Erasmus+

# SESAME

Encourage the deployment of agricultural projects in urban & peri-urban areas through the development of innovative training

## MODULE 2 :
## USE OF RESOURCES FROM A CHALLENGING PERSPECTIVE

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# 1. Urban agriculture in biodiversity and ecology

## 1.1. Urbanization and biodiversity loss

In the last century, people have gradually moved from rural areas to cities. Almost half of the world's population lives in urban environments. Food production areas have to be located closer and closer to the main centers of consumption. As a result, urban agriculture is gaining importance worldwide and new strategies need to be developed to ensure food supply and food security for the population. The trend is that by 2050 the urban population will make up 70% of the total population.

Hot spots are characterized by exceptional levels of plant endemism (at least 1,500 species of vascular plants) and severe levels of habitat loss (at least 70% of their original habitat has been lost). Worldwide, 34 biodiversity hotspots have been identified. It is estimated that, collectively, these sites host high levels of biodiversity, including at least 150,000 endemic plant species and 77% of the world's total terrestrial vertebrate species. The 34 biodiversity hotspots identified worldwide by Conservation International contain urban areas. Biodiversity-rich cities are numerous and are found in a multitude of geographic locations, such as Brussels, Cape Town, Chicago, Curitiba, Frankfurt, Mexico City, New York and Singapore, to name a few. Brussels, for example, contains more than 50 percent of the flower species found in Belgium.

A global loss of biodiversity is occurring. Globally, ecosystems have continued to be converted for agricultural and other uses at a steady rate for at least the past century. Species extinction is a natural part of Earth's history. However, over the last 100 years humans have increased the extinction rate by at least 100 times compared to the natural rate. The current extinction rate is much higher than the rate at which new species emerge and translates into a loss of biodiversity.

The growth of cities leads to the reduction of agricultural land, deforestation and loss of habitats, reduction of open spaces, pollution and soil sealing, generally resulting in reduced climate resilience, fragmentation of ecosystems and loss of biodiversity.

Urban ecosystems are artificial and offer specific habitat conditions. Biodiversity in urban environments is highly specific and varies in relation to human pressure and activities.

The ecosystem is a way of describing the functioning of nature and consists of components (plants, animals, microorganisms, water, air, etc.), as well as interactions between these components.

The benefits that humans obtain from nature are known as ecosystem services. They can be divided into four categories: supply services, regulation services, habitat or support services and cultural services.

## 1.2. Urban agriculture and green corridors

Well-designed cities can sustainably accommodate a large number of people in a relatively small space, offering an improved quality of life and allowing for greater resource efficiency. Green infrastructures and the corresponding ecological services are key factors for the viability of cities. Urban agriculture can become, through the construction of green (ecological) corridors in cities, a determining factor in improving human well-being and environmental protection.

Urban biodiversity is the variety and richness of living organisms and the diversity of habitats found in and around human settlements.

Key messages:

1. Urbanization is both a challenge and an opportunity to manage ecosystem services around the world.
2. Cities can be rich in biodiversity.
3. Biodiversity and ecosystem services are critical natural assets.
4. Maintaining functioning urban ecosystems can significantly improve people's health and well-being.
5. The services of urban ecosystems and biodiversity can contribute to the reduction and adaptation of climate change.
6. Increasing the biodiversity of the urban food system can improve food and nutritional security.
7. Ecosystem services must be integrated into urban policy and planning.
8. Successful management of ecosystem services and biodiversity must be based on multi-level involvement.
9. Cities offer unique opportunities for learning and education about a resilient and sustainable future.
10. Cities have great potential to generate innovations and governance tools and must take the lead in sustainable development.

In cities, there are different types of green infrastructures: intensive green ground, extensive green ground, urban gardens and wild flowers in gardens.

Ecological corridors help maintain cohesion in highly fragmented ecosystems. By connecting fragmented habitats, the viability of animal and plant species is improved through habitat expansion, dispersal of young animals, and reuse of habitats that are in decline. The ecological corridors consist of central areas, corridors and buffer zones. The corridors create a permanent connection between the central areas. The central areas and connecting corridors are surrounded by buffer zones, which serve as protection against possible external influences that could interfere with them. Beyond the central areas and connecting corridors, there is another zone with land selected for sustainable use with the preservation of various ecosystem functions.

## 1.3. Sustainable management of agricultural inputs

Urban agriculture is an attractive activity because it is considered a sustainable activity that produces local food, creates communities and a sense of relevance, enables physical activity and improves well-being in cities. In fact, when plants are grown in urban environments, several agronomic issues are raised. Is it really more sustainable to grow plants on individual plots than on larger farms? Is the product healthy? How can a non-format urban farmer grow agricultural plants in a sustainable way? How can resources (for example, water, plant nutrients) be managed wisely? How can pests and diseases be controlled without harming the environment and users?

These questions were addressed in the framework of the EU project HORTIS (Horticulture in cities for inclusion and socialization). The project's objective was to disseminate good urban agricultural practices, with the ultimate goal of developing sustainable urban agriculture in European cities. Among the results of the project, a series of electronic books were produced, which can be downloaded free of charge from the project's website (www.hortis-europe.net). These books dealt with sustainable community gardening in cities, sustainable management of urban gardens, urban gardening cultivation systems, soil-less cultivation systems for urban vegetable production and eating closer to home (urban consumption manual).

