

Article

# Urban and Peri-Urban Agriculture as a Tool for Food Security and Climate Change Mitigation and Adaptation: The Case of Mestre

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**Abstract:** Urban and peri-urban areas are subject to major societal challenges, like food security, climate change, biodiversity, resource efficiency, land management, social cohesion, and economic growth. In that context, Urban and Peri-urban Agriculture (UPA), thanks to its multifunctionality, could have a high value in providing social, economic, and environmental co-benefits. UPA is an emerging field of research and production that aims to improve food security and climate change impact reduction, improving urban resilience and sustainability. In this paper, a replicable GIS-based approach was used to localize and quantify available areas for agriculture, including both flat rooftop and ground-level areas in the mainland of the city of Venice (Italy). Then, possible horticultural yield production was estimated considering common UPA yield value and average Italian consumption. Climate change mitigation, like CO<sub>2</sub> reduction and sequestration, and climate change adaptation, like Urban Flooding and Urban Heat Island reduction, due to the new UPA areas' development were estimated. Despite the urban density, the identified areas have the potential to produce enough vegetables for the residents and improve climate change mitigation and adaptation, if transformed into agricultural areas. Finally, the paper concludes with a reflection on the co-benefits of UPA multifunctionality, and with some policy suggestions.

**Keywords:** urban and peri-urban agriculture; food security; climate change; multifunctionality; edible green infrastructure



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## 1. Introduction

Urbanization, climate change, and food security are three closely linked issues. It has been estimated that by 2050 more than 70% of the world's population will live in urban areas [1]. Urban areas generate over 70% of the global greenhouse gases (GHGs) and half of the global waste, and they are responsible for consuming 75% of the world's resources [2]. Moreover, due to rapid population growth, cities need a growing supply of food, but at the same time, the cities' growth reduces urban and peri-urban green space, and drives away food production, while in order to be sustainable it should be located near consumption centers. Consequently, in the last decade, an increasing amount of research has addressed Urban and Peri-urban Agriculture (UPA) and the urgency to develop new strategies to ensure food supply and food security for people living in urban areas [3,4]. In urban areas, UPA can be considered as Edible Green Infrastructures (EGIs) able to produce food, but also to support climate change mitigation and adaptation [5–7]. The EGIs provide innovative solutions using natural capital and counteract urban and societal challenges.

In such a context, food security and climate change mitigation and adaptation are considered relevant urban challenges, to which UPA should be a possible solution, useful to build more resilient cities [8,9]. Moreover, covering most of the empty urban areas, flat rooftops, and vertical walls with edible green could be a new ecological achievement. It may

reduce urban pollution and noise, and mitigate and adapt to climate change, increasing carbon sequestration, water infiltration, and retention, and controlling the Urban Heat Island (UHI) effect. Green rooftops and vertical walls can reduce heating and cooling, and at the same time, improve air quality and contribute to increasing biodiversity and ecosystem services [8]. Producing food locally can also reduce CO<sub>2</sub> production associated with long-distance food distribution. Although urbanized areas may not be able to provide the entire quantity and variety of food that their residents demand, the production of selected crops could increase food security and address various urban challenges. Usually, in urban areas, UPA are experimented as vegetable gardens with horticultural production. This is due to the size of the plots, possible machinery use, and citizens' preference [4].

UPA has received a renewed interest as a sustainable, nature-based, and smart solution for urban issues thanks to its several positive impacts, like social, economic, and environmental sustainability [10], resilience, and reduction of the impacts of climate change [11]. Moreover, last but not least, UPA is also viewed as a tool to achieve the transition to a Circular City [12], since it considers many aspects of Circular Economy (CE) [13] and Urban Metabolism [14]. There is a general agreement on its multifunctionality that includes food security, waste recycling, reduction in air pollution and soil erosion, community empowerment and education, climate change mitigation and adaptation, biodiversity, and ecological and social sustainability. UPA can be considered a general term able to describe a wide range of food-growing practices, such as home gardens, green roofs, community gardens, allotments, school gardens, and balconies. They work at various scales in the city and its surroundings [15]. In an urban environment, these practices could be very different from each other, and can include the cultivation of vegetables, medicinal plants, fruit trees, and other plants, as well as livestock for eggs, milk, meat, and wool [16]. The production methodology can vary due to the economic contexts, social and community preferences, and environmental framework, and also in terms of technology, from the very simple ones, such as community gardens, to very complex ones, such as climate-controlled plant factories. Urban agriculture practices rarely compete with rural agriculture, but instead, offer compatible and synergic products and functions. Agriculture activities that take place in urban space as EGI are able to provide benefits for ecosystem services, biodiversity, climate adaptation, human well-being, and cultural and health issues [17] through food production. Furthermore, differently from other GIs, UPA can be viewed as an important element for society because it can support community integration, and combat food deserts and urban poverty [18].

The ongoing loss of agricultural land makes food security a growing issue in developed countries, especially for the population that lives in urban areas [19], where innovative solutions are needed. Food security can be defined as the condition in which "all community residents obtain a safe, culturally acceptable, nutritionally adequate diet through a sustainable food system that maximizes community self-reliance and social justice" [20]. This definition provides evidence that food security is not an issue only for the poorest countries and only related to nutrition, but it is a complex term with a multifunctional character: social, economic, ecological, cultural, political, and psychological [21]. Moreover, the food security issue is defined in a perspective related especially to access to sufficient healthy food, rather than the supply of food. The problem is not just economic, namely having enough money to buy some food. Currently, urban food demand has been satisfied through a food system based on an industrialized and global supply chain, but this model is unsustainable, both from a social and an environmental point of view. Achieving a sustainable food system requires a real change, able to promote local food production and consumption [22], and urban areas are to become key actors integrating green and edible vegetation into their boundaries. From a theoretical point of view, cities must be re-imagined and re-designed to incorporate agricultural practices as a new socio-ecological space, where the conflict between urban and rural is overcome, and sustainability is achieved [23].

Finally, it is relevant to consider that the climate is changing and the future implications will be relevant for both natural and human life, especially if the global temperature increase is above 2 °C. The 5th Assessment Report of IPCC [24] highlights the importance and urgency to reduce climate greenhouse emissions and adapt the urban system to adverse impacts through solutions able to increase resilience. It is widely accepted that climate change is due to urban areas. However, the solution for climate change problems can be found in urban areas adaptation. Thus, sustainable development challenges should be increasingly concentrated in urban areas [1]. Urban areas have to reduce and mitigate their impact on climate change, reducing CO<sub>2</sub> production and improving CO<sub>2</sub> sequestration and storage capacity, and they have to adapt themselves to climate change's impacts. The principal impacts of climate change in Mediterranean urban areas are usually Urban Flooding (UF) and Urban Heat Island (UHI) [25,26]. UF is mainly caused by continuous land-use changing processes that transform natural soils into impermeable surfaces. Impermeable surfaces modify the hydrological nature of local runoff, reducing water ground infiltration, and affecting the capacity of managing peaks and volumes of water released during extreme events [27]. UHIs are urban areas where temperatures are higher than the ones recorded in rural areas, and which could cause physical damages and death to sensitive people [28]. One of the principal tools to mitigate climate change, reduce its impacts, and support urban sustainability and resilience is the development of Green Infrastructures (GIs) [29]. GIs can be described as “an integrated network of natural and semi-natural areas and features, such as urban green spaces, greenways, parks, rain gardens, greenways, urban forestry, urban agriculture, green roofs, and walls, etc.” [30]. They are considered as a cost-effective mitigation and adaptation strategy for solving climatic urban challenges by building with nature. GIs can reduce pollution, sequester and store CO<sub>2</sub>, indirectly reduce CO<sub>2</sub> production, manage water and reduce the UHI effect.

Although the relation among urban agriculture, food security, and climate change is recognized, there are very few studies that jointly consider UPA's benefits on climate change and food security (see the review [31]). In this paper, the research conducted in the city of Venice (north of Italy) can be considered as a first step to fill this gap. In this research, first, a map of all the urban and peri-urban available and suitable spaces for UPA was identified using a Geographic Information System (GIS). Then, the amount of food that can be produced in such areas was estimated, as well as how it can cover the needs of the urban population. The climate change mitigation and adaptation effects given by urban agriculture, in terms of CO<sub>2</sub> sequestration and reduction, water retention, and decreased temperature, were accounted. Concluding, urban agriculture multifunctionality is considered as a possible new urban foodscape; thus, some urban food policy recommendations and further possible research are suggested.

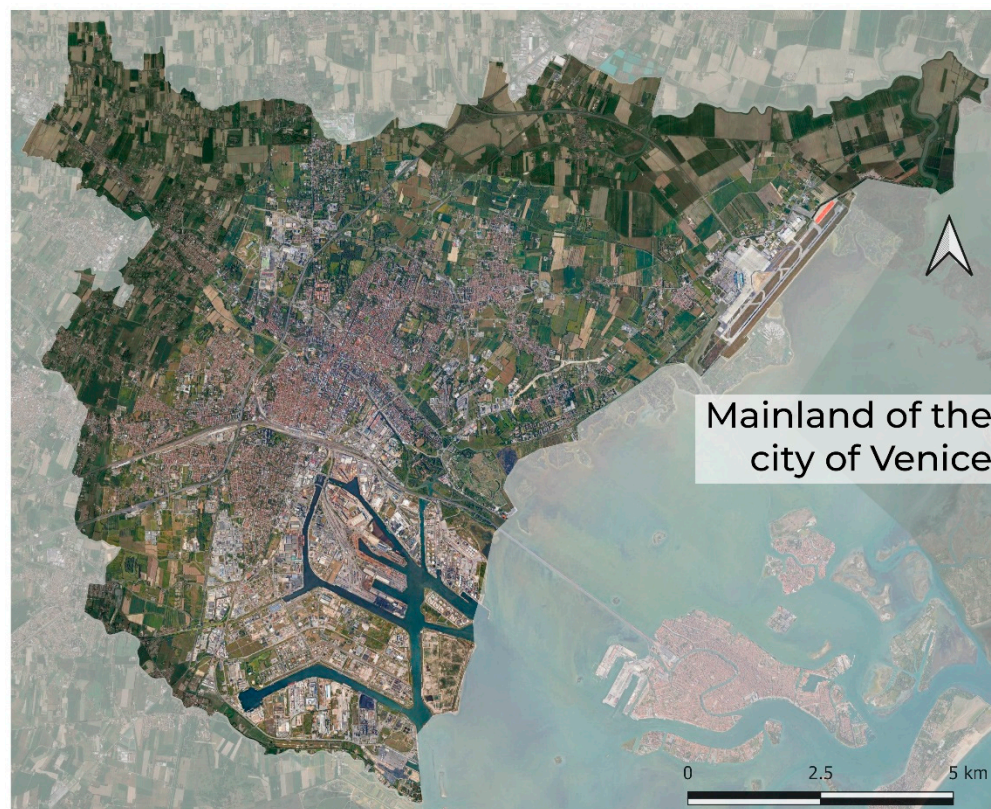
## 2. Materials and Methods

### 2.1. Case Study

The case study selected is the mainland of the city of Venice—north-east of Italy (Figure 1). The study was conducted not considering the islands, because due to its historical urban fabric and its complex logistics, the islands would require a specific and dedicated study. Thus, we take into account only the administrative boundaries of the mainland, consisting of the municipality of Mestre, Marghera, Favaro Veneto, Carpenedo, Chirignago, and Zelarino. The whole mainland covers an area of 130.57 km<sup>2</sup> and has a population of 177,759 inhabitants (Comune di Venezia—Servizio Statistica su dati di Anagrafe Comunale, 2020). The climate is warm-temperate, and it is characterized by foggy winters and sultry summers. According to the Corine land cover 2018 dataset elaborated by the Veneto Region with Copernicus data, the area is covered by 35.75% artificial surface, 30.05% agricultural areas, 0.91% forest and semi-natural areas, and 33.29% water bodies (without considering the lagoon). During the last years, the Veneto Region has undergone a severe urbanization process that has led Veneto to be the second Italian region with the largest loss of potential agricultural land [32]. This dynamic has heavily involved also



the case study area, leading to the degradation of natural ecosystems and landscapes and determining a progressive removal and lengthening of the food supply chain. Moreover, this dynamic has exacerbated the UHI effect, which has been found to be between 4 and 7 °C, with a major intensities during the night and a small effect during the day [33].



**Figure 1.** Mainland of the city of Venice.

Urban food policy and food production are considered and recognized as relevant by the local policymakers, who were among the first to sign the Milan Urban Food Policy Pact [34], and also by the citizens, with regard to the increase in local markets and other local and sustainable purchasing groups.

In our case study, we consider urban spaces where food production could take place. We identify and select EGIs or multifunctional ecological areas like backyards, rooftop gardens, public gardens, and open spaces with features suitable for food production. Moreover, we will try to understand and quantify the potential benefits of these areas concerning climate change, both in terms of mitigation and adaptation.

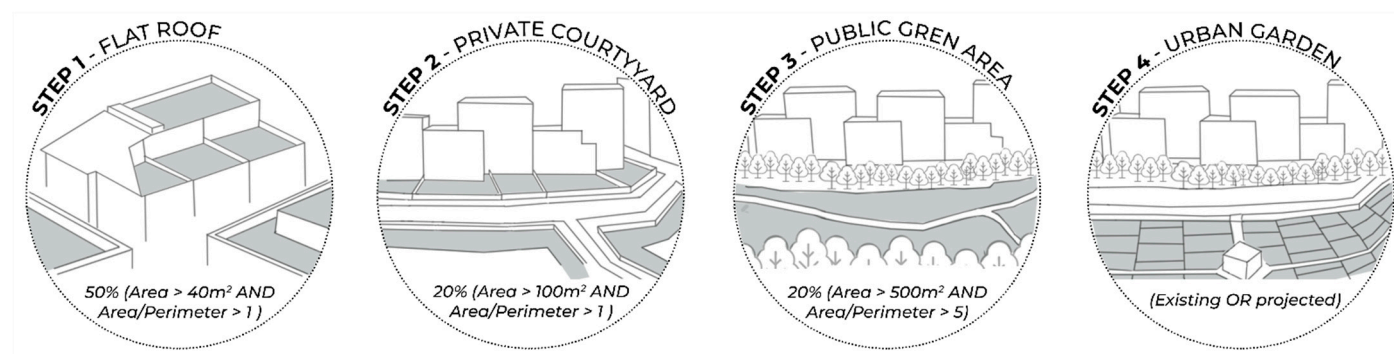
## 2.2. Mapping Approach

In this study, some possible future scenarios were developed through a GIS-based approach (as already experimented by [35–37]). A geospatial evaluation of UPA areas was based on the Veneto Region Land Information System and Cartography images and data (the system is regularly updated), from which some layers have been selected to satisfy the paper's objectives. The selected informative layers are (Table 1): (i) rooftop; (ii) type of building use; (iii) private courtyards; (iv) public green areas; and the other two layers, (v) existing urban gardens and (vi) designed urban gardens, which were specifically created for this paper using the information of [38].

**Table 1.** Layer used for GIS-based approach.

Layers	Description	Dataset/Layer	Attribute/Column	Profile (Code)
Rooftop	This layer identifies the morphology of urban roofs, differentiating their shape, slope, and type	ELE_CP.shp	ELE_CP_TY	04
Type of building use	This layer identifies the main destination of the urban buildings (residential, industrial, commercial, public services)	EDIFC.shp	EDIFC_USO	01 OR 02 OR 03 OR 071
Private courtyards	This layer identifies equipped private ground areas, namely, areas pertaining to the settlement units ancillary to the building.	AATT.shp	AATT_TY	01
Public green areas	This layer identifies public green areas, areas for ornamental or recreational purposes. The areas of flower beds, gardens, lawns, wooded areas within the urban area for public use.	AR_VRD.shp	AR_VRD_TY	02 OR 04
Existing urban gardens	This layer identifies urban gardens managed collectively and not. Namely, a piece of land intended for the production of fruit and vegetables. These include small plots of land for cultivation for domestic use, possibly aggregated into unitarily organized colonies.	-	-	-
Designed urban gardens	This layer identifies urban gardens under construction or planned in the short term. Namely, part of land intended for the production of fruit and vegetables. These include small plots of land for cultivation for domestic use, possibly aggregated into unitarily organized colonies.	-	-	-

The mapping approach follows four steps, as shown in Figure 2. These steps were developed using a set of spatial criteria to identify and quantify areas potentially suitable for UPA.

**Figure 2.** Steps of the mapping approach.

**Step 1.** This step was dedicated to detecting the flat rooftops suitable to be converted into a green roof. Using the Topographic Database of the Veneto Region, all the flat rooftops of the residential, administrative, public use, and commercial buildings were selected, then all the rooftops with a ratio of area to perimeter less than 1 ((area/perimeter) > 1), and

with a surface less than 40 m<sup>2</sup> were removed. In many Italian cities, the municipal law defines the smallest UPA as 20 m<sup>2</sup> [39], with the above restriction criteria, this requirement is guaranteed. In that way, only the rooftops with an appropriate area and adapted to agricultural practices were included. Finally, only 50% of the selected surface was accounted, to consider other rooftop destinations, like space for composting, water accumulation, tool shed, or solar panels, but also to guarantee safe access and space for people and supplies.

Step 2. This step was dedicated to detecting the private green areas on the ground, namely the courtyards. Using the Topographic Database of the Veneto Region, all the courtyards were selected, then all the courtyards with a surface with less than 100 m<sup>2</sup> and with a ratio of area to perimeter less than 1 ((area/perimeter) > 1) were removed. Finally, only 20% of this surface was considered suitable for urban agriculture. In that way, areas too small, designed for parking, flower gardens, and relaxation areas were avoided, and only areas appropriate and adapted to agricultural practices were included.

Step 3. This step was dedicated to detecting the public green areas on the ground, namely the parks and flowerbeds. Using the Topographic Database of the Veneto Region, all the parks and flowerbeds were selected, then all the parks and flowerbeds with a surface with less than 500 m<sup>2</sup> [39], or with a ratio of area to perimeter less than 5 ((area/perimeter) > 5) were removed. This made it possible to limit the areas that, due to their morphology and shape, are capable of hosting urban agriculture. Finally, only 20% of this surface was considered suitable for urban agriculture, to consider other public green area destinations, like playgrounds, flower gardens, relaxation areas, and so on. In that way, only the parks and flowerbeds with an area appropriate and adapted to agricultural practices were included.

Step 4. This step was dedicated to detecting the urban gardens already existing or projected in the city. Using the [38] document, all existing and designed urban gardens of the city of Venice were added. In that way, all the urban areas already dedicated or that will be dedicated in a near future to urban agricultural practices were included.

Finally, in order to validate this spatialization process, ten rooftops and ten parcels at the ground level were randomly selected and analyzed with high-resolution ortho-imagery for visual comparison, and where possible, the validation was developed with a real on-site visit. Thus, the process was demonstrated to be sufficiently sure and robust.

### 2.3. Productivity and Consumption

To understand and estimate the potential food production for the mainland of the city of Venice, the mapped potential UPA was considered as vegetable gardens with horticultural production. Taking into account recent studies that evaluate the productivity of the urban garden on the ground in Padua [40] and Milan [17], two cities that can be considered very similar to the case study for temperature, precipitation, and other climatic parameters, it is reasonable to assume an average production value of 5.73 kg m<sup>2</sup> year. While for the productivity of the urban green roof we consider the study of [11] developed in Bologna, another Italian city similar to the case study for climatic parameters, where the average production of vegetables is valued at 15.2 kg m<sup>2</sup> year. In the literature, there are other many studies on urban garden productivity [35,40–43], which also consider the differences of the continent, weather, soil, and gardeners conditions, and the data collected substantially confirm the assumption made. These average yield values, as expressed above, represent open-air conditions, but they could be improved using greenhouses, hydroponic systems, and other combined technologies of production.

Following these premises, in this study, the productivity for horticultural urban gardens was calculated by multiplying the area available at the ground with the related average production value (5.73 kg m<sup>2</sup> year), and the area available at the rooftop with the related average production value (15.2 kg m<sup>2</sup> year), then the total was obtained by adding up the two types of production.

Moving on to consider food consumption, in this study the food provisioning potential was calculated using daily per capita average consumption of vegetables for the entire



population. The average Italian consumption of vegetables for men and women of all ages is equal to 74.8 kg per capita yearly, as evaluated by [44]. Thus, the feeding population was calculated by dividing the total potential production in the study area by the average per capita consumption.

## 2.4. Climate Change

### 2.4.1. Mitigation

One of the main important services that UPA can provide for urban areas is related to climate change mitigation through biological carbon storage. Davies et al. [45] estimated that domestic gardens would be able to capture about  $0.76 \text{ kg cm}^{-2}$ . Thus, considering this data, it was possible to calculate how much  $\text{CO}_2$  the new UPA areas could capture in the mainland of the city of Venice. In order to avoid an overestimation, only the sequestration of the green roof was considered, since the other surfaces potentially converted in UPA were natural even before. For these areas, calculating the  $\text{CO}_2$  sequestration improvement is complicated and probably negligible. However, it is important to underline that increasing organic carbon sequestration through agronomic practices is a real possibility that in the last few years has gained high attention [46]. Thus, in this study, the amount of  $\text{CO}_2$  sequestration by the new green roofs was calculated by multiplying the average storage capabilities ( $0.76 \text{ kg cm}^{-2}$ ) with the identified areas available for the green roof.

Moreover, green roofs can produce other mitigation benefits. In summer they reduce the rooftops' surface temperature and the energy requirements for cooling, while in winter they minimize the heat losses. Saiz et al. [47] assessed that green roofs could save 5% of annual energy use on average (up to 25% in summer). Thus, considering that the EU [48] identify an average energy consumption of  $200 \text{ kWh m}^2$  for residential use and  $300 \text{ kWh m}^2$  for non-residential use, and the surfaces identified in our case study of  $739,155.41 \text{ m}^2$  of residential and  $809,704.98 \text{ m}^2$  of non-residential (considering only the last building level), it is possible to estimate that in a year, the total consumption should be  $1,172,504,321,920 \text{ kWh}$  (8 h day). Then, using the assessment made by ENEA [49] about the primary energy mix used in the country, it is possible to convert energy in  $\text{CO}_2\text{eq}$  using  $352.4 \text{ g CO}_2/\text{kWh}$  and to calculate the  $\text{CO}_2$  avoided with an energy reduction of 5%.

Finally, by avoiding food transportation,  $\text{CO}_2$  emissions are reduced; thus, reducing "food miles", or the distance between production and consumption, can be considered as a mitigation action [50]. However, the  $\text{CO}_2$  reduction due to local food production vs. global food production was not estimated in this work.

### 2.4.2. Adaptation

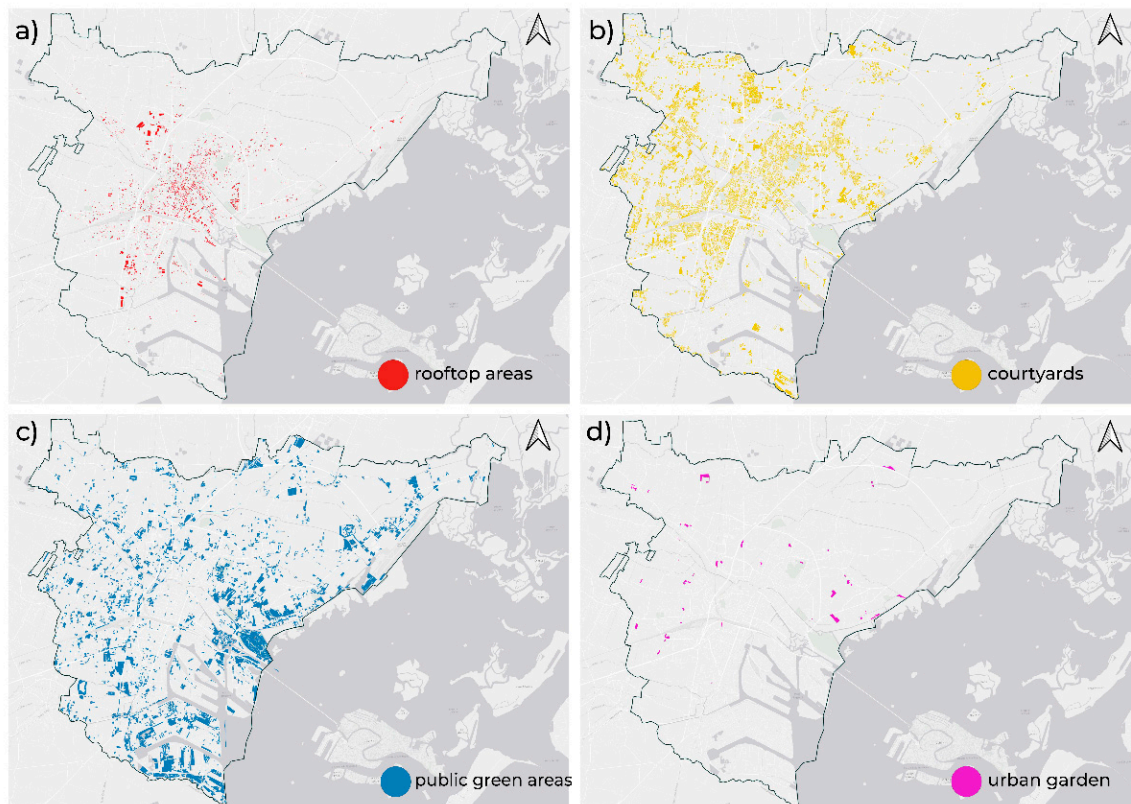
UPA should be useful also as an adaptation tool for two of the most relevant impacts of climate change: UF and UHI. In fact, UPA as EGI is able to increase water runoff and reduce the peak flow, allowing one to avoid overloading of the city sewage infrastructure, which is usually the cause of UF. In this case study, in order to avoid an overestimation of that adaptation effect, only the improvement due to the green roof has been considered and calculated, which passes from a state of complete impermeability to a permeable one. UPA developed at the ground level could change their state in two levels: (i) impermeable to permeable and (ii) permeable to more permeable; however, the mapping approach used in this study does not allow us to make this distinction. To calculate green roof water retention, the work done by [51] has been followed as a reference. They estimated that the green roofs are able to reduce runoff through water interception and evapotranspiration, and with an average retention of 56% of precipitation. These data are also supported by other studies in which similar retention data were found [52]. Thus, considering the rain that fell ( $\text{mm m}^2$ ) in the city of Venice during 2020 (<https://www.arpa.veneto.it/dati-ambientali/open-data/clima/principali-variabili-meteorologiche>, accessed on 20 March 2020), it is possible to calculate the retention effect due to the green roof surfaces by multiplying the 56% retention by the rain that fell and by the total surface of developed green roof.

Moreover, the creation of UPA as new EGIs elements on the rooftops (green roofs) and the ground level (green areas and permeable soil) can reduce the UHI effect. Increasing the green areas of the city, it is possible to modify the urban heat balance by two phenomena: the solar radiation change (reflection, diffusion, and shadow) and air temperature decrease through plant evapotranspiration [53]. Susca et al. [54] in a New York case study evaluated that green areas are fresher at a temperature of  $-2\text{ }^{\circ}\text{C}$  compared with non-green ones on average. In the case of UPA, this effect depends on its specific design (i.e., crops, cultivation techniques, garden surface, etc.), because these aspects determine the real evapotranspiration. However, considering the UPA distribution in the mainland of the city of Venice as developed by the mapping approach, it is possible to consider the reduction of  $2\text{ }^{\circ}\text{C}$  in the whole urban area homogeneous. In this case study, to calculate the UHI reduction, it was decided to consider the remaining days, between June and August, with a temperature above  $30\text{ }^{\circ}\text{C}$  after subtracting  $2\text{ }^{\circ}\text{C}$  (<https://www.arpa.veneto.it/dati-ambientali/open-data/clima/principali-variabili-meteorologiche>, accessed on 20 March 2020). In that way, it was possible to calculate how many days with a temperature above  $30\text{ }^{\circ}\text{C}$  could be avoided by developing UPAs.

### 3. Results

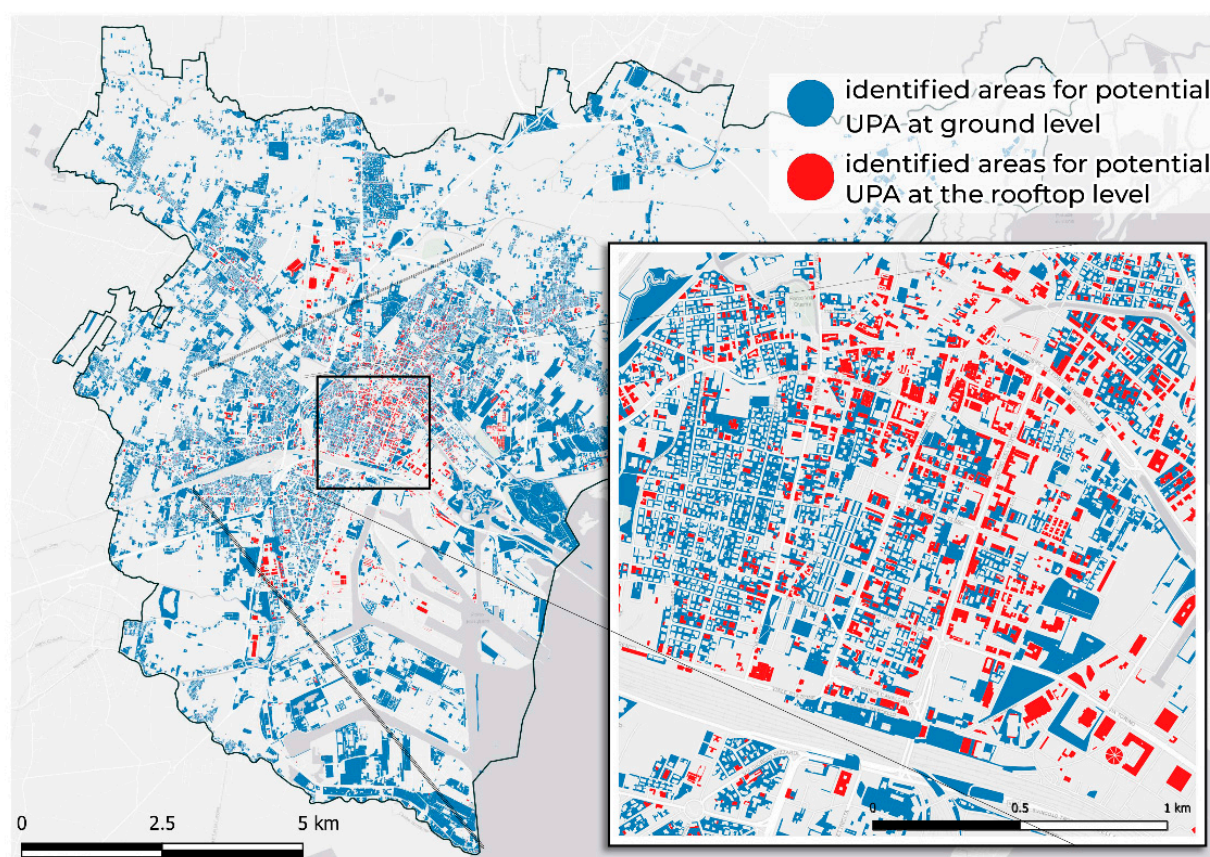
#### 3.1. Mapping of UPA

GIS-based approach results are displayed in Figure 3, where the four steps are developed. Then, in Figure 4, the areal distribution of suitable space for UPA is visualized, on both the rooftops and ground. Approximately  $6122.5\text{ km}^2$  of potential area for UPA was identified and mapped,  $774,493.4\text{ m}^2$  on the rooftops and  $5,348,052.13\text{ m}^2$  on ground level. Of this, 12.65% consists of private rooftops or courtyards, while 87.35% consists of public areas and lots.



**Figure 3.** In this figure are identified and mapped the different potential areas for UPA. (a) Rooftop areas that can be converted into UPA; (b) courtyards that can be converted in UPA; (c) public green areas that can be converted in UPA; (d) existing and designed urban garden—mainland of the city of Venice as identified in [37].





**Figure 4.** Mapped ground-level (courtyards, public green areas, urban garden) and rooftop areas (flat roof) for potential UPA—mainland of the city of Venice.

Figure 3a identifies and maps the flat rooftops available for green roofs: 739,155.41 m<sup>2</sup> in residential buildings, 44,331.81 m<sup>2</sup> in administrative buildings, and 203,409.55 m<sup>2</sup> in public buildings. These areas are all mainly located near the center of the city in an area developed in the last forty years. On the other hand, 561,963.62 m<sup>2</sup> is located in commercial buildings, which are mainly located on the edge of the city center. Figure 3b identifies and maps 2,037,991.14 m<sup>2</sup> of private courtyards available for UPA. These areas are distributed in the principal residential areas, where there are principally single or semi-detached houses with gardens. It is relevant to underline that the area of Marghera (south-east) was founded as a garden city. These available areas are located mainly in the peri-urban areas of the city and can be used as the connection between rural and urban areas, supporting green corridors and ecosystem services continuity. Figure 3c identifies and maps the public green areas, of those 2,895,598.58 m<sup>2</sup> are parks and vacant public areas and 5998.41 m<sup>2</sup> are large flowerbeds. These areas are mainly located in peri-urban areas facing towards the lagoon, where there are the main equipped parks of the city and the vacant and dismissed industrial area. Finally, Figure 3d identifies and maps 32,042 m<sup>2</sup> of existing urban gardens and 376,423 m<sup>2</sup> of the designed and planned ones. These, compared with the other identified surfaces, are limited, and are located just outside the most central areas.

Taken together, the rooftops and ground-level results (Figure 4) suggest that the mainland of Venice has significant areas that should be potentially available for UPA, both for domestic and for small commercial food production. Moreover, these areas cover the whole territory in a fairly homogeneous way, which means that the mainland of the city of Venice has the opportunity to benefit from real integration between nature and urban systems. The mapping framework developed can be easily replicated to other cities with similar data availability and can be used to provide potential benefits of UPA.

### 3.2. Production and Consumption Assessment

The results of the production and consumption assessment developed in this case study are summarized in Table 2. Considering a productivity scenario of 5.73 kg m<sup>2</sup>/year, with over 5,348,052.13 m<sup>2</sup> available on the ground, the yield is equal to 30,644,338.7 kg/year, and with a productivity scenario of 15.2 kg m<sup>2</sup>/year over 774,493.4 m<sup>2</sup> available on the rooftops, the yield is equal to 11,771,478.88 kg/year. The total amount of vegetables that can be potentially produced combining the two yields is 42,415,817.58 kg year. With an average Italian consumption of vegetables equal to 74.8 kg per capita yearly [44], it was estimated that the urban garden areas that can be developed in the mainland of the city of Venice could feed a population equal to 567,056 inhabitants (Table 2).

**Table 2.** Production and consumption assessment.

UPA Typology	Area (m <sup>2</sup> )	Productivity (kg m <sup>2</sup> /year)	Yield (kg/year)	Consumption (kg per capita/years)	Feeding Population (Inhabitants)
ground	5,348,052.13	5.73	30,644,338.7	74.8	567,056
rooftop	774,493.4	15.2	11,771,478.88		

The assessment conducted in the mainland of the city of Venice revealed that the potential vegetable productivity is very high. However, even considering that our hypothesis is too optimistic both in terms of available and suitable areas, and in terms of productivity, the potential to feed the whole mainland population is not compromised. In fact, considering only a yield of 31%, it is possible to cover the city's horticultural vegetable demand. This data and estimation are credible if compared with similar studies [11,17]. However, it is important considering that, as other studies suggest, meeting the vegetable demand depends on several factors not considered in this study, such as (i) the management intensity of UPA, (ii) the specific type of vegetable provided, (iii) the individual interest in growing food, and (iv) the real suitability of space (building structure, healthy adapted soil, air pollution, and water contamination).

### 3.3. Climate Change Mitigation and Adaptation Effects

The results of the climate change mitigation and adaptation effects were basically of three typologies: (i) climate change mitigation, therefore based on sequestration and reduction of CO<sub>2</sub>; (ii) climate change adaptation of UF impacts; and (iii) climate change adaptation of UHI impacts. For this case study, the impact reduction of climate change is summarized in Table 3.

**Table 3.** Climate change mitigation and adaptation effects.

Climate Change	Impact Typology	Data	Total
Mitigation	CO <sub>2</sub> sequestration	588,614.9 kg CO <sub>2</sub> year	754,974.7 kg CO <sub>2</sub> year
Mitigation	CO <sub>2</sub> reduction (heating/cooling)	166,359.8 kg CO <sub>2</sub> year	
Adaptation	UF reduction	465 mm m <sup>2</sup> year	360,139.4 m <sup>3</sup> year
Adaptation	UHI reduction	June, 4 days; July, 10 days; August, 10 days	24 days year

Regarding the mitigation in our case study, we act in two scenarios, the first one of which is realized directly by the UPAs, which act on CO<sub>2</sub> sequestration. In this situation, the amount of CO<sub>2</sub> sequestered depends on the typology of vegetables (or crops), the size of the plot, and also the typology of soils and their processing. However, considering the literature, is possible to estimate a sequestration average of 0.76 kg cm<sup>-2</sup>. In this case study, it was decided to consider only the green roofs, because the starting point was

zero sequestration, while for the UPA developed at the ground level, the starting point could be different. With these premises, the UPA available surface is 774,493.4 m<sup>2</sup>, and the sequestration is estimated equal to 588,614.9 kg CO<sub>2</sub> year. The second mitigation scenario is realized indirectly by the UPA because green roofs are able to reduce 5% of energy consumption for heating and cooling. Thus, knowing that in our case study there is 739,155.41 m<sup>2</sup> of residential and 809,704.98 m<sup>2</sup> of non-residential surfaces that can use less energy, and knowing the average EU energy consumption and the specific Italian conversion rate, it was possible to estimate a CO<sub>2</sub> reduction of 166,359.8 kg CO<sub>2</sub> year. Finally, the two scenarios together can produce one benefit of less than 754,974.7 kg CO<sub>2</sub> year.

Regarding the adaptation in our case study, the UPA implementation produces two distinct benefits. The first one is about the UF impact reduction, and the second one is about the UHI impact reduction. In the first case, the benefit is related to retention capacity, which depends on UPA design. However, considering the literature, it is possible to estimate water retention of 56% on average for the green roofs. In this case study, it was decided to consider only the green roofs, because for them, the starting point was zero retention (surfaces completely impermeable), while for the UPA developed at the ground level, the starting point could be different (mixed surfaces partially or totally already permeable). Thus, considering 774,493.4 m<sup>2</sup> of green roofs and the 831 mm of rainfall in 2020, a total water retention of 360,139.4 m<sup>3</sup> year was estimated. In the second case, the benefit is related to the capacity to lower the temperature. In this case, the UPA's capacity depends on its design; however, by the literature, it is possible to estimate a temperature reduction of 2 °C on average. Thus, considering the temperature of the city of Venice in 2020, and assuming a decrease of 2 °C [54], the reduction of days with temperatures above 30 °C was estimated as follows: from 5 to 1 in June, from 13 to 3 in July, and from 16 to 6 in August, for a total reduction of less 24 days of UHI.

### 3.4. Other Benefits Associated with UPA Multifunctionality

Beyond the benefits associated with food security and climate change mitigation and adaptation, UPA implementation is claimed to improve many other aspects, from the environmental to the socio-economic. The multifunctional character of the UPA is viewed and valued because of its role in public health costs, natural resources, and national security threats.

In recent years, there has been a growing recognition of the value of biodiversity in both rural and urban areas. UPA management may be a crucial element to promote urban green corridors, reproducing habitats as green edges and beehives for beneficial insects [55]. Several studies have highlighted that green rooftops and other greenhouse structures should increase the population of urban fauna, and as a consequence, urban biodiversity [56].

UPA also has benefits for human well-being, especially related to mental and psychological health, and stress recovery [57,58]. Moreover, UPA can be considered as a catalyst of a resilient community in which the people contribute to constructing resilient urban neighborhoods, able to adapt and recover themselves when faced with some kind of crisis [59]. Benefits are given by the social interactions, especially for vulnerable groups of people that use gardening as a restorative greening activity.

UPA as suggested by the European Commission [60] should also be used for urban renewal and regeneration, through requalifying vacant or abandoned space from a community garden perspective [61], improving the city's image.

## 4. Discussion

This study analyzes and describes the horticultural yield and the climate change impact reduction due to the implementation of UPA in the mainland of the city of Venice. This contributes to partially filling the gap in knowledge in the field, since UPA as EGIs were rarely studied as a tool for climate change impact reduction. The study shows step-



by-step how to develop a GIS-based approach for identifying potential areas for UPA, then how to assess potential local food production, and also how to estimate climate mitigation (CO<sub>2</sub> reduction and sequestration) and adaptation (water infiltration and UHI reduction) effects.

The mapping approach developed was able to properly support the investigation of the case study about food security and climate change. Although using a more detailed database should make it possible to know the yield, CO<sub>2</sub> reduction, FU reduction, and UHI reduction in greater detail, the proposed methodology allows making a relevant and pertinent estimation, in a relatively simple way. The advantage of this approach is the ease of replicating it in other cities, because it uses not experimental layers but an informative framework usually held by the local administration, or that can be produced with the open data of Copernicus.

In estimating total potential yield, 100% of the available area was not considered, because that is very improbable—many factors can reduce and stop the conversion of these areas to UPA, such as competition for other types of development or use, contamination or quality of soils, lack of business or community, citizens' behavior and availability, and safety concerns. Thus, several assumptions were taken that reduced the available area. Therefore, the results achieved here should be interpreted as a credible but not maximum potential area and yield. Several potential challenges need to be considered in promoting and supporting UPA, for example, urban soils could be contaminated or not high-quality, and thus, local production and consumption must be monitored [62]; air pollution could decrease the productivity and safety of UPA; and access to water could also reduce UPA implementation [63]. Pollution could be one of the major problems for the safety of UPA production. However, there are several techniques and tricks to reduce it and make healthy food, which must be chosen on a case-by-case basis after a pollution assessment [64]. Notwithstanding these limitations, we believe that the methodology and the study developed can be easily transferred to other contexts for analyzing other cities and their UPA sustainability, to suggest food policy orientations, and to integrate food considerations in urban planning. From an administrative and political point of view, it is important to avoid reducing the urban food question to a narrow nutritional agenda, due to its multifunctional character: social, cultural, economic, ecological, and political.

The results obtained by the analysis of climate change adaptation and mitigation effects produced by the EGIs' implementation are positive and encouraging. In this type of estimation, 100% of the available area was again not considered, because there are several limiting factors, relating both to limited knowledge of certain environmental and societal aspects and to the real availability of people, and their engagement and behavior.

However, it is evident also that even using just a small part of the potential surfaces identified, the estimated benefits are high. Mitigation and adaptation effects can be achieved by implementing urban food policies.

Overall, the results show the high impacts of the proposed scenarios. Food production and consumption and climate change mitigation and adaptation can support the city's sustainability both in quantitative and qualitative terms. The analysis conducted, also considering all the limits, represents a starting point in assessing and evaluating the contributions of UPA to city resilience, not just under a single view but considering its multifunctionality. All this demonstrates that the multifunctionality of UPA has great potential. However, to date, this potential has not yet been sufficiently explored and studied. More exploration and practical implementation have to be developed in order to construct important knowledge and fill the existing gap.

UPA is viewed, valued, and used in the current society as a lever for sustainable development. There is a need to comprehend how to successfully implement EGIs. Regulations and their designs can influence the success of UPA, both in terms of food security and climate change mitigation and adaptation, therefore the institutional framework conditions for UPA implementation must be studied and defined properly, considering environmental and socio-economic frameworks.



Finally, it is clear that without a coordinated planning process developed by the administration and a strong community engagement, it is difficult for private citizens to work in a systematic way to produce food or be engaged in cooperative or commercial farming practices. To successfully implement UPA, there is a need for institutional and governance structures. These structures should be able to define and implement an urban food policy coherently with the other planning decisions, and food implications should be mainstreamed in urban planning and management plans and tools [65], such as green space management plans, urban development plans, and/or building management plans. Moreover, local administrations and municipalities play a crucial role in UPA development, also providing access to land through permissions (“top-down policymaking”), even if initiatives such as community gardens are usually promoted and driven by local associations and NGOs (“bottom-up policy-making”) [66].

## 5. Conclusions

By UPA, it is possible to improve food security and to reduce climate change impacts. In fact, considering UPA as productive UGIs, it is possible to develop a systemic urban/nature approach full of societal benefits and advantages, that is, producing food, reducing food miles and reducing transportation, and shortening the supply chain; it could connect people with nature, promote healthy lifestyles, and support biodiversity and the environment.

This paper with its case study sets out to develop the UPA in the mainland of the city of Venice and to assess vegetable self-sufficiency potential for the inhabitants. A mapping approach was developed to understand possible UPA expansion, both on the ground and the rooftops. Food production was evaluated considering a possible scenario of productivity for vegetables, and compared with the Italian average per capita vegetable consumption. The measurement showed that implementing UPA, both on the rooftops and the ground, could cover the horticultural vegetable demand of the city, and at the same time, could mitigate climate change and reduce the impacts of climate change in direct and indirect ways. CO<sub>2</sub> sequestration and reduction allow better sustainability of the urban environment, while the reduction of UF and UHI supports the city’s adaptation to climate change, reducing damage and health problems for the citizens.

In conclusion, expanding the area for horticultural vegetable crops through the planning process and land rearrangement with more equitable UPA development projects could be one solution to ensure food security, new opportunities for local community food systems, and a strong measure for climate change mitigation and adaptation.

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