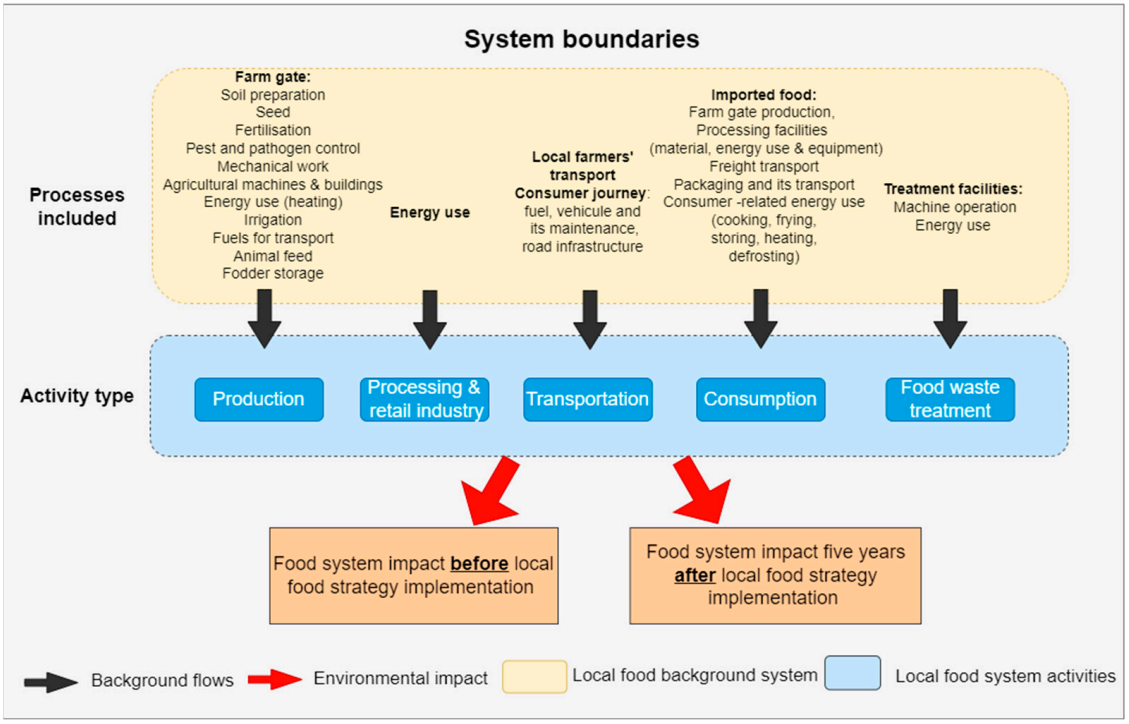

Figure 2. System boundaries and processes allocation related to each local food activity type.

The system boundaries comprise background processes that can be influenced by territorial actors. This means for instance that the construction of already existing agri-food or retail buildings is not considered in the scope.

The entire system's impact is assessed two times: before and after the implementation of territorial food policies. The comparison between these two assessments allows modeling of the impact of food-related changes during the period under interest from both the producer and consumer sides. The link between these changes and the local policies is studied during the questionnaire phase.

Despite the engagement of the municipality during the past 20 years, the period of the previous five years was retained for the assessment. A longer period makes it difficult to characterize the initial state. Furthermore, from the municipality representatives' point of view, this period particularly marked the acceleration of the food policies due to the implementation of a food territorial project and the creation of the MEAD in 2016.

2.2.2. Data Collection & Life-Cycle Inventory

Preliminary data related to local food system activities are obtained from open data sources (RPG data for local farmers, INCA3 for local diets, and INSEE for local distribution). In addition, precisions about the data related to local distribution and farmers were given by the municipality representatives. Further precisions and the changes taking place over the past five years, necessary for the policy assessment, were obtained through interviews and questionnaires. More specifically, three types of questionnaires were conducted:

- Semi-structured interviews with four local farmers (e.g., 70% of the local farmers)
- Semi-structured interviews with 13 local food retail managers (e.g., 60% of the local industries)
- Online and direct survey with a representative sample of the municipality population of 218 respondents (e.g., 5% of households).

For the interviews with professional actors, all voluntary participants were chosen to be interviewed.

The municipality population survey divided the population into two sub-samples:

1. the respondents who participated or benefited from diverse activities of the MEAD and municipality's local food policies (schools, companies . . .),
2. the respondents who did neither participate nor are implicated in any form of those policies.

Both sub-samples are of the same size and were selected to be representative of the population in terms of age groups and socio-professional categories. An online version of the questionnaire was sent by the municipality to the mailing list of all parents of children in local schools benefiting from the local and organic canteen and other participants of food-related initiatives such as urban gardening or sustainable diet challenges. For the overall population, the questionnaire was shared on municipal social networks and in public buildings such as libraries. To equilibrate the representativity of the sample, the group of researchers interrogated dozens of individuals in publicly available places. Thanks to the sample representativeness in terms of the age groups and socio-professional groups, representing 5% of households, the data obtained through the population survey are extrapolated to the municipality population for the result analysis.

During the survey, the professional respondents (farmers or local retail managers) were asked about the changes they undertook including the possible conversion of local farmers to organic production, energy decrease or renewable source in food retail, and decreased transport. For the consumer respondents, the questions were devoted to characterizing changes related to travel to a supermarket and diet composition. It includes collecting quantitative data related to the volume of food produced by local farmers, their farming practices, their transport, the energy consumed by local food industries, and the volume and character of food consumed by the local population.

The participants were equally asked about the degree of the influence of the local food strategy on their behavior change. The local food policies with potential influence on local actors include essentially the protection of agricultural land for local farmers, providing a local marketplace, setting up urban farming, and raising awareness about sustainable diets in schools and companies or through challenges such as FAAP and other events dedicated to the general population. Full surveys and interview guides are available in Supplementary Material Section SII.

Based on the principles of territorial LCA, the locally collected data (called activity descriptors) are afterward linked to existing LCA databases such as Ecoinvent 3 [71] and Agribalyse V3.0 [72] to incorporate the data of all background processes which are unable to be locally collected due to the magnitude of data needed (Table 1).

Table 1. Data sources for activities of the local food system and corresponding LCIs for background data.

Activity Type	Activity Descriptors	Units	Public Data Sources	Precisions about the Data	Background Data LCI
Production	Annual production	t	RPG data (RPG, 2019) [73]	Municipal agricultural board Farmers' interview	Agribalyse V3.0
Processing & retail industry	Annual electricity consumption	MWh	Industry identification: SIRENE database (INSEE, 2021) [74] Annual consumption: Enedis Open data (Enedis, 2021) [75]	Municipal electives Retail managers' interview	Ecoinvent 3
Transport	Annual farmers transport	kg-km	Agribalyse data on the transport of French food products	Farmers' interview	Ecoinvent 3
	Consumer trips to the shopping	km	NA	Population survey	Ecoinvent 3
Consumption	Annual food consumption by the local population	kg	Local food diets: INCA3 database (Anses, 2017) [76]	Population survey	Agribalyse V3.0

Note: The data inventory related to the case study and a more detailed data description can be found in Supplementary Material Section SI.

Regarding the choice of the LCI databases for background data, the existing modeled processes found in Ecoinvent 3 and Agribalyse 3 databases are considered comparable to the processes observed in the territory. Yet, an exception involves the organic products datasets which are at this point still nascent. To be able to include organic production, the Agribalyse database is selected despite its use not being advised for the comparison of organic and conventional agriculture. This is mostly due to the limited sample of farms which increases the data uncertainty [72]. Despite its drawbacks, we decided to use the database as it is the most accurate available database. Yet its limits will be discussed during the interpretation.

2.2.3. Impact Assessment

The impact of different food system activities in the territory before and after the launch of the Food territorial project in 2016 is modeled on four indicators:

- Global warming: characterizing global warming potential in yr kg CO_2-equivalent affecting the entire world ecosystems
- Land use: characterizing the amount of natural agricultural and urban land transformed and occupied in $m^2 \cdot yr$ measuring their degradation and consequent biodiversity loss
- Water consumption: characterizing freshwater depletion in m^3 considering its scarcity in selected world regions
- Fossil resource scarcity: characterizing the amount of extracted fossil fuel (coal, oil, natural gas) based on the lower heating value in kg oil equivalent (having a lower heating value of 42MJ)

The selection was based on the leading contribution of the food system activities on the determined indicators [1,2,77–79] which consequently allows studying the possible contribution of local food policies to global sustainable dynamics.

The empirical data related to the impact of the local food policies on the environmental practices of local actors is obtained through questionnaires and interviews. The participants provided quantitative replies related to the changes in farming practices, transport, energy consumption, or the volumes of distinct types of food consumed for the population survey. The questionnaires are translated to an LCA by modifying the activity descriptors or inventory background data used for the two time periods. For instance, if a farmer converted a part of apple production to organic agriculture, the background database of conventional apples is replaced by organic one or if inhabitants decrease their consumption of red meat by 10% the activity descriptors of the annual consumption of red meat are modified.

The analyses are conducted in SimaPro9.2.0.2 software using Recipe Midpoint 2016 [80,81] and its hierarchist perspective, considered the most relevant approach for European agri-food assessment [82].

2.2.4. Interpretation

In the interpretation phase, we analyze the changes undertaken by local actors (producers and consumers) in the past five years and their contribution to environmental impact reduction. To further confirm whether the local policies are influencing the local actors or whether it is a societal trend, the results of the local changes in consumption practices are compared to national changes over the same period. Similarly, we compare the magnitude of changes in the two sub-samples (the survey participants that benefited from local food policies and those who did not) to analyze the possible influence of local institutions. This analysis, and in particular differences between the two sub-samples, were based on statistical analysis (Z-test and Khi2 tests) to select solely statistically significant results.

Consequently, we compare the environmental impact of the entire life cycle of the local food system before and after the launch of the food territorial project on selected impact categories to seize a cradle-to-grave impact reduction between the two time periods.

A more precise analysis is conducted for the global warming indicator to estimate the ability of local food policies to fight climate change. To do so, we observe the mean degree

of changes for the two sub-samples and estimate a generated reduction in their carbon footprint in kg CO_2-eq.

The findings are used to formulate recommendations for local, national, and international policymakers. (Resume of the methodology in Figure 3).

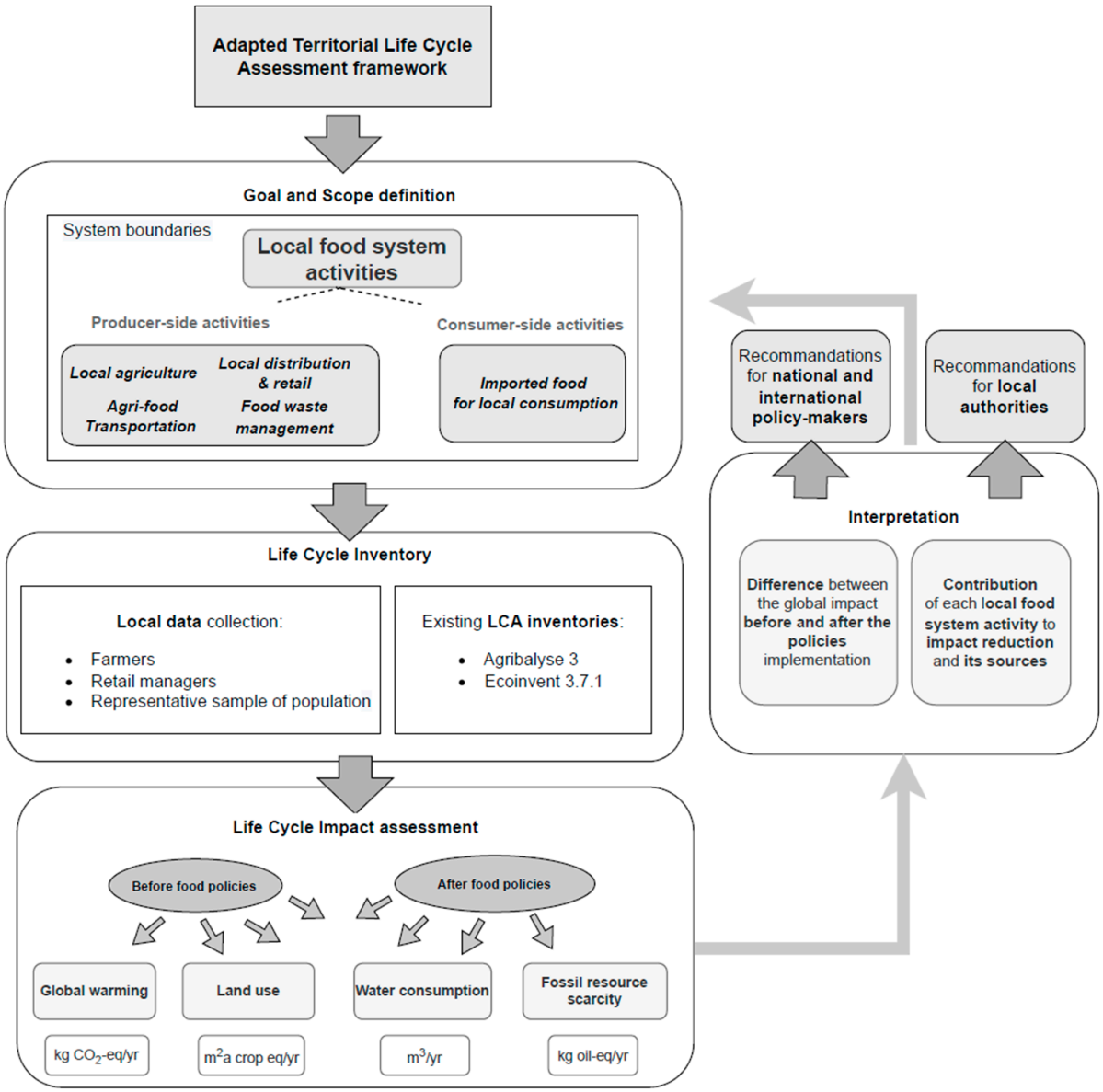

Figure 3. Framework chart of the methodology used in this research based on territorial life cycle assessment (TLCA) adapted to the environmental impact assessment (EIA) of local food policies.

2.2.5. Adaptations to Territorial LCA: System Functions

Compared to the TLCA methodology developed by Loiseau et al. [83], the first part of the methodology used in this paper is simplified, but the steps included are more detailed and adapted for policy assessment.

More precisely, the land-use functions assessment (e.g., economic, societal, and environmental functions of the territory) and the division of on-site and off-site impacts are not included in this research per se. For agricultural systems TLCA, three main functions can be economic profit, food production, and land occupation [61]. Our analysis of the related function indicators revealed little or no change in the territorial circumstances during the two studied periods. For instance, despite the efforts to increase the number of farmers and protect agricultural land, in the past five years, only two additional hectares were used

to produce food within the municipality's borders. Despite a consequent slight increase in food production, this does not significantly influence the local self-sufficiency potential. The current agricultural production based on organic horticulture engenders negligible pollution with little evolution in the past decade. This results in the overwhelming part of the impact being off-site for both periods. It can be therefore considered that the functionality of the territory remains intact which implies that any impact reduction improves the eco-efficiency of the territory.

To adapt TLCA to policy assessment we included a longitudinal dimension by looking at the dynamics of the entire food system of the territory in parallel with policy implementation and global trends. This is conducted by collecting detailed data about specific territorial practices and monitoring their evolution (farming practices, agri-food industry energy consumption, and diet preferences).

3. Results

3.1. Changes Driven by the Municipal Food Strategy

The field study reveals that during the past five years, and partially under the impulsion of the local food policies, several changes occurred. From the producer side, one farmer converted to organic production indirectly being influenced by the municipal services, and two organic shops moved to the territory thanks to its reputation or engaged actions in energy reduction and renewable energy consumption. Yet due to the profile of the municipality (suburban area, small farmer population) and the activities of the MEAD, which focuses principally on awareness-raising and access to sustainable food, the positive impact of the studied food territorial project is predominantly due to the consumption activities, i.e., individual changes in eating habits. The questionnaire's results demonstrate that globally 14% of the respondents changed the way to go to the supermarket from car to bike, 46% reduced their food waste, and 59% changed their diets (reducing meat, ultra-processed food, eating more organic, seasonal, and local food).

Two-thirds of all participants state that their behavioral shift was influenced by the municipality's activities. The findings equally show that the respondents of the sub-sample benefiting from the local food policies were two to three times more likely to change their behavior than the other sub-sample (Table 2).

Table 2. The degree of changes in the Mouans-Sartoux population for the two sub-samples (%).

Studied Change (2017–2022)	Evolution of Implicated Sub-Sample	Evolution of Non-Implicated Sub-Sample	Average Evolution of Mouans-Sartoux Inhabitants	National Evolution
Consumption of ultra-processed food	−40%	−20%	−30%	On the increase (precise % NA)
Consumption of meat	−32%	−14%	−23%	+0.7%
Consumption of organic products (% of the consumption of organic products on regular basis)	39%	18%	28%	15%
Use of bike to the supermarket	+21%	+6%	+14%	NA
Food waste reduction	−4%	−1.5%	−2.7%	NA

Note: Those implicated or benefiting from local food policies include the parents of pupils consuming food from municipal plots, participants of sustainable diet challenges, or inhabitants involved in urban farming amongst others.

The behavioral changes evoked cannot be entirely attributed to local policies and are multifactorial. Despite this, the implicated sub-sample demonstrates significantly far-reaching transformation. In addition, the changes observed in our case study counter the current trends in France or are more pronounced. For instance, the respondents globally decreased the consumption of ultra-processed food by 30%, which is on increase in France [76], and they decreased the overall meat consumption by 23%, which is on the

increase of 0.7% per habitant per year [84]. Similarly, 28% of inhabitants consume organic products on an everyday basis compared to 15% in France [85] (Table 2).

3.2. Environmental Impact Reduction

Figure 4 provides the results of the annual decrease or increase of the food system's environmental impacts per change that occurred between 2017 and 2022 and can be linked to local food policies. The positive impacts correspond to a reduction while the negative impacts to an augmentation over the five years. By analyzing the contribution of each change, the findings reveal that the diet composition change undeniably influences the overall impact reduction (ranging from 45% to 95 % of the overall impact reduction). This includes the reduction of meat and ultra-processed food consumption, and an increase in fruits, vegetables, legumes, and nuts. Approximately 60% of this reduction is due to the decrease in the consumption of animal protein and another 40% is thanks to the decrease in ultra-processed food and beverages, including desserts and alcohol. Solely changing the inhabitants' diet results in a reduction of 2880 tCO_2-eq, 2,870,000 m^2 crop-eq of soil, 20,800 m^3 of water, and 140 tons of oil equivalent.

While the overall food waste reduction of the population is inferior to 3%, its impact reduction potential is substantial. It is the second most important source of the impact decrease, especially for the indicators of water and fossil energy scarcity, decreasing by 17,700 m^3 of water and 60 tons of oil equivalent respectively.

For climate change and fossil energy indicators, changing the transport mode from food shopping to biking is the third most important change to initiate, counting for 4% and 16% of the global impact reduction respectively representing economies of 150 tCO_2-eq and 44 tons of oil eq.

The use of renewable electricity in local organic stores, consumption of seasonal products, and buying in bulk or composting generated only a marginal impact diminution compared to other studied activities (0–4% of the overall impact reduction).

The increase in the consumption of organic products significantly decreased the use of fossil energies and greenhouse gases but slightly increased the use of water and land (Figure 4).

The increase in water use due to the consumption of organic food stems from the consumption of organic apples, responsible for a 64% increase in water consumption, followed by organic peaches. Both products consume 60% more water per kg produced than their conventional equivalent. Contrary to what might be believed, most of the water footprint does not come from irrigation on farms, but from industrial processes such as electricity or diesel production used on farms for harvest, trellising, or trimming. It is relevant to mention that the increase of 18,440 m^3 of water used represents only a 2.66% increment in global impact and is entirely compensated for by other changes.

This result should be interpreted preciously due to the limits of the Agribalyse database. The functional unit of kg/produced is disadvantageous for organic systems that are more extensive and produce lower crop yield. In the database, the average yield considered for organic apples is 22,041 kg ha^{-1} yr^{-1} compared to the average conventional yield of 46,160 kg ha $^{-1}$ yr^{-1} (+52%) which might not reflect local real-life conditions.

The impact of consuming more local food could not have been measured due to the diversity and multiplicity of existing supply chains as well as insufficient regional data. The fruits and vegetables produced within municipal borders do not represent more than 3% of the local vegetable consumption and are partly exported to neighboring municipalities. The environmental efficiency of local supply chains was found similar to conventional chains (accounting only for the transport part) and any advantage to decreased travel distance was found apart from the exception of the municipal agricultural plot. The delivery of the vegetables from the municipal plot to school canteens shortened the food miles to 3 km but its positive impact is negligible in the entire life cycle of the local food system.

Figure 5 shows the global impact reduction in percentage over the five years analyzed for the four same impact categories. The reduction of the environmental impact ranges

from 7 to 19% of the whole life cycle of the local food system depending on the impact category. The reduction is more pronounced for the indicators of land use (m^2 a crop-eq) and climate change (kg CO_2-eq), 18% and 19% respectively. The impact categories of water (m^3) and fossil resource scarcity (kg oil-eq) display a reduction inferior to 10%. This leads to an overall decrease in 20,192 m^3 of freshwater, 308,247 kg of oil-equivalent, 3.02 million m^2 of land, and 3.66 million CO_2-eq for all changes combined. Such a decrease diminishes the local food system's dependency on external inputs, reinforcing its resilience (Figure 5).

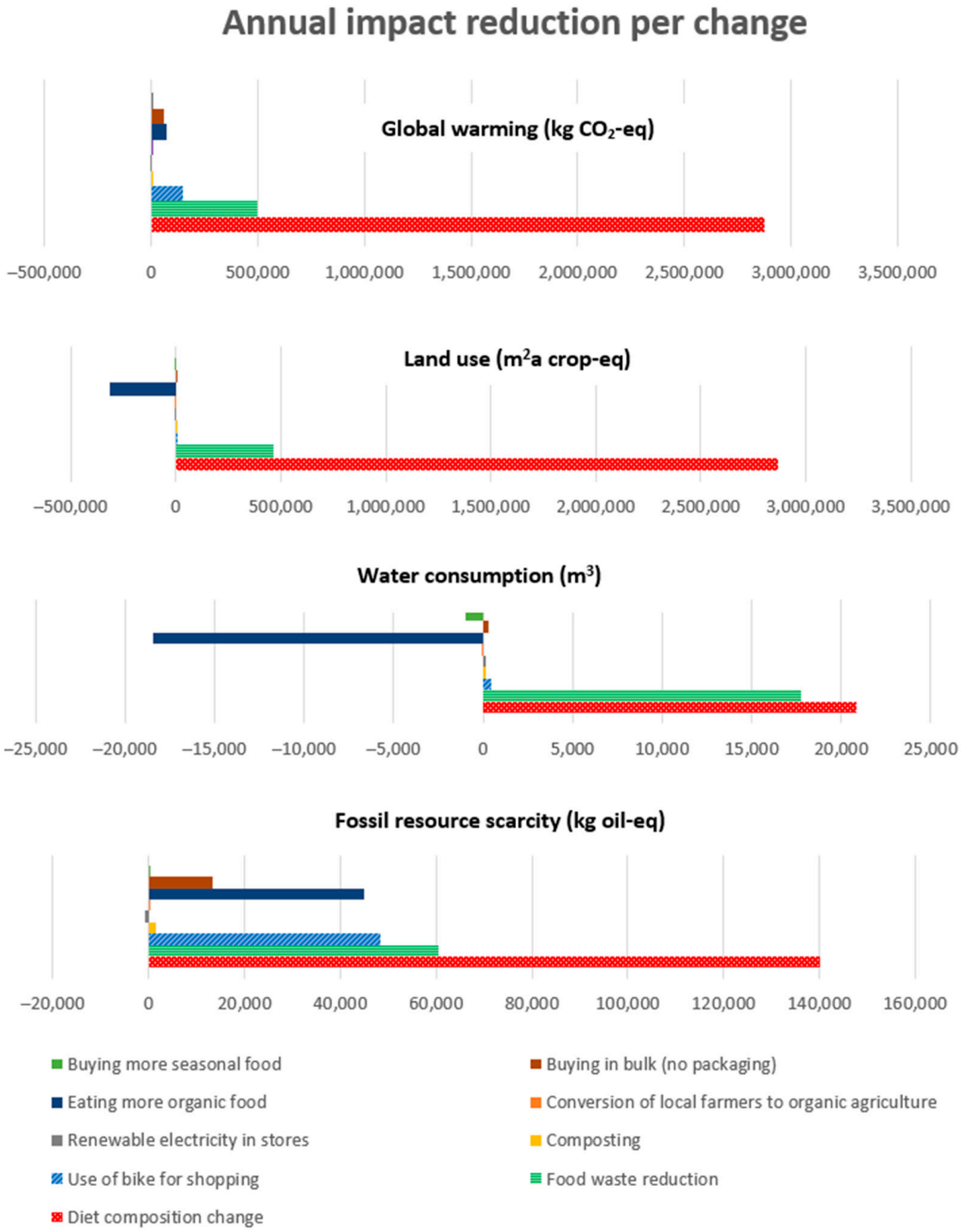

Figure 4. Environmental impact reduction per changes partially or directly driven by the food territorial project of Mouans-Sartoux.

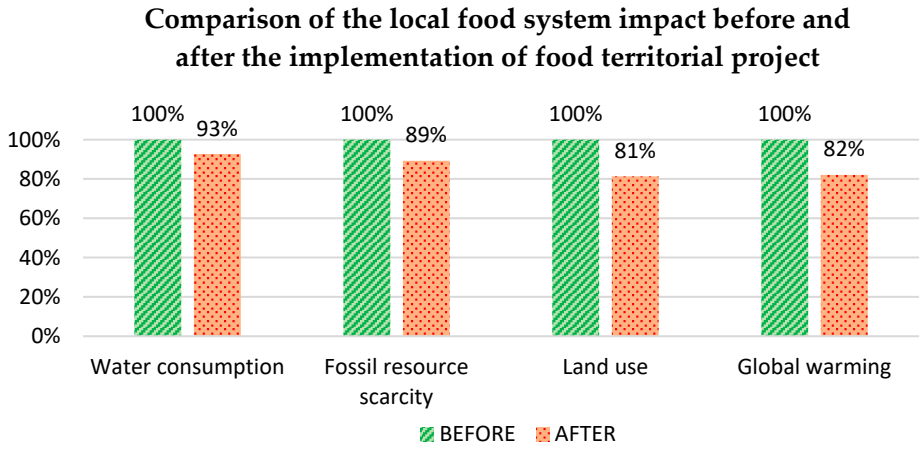

Figure 5. Comparison of the environmental impact of the entire local food system of Mouans-Sartoux before and after the initiation of its food territorial project (2017–2022).

The analysis of the ability of consumer-based changes to contribute to the climate change fight indicates significantly positive results as illustrated by Figure 6. For the sub-sample that is implicated or benefiting from local food policies (a), the average impact reduction sums up to the decrease of 515 kg CO_2-eq yr^{-1} pp which is equivalent to a 26% reduction of the average food carbon footprint of a French citizen being 2000 kg CO_2-eq yr^{-1} pp. The diet composition change is the principal driver of this reduction (413 kg CO_2-eq yr^{-1} pp). The sub-sample that has not benefited from local food policies equally displays an impact reduction (b), but the latter is less consequent with the overall average reduction of 236 kg CO_2-eq yr^{-1} representing a 12% decrease in their food carbon footprint (Figure 6).

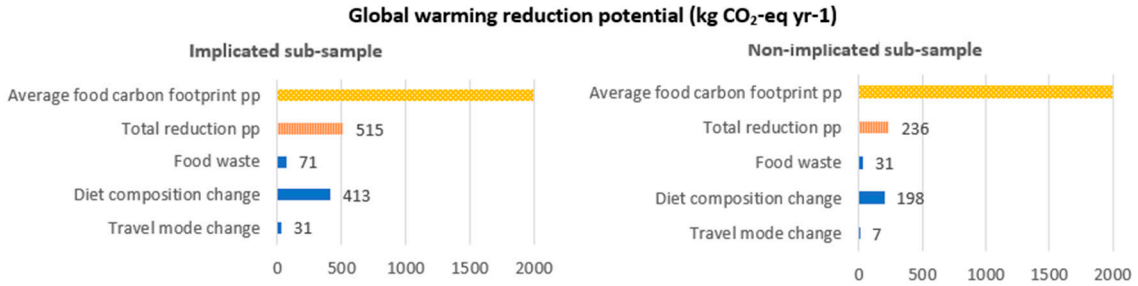

Figure 6. The mean contribution of changes of Mouans-Sartoux inhabitants to their food carbon footprint reduction. (**a**) The sub-sample implicated or benefiting from local food policies; (**b**) the sub-sample that has not benefited from local food policies.

4. Discussion

4.1. Application of Adapted Territorial LCA to Policy Assessment

Despite the results based on a well-defined and specific area of Mouans-Sartoux, that cannot be considered representative of other French or European territories, the insights derived from this experiment contribute to an understanding of the dynamics of environmental impact stemming from local policy implementation. Interrogating the changes taking place in the entire local food system and coupling producer and consumer-based approaches allows accounting for indirect consequences offering thereby a holistic vision of the impact reduction.

The findings demonstrate that the environmental consequences of local food policies reach far beyond the reduced food miles, the modifications of the menu of school canteens, or the observed local indicators. This proves that a life-cycle-based assessment of local food

policies allows for seizing an enlarged positive environmental potential of territorialized food systems. As an example, before the present assessment, the estimated GHG reduction of local food strategy obtained by adding separate initiatives was approximately 100 tCO_2-eq [69], which seems negligible compared to the results of more than 3660 tCO_2-eq thanks to the applied methodology. Such a systemic vision affirms the benefit of the deployment of lifecycle-based methodology at the meso-level [86] and confirms the research hypothesis assuming the enlarged benefits related to the application of TLCA-based assessment on the local food system and policies.

The study provides a novel methodological framework for the assessment of integrated environmental policies at the local level replying to emerging environmental research related to local food issues, especially in the Global North [8,10]. While this approach might still disregard certain local changes, it proposes a more comprehensive view of local food strategies' direct and indirect impact. As such, this TLCA-based framework can be used a basis for further research of local food systems at a wider level and to enlarge the research on the benefits of shorter and more local supply chains currently based predominantly on evaluating transport efficiency [18,19,21,22].

Benefiting from the favorable political context in some European countries [87], such as in France [32], the framework and its results can be used as a foundation for local food planning adding an empiric impact evaluation to already-existing frameworks [40,88]. More precisely, it can be used to assess the implementation of food policies at the sub-national level such as Food territorial projects (PAT) or similar integrated policies. It can also be used to understand the dynamics of local food systems and their link to institutional changes and thus serve as a basis for regional, national, or international planners.

4.2. Positive Impact of Local Food Policies & Policy Implications

The positive potential of diminishing the food system's environmental impact through local food policies emerging in numerous European and French regions was confirmed using the TLCA-adapted methodology. This confirms the determinant role of local authorities in shaping sustainable food systems as well as the positive externalities of reconnecting producers and consumers as suggested by previous research [10,32,89,90]. It thus validates the hypothesis claiming the positive consequences of local food policies on the local actors and their environmental practices. Globally, the changes partially or directly influenced by the Mouans-Sartoux local food strategy contributed to the reduction of up to one-fifth of the environmental impact of the entire life cycle of the local food system. Meanwhile, this impact reduction did not weaken the potential food autonomy. Similarly, the food policies reinforced the resilience of its system by decreasing its dependence on external inputs such as fossil resources.

The contribution of each action to the impact reduction is highly variable, with the individual diet change absorbing the major part. In our case study, the environmental advantage of a more territorialized food organization is therefore predominantly due to the changes it drives in consumer habits rather than diminished food miles as initial studies assumed. This result is consistent with other food impact studies exposing dietary changes as having the highest mitigation potential [35,41,43]. It means that while policies supporting local farmers are essential, awareness-raising actions with local schools, industries, and inhabitants encouraging a shift to a more plant-based and fresh diet are identified as the most beneficial environmental actions in the given context.

The impact reduction is greater for the sub-population directly benefiting from local food policies, leading to a one-fourth decrease in their food carbon footprint. They thereby participate in achieving national climate objectives coherent with the targets presented in future scenarios such as Afterres2050 [91] or TYFA [92] as well as with the National Low-Carbon Strategy [14] and European objectives [93] conceiving a more sustainable food system by 2050. It thereby validates the final hypothesis formulated by this paper assuming a positive environmental contribution of local food policies to national and European climate targets.

Considering policy implications, the outcome of this analysis proves the relevance of consumer-based educational actions in municipal agendas and prompts urban planners to include similar strategies in their local food agenda. Considering their impact reduction potential, national governments should dedicate sufficient financial and methodological resources to sub-national governments' food strategies. Internationally, the results of this study advocate for more national and local authorities' intervention in food systems, encouragement of plant-based and fresh diets through policy implementation, and protection and development of territorialized food systems. The introduction of integrated sustainable policies aiming to transform both producers and consumers, such as French food territorial projects, should be promoted.

4.3. Lack of Appreciation for Alternative Farming Systems in LCA

In our results, the increased consumption of organic food raised water consumption mostly due to organic apple production. These findings correspond to already existing LCA studies of organic orchard systems [94]. Yet similar studies analyzing organic and low-input production of apples revealed a positive impact if the functional unit per hectare is used [95]. That is why the major limitation of the used methodology is its insufficient recognition of the benefits of organic farming systems. The LCA and its existing databases are conceived on the efficiency logic using a functional unit of 1 kg of produced food. This results in a more optimized and intensive system having a better environmental score than an extensive organic system, especially for livestock farming [96]. The French institute of organic agriculture denounces this major drawback of the Agribalyse database and alerts on its use for the assessment of organic systems. It shows for instance that out of eight different farming systems for egg production, the three organic systems display the worst environmental score contrary to the most efficient caged egg production [97].

Apart from this productivist aspect of LCA being unfavorable to extensive production, LCA only models indicators that have negative consequences on the environment. Existing meta-analyses demonstrate that organic farming systems provide numerous ecosystem services such as improving water infiltration, precluding soil erosion, and maintaining more diversified and resilient ecosystems with greater landscape diversity [98,99]. Yet many of those impacts are not accounted for in traditional LCA studies or are poorly modeled such as ecotoxicity or biodiversity indicators [100] despite research and projects being initiated on their improvement [101,102].

Despite these shortcomings, and as proved by this study, the LCA approach and Agribalyse database allow us to provide an enlarged vision of the benefits of local food systems, which could be hardly achievable by any other method. In its application in territorial assessment for highly agricultural regions, a complementary method could be used to assess farming systems such as the method Clim'agri [103], Dialecte [104], or ecosystem services-based assessment methods [105].

5. Conclusions

This paper empirically demonstrates the positive environmental consequences partially or entirely induced by local food policies through the adaptation of territorial life-cycle assessment. It thereby broadens the research debate on the environmental benefits of local food systems and shorter supply chains. The research question interrogating the environmental potential of integrated local food policies has been addressed by confirming significant direct and indirect environmental benefits. The globality of the changes triggered under the local food policies over five years generated annual economies of 20,192 m^3 of freshwater, 308,247 kg of oil-equivalent, 3,015,406 m^2 of land, and 3,660,702 kg CO_2-eq for 9500 inhabitants. The awareness-raising institutional policies proved to generate the greatest proportion of the impact reduction.

This positive outcome reinforces the need for future institutional, methodological, and financial support to local food projects to magnify their efficiency and encourage their emergence. Such support is not only needed to be able to implement this sort of policy

but also to engage in proper impact assessment and initiate more relevant policies. The imperative to modify dietary patterns to engage in ecological transition and achieve the 2050 sustainability targets is also proven.

The adapted TLCA framework used in this study has proved relevant for assessing complex local food policies and can be used in other environmental meso-level assessment studies. It, therefore, fills in a gap related to the assessment of systemic territorial policies. The paper exposes the need for more lifecycle-based thinking in policy assessment to include the externalities taking place outside of the territory lenses, especially for urban areas or industrialized countries. Yet, the necessity to better account for the benefits of agroecological farming should be explored in further research.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su15064740/s1. Table S1. Local agri-food activities considered in the scope. Table S2. Data sources and background LCI databases used for each activity descriptor. Table S3. Foreground data for Mouans-Sartoux case study including years 2017 and 2022. File S1. Interview guides & questionnaires. References [71–76,96,97,106] are cited in the Supplementary Materials.

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