## 1.4. Ecosystem services with old and new genotypes

### 1.4.1. Agriculture and plant selection (plant breeding)

In recent years, it appeared a concern about the adoption of commercial hybrids in agriculture. Genetic selection has been associated with the loss of traditional genotypes, the insurgence of allergies and pathologies, and a decrease in resistance to environmental and climatic changes. However, plant selection may not be considered a recent trend in agriculture and, in fact, it is estimated to have taken place between 9 and 11,000 years ago. Initially, farmers selected plants with interesting characteristics from their point of view (those that produced more) and used them as a fertilizer for subsequent generations, achieving an accumulation of desired characteristics over time. From Mendel's experiments, hybridization was introduced, which led to the development of modern plants, covering a range of disciplines, such as molecular biology, cytology, systematics, physiology, pathology, entomology, chemistry and statistics.

The main interactions between agriculture and global biodiversity appeared between the end of the 19th and the beginning of the 20th century, when there was a marked decrease in the use of pastures and pastoral lands for extensive use, became established as an innovation in agricultural technologies. This intensification accelerated in the second half of the 20th century with the adoption of common agricultural policies (CAP) and the globalization of agricultural markets. This led to an increase in the degradation of the habitat, the overproduction of food products, the intensification of agricultural practices and the concentration of production in larger and more specialized farms. It was not until the 1990s that CAP reforms began to recognize the environmental role of agriculture, integrating policies that valued the promotion and preservation of biodiversity. The results of these agri-environmental schemes in achieving biodiversity conservation objectives vary considerably across Europe.

The agricultural landscape covers 45% (180 million ha) of the territory of the European Union. However, agricultural land changes considerably in terms of biodiversity, depending on soil condition, water availability, climate, slope and management factors. For this reason, the European Environmental Agency (EEA) identified three types of High Nature Value (HNV) farmland:

- Type 1: croplands with a high proportion of semi-natural vegetation;
- Type 2: croplands dominated by low intensity agriculture or a mosaic of small-scale semi-natural croplands;
- Type 3: coniferous lands that support rare species or a high proportion of European or global populations.

From this classification, the maintenance of biodiversity depends directly on the traditional types of agricultural land use, which are generally decreasing both due to the abandonment of farmland and the intensification of silt use. As the agricultural lands of the VNH diminish, the survival of all those species adapted to its diversity of structures and resources is threatened.

European and national legal and administrative schemes have been adopted to support biodiversity in agricultural and urban landscapes. These include, among others, the following:

- The creation of nature reserves (Natura 2000 network, which includes more than 25,000 areas with an area of 1 million km2 (EU, 2007)).
- Buy land and manage it for biodiversity purposes, as is done in the Netherlands and the United Kingdom.
- To undertake the maintenance or restoration of natural habitats through dedicated funding opportunities (e.g., EU-LIFE + program).
- Biodiversity conservation programs aimed at the purchase of agricultural land, e.g. www.euronatur.org.
- Support measures promoted by private companies (e.g. IUCN project on Sustainable Agriculture and Steppe Biodiversity in Russia and Ukraine).
- Support measures promoted by regional / national administrations for the promotion of the local or regional market or tourism.

In addition, organic labeling ( for example, organic production) and community-supported agriculture (for the short food chain) improve the environmental sustainability of agriculture and promote biodiversity.

### 1.4.2. The role of urban agriculture in biodiversity conservation

Urban agriculture can play a key role in the preservation of biodiversity for the following reasons:

- It is located near urban centers, where biodiversity is of crucial importance but also at risk.
- It can represent both a risk and a boost to urban biodiversity, depending on how it is managed.
- It can raise awareness among citizens about the importance of an environmentally friendly way of life.
- It can constitute a biodiversity deposit when traditional/local crops and species are cultivated.

### 1.4.3. Miquel Agustí Foundation

In the metropolitan area of Barcelona we can find the Miquel Agustí Foundation. This foundation is made up of a multidisciplinary group of specialists in genetic improvement, agronomy, sensory analysis, chemical analysis, food technology and biostatistics. The foundation encourages research into traditional Catalan agricultural varieties and promotes local products from our land. It works closely with the agri-food sector to improve the efficiency of processes and the organoleptic and nutritional quality of products.

It contributes to the conservation of the Catalan agrobiodiversity, through different programs of germplasm collection around the Catalan territory and strategies of ex situ conservation of the genetic variability of traditional Catalan varieties.

The Germplasm Bank of the Miquel Agustí Foundation is a structure in which the seeds of traditional varieties are conserved, donated by Catalan farmers. It is a living collection, which serves as a base for the different programs of recovery and improvement of the traditional Catalan varieties.

The collaboration agreements with different official Germplasm Banks that are dedicated to long-term ex situ conservation guarantee that the plant will be available, in the future, for the whole of Catalan society. Innovative strategies to make plant genetic resources available to society are being promoted, such as the lending service created at the library of the Universitat Politècnica de Catalunya.

They also develop scientific studies that give content to the set of conditions of the quality seals of the traditional Catalan varieties. In collaboration with the production sector and the administration, promoting European quality seals to distinguish traditional Catalan varieties and promote their cultivation in the area of origin. This scientific team assesses:

- The Protected Geographical Indication (PGI) Calçot of Valls
- The Protected Designation of Origin (PDO) Mongeta del Ganxet
- The Protected Designation of Origin (PDO) Fesols de Santa Pau

# 2. Urban agriculture to reduce the ecological waste of the city

The ecological footprint (impact of human activities measured in terms of the area of biologically productive land and water needed to produce the goods consumed and assimilate the waste generated) refers to the sustainability dimension that seeks to ensure a livable future. Therefore, the ecological target includes the necessary resources to maintain a certain activity. In the case of cities, although they represent less than 3% of the Earth's surface, they contribute greatly to global environmental impacts. The current urban metabolism involves the consumption of various resources (food, water, energy or land) that are converted into waste and emissions by the multiple urban activities. Urban designers and managers seek to implement sustainable strategies in the urban environment in order to reduce the current problem. These initiatives focus on reducing resource consumption and minimizing emissions and waste, while promoting self-sufficiency, local production and circular metabolism (reuse, recycling, circular economy).

## 2.1. Climate change mitigation: local production and food industries

The sector that produces the largest amount of greenhouse gas emissions in Europe is the food sector. While agricultural production contributes to climate change (land use changes, resource consumption, fertilizer application, fuel consumption, food loss and waste), the effects of climate change greatly affect agriculture and food production (desertification or soil erosion). The entire food supply chain contributes to climate change, particularly in stages involving transport needs. In the context of designing a sustainable future, local food movement networks have been created to reduce long distances and at the same time reduce the contribution to climate change. The concept of "avoided food miles'' has begun to be used to evaluate the different environmental impacts of imported and local food supply chains, mainly in terms of energy consumption and climate change. Thus, local food systems are also known as "km 0". The use of urban spaces to promote local food production through urban agriculture initiatives can contribute positively to reduce the environmental impacts related to food consumption.

## 2.2. Boosting freshness: reduction of food waste and environmental impact

According to the United Nations Food and Agriculture Organization (FAO), around 30% of the food that is produced is wasted, representing 1,300 million tons of food waste per year. According to data from the European Commission, 100 million tons of food waste are generated in Europe alone, and this value could increase to 120 million tons by 2020 if mitigation actions are not implemented. Thus, food waste has to be put in the spotlight of global food safety. Plans and programs are being designed and implemented to promote the reduction of food waste generation at the production and consumption stages. Local food production can contribute positively to this goal by minimizing the food supply chain.

### 2.3. Environmental justice: Minimizing geographic inequalities by promoting localism

The globalized food industry generates several environmental injustices, such as soil erosion, deforestation, loss of biodiversity, water depletion and pollution. In addition, urban development has progressively created a local environmental injustice, as poor neighborhoods have deteriorated environments and a lower quality of life. Local food movements seek to minimize the geographic inequalities of the global food industry by developing alternative food systems. In addition, urban agriculture projects improve social justice in cities.

### 2.4. Assessment of the sustainability of urban agriculture.

Urban agriculture systems aim to minimize the impacts of local food production. Currently, academics are working on the development of tools that evaluate sustainability from a global perspective. For example, tools have been developed to assess the life cycle for the environment (life cycle assessment), the economy (life cycle cost) and society (social LCA). In this unit, we will discuss how to evaluate sustainability from a quantitative perspective.

# 3. Urban agriculture to facilitate a more efficient use of resources and better waste management

## 3.1. Greenhouses and green floors: acclimatization of low energy consumption buildings

Why grow crops on the ground and walls? There are many reasons to include greenhouses on the ground or on the sides of a building:

- Improvement of the quality of life
  - Improve the visual aspect (it is only about the walls or plantations on the ground without greenhouse).
  - Reduce the level of litter.
  - Respond to the social and environmental need to return to nature within the cities, as it provides animal and plant species with a living environment.
- Improved stormwater management, as crops on the land can temporarily store a little water, reducing stormwater runoff.
- It is a source of local food production, mainly on the land because it is easier to establish a crop there.
- Reduce energy demand:
  - Screen mural,
  - Greenhouse on the ground,
  - Facade of double skin view.

### 3.1.1. Cultivation systems

*Land cultivation systems*

There is a wide range of cultivation systems on the land, from ornamental plants to food-producing greenhouses. This diversity entails great variations in the complexity and cost of the installations. From a technical point of view, the different cultivation systems can be distinguished by their grain, mainly by the substrate. The thinner substrates are simpler but cannot allow the cultivation of large plants, while with a sufficient amount of substrate we can plant tall trees (over 30 cm).

These differences will affect the energy transfers between the inside and outside of the roofs, since a thicker substrate provides better thermal isolation.

In Barcelona has emerged the movement called Huertos in the Sky, an initiative that seeks to encourage green spaces in the city through the creation of gardens on the grounds of Barcelona. The project has three purposes: to connect with nature by producing km0 food, to revitalize communities and to generate employment. They claim that Barcelona is ideal for developing agriculture on the land, because 67% of the city's land is flat. It is estimated that 100 hectares could be arable, which is the equivalent of 150 soccer fields, so there is a lot of potential in terms of space. The growing interest in healthy eating, organic and zero-meter food is another reason to promote Huertos in the Sky.

The following video talks about this project:

https://www.youtube.com/watch?v=fCWsr8baGjY&feature=emb_logo

*Growing systems in green walls*

In green walls, there are several limitations, such as their vertical geometry and the presence or not of a growing medium across the entire height of the wall.

The plants, and particularly the foliage, reduce the insolation and surface temperature, thus reducing the cooling needs of the building in the summer. In addition, the presence of substrate or growth medium would increase the building's isolation.

*Greenhouses on top of the buildings*

The greenhouse installed on the ground is more or less the same as a normal greenhouse.

The difference with common greenhouses, and the advantage in terms of energy consumption, is the cohabitation with the surrounding building. The reuse of energy from a part of the building allows saving. The greenhouse could be used as an aid for the air conditioning of the adjacent building in the summer. The heating system would be used to cool the greenhouse in winter.

Some buildings are constructed with a so-called "double skin" facade where the walls of the structures are doubled, with a glass casing on the outside. The objective is to use the greenhouse effect to cool the intermediate space in the winter, and then use it to temper the interior air. In the summer, the space of the double-skin facade is used to collect or evacuate the solar radiation absorbed by the facades.

However, during a hot summer, cooling needs may increase. In this context, the use of plants can be a cheap and effective way to limit the drain on this cooling system. The resulting system is very similar to a vertical greenhouse.

The cooling effects are mainly due to the reduction of sunlight reaching the inside wall thanks to the shading generated by the shades. In addition, plant transpiration plays an important role in reducing air temperature.

### 3.1.2. Temperature transfer principles

There are three types of heat transfer:

- Conduction: This is the main form of heat transfer in solids. It occurs when one part of a thing is hot, its molecules vibrate faster than those of the cooler part of the thing. Its kinetic energy is transferred to the adjacent part of the body molecule by molecule until the kinetic energy (and therefore the temperature) is homogeneous.
- Convection: The transport of heat from molecules to adjacent molecules is accompanied by a transport of the molecule through fluid motions. In general, the heat transport is faster, since the velocity of the molecule can be high. It is mainly fluids (liquids and gases). If heat transport is the origin (the driving force) of fluid movement, it is called natural convection. Fluid movement can also exist without heat transfer, then it is called forced convection.
- Radiation: This mode of heat transfer consists of heat exchange between surfaces at different temperatures. It is caused by the fact that each surface emits electromagnetic energy. The energy is radiated from warm to cool surfaces, but unlike conduction and convection, it can also travel from cool to warm surfaces.

In general, all three modes of heat transfer occur in a building. The modernization of buildings to make them more sustainable involves major changes in radiative and conductive heat transfer between the building and the outside environment, while convective heat transfer is less modified.

### 3.1.3. Interest in green buildings

Due to human activity, the climate in urban areas is significantly warmer than in rural areas. This causes problems for habitats, especially during the summer season, as global climate change is expected to increase the temperature in the summer and aggravate the situation.

In developed (and developing) countries, there is an increasing use of air conditioning to make buildings comfortable for their occupants, even though the use of air conditioning means that the outside air has to be cooled, thus aggravating the situation. In addition, the widespread use of fossil fuels to produce electricity generates a large amount of greenhouse gases.

In this context, constructing more sustainable buildings is a means to reduce the energy consumption of the building by limiting air conditioning needs. On the other hand, some of the solutions described below may be interesting to limit heat loss in cold conditions, so that energy consumption is reduced during the winter.

In cities or in neighborhoods, studies show that vegetation (whether trees or grasses) is very positive for the summer climate. For example, Armson (2012) attributes a decrease in surface temperature by 24°C to the presence of grass.

In order to reduce the need for cooling in the summer (the energy that passes through the support and walls (G in the previous diagram), it is necessary to reduce the inflow or increase the outflow.

The presence of vegetation is an efficient way to act on all the affected heat flows.

*Radiative exchanges*

The first step in limiting the heat input of a building is to reduce the direct solar illumination reaching the roof and walls by reducing the shading, or increasing the albedo of these surfaces, that is, the amount of reflected sunlight. Transmittance (the part of the radiation that passes through the sheet) is limited and reflects a good part of the incoming radiation.

The figure above shows the radiative balance of a dish. Less than a third of the incoming radiation is transmitted, which explains the extensive use of trees to provide shade.

*Opacity (to prevent radiation from reaching the building)*

The first way to reduce the energy input into a building is to avoid the input of energy through solar radiation. To achieve this, it is common to use trees to shade the building.

Numerous studies have been carried out to confirm that shading reduces the temperature of the outside wall.

The benefits of cooling vary with climate and latitude, with most studies being found in low latitude cities where the expected gain is greater. The literature presents some examples of energy savings for cooling load: 3.23 and 6.46 kWh m-2 in California (Akbari and Konopacki, 2005).

The same principles are applicable for both green walls and green terraces (Pulselli et al., 2014). The shading effect is closely linked to the LAI (Leaf Area Index, which is the surface area of the leaf per m2 of soil (wall or support)).

There is a linear relationship between LAI and the effect of shading (Wong et al., 2009) and for a very low light transmittance factor (achievable with a dense crop), energy losses can be reduced by 40% (Wong et al., 2009). This is interesting from the energy point of view of the buildings, since the foliage isolates the buildings from the sun in the summer, when cooling is needed, while deciduous plants lose their foliage in the late afternoon and winter when the sun helps to cool the buildings.

*Albedo*

In addition to solar insolation, the external surface temperature of surfaces depends on albedo, the portion of the sun's radiation reflected by a surface. In cities, materials have historically been used that are not greatly influenced by this phenomenon, which is one of the main causes of the urban heat island effect.

For this reason, new constructions use materials that reflect more radiation, reducing their surface temperature. This is a reduction of conductive heat transfer through the walls and the substrate.

Measurements of albedo, air temperature and surface temperature show that the higher the albedo, the lower the temperature (Chatzidimitriou and Yannas, 2015). If the surface temperature is influenced by the surface albedo, the air temperature will hardly be modified. The average temperature reduction is approximately 0.3 K for an increase of 0.1 albedo points (Santamouris, 2014).

The cooling benefits of high albedo surfaces are 10/40% in the summer, with a 5-10% reduction in heating (Santamouris, 2014). In southern California, the average conditioned air consumption is between 40 and 70 Wh m-2 day-1 depending on the type of building (Akbari et al., 2005).

For a temperature of 33° C, Simmons et al. (2008) report a surface substrate temperature of:

- 68° C for a black roof
- 42° C for white roof
- between 31 i 38° C for a green roof

However, the gain in green surfaces is not entirely due to radioactive properties, but largely due to evaporative cooling (Santamouris, 2014).

*Evapotranspiration*

Plants absorb a large amount of energy through their leaves, but maintain their temperature through transpiration, converting liquid water into vapor. The necessary energy is taken from the cells and the air that surrounds them, allowing their temperature to drop.

As a consequence, the vegetated surfaces are cooler than the surrounding areas. Normally, about 30% of solar radiation is dissipated by transpiration (Tilley et al., 2012). Plants cause a similar shading to artificial systems (Pérez et al., 2011), the temperature of the walls and floors can be much lower than that of the uncovered surface. The surface temperature of a green roof can be up to 8º C below that of a cool roof.

In contrast, this effect only exists while the plants are transpiring. If plants are subjected to water stress, biological regulation prevents them from losing water and reduces transpiration. For these reasons, the cooling effect of the green wall/shade depends very much on the availability of water in the substrate.

Depending on the plants and their development, between 40 and 80% of solar radiation can be reflected and absorbed (Wong et al., 2010). A test carried out in the southern United States by Pérez et al. (2011) states that only 15% of the incoming solar radiation passes through a green vine (Parthenocissus quinquefolia), 18% through the honeysuckle, 41% through Clematis and 20% through the ivy. More than the species, the LAI and the cover crop have a fundamental role in the final heat input (Kumar and Kaushik, 2005).

In addition, transpiration leads to a modification of the water content and relative humidity of the air (Pérez et al., 2011). The resulting microclimate is beneficial, as it is more comfortable from a human point of view. However, the influence of these types of buildings on the urban heat island effect is limited to a cooling of approximately 1° C at 60 cm from the wall (Wong et al., 2010) due to the effect of the wind.

Finally, not only does vegetation on buildings reduce the heat entering a building, but the creation of a cooler and more humid climate is beneficial to the functioning of air conditioning. In fact, it allows the thermodynamic cooling cycle to operate at a higher efficiency (Getter and Rowe, 2006).

### 3.1.4. Effect of green walls and cultivation on soils

The first effect of growing green walls/roofs is to reduce the surface temperature, as described above. This will imply a reduction of the conductive heat flow inside the buildings. Apart from plant-dependent parameters ( soil thickness, LAI, etc.), the effect of vegetation also depends on the construction parameters:

- Geographical position, at lower latitudes there is a greater effect of shading;
- Location, if a building already has a shading element, this effect will be greatly reduced;
- Exposure, better if they are oriented to the south;
- Climate, there is a greater evaporative potential in hot and dry environments.

Consequently, a wide range of cooling effects can be found in different published articles and therefore a correct implementation of green walls/terraces is pending.

As mentioned above, the cooling effect on surface temperature depends on latitude. An effect of 5 to 10° C can be expected throughout the summer at 40° latitude, with a maximum cooling around 15° C (Tilley et al., 2012, Pérez et al., 2011).

The cooling effect is greater when the latitude decreases or the climate is drier. In fact, at approximately the same latitude, the average cooling effect can reach 20°C in northern Greece (Kontoleon and Eumorfopoulou, 2010), and up to 38°C in Texas (Simmons et al., 2008). However, in Singapore (1.3 degrees latitude) the gain is "only" 30°C due to a higher relative humidity of the air.

While outdoor surface variations can be significant due to the insulation and inertia of the building structure, indoor air variation is limited. In addition, indoor conditions are generally controlled by air conditioning systems.

Under these conditions, the average reduction in the indoor temperature of the walls or the green roof is limited to plus or minus 4°C (Getter and Rowe, 2006; Tilley et al. 2012). In contrast, small temperature variations can reflect large variations in the climate control system, and a temperature decrease of 0.5°C can correspond to an 8% saving in cooling electricity consumption (Getter and Rowe, 2006).

*Influence of the irrigation and water demand*

The effect of vegetation depends largely on the water level. In fact, if the water available to the plants decreases, the plants reduce their transpiration. This cancels out the cooling effect of transpiration.

For this reason, vegetated surfaces are cooler just after watering. For example, grass is 3.5°C cooler just after watering (Chatzidimitriou and Yannas, 2015). In addition, the wet soil produces additional isolation (Wong et al., 2003).

In the summer, irrigation water can be difficult to justify due to water limitations. If it is not adequately irrigated, the efficiency of wall/green roof planting decreases (Virk et al., 2015).

For a LAI of between 3 and 4, water consumption is between 0.5 and 2.6 mm/day depending on the climatic conditions in Toronto (Tilley et al., 2012). The latent heat of vaporization of this water represents one-third of the solar radiation. For a warmer and drier climate, evaporation can account for a greater amount of water. Marasco et al. (2014) measured up to 15.4 mm/day in New York, and Takebayashi and Moriyama (2009) measured up to 18 mm/day in Japan.

*Crop system as an isolating layer*

Energy inputs through the building structure are limited by the cultivation of green walls/roofs, not only because of the surface temperature, but also because of the isolating effect of the cultivation system.

In fact, the cultivation systems form layers attached to the wall or support that increase the thermal resistance of the structure. The thickness of this layer depends on the vegetation system, from a few millimeters for living walls made of layers of felts, to a meter of substrate for deep-rooted plantations.

Since common substrates have low thermal conductivity, they represent good isolation layers. The benefits in electrical consumption depend on the initial structure of the building and its pre-existing isolation.

Minke and Witter (1982) (via Bass and Baskaran (2003)) calculate that a roofing system consisting of 20 cm of substrate and 20-40 cm of dense gespa offers a thermal resistance equivalent to 15 cm of rockwool. And a substrate layer of approximately 50 cm can reduce the maximum cooling consumption by 25% (Bass and Baskaran, 2003).

Measurements show that 40 cm of substrate increases the R-value of the roof from 1.72 to 2.20 (Wong et al., 2003), which represents a decrease of almost 30% of the heat flux. Castleton et al. (2010) cited an increase of the R-value from 1.7 to 2.4, and induced an annual increase of 6% in cooling and 0.5% in heating. In both cases, classical isolation continues to be necessary.

The changes in the R-value lead to a reduction in the heat transfer between outside and inside, thus reducing the cooling load in summer and the heating load in winter.

### 3.1.5. Greenhouses

*Roof greenhouses*

For the Mediterranean climate, Cerón-Palma et al. (2012) state that a tanned or semi-drying greenhouse would be effective for designing low-emission production systems. The objective is to reduce energy consumption for poaching during the cold season and to recycle drainage water from irrigation ponds (Montero et al., 2009). The proposed "Rooftop Eco.Greenhouses"

(RTEG) consists of a greenhouse connected to a building in terms of energy, water and $CO_2$ flows.

The study carried out in Barcelona by Cerón-Palma et al. (2012) on an integrated greenhouse concludes that the greenhouse studied has a higher environmental impact (between 17 and 75%) than a multi-tunnel greenhouse, in addition to an economic cost 2.8 times higher. However, when considering the entire supply chain up to the point of consumption, the terrestrial greenhouse has a 42% saving in ecological costs and a 21% saving in economic costs.

A comparison between the conventional supply chain and the local RTG supply chain showed that RTG tomatoes grown in Barcelona could replace the traditional location of tomato production, thus avoiding 441 g $CO_2$ eq and 12 MJ of energy consumed per kg of tomato. In the building greenhouse system, Ceron-Palma et al. (2011) performed a preliminary model and showed that the introduction of waste heat from the greenhouse into the building on an ideal winter day could replace 87 kWh of heating demand.

Caplow and Nelkin (2007) used a classic greenhouse in a building in New York. The greenhouse was equipped with evaporative cooling pads, so that cool air could be used to cool the building. In addition, the conservatory also provided isolation in the summer. In the summer, when the structures are combined, the elimination of increased solar radiation by means of the building's support is estimated to eliminate 37 kWh per day of cooling demand, with an approximate consumption of 3.9 metric tons of water.

In the winter, the thermal losses through the building's roof are reduced thanks to the winterization because this surface is also the greenhouse floor, with an intermediate temperature between the inside temperature of the building and the outside.

From the perspective of traditional energy conservation, the possible annual savings are approximately equal to the total cooling load of the building, 44 MWh, because this load will be assumed by the forced ventilation and low consumption evaporation systems of the greenhouse if the structures are integrated.

*Double skin green facade*

The use of plants in double skin facade is an efficient way to reduce solar energy input into a building. Fang et al. (2011) cited that 60% of incoming solar radiation is absorbed by plants (Tillandsia usneoides for a building in Shanghai). This is consistent with the findings of Stec et al. (2005) which gives a decrease between 50 and 70%. Its efficiency may be higher than the classical louver.

This results in a significant reduction of the temperature variation of the interior wall during a hot day. Stec et al. (2005) measured a thermal amplitude of 5-30° C with plants and 10-60° C without plants.

The air temperature decreases slightly, Fang et al. (2011) recorded a decrease of 2.3°C in the double-skinned facade at a plant density of 750 g/m2 of plant in the double-skinned facade in a warm climate (Shanghai). This can lead to significant decreases in climate control waste. Chan et al. (2009) cited a 26% decrease in energy used in annual cooling compared to the standard double-pane building with reflective glass. This is consistent with the finding of Stec et al. (2005) that proposed a 20% saving.

However, plants can cause problems, such as inconsistencies between their growth and the needs of the building occupants. In fact, the density of plants and the growing process cannot be controlled by the occupants. Moreover, the maintenance of the plant and the cultivation system (watering, harvesting of fallen plants, etc.) is expensive. Finally, plant triage is difficult due to low environmental and maintenance pressures (Fang et al., 2011).

## 3.2. From waste to resources: the potential uses of bio-residues

In Europe, more than 75% of people live in cities. The main consequence is the large consumption of raw materials to build the city and a large production of waste that is exported out of the city. The city can be considered as an urban ecosystem with a linear metabolism, which can be compared to an input/output model of materials.

In Europe, 16 tons of material are currently used per person per year, 6 tons of which become waste. In 2010, total waste production in the EU amounted to 2,500 million tons. Of this total, only 36% was recycled, the rest was either thrown away or recycled (European Commission, http://ec.europa.eu/environment/waste/compost/).

All these wastes have a huge impact on the environment: (i) pollution, (ii) greenhouse gas emissions and (iii) material losses (http://ec.europa.eu/environment/waste/pdf/WASTE%20BROCHURE.pdf).

So, the question is: how to limit the export of waste out of the city?

It is necessary to change the urban metabolism to a circular model converting waste into a potential resource of "secondary raw materials" in order to find a more efficient and sustainable way. The main actions of the waste management policy are to improve waste prevention (changing consumer behavior), waste recycling, limiting the incineration of non-recyclable materials and the use of disposers.

Optional material:
http://ec.europa.eu/environment/action-programme/

### 3.2.1. Types of urban waste

Municipal waste is composed of domestic waste and other waste similar to household waste (commercial, office and public institutions). Its management depends on public policy and budgets. Biological waste represents one third of municipal waste. Currently, each European produces half a ton of this waste.

Biowaste is biodegradable and consists of (i) waste from gardens and parks, (ii) food and kitchen waste from homes, restaurants, canteens and commercial premises, and (iii) waste from food processing plants. It does not include forestry waste, agricultural waste, wastewater sludge or other biodegradable waste such as natural toxins, paper or processed wood. It also does not take into account those by-products of food production that never become waste (European Commission, http://ec.europa.eu/environment/waste/compost/).

### 3.2.2. Ways to recycle biological wastes

Several EU legal instruments address the treatment of bio-waste. Currently, the main environmental threat from bio-waste (and other biodegradable waste) is the production of methane from waste that decomposes in landfills, which accounted for 3% of total greenhouse gas emissions in the EU-15 in 1995. Landfilling is the worst waste management option for biological waste with negative impacts, due to the deterioration of the landscape and the pollution of water and air by the generation of methane and effluents. The Landfill Directive (1999/31/EC) obliges member states to reduce the amount of biodegradable municipal waste going to landfills to 35% of 1995 levels by 2016 (in some countries by 2020), this measure will significantly reduce this problem.

The most significant advantages of biowaste management would be the production of renewable energy sources and recycled compost that contributes to improve resource efficiency and soil quality. Composting is the most widely used biological treatment for green waste and bulky material.

Optional material for more information:
http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32008L0098
http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31999L0031
https://www.youtube.com/watch?v=B660d2c-RkA
https://www.youtube.com/watch?v=QBSGuUq2D9E

### 3.2.3. Potential uses of biological waste for plant production

Compost is used in agriculture, landscaping and land restoration. The EU legal instruments regulating the use of biowaste are presented in the "Green Paper on the management of biowaste in the European Union" (http://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A52008DC0811).

The popularity of the roof gardens and urban gardens initiated by associated community groups or urban gardeners increases the demand for urban soils. Urban gardeners and farmers want information about the quality of soil and its pollutant content in order to have healthy food and healthy landscapes.

There are solutions to improve the fertility of urban soil. Among them, introducing high amounts of organic matter (up to 40% of the volume) is important to enhance long-term soil fertility (Vidal-Beaudet et al., 2012; Cannavo et al., 2014). In fact, organic matter provides important soil benefits: physical fertility (soil structure for better water retention and air circulation), chemical fertility (nutrient density, capacity for exchange of carbon) and biological fertility (carbon, mineral and energy resources for soil organisms). Among the available composts, green waste compost is the most widely used in peri-urban and urban areas, due to the high amounts of plant pruning produced by cities.

The use of soils from agricultural plots to construct new buildings is controversial, given the decrease in arable land. An alternative for the protection of these natural resources is the reuse of waste to build functional silos (Séré et al., 2008). Cities are continually being renovated by demolishing older structures and producing demolition waste, such as masonry, concrete, track fill and excavated soils. This waste is regularly transported out of the cities and only a fraction is recycled (Marshall and Farahbakhsh, 2013). In 2009, it is estimated that civil engineering activities generated 250 million tons of waste in France. Compostable materials and green waste derived from the maintenance of gardens and city parks are also generated and massively exported outside urban areas to produce compost or energy. Some of these materials could be combined to generate solids adapted to the urban environment. They must show adequate bearing capacity, agronomic properties and drainage capacity. In addition, they must comply with environmental restrictions to avoid the release of pollutants into the surrounding aquifers.

Optional material: for more information
https://www.youtube.com/watch?v=QBSGuUq2D9E

## 3.3. Rainwater collection and greywater recovery

By 2050, 66% of the world's population will live in urban areas. The water cycle in urban areas is considerably different from that in natural areas. In fact, the presence of important impermeable areas causes flooding. Moreover, water infiltration is only possible when there are planted soils. Therefore, one of the main challenges is to promote water retention and/or infiltration by increasing green areas such as green areas, parks and gardens.

People living in cities are increasingly demanding more green spaces for their well-being. In fact, urban vegetation can offer various services such as:

- human benefits (health, social bonding),
- natural balance benefits (biodiversity, thermal regulation, air quality, water circulation and soil protection),
- economic benefits (construction promotion, plant waste repopulation, urban agriculture, attractiveness of the territory).

Cities develop rehabilitation strategies, the success of which depends on the quality and function of the soil that supports the plants and the quality of the water used to irrigate these plants.

### 3.3.1. Urban water hydrology

In a natural landscape, soil and vegetation naturally absorb 90% of precipitation through infiltration to the ground and evapotranspiration. In a city, asphalt, pavement and roofs quickly absorb water, creating large volumes of rapidly flowing runoff. Developed areas create more than 500% more runoff than natural areas of the same size. Runoff increases pollutant runoff and more treatment is required to reuse or dispose of the water.

The solutions for urban water management are water harvesting with open or underground water storage tanks or infiltration through innovative porous pavements.

Green infrastructures can facilitate water management at the neighborhood level:

- tree leaves reduce water runoff due to interception of rainfall;
- green soils temporarily dampen rainfall and enhance evapotranspiration;
- infiltration of field water decreases the volume of water and reduces the maximum head.

In general, runoff increases when vegetated areas decrease and decreases if there are green roofs. In dense infrastructure areas, green roofs are an efficient way to reduce runoff.

The infiltration of water into the soil depends on the physics of the soil properties: soil structure, granulometry and hydraulic conductivity of the soil.

### 3.3.2. Potential of green groundwater for water runoff control

Modern green roofs are formed by a system of layers placed on the support to support the environment and vegetation. It is a relatively new phenomenon and was developed in Germany in the 1960s, and has spread to many countries. Green roofs are also becoming increasingly popular in the United States, although they are not as common as in Europe. There are three types of green covers:

- Intense soils, which are thicker, with a minimum depth of 12.8 cm, and which can support a wider variety of plants but are heavier and require more maintenance;
- Extensive, shallow, 2 cm to 10 cm deep, lighter than the intense green ones and with minimal maintenance requirements;
- Semi-intense, with intermediate characteristics.

### 3.3.3. Grey Waters

Greywater is all the wastewater that is generated in office buildings without fecal contamination. The source of greywater includes toilets, toilets, bathrooms, shower stalls, washbasins. Fecal water of any kind is called blackwater to indicate that it contains human waste. However, under certain conditions, some leftover waste may enter the greywater stream through effluent from the sewer or wastewater treatment plants.

In general, greywater is safer to handle and easier to treat and reuse. The application of greywater reuse in urban water treatment systems reduces the demand for fresh water and the amount of wastewater that needs to be transported and treated.

The composition of greywater depends mainly on the geographical origin, the category of building, the activity of the occupants. Most greywater is easier to treat and recycle than blackwater, because the levels of pollutants are lower. If it is collected with a separate plumbing system from blackwater, it can be used directly. If it is treated, it must be used within a very short period of time or it will begin to rot due to the organic solids present in the water. It cannot be used for drinking.

The treatment processes used are biological systems (constructed wetlands, living plants, bioreactors) or mechanical systems (sand filtration).

The main advantages of using greywater for irrigation are the preservation of water resources and the supply of nutrients; the main disadvantages are salinity, metal accumulation and the presence of pathogens.

### 3.3.4. Water storage from roadways

Water flows in urban areas are different from natural areas. The runoff of rainwater on the road is a source of pollution. A possible solution is to store this water.

# 4. Urban Agriculture to improve the city's climate

## 4.1. Urban agriculture to improve the city climate

The last decades have been characterized by a continuous, intense and complex urbanization process, and today almost 54% of the world's population lives in urban areas while three quarters of European citizens live in metropolitan regions (WHO, 2015). The development of cities must respect and protect the environment. Cities are composed of structures and external interventions of anthropogenic origin, which can become environmental problems (Naishi et al., 1998). Much of the city's subsoil is often sealed with impermeable materials and surfaces that do not absorb water and increase the presence of runoff. Furthermore, most of the structural materials used in these environments are characterized by low light reflection (low albedo), a fact that intensifies the conversion and storage of thermal radiation. Therefore, the urban surface layer tends to be warmer than the rural one (Naishi et al., 1998; Britter and Hanna, 2003).

This effect is exacerbated in cities where there is almost no green infrastructure. In other words, as green breathable surfaces are replaced by impermeable soil cover, the water available for evaporation is reduced, affecting the latent heat flow. Therefore, especially in the absence of precipitation, the value of the Bowen ratio (sensible heat flux / latent heat) is very high (Bonafè, 2006).

When isothermal corbes are represented on a meteorological map, a profile is observed that resembles the topographic contour of an island.

This is the reason why the urban surface layer is also called "heat island" (urban heat island or UHI) (Naishi et al., 1998). In densely populated cities, higher temperatures are associated with an increase in energy emitted by building air conditioners and the effect of pollution associated with road traffic, such as the emission of pollutants, including sulfur dioxide, carbon monoxide, nitrous oxides, and suspended particles (Henderson et al., 2007). Pollution effects can be aggravated in climates with a very hot season (White et al., 2001; Koppe, 2004). Air pollution has become a problem since the beginning of the industrial revolution. Transportation, industrial activities, domestic heating and waste incineration are the main sources of air pollutants. