Carbon footprint in green public procurement: Policy evaluation from a case study in the food sector

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Carbon footprint in green public procurement: Policy evaluation from a case study in the food sector

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Abstract
Several projects across Europe are focused on improving sustainability of public procurements; however, few of them are measuring the environmental savings achieved by specific policies through the application of environmental impact assessment indicators. In this paper, we calculate environmental savings by applying a carbon footprint analysis to three food policies implemented by the City of Turin (Italy) in the school catering service (school years 2012/13 and 2013/14). The policies are focused on (I) the production of food (with the requirement of integrated or organic products), (II) the geographical origin of the food (with the requirement of regional food provisioning) and (III) the improvement of urban distribution (with the requirement of shifting to natural gas vehicles). The climate change potential of five of the most consumed foods were studied according to three main phases of the supply chain: production (including all processes in a cradle-to-gate perspective), provisioning (focusing on the transportation from production sites to the peripheral food hubs of the city), and distribution (focusing on the transportation from the city hubs to schools). The results of this study highlight the different climate impacts of the three phases of the supply chain, in particular 61–70% of the greenhouse gases are emitted in the production phase, 6–11% in the provisioning phase and 24–28% in urban distribution. As a consequence, policies that affect production practices have the greatest potential for reducing the carbon footprint of the catering service. Other policies (such as those on transportation) can have controversial effects. Therefore, to improve planning of sustainability policies, the greenhouse gas emission savings achieved by each policy must be analysed in-depth.

Introduction

Challenges of GPP in the food sector

Analyses of public procurement as a tool for the development of economic, social and environmental issues are finding growing recognition at the international level. According to the report 'Procuring the Future' (Department for Environment, Food and Rural Affairs [DEFRA], 2006), the most agreed-upon definition of sustainable procurement is a process whereby organisations meet their needs for goods, services, works, and utilities in a way that generates benefits not only for the organisation but also for society and the economy while minimising damage to the environment.

Zhu et al. (2013) calculated that industrialised countries spend over 10% of their gross domestic product on public procurement, and a recent analysis by the United Nations (UNEP, 2013) reports that at least 44 states have adopted Green Public Procurement (GPP) policies to varying degrees. In Europe, the share of gross domestic product devoted to public procurement is approximately 19%, representing a total expenditure of over two trillion euros per year (European Commission, 2011). Within the European Union, there are numerous services run by public bodies (European Commission, 2011); in this study it is highlighted that in Europe, more than in other regions of the world, GPP is considered central to sustainable growth. Public procurement has high potential for the dissemination of best practices by providing an example of sustainable consumption practices to broader society and stimulating eco-innovation (Brammer and Walker, 2011; Testa et al., 2012).

GPP establishes environmental criteria for the purchasing of products and services (Uttam and Roos, 2015). Thus, implementation of an environmentally sustainable supply policy is often achieved through the definition of specific environmental requirements in the call for tenders (e.g. European Parliament Directives 2004/17/EC and 2004/18/EC). These requirements may be general criteria (such as a maximum distance for provisioning and seasonality of food) or may refer to standards already developed both at the European level (such as Ecolabel certification or Product Environmental Footprint) and at the level of individual Member States. Such standards often include quantification of direct environmental impacts, such as energy consumption, transportation emissions and natural resource consumption, but sometimes also include indirect impacts, such as those resulting from energy production (Uttam and Roos, 2015) and other production inputs. Considering both direct and indirect environmental pressures, DEFRA (2006) has estimated that more than 50% of the environmental impact of the public sector comes from the supply chains of products. If this statement holds true for the public sector in general, the percentage is most likely greater in the supply chains of public catering because of the large material and energy intensity of food products in comparison to other products and services (De Koning et al., 2015). Furthermore, public services related to the food sector are numerous and they support a large number of meals every day throughout a country, including schools, hospitals, universities, prisons and others.

Specifically for the food sector, the European Union takes into account environmental criteria (European Commission, 2011) based not on threshold values from environmental impact indicators, but rather on the sustainability of practices, such as the seasonality of products, harvesting practices, minimisation of waste and packaging, and professionalisation of operators (European Commission, 2011). This division between sustainable practices and environmental labelling in the food sector arises from the difficulty of harmonisation (Notarnicola et al., 2015). Studies on the feasibility of applying the EU Ecolabel to food products (Sengstschmid et al., 2011) illustrate that the environmental performance of food is strongly related to its whole life cycle, including production, transformation and distribution (Caputo et al., 2014). Because of this property, in general the use of sustainability practices in public calls for tenders (instead of using threshold values in environmental impact categories) clearly aims to reduce environmental impacts. However, if sustainability practices are not associated with a specific evaluation of an environmental indicator (such as emissions of climate-changing greenhouse gases (GHGs) or water depletion or soil consumption), they do not allow quantification of the actual environmental savings.

Aim of the study

Studies applying life cycle assessment (LCA) to products and services demonstrate that despite the goals of environmental improvement, unless one or more indicators are applied in the policy planning stage, there is a real risk that the environmental impacts will not actually be reduced but simply shifted from one stage of the production process to another (Ridoutt and Pfister, 2013; Samaras and Meisterling, 2008). As an example close to the case studies of this paper, Caputo et al. (2014) applied LCA to the main foods on the menu of six school caterings in Lombardy (northern Italy). Despite the potential use of results in policy development, life cycle-based methods are rarely used to quantify the environmental performance of GPP policies. In the scientific and technical literature, only a small number of studies can be found for the construction sector (Tarantini et al., 2011; Uttam and Roos, 2015), the transport sector (Parikka-Alhola and Nissinen, 2012a, 2012b), and the service sector (Alvarez and Rubio, 2015), while no studies are available for the food sector. This gap is important because assessment indicators are necessary for evaluating the environmental performance of public policies (Bento and Klotz, 2014; Bravo et al., 2013).

The aim of the paper is to quantify the climate change reduction potential of three GPP policies introduced in the school catering service of the City of Turin (Italy) within the context of the INNOCAT project (Procurement of Eco-Innovation in the Catering Sector). In particular, these policies are focused on (I) the production protocols of purchased food (a requirement of integrated or organic products), (II) the geographical origin of the food (a requirement of regional food provisioning) and (III) reducing the impacts of urban distribution (a requirement to shift from petrol to natural gas vehicles). As the focus of the study is to quantify the effectiveness of three specific public food policies in terms of climate change reduction, not all phases and products of the school catering service have been considered, but only those that are targeted by the GPPs.

Food policies for school canteens of Turin

The city of Turin, with a population of more than 900,000 people, is one of the principal cities in north-western Italy and is the administrative centre of the Piedmont region. The municipal commitment to becoming a ‘smarter’ city is evident from the city’s participation in a number of projects focused on fostering sustainable, intelligent and inclusive urban growth, such as the Covenant of Mayors and Smart City initiatives. In 2013, together with the Smart City Foundation, Turin’s Smart City Master Plan – ‘Smart Mobility Inclusion Life & Health and Energy’ (SMILE) – was launched.1 In this Master Plan, several actions were designed along with relevant key performance indicators to measure their impacts. In particular, one goal was to achieve low-carbon school catering services. School catering represents a significant component of the procurement budget for the City of Turin: approximately eight million meals are delivered annually with a total value of approximately 40 million euros per year. This service is provided to approximately 71,500 pupils between the ages of 0 and 13 years old. Including the children’s teachers and families, 230,000–250,000 citizens are connected to the school catering services in some manner. Therefore, policies applied to this service have great potential to reach the urban community. School canteens can be considered as ‘a kind of a meeting place for skilled and motivated change agents with a whole host of worthwhile agendas’ (Poppendieck, 2010), and these agendas often conflict on social, cultural and religious issues (Ashe and Sonnino, 2013a). An example is the ‘Create your menu!’ an initiative, in which selected school classes in Turin participated in meetings with all the actors of the school catering service (from farmers to suppliers, including the managers of the urban food platforms) to understand the ‘history’ and the complexity behind the food supply chain. After these meetings, the students were asked to design a new menu that would take into account their wishes, but also the needs of all the actors involved (Provincia di Torino, 2013), although without including aspects of environmental sustainability. To improve knowledge of environmental issues related to school catering services, Turin decided to participate in the INNOCAT project (Procurement of Eco-Innovation in the Catering Sector) ,3 coordinated by ICLEI (Local Governments for Sustainability). Within this project, local authorities introduced a number of measures and included various criteria into the school catering contract with the aim of reducing the associated carbon footprint (CF). These included the acquisition of energy-efficient appliances (mainly ovens and dishwashers) for schools, the utilisation of tap water, the use of low environmental-impact transportation and a significant reduction in packaging and waste .4 In particular, contractors were required to shift from plastic to reusable dishes, to manage the separate collection of waste (in particular primary and secondary packaging) and to redistribute leftover food to social projects in the city.

Additional criteria were applied to reduce other environmental impacts associated with the catering contract, such as requiring the use of ecological cleaning products and awarding points to bidders offering a wider range of organic or fair trade products than were specifically requested.

In relation to the food supply chain, three specific policies have been adopted in the current school catering service:

(I) Production protocol. In the school year 2012/13, organic production protocols for several food items were set as procurement requirements. Because of the difficulty of procuring the necessary quantity of organic food, the requirements were extended to integrated production for the school year 2013/14.
(II) Geographical origin. In the school year 2012/13, all major food items were requested to be procured within the EU (excluding tropical fruit and other minor goods). To reduce "food miles", the City of Turin decided to restrict the place of origin for all major fruit and vegetables to the Piedmont region for the school year 2013/14.
(III) Vehicles for urban distribution. To improve air quality, in the school year 2013/14 the City of Turin introduced the requirement that the catering company's transportation fleet used at least 50 natural gas vans. As a consequence, the urban distribution fleet changed from 16 (of 67) vans fuelled by natural gas in 2012/13 to 54 (of 63) vans fuelled by natural gas in 2013/14.

Methodological choices

Investigated food supply chains

To ensure that the local authority was on track to achieving a low-carbon catering service and to identify areas for continuous improvement, the municipality commissioned the University of Turin to monitor and evaluate the CF of the school catering service. A preliminary analysis of the catering service structure (including the number and quantity of food items procured, the main food production areas, the number of catering companies, and the structure of the transportation fleet) was performed to obtain an overview of the system. Only fruit and vegetable products could be chosen as case studies because it was only for these products that all three GPP policies could be tested (e.g. for animal-based products organic production is not a tender requirement). Five of the most consumed fruit and vegetables were chosen as case studies to test the climate change reduction performance of the applied GPP policies: potatoes (annual consumption of 300 t), apples (290 t/year), carrots (200 t/ year), and pears and peaches (60 t/year each).
The preliminary analysis revealed that the three GPP policies (see previous chapter) were related to different parts of the food procurement supply chain. Therefore, we decided to study the three phases separately, as follows:
(I) The production phase, which includes all agricultural practices and the production of all agricultural inputs including fertilisers and pesticides, as well as electricity from the

4 Details about the initiatives taken by the City of Turin within the INNOCAT project are available at http://www.sustainable-catering.eu/.

national power grid mix, water management and machinery use. By calculating the change in production-phase CF over two years, it is possible to assess the performance of the integrated and organic production policy requirement.
(II) The provisioning phase, which includes the transportation of goods from the production sites to the local hubs located on the outskirts of Turin for city distribution. Each of the five products has a different supply structure based on the characteristics of production (geographical origin, freight requirements for conservation and shelf life). In this phase, it is possible to assess the performance of the geographical origin policy.
(III) The distribution phase, which includes transporting food from the periurban city hubs to the school canteens. This phase is organised into three distribution blocks: the supply of prepared meals (pre-cooked meals that just have to be warmed in the school canteens), the supply of raw food (mainly vegetables that have to be prepared on-site) and the supply of fruit. The supply chain of potatoes and carrots falls into the second distribution block, and the supply chains of apples, pears, and peaches falls into the third distribution block. In this phase, it is possible to assess the performance of the vehicle and urban logistics policies. Although the first distribution block (prepared meals) is not involved in the product supply chains of the fruit and vegetable case studies, the CF of the full distribution phase was calculated.
Because of the interest of the study in evaluating the climate impact reduction of the three GPPs (one for each main phase of the supply chain), each part of the service has been considered as a separate system. In particular, the climate impacts of the production phase are quantified using 1 kg of product at the farm gate (therefore applying a cradle-to-gate perspective) as a functional unit; the climate impacts of the provisioning phase refer to 1 t of product from the farm gates to the Turin food hubs; the climate impacts of the distribution phase refer to one serving portion that has been prepared in the food hubs and then delivered to schools. Specifically, one serving portion changes according to the kind of product in question: one standard fruit of 150g in the case of apples, pears and peaches; one plate of boiled carrots equal to 130 g of pre-peeled carrots; and one plate of baked potatoes equal to 140 g of pre-peeled potatoes.
Furthermore, as the three functional units of the three phases are all mass-based, it is possible to convert all GHG emissions into a common functional unit in order to have the total GHG emission reduction when all the three GPPs are applied. In particular, by referring the climate impacts of all phases to the serving portion it is possible to link all three phases of the supply chain modules into one single process (as three modules of a single modular LCA) and to evaluate the CF through the entire supply chain (excluding the cooking phase, which is out of the target of the GPPs).

Description of the assessment method

Several environmental impact indicators are currently available in the scientific literature. These assessment methods are generally based either on the quantification of substances harmful to the environment, such as the CF, or on the calculation of the consumption of natural resources, such as the ecological footprint (Galli et al., 2012). Both types of indicators can be based on an LCA approach that considers the environmental impacts or the consumption of natural resources of each phase of the life cycle of a product or service. LCA studies are now the basis for many applications, including the processes of eco-design, environmental product certifications, and environmental assessments of the effects of policies (Weidema et al., 2008). A full LCA study includes the environmental consequences resulting from the use of resources and emissions in several impact categories (such as global warming potential, acidification potential and nutrient enrichment potential) to avoid the shifting of ecological burdens from one type of environmental impact to another. Traditionally, the results were used for the eco-design of products, with the help of first-hand and often detailed interpretation by an LCA expert (Ridoutt and Pfister, 2013). The advent of the CF indicator has made LCA results available to a wider audience (Weidema et al., 2008). A key difference is that the public is typically remote, largely non-technical, and in need of first-hand interpretation (Finkbeiner, 2009). Another difference is the focus on a single aspect, namely GHG emissions, which disregards the potential of LCA for comprehensive analysis and the evaluation of trade-offs (ISO 14067:2013).

In LCA, the CF analysis corresponds to the 'global warming potential' category and expresses the amount of CO2 equivalents (CO2eq. – a collective unit for all molecules with a global warming potential) associated, directly and indirectly, with all stages of development of the system under consideration. The term CO2eq. is intended to express the set of all GHGs, with each being weighted according to their global warming potential.

The production of food

The life cycle inventory (LCI) for each fruit and vegetable included five farms producing each food according to each production protocol (conventional, integrated and organic). The study farms are spread throughout the two main provinces of production (the provinces of Cuneo and Turin for fruit, the provinces of Alessandria and Cuneo for potatoes and the provinces of Alessandria and Novara for carrots). Data on farm structure, agricultural inputs, resource consumption, yield and field management practices were obtained directly from the growers, who filled in a questionnaire for the 2013 season.

Differences of production protocol are reflected mainly in a different use of agricultural inputs (fertilisers, pesticides and machinery) and different yields. Typically, conventional production is high input/high output, as it uses a lot of energy to support commercial yield, while on the contrary organic production is a low input/low output system, as it strongly limits anthropogenic inputs (Hayashi, 2013). As a general remark, it is important to highlight that neither extensive nor intensive farming systems per se are sustainable, and that the ecological optimum depends on the specific situation (Nemecek et al., 2005). Integrated production systems are considered to be half way between these two systems and in general to be more environmental friendly than conventional production because they use integrated pest management practices and adhere to UNI 11233:2009 technical norms for pesticide use. Although there were differences in cultivation practices, the system modelling for all three production protocols was the same; in particular the CF of the production phase was calculated according to the ISO 14040 standard series, adopting a cradle-to-gate approach as the basis for the emission inventories. A life cycle-based environmental impact assessment method was applied to fruit products according to international recommendations (Cerutti et al., 2014, 2015). In particular, orchards are multiannual biological production systems, yield is not constant each year, and production has to be modelled for the whole production cycle (Cerutti et al., 2015). Based on information provided by growers, the production stage was divided as follows: sub-stage (I), which is characterised by low yield production due to young plants; sub-stage (II), which is characterised by high production during the mature stages of the orchard; and sub-stage (III), which is characterised by low production due to ageing plants. The duration of each of the three sub-stages varies according to cultivar. Irrespective of yield, each productive stage includes all one-year field operations, in particular tree management, pest and disease management, soil management, irrigation, weather damage prevention and harvesting.

The life cycle approach has also been applied in horticultural production systems. For these systems the most recent recommendation for correctly modelling crops has been considered (Perrin et al., 2014), including the issue of modelling crop rotation in LCA (Brankatschk and Finkbeiner, 2015) and the quantification of different fertilisation sources (Martínez-Blanco et al., 2014). For both perennial and annual production systems, environmental exchanges associated with fertilisers were accounted for both during production and as field emissions. Nutrient balances considering the physiological requirements of the plants (VV. AA., 1997) were calculated in order to quantify average nutrient surplus and relative emissions. The estimated emissions of climate-changing GHGs were converted to CO2eq. according to factors proposed by IPCC (2007) for 100-year Global Warming Potentials.

The logistics of the food (provisioning and distribution)

The logistics of the food include two phases: transportation of the food from farms to periurban hubs (provisioning phase), and the distribution of goods from the hubs to school canteens (distribution phase). For both phases, baseline data (including transportation quantities, distances and modalities) have been collected from the suppliers that were contracted by the City of Turin for the school years 2012/13 and 2013/14. In particular, regarding the provisioning phase, suppliers filled in a questionnaire with details about the origin, timing, approximate route and the transportation system for each provisioned foodstuff that was destined for school canteens in 2012/2013 and 2013/2014.5 The calculation of the CF in the provisioning phase allows the climate impact performance of policy number two – the policy focused on the limitation of the geographical origin of food – to be quantified.

Data on the distribution phase were also collected directly from suppliers. In this case, they were asked to show the registry of deliveries, which is a schedule of all the deliveries made by each van, including timing, route, food block delivered (prepared meals, fruit or raw food – see the section 'Investigated Food Supply Chains') and the type of fuel the van used. For this phase, the quantification of GHG emissions tests the policy of the substitution of transportation

vehicles as a possible policy strategy for improving the environmental efficiency of transportation. In particular, the city administration decided to progressively update the transportation fleet from diesel-fuelled to natural gas-fuelled vans. From 2012 to 2014, the proportion of gas-fuelled vans that the City of Turin operated increased from 24% to 86%.
The analysis therefore assessed the carbon emissions of road transportation (for goods and passengers) using different fuels. However, a survey of the scientific literature revealed that the most common LCA databases generally omit emissions of natural gas-fuelled vehicles (Table 1). Only GEMIS reports the emission of trucks fuelled by compressed natural gas, whereas GEMIS and Ecoinvent include data for natural gas-powered passenger cars. The main conclusion from the survey is that there is large variability in transport emissions. This is due to several causes, including system boundaries (different ways of including the impacts of car manufacturing, maintenance, and capital equipment), emissions from the production of the fuels, the inclusion or exclusion of biogenic carbon emissions (depending on the age of the data), assumptions about operations (e.g. average and maximum load, type of route, number of passengers), engine volume, the age of the transport vehicles and related regulations.
This analysis focused on the available information on the vans purchased by the City of Turin, specifically the emissions values declared by the manufacturers (direct emissions, sometimes referred to as tank-to-wheel emissions (López et al., 2009)). This information was complemented by the life cycle impacts of fuels (indirect emissions, sometimes referred as well-to-tank emissions (López et al., 2009)) derived from the LCA database. The indirect impacts of vehicle manufacture and capital equipment were not considered. However, it can be assumed that the impacts of manufacturing and capital equipment are similar to the two types of vehicles.
The calculation of gas- and diesel-fuelled van emissions are illustrated in Table 2. Direct emissions calculated for urban transport routes include:
– Direct CO2 emissions from fuel combustion, as declared by the manufacturers' websites or the vehicles' documentation.
– Direct emissions of CH4 and N2O during operation, according to the average emission values in 'Guidelines for National Green-house Gas Inventories' (IPCC, 2006). For the characterisation factors of CH4 and N2O for global warming potential, refer to 'Climate Change 2007: The Physical Science Basis' (IPCC, 2007).
Indirect emissions have been calculated by multiplying the average consumption of fuels (as declared by manufacturers (MISE, 2014)) by the life cycle GHG emissions for the production and distribution of fuels. Average European Life Cycle Inventories have been considered (ELCD, 2011).
The results show that emissions per kilometre of natural gas-fuelled vans are 17% higher than those of diesel vans. The reasons for this include releases of natural gas during the operation of gas-fuelled vans and the high indirect emission factors of natural gas due to leakage in the supply chain (Alvarez et al., 2012; Jacobson, 2009).
The maximum capacity of the vans is 2–2.5E103 kg. Assuming an average load of 1000 kg, the results in Table 2 can be considered as impacts per ton-kilometre. These values are higher than the literature values presented in Table 1 (for both diesel and gas vehicles). The two main reasons for this are that (1) the present study considered the operation of the vehicles only for urban transport, and (2) the load capacity of the vans is lower than the literature values due to the function of the vans (delivering food and meals at low density).

The reference scenario

Climate change results are presented for each phase of the full procurement service (production, transportation and distribution). To assess the performance of the applied polices, the GHG emissions of the school year in which policies were in effect are compared to a business-as-usual scenario in which these policies were not implemented. In the case of the transportation and the distribution phases, the comparison is of school year 2013/14 to the previous year. In particular, annual food quantity per main area of provisioning is reported in Table 5 and the annual distances of the distribution phase per distribution block are reported in Table 6.
It was more complex to define a reference scenario for the production phase: some requirements in the call for tenders were active in the year before the start of the INNOCAT project; therefore, a CF comparison of two different years would not have properly assessed the organic and integrated production requirement. To fairly evaluate the performance of the policies in the production phase, the 2013/14 school year was compared to a constructed scenario in which the same quantity of food was supplied by conventional production systems instead of organic and integrated systems. Food quantities for the school year 2013/2014 and the reference scenario are reported in Table 4.

Uncertainty analysis

Uncertainties can affect Food LCA studies mainly because of the biological nature of the production systems and the correlation with local conditions and climatic events (Notarnicola et al., 2015). Therefore it is necessary to identify the uncertainty sources in the study and evaluate the magnitude of their effects.
In the investigated systems, the higher source of uncertainty is associated to the production phase. In particular, the yields of the considered production systems can vary due to differences in the geographical areas (different climatic conditions), genetic issues (different cultivars) and slightly different agricultural practices within the same production protocol (as applied by different farmers). Several studies (Nemecek et al., 2005; Cellura et al., 2012; Hayashi, 2013; Perrin et al., 2014) remark that the yield of an agricultural system play a pivotal role in the quantification of the environmental impacts of such systems. First of all, there is a physical relation between the quantity and quality of the yields and the amount of inputs (e.g. materials and energy) and externalities (e.g. emissions) of the agricultural

practises. Furthermore, the environmental impacts are referred to the yield, because of the assumption of a mass-based functional unit in the LCA of food. Relatively small variations in yields can significantly affect the results and, consequently, their interpretation (Cerutti et al., 2014). Therefore variations of the yield should be considered for the assessment of the uncertainty of the production phase. According to data collected from previous studies (Cerutti et al., 2013) and technical literature (VV. AA., 1997), it has been assumed for the present analysis a variation range of 20% of the yields of the different products.
Another potential source of uncertainty is the distance travelled by trucks during the provisioning phase. In particular, the assessment of the distances between the national food platforms food hubs of Turin has a low uncertainty. On the other hand, there is a higher uncertainty in the estimation of the local transport between the farms and the regional hubs of each nation. As a consequence we assumed a variation range of ±20% of the distances travelled from the farms to the hubs of Turin in the case of international supply chains, and in an average variability of ±10% of the distances from farms to hubs of Turin in the case of national and regional supply chains.
The last important source of uncertainty is in the distribution phase within the urban area. The average speed of 25 km/h has been assumed as a reference for the calculation of the emissions of the vans. However, this assumption might be affected by the variability of the traffic. Consequently it has been assumed a variation of 10% of the emissions during the distribution.

Climate change results

The production phase

On all farms, conventional production practices have higher GHG emissions (Table 3). In particular, the CF for conventional products is 30–40% higher than the mass-weighted average6 of organic and integrated production for fruit and 55–60% higher for potatoes and carrots. The GHG emissions per unit of production are lower for integrated than organic production (Table 3). This is due to the increased productivity of the integrated systems compared to the organic systems. For the same product, integrated systems use fewer resources and therefore generate lower GHG emissions than organic systems. Several studies (e.g. Fedele et al., 2014; Hayashi, 2013) show that although organic production (orchard or field) systems use much fewer resources per hectare, if we consider production then organic systems require more inputs because they have lower yields. As a result, although organic cultivation systems usually have lower environmental impacts per hectare, they have higher environmental impacts per kg of product.
As this effect is related to the specific yield of the individual company, it is highly dependent on the type of product grown, the plant variety, soil properties and climate conditions. Consequently, the CF results might change significantly with changing production areas or among several years of production (Cerutti et al., 2015).
An interesting result, although partial as it only refers to the five products in the study, is the total quantification of GHG emission reduction due to integrated and organic production requirement in the 2013/14 school year (Table 4). In particular, for the five products in the study, the production phase climate impact amounted to 138.12 tCO2eq., compared with 204.22 tCO2eq. that would have been emitted if the same quantity of food had been procured from conventional production systems. The introduction of the organic and integrated production procurement requirement saved 66.10 tCO2eq. (corresponding to -32% in the CF).

The provisioning phase

Each product has a different supply structure based on the characteristics of its production. The main results of the analysis are illustrated in Table 5.
As mentioned above, apples were the most common fruit on the menus for both years and the City had already required a complete regional procurement for this fruit in 2012/2013; therefore, both distances and relative GHG emissions are the same in the two years of the analysis. In total, the provisioning phase for apples accounted for 3.41 tCO2eq., corresponding to 11.76 kgCO2eq. for each ton of apples delivered.
For pears, peaches, and potatoes, the City changed the provisioning requirement from EU Countries to exclusively the Piedmont region, which dramatically decreased the CF. Footprints decreased by -45% for pears, -59% for peaches, and -56% for potatoes, amounting to 5.88 tCO2eq. reduction in 2013/14 compared with 2012/13 for the three products.
In the case of carrots, suppliers alerted the municipality that it would be difficult to fulfil the regional requirement with integrated and organic product; therefore, the 2013/14 requirement was for all of Italy rather than the Piedmont region only. As a consequence, the CF reduction is less than in the case of pears, peaches, and potatoes, but still significant. As a result of this provisioning requirement, 1.12 tCO2eq. were saved, which corresponds to a reduction of 16%.

The distribution phase

In the two years of the study, different suppliers were involved in the catering service for school canteens in Turin, and different peri-urban hubs were used (Fig. 1). In 2012/13 there were three platforms in the southern metropolitan area and four in the north, whereas in 2013/14 four hubs were located in the south and just one platform was located in the north.
The reorganisation of the distribution routes was a side effect of the change of suppliers in the two school years. Despite being an unplanned modification, the change of the food hubs led to a 12% reduction in distance, corresponding to 392 km saved per day in the school year 2013/14 (Table 6).

Following contract requirements, suppliers changed their vehicle pool, increasing the number of vans fuelled by natural gas in 2013/14. The food distribution distance by natural gas vans increased from 860 km daily (27% of total daily distance) to 2,527 km daily (89% of total daily distance). Because of the higher GHG emission per km of natural gas, this carrier shifting lead to a relative increase of CF per average delivery from 1.89 kgCO2eq. in 2012/13 to 1.97 kgCO2eq. in 2013/14. The combined effect of reducing transportation distances on the one hand and shifting to natural gas vans on the other resulted in an almost insignificant reduction of -0.23% to the daily CF of the distribution service (Table 6).
To compare the climate impact of urban transportation in relation to the other phases of the supply chain that were investigated, it is important to differentiate the environmental performances of the three distribution blocks (prepared meals, fruit and raw food). Due to the high variability of meals during the year, it is difficult to assess the exact number of food portions delivered in an average delivery. A more reliable GHG emission inventory can be achieved by considering the number of daily portions delivered per distribution block (pre-cooked meals, raw food and fruit) and the daily GHG emissions per distribution block (Table 7). It is interesting to observe that blocks of prepared meals and raw food saw an average reduction in GHG emission per portion delivered in 2013/14 as a result of the reductions from better-planned distribution routes outweighing the increased GHG emissions of the natural gas vans. In contrast, a centralisation policy was applied to the fruit distribution block and almost all deliveries started from one single platform, translating to a significant increase in GHG emissions per portion delivered (from 8.28 gCO2eq. in 2012/13 to 7.38 gCO2eq. in 2013/14 – Table 7).

Aggregated climate change reduction of the three phases

Interesting results appear when combining the GHG emissions of the three modules into one functional unit and breaking down the CF for the three parts of the supply chain (as described in the 'Investigated Food Supply Chains' section). These results are presented in Table 8 for fruits and Table 9 for vegetables. It is important to remember that GHG emissions from the cooking phase are not included in the calculation, and therefore the aggregation of the three modules represents the climate change potential of the production and the handling of the five products within their supply chains.
Results from the aggregation of the three modules for apples are strongly coherent with the study of Caputo et al. (2014). In their study, the climate impact of 200 g of apples was 40 gCO2eq. in the production phase, 18 gCO2eq. in the transportation to the factory and 11 gCO2eq. in the transportation to the catering site. The main variation can be found in the provisioning phase, although this is related to the provision route of the apples in the case study.
As a result of the study, the production phase dominates the aggregated GHG emission patterns, ranging from 63–81% for fruits and 46–73% for vegetables. The shift from conventional production to organic allows, on average, a reduction of the total GHG emissions per serving of -15% for fruits and -22% for vegetables. The shift from conventional production to integrated allows, on average, a GHG emission reduction per serving of -22% for fruits and -28% for vegetables, representing the best reduction available from a single procurement practice that affects the supply chain of all five products.
Surprisingly the provisioning phase (food miles) played a minor role in generating GHG emissions along the considered phases of the supply chain, contributing to 3–12% of the CF of fruit and 6– 16% of the CF of vegetables. The shift from EU provisioning to regional provisioning allows, on average, a CF reduction (total aggregated GHG emissions per serving portion) of -5.16% for pears and peaches (apples are excluded because they were already procured exclusively in the Piedmont region during the first year) and -7.94% for potatoes (carrots are excluded because the 2013/14 procurement was national and not regional). Urban distribution ranged from 16% to 32% of the CF for fruit and 18% to 29% of the CF for vegetables. Evaluating the policy effect on this part of the supply chain (compared with the aggregated supply chain) is not possible because two policies with different effects were applied: the reduction of km (with a GHG emission reduction) and the partial shifting to natural gas vans (with a significant GHG emission increase). Nevertheless, it is interesting to note that for logistic phases of the supply chain, the size of the delivered goods makes a difference. The provisioning phase has less impact (in terms of aggregated GHG emissions per serving) because of the high number of serving portions that are moved in one delivery. However, because of the capacity of the vans, the number of serving portions distributed per delivery in the city is low, leading to higher GHG emissions per serving portion.

Results of the uncertainties analysis

Results of the uncertainty assessment have been illustrated in Table 10 for apples and potatoes (as the most consumed fruit and vegetable in the analysis). Similar trends have been observed for the other products. Compared to values of the reference scenarios (in Tables 8 and 9), the CF varies from -13% to +17%. The uncertainty analysis confirms the key role of the production phase, in terms of largest contribution to the impacts and phase with the highest variability, primarily due to the variation of the yield. A decrease of 20% of the yield causes an increase of +14% of CF of the production phase; while an increase of +20% of the yield causes a decrease of 18% of CF. Although the estimated variability range is quite large, it is observed that the integrated production and local provisioning remain the options with the lowest impact. It is interesting to highlight that in the extreme scenario (which is reasonable rare to occur in reality) the supply with conventional production can be less impacting than the one with organic production.

Policy lessons and conclusions

As is being reported by an increasing number of scholars (Ashe and Sonnino, 2013b; Lang, 2005), it is necessary to develop new models of public nutrition and food policy that include ecologically complex analyses and more systemic, structural, and environmental interventions. To make wise environmental decisions, it is necessary to apply specific environmental impact assessment indicators. In this case study, the CF results, allow us to draw several conclusions that can be used to improve food policies. The first observation is the different climate change impact of the three parts of the supply chain. In the case of fruit, the average share of CF is 70% for the production phase, 6% for the provisioning phase, and 24% for the urban distribution phase. The shares of GHG emissions are similar for the two vegetables: 61% for the production phase, 11% for the provisioning phase, and 28% for the urban distribution phase. As a consequence, policies that affect production practices are those with the highest potential for reducing the CF. On the contrary, policies that affect the provisioning phase focus on a minor share of GHG emissions in the overall supply chain.

The analysis of the GHG emissions of the entire supply chain helps us understand climate hotspots; however, to correctly plan sustainability policies, the effectiveness of each policy has to be considered, in particular:

(I) Production protocols. The requirement of organic or integrated production reduced the GHG emissions by 66.10 tCO2eq. compared with the scenario of acquiring the same products from conventional systems. The GHG emission reduction corresponds to -32% in the CF of the production phase, making this policy extremely effective. According to this study, integrated production systems should be preferred over organic systems to reduce the CF even further. Nevertheless, because of the high sensitivity of LCA results to yields of fruits and vegetables (Cerutti et al., 2015), this suggestion may not be valid in all cases. This issue is also a matter of priorities, as integrated production shows the best performance in reducing GHG emissions per unit of product, but organic production reduces the total amount of GHG emissions per land area (e.g. Fedele et al., 2014; Hayashi, 2013). Furthermore, the choice between integrated and organic should not focus only on reducing GHG emissions, but also on other parameters such as food quality and healthiness.

(II) Geographical origin. Despite the low impact of the transportation phase compared with other phases of the supply chain, the introduction of short distance requirements in the contract for the school year 2013/14 has proved to be an effective measure. Requirements for regional provisioning of the five products considered have led to an overall saving of 7 tCO2eq., corresponding to a -33% reduction compared with the previous school year's GHG emissions for the same phase of the supply chain. Therefore, although the absolute value is quite limited, the performance of the policy is very high. Furthermore, the GHG emission reductions of local food provisioning policy can bolster other motivations for applying this approach, such as the improvement of the local economy, defending traditional local products (such as the ancient apple cultivars of Piedmont) (Donno et al., 2012), or adding healthy foods from local producers to the standard diet (Donno et al., 2015).

(III) Vehicles for urban distribution. The GHG emission share of urban food distribution is surprisingly high (24–28% of the total CF); therefore, interesting possibilities for GHG emission reductions in the urban part of the chain are expected. Nevertheless, the simple shift of energy vectors is not an efficient measure for reducing GHG emissions. Due to the high traction efficiency of petrol motors and the high particulate removal performance of new generation filters, natural gas no longer gives significant GHG emission reductions, but rather increases direct GHG emissions. Logistic organisation plays a major role in the GHG emissions of the urban part of the supply chain. Changes in food hubs and distribution routes adopted in 2013/14 allowed a reduction of 12% of the daily delivery kilometre compared with 2012/13. Considering the distribution system from a broader perspective, it could be interesting to establish school kitchens (maybe one kitchen serving a few schools) to further reduce the transportation of pre-cooked meals and focus on the transportation of raw foods. Ad hoc studies should be performed to test the feasibility of this option.

The results of this study support the conclusions of ParikkaAlhola and Nissinen (2012b), according to whom defining a trans-port distance as an award criteria in calls for tenders is not recommended, but rather including transport distance in the calculation of the climate impacts of the transportation process by asking for data on the determination of its climate impacts (e.g. fuel vector and average payload).

It is important to clarify that the CF in just one of the environmental impact indicators that could be applied. For example, the entire environmental footprint (including also ecological and water footprints) or the full set of impact categories of a standard LCA could be estimated. Using the same data for the assessment of water or ecological footprints might yield significantly different results, as has been reported in other studies (Ridoutt and Pfister, 2013). If the policy target is not just reducing GHG emissions, but increasing overall environmental sustainability, we strongly advise coupling CF analysis with other indicators.

Another important recommendation is to set a baseline for GHG emissions (or other impacts or resource uses) before implementing new GPP requirements in order to monitor the effects of policies over time and to highlight specific hotspots. One of the main objectives of the City of Turin within the INNOCAT – Procurement of Eco-innovative Catering project7 is the continuous monitoring of the CFs of actual and future contracts to redesign the school catering service towards a 'zero emission model'.

Note

The information and views set out in this publication are those of the authors and do not necessarily reflect the official opinion of the City of Turin, Italy. Neither the offices or bodies of the City of Turin, nor any person acting on their behalf, may be held responsible for the use which may be made of the information contained herein.

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Tables

Table 1
Survey of the carbon footprint of means of transport according to different data sources.

Transport (diesel)	Emission factor	Unit	Transport (gas)	Emission factor	Unit	Data source
7.5-t to 12-t truck (diesel) (payload 4 t – highway transport) EURO 3 (estimation)	0.15	kgCO_2 eq./t km	–	–	–	GaBi professional
Passenger car (engine vol. > 2 L) (diesel) EURO 3	0.197	kgCO_2 eq./vehicle km	–	–	–	
7.5-t small lorry (diesel) (operation phase) EURO 3	0.136	kgCO_2 eq./t km	–	–	–	ELCD
3.5-t to 7.5-t truck (diesel – including biogenic sources) – base case (2010)	0.142	kgCO_2 eq./t km	3.5-t to 7.5-t truck (compressed natural gas) – base case (2010)	0.140	kgCO_2 eq./t km	GEMIS
3.5-t to 7.5-t truck (diesel – excluding biogenic sources) – base case (2005)	0.155	kgCO_2 eq./t km	–	–	–	
Car (big) (diesel – including biogenic) (2010)	0.262	kgCO_2 eq./person km	Car (compressed natural gas) – base case (2010)	0.268	kgCO_2 eq./person km	
Car (big) (diesel – excluding biogenic) (2005)	0.279	kgCO_2 eq./person km	–	–	–	
<3.5-t van (diesel), (operation phase)	0.284	kgCO_2 eq./tkm	–	–	–	Ecoinvent 2
3.5-t to 7.5-t lorry (diesel) (operation phase) EURO 4	0.521	kgCO_2 eq./vehicle km[a]	–	–	–	
Passenger car (diesel) EURO 4	0.209	kgCO_2 eq./person km	Passenger car (natural gas)	0.166	kgCO_2 eq./person km	

[a] Corresponds to 94.7 gCO_2 eq./t km, considering an average load of 5.5 t.

Table 2
Emission factors considered in the study.

Vehicle	Emission			Data source
Natural gas van	Direct			
	Carbon dioxide	0.239	kgCO_2/km	MISE (2014)
	Methane	0.47	gCH_4/km	IPCC (2006)
	Nitrous oxide	48.5	mgN_2O/km	IPCC (2006)
	Total	0.264	kgCO_2eq./km	–
	Indirect			
	Natural gas	0.436	kgCO_2eq./kg	ELCD (2011)
	Consumption	0.12	kgCH_4/km	MISE (2014)
	Total	0.052	kgCO_2eq./km	–
	Total			
	Total	0.316	kgCO_2/km	–
Diesel van	Direct			
	Carbon dioxide	0.224	kgCO_2/km	MISE (2014)
	Methane	0	gCH_4/km	IPCC (2006)
	Nitrous oxide	15	mgN_2O/km	IPCC (2006)
	Total	0.23	kgCO_2eq./km	–
	Indirect			
	Diesel	0.388	kgCO_2eq./kg	ELCD (2011)
	Consumption	0.085	kgdiesel/km	MISE (2014)
	Total	0.033	kgCO_2eq./km	–
	Total			
	Total	0.262	kgCO_2/km	–

Table 3

Carbon footprint of the production phase for the five products under study.

	Conventional gCO_2 eq./kg product	Integrated gCO_2 eq./kg product	Organic gCO_2 eq./kg product
Apples	284.31	198.67	204.3
Pears	211.52	155.36	171.25
Peaches	208.91	145.33	168.4
Potatoes	129.65	71.46	90.35
Carrots	235.37	143.9	155.14

Table 4

Carbon footprint of the production phase from the 2013/14 school year compared with a reference scenario in which the same amount of food is procured via conventional production systems.

	Reference scenario tCO_2 eq.	School year 2013/2014 tCO_2 eq.	Annual reduction tCO_2 eq.	Variation (%)
Apples	82.45	57.89	-24.56	30
Pears	12.69	9.48	-3.21	25
Peaches	12.53	8.95	-3.58	29
Potatoes	70.61	43.73	-26.88	-38
Carrots	25.93	18.07	-7.86	-30
Total	204.22	138.12	-66.10	32

Table 5

Annual carbon footprint of the provisioning phase for both school years.

	School year 2012/2013		School year 2013/2014		CO_2 eq. variation
	Product (t)	CO_2 (t)	Product (t)	CO_2 (t)	(%)
Apples					
Province of Turin	38.13	0.15	38.13	0.15	
Province of Cuneo	238.63	3.12	238.63	3.12	
Rest of Piedmont	13.24	0.14	13.24	0.14	
Total	290.00	3.41	290.00	3.41	0
Pears					
Province of Turin	2.18	0.01	8.34	0.03	
Province of Cuneo	11.87	0.16	47.48	0.62	
Rest of Piedmont	3.95	0.04	4.17	0.04	
Rest of Italy	33.48	0.28	0.00	0.00	
Rest of Europe	8.52	0.37	0.00	0.00	
Total	60.00	1.32	60.00	0.70	.47
Peaches					
Province of Turin	2.65	0.01	7.24	0.03	
Province of Cuneo	14.11	0.18	40.27	0.53	
Rest of Piedmont	8.47	0.09	12.49	0.13	
Rest of Italy	31.53	1.21	0.00	0.00	
Rest of Europe	3.20	0.17	0.00	0.00	
Total	60.00	1.66	60.00	0.69	.59
Potatoes					
Province of Turin	8.63	0.03	35.29	0.14	
Province of Alessandria	57.60	0.68	200.74	2.37	
Province of Cuneo	28.02	0.37	55.19	0.72	
Rest of Piedmont	4.75	0.05	8.77	0.09	
Rest of Italy	110.43	3.71	0.00	0.00	
Rest of Europe	90.57	2.76	0.00	0.00	
Total	300.00	7.60	300.00	3.32	.56
Carrots					
Province of Turin	0.44	0.00	1.06	0.00	
Province of Novara	29.01	0.38	48.74	0.64	
Province of Alessandria	14.36	0.17	24.12	0.28	
Rest of Piedmont	6.19	0.08	7.88	0.10	
Rest of Italy	147.49	6.14	118.19	4.77	
Rest of Europe	2.51	0.14	0.00	0.00	
Total	200.00	6.92	200.00	5.80	.16

Table 6

Distance and carbon footprint for the distribution phase divided into prepared meals, fruits, and raw foods. Results expressed in daily values.

	School year 2012/2013		School year 2013/2014		Variation	
	Daily distance (km)	Daily emissions ($kgCO_2eq.$)	Daily distance (km)	Daily emissions ($kgCO_2eq.$)	Daily distance (%)	Daily emissions (%)
Prepared meals	999.06	280.66	775.24	237.06	.22	.16
Fruit	912.08	248.29	1057.59	335.37	16	35
Raw food	1312.15	362.79	998.38	317.27	.24	.13
Total	3223.29	891.74	2831.21	889.7	.12	.0.23

Table 7

Carbon footprint of the distribution phase expressed in terms of emission per portion delivered considering the total number of daily portions delivered.

		School year 2012/2013		School year 2013/2014	
	Daily portions delivered	Daily emissions ($kgCO_2eq.$)	Emissions per portion delivered ($gCO_2eq.$)	Daily emissions ($kgCO_2eq.$)	Emissions per portion delivered ($gCO_2eq.$)
Prepared meals	30,000	280.66	9.36	237.06	7.90
Fruit	30,000	248.29	8.28	335.37	11.18
Raw food	43,000	362.79	8.44	317.27	7.38

Table 8
Carbon footprint of the three phases of the supply chain of fruit products investigated in the study (apples, pears, and peaches) matching different production practices and green public procurement requirements for school years 2012/13 and 2013/14. Results expressed in terms of $gCO_2eq.$ per standard fruit (150 g).

		Production phase gCO_2/fruit	Provisioning phase gCO_2/fruit	Distribution phase gCO_2/fruit	Total gCO_2/fruit
Apples					
School year 2012/2013	Conventional	42.65	1.77	8.28	52.69
	Integrated	29.80	1.77	8.28	39.84
	Organic	30.65	1.77	8.28	40.69
School year 2013/2014	Conventional	42.65	1.77	11.18	55.59
	Integrated	29.80	1.77	11.18	42.74
	Organic	30.65	1.77	11.18	43.59
Pears					
School year 2012/2013	Conventional	31.73	3.30	8.28	43.31
	Integrated	23.30	3.30	8.28	34.88
	Organic	25.69	3.30	8.28	37.27
School year 2013/2014	Conventional	31.73	1.75	11.18	44.65
	Integrated	23.30	1.75	11.18	36.23
	Organic	25.69	1.75	11.18	38.61
Peaches					
School year 2012/2013	Conventional	31.34	4.16	8.28	43.77
	Integrated	21.80	4.16	8.28	34.24
	Organic	25.26	4.16	8.28	37.70
School year 2013/2014	Conventional	31.34	1.72	11.18	44.23
	Integrated	21.80	1.72	11.18	34.69
	Organic	25.26	1.72	11.18	38.16

Table 9
Carbon footprint of the three phases of the supply chain of vegetables investigated in the study (potatoes and carrots) matching different production practices and green public procurement requirements for school years 2012/13 and 2013/14. Results expressed in terms of $gCO_2eq.$ per standard serving portion (140 g of raw potatoes and 130 g of raw carrots).

		Production phase gCO_2/portion	Provisioning phase gCO_2/portion	Distribution phase gCO_2/portion	Total gCO_2/portion
Potatoes					
School year 2012/2013	Conventional	18.15	3.55	8.44	30.13
	Integrated	10.00	3.55	8.44	21.99
	Organic	12.65	3.55	8.44	24.63
School year 2013/2014	Conventional	18.15	1.55	7.38	27.08
	Integrated	10.00	1.55	7.38	18.93
	Organic	12.65	1.55	7.38	21.58
Carrots					
School year 2012/2013	Conventional	30.60	4.50	8.44	43.53
	Integrated	18.71	4.50	8.44	31.64
	Organic	20.17	4.50	8.44	33.10
School year 2013/2014	Conventional	30.60	3.77	7.38	41.74
	Integrated	18.71	3.77	7.38	29.85
	Organic	20.17	3.77	7.38	31.31

Table 10
Results of the uncertainty analysis for apples and potatoes, based on the variation of assumptions for the production, provisioning and distribution phases.

		Production phase		Provisioning phase		Distribution phase		Total	
		Min	Max	Min	Max	Min	Max	Min	Max
Apples	(gCO_2/fruit)								
School year 2012/2013	Conventional	36.68	50.32	1.59	1.94	8.28	9.10	46.54	61.37
	Integrated	25.63	35.16	1.59	1.94	8.28	9.10	35.49	46.21
	Organic	26.35	36.16	1.59	1.94	8.28	9.10	36.22	47.21
School year 2013/2014	Conventional	36.68	50.32	1.59	1.94	11.18	12.30	49.44	64.56
	Integrated	25.63	35.16	1.59	1.94	11.18	12.30	38.40	49.40
	Organic	26.35	36.16	1.59	1.94	11.18	12.30	39.12	50.40
Potatoes	(gCO_2/portion)								
School year 2012/2013	Conventional	14.38	21.42	2.84	4.25	8.44	9.28	26.88	34.95
	Integrated	14.29	11.81	2.84	4.25	8.44	9.28	19.88	25.34
	Organic	21.04	14.93	2.84	4.25	8.44	9.28	22.15	28.46
School year 2013/2014	Conventional	14.38	21.42	1.39	1.70	7.38	8.12	24.38	31.24
	Integrated	14.29	11.81	1.39	1.70	7.38	8.12	17.38	21.63
	Organic	21.04	14.93	1.39	1.70	7.38	8.12	19.65	24.75

Figures

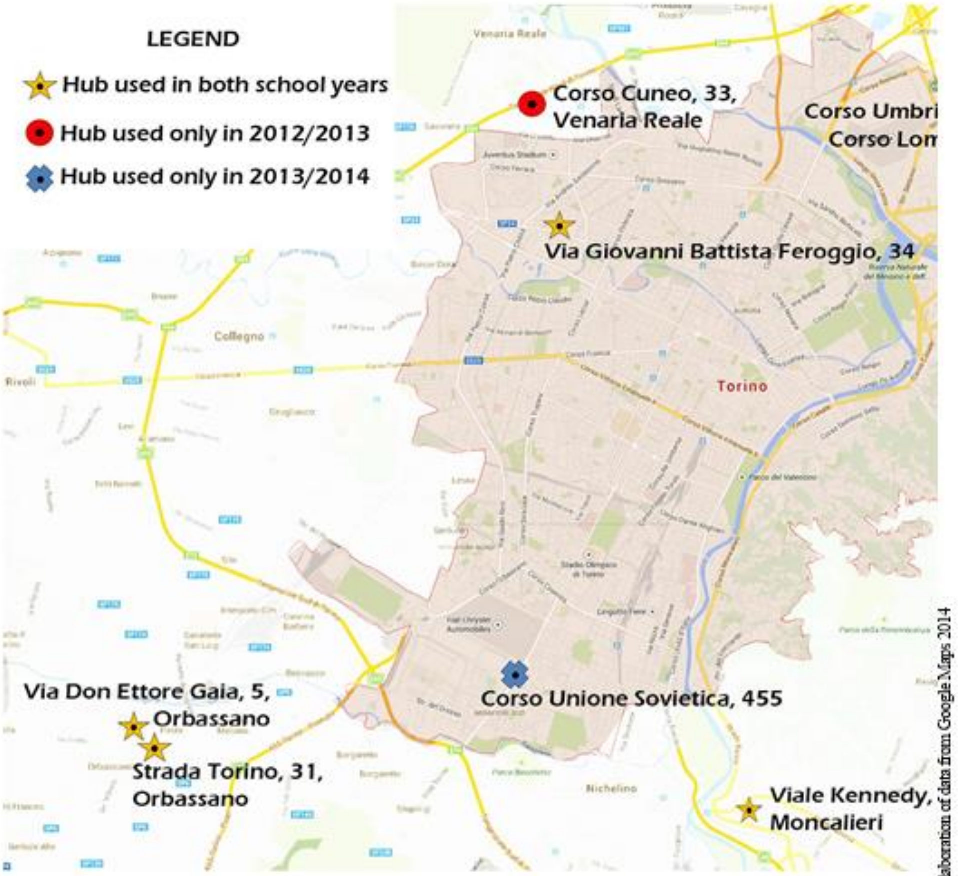

Fig. 1. Locations of peri-urban food hubs in school years 2012/13 and 2013/14. Hubs used in both school years, only in 2012/2013, and only in 2013/2014 are highlighted with different symbols. The shaded area identifies Turin Municipality, and therefore the area where schools are located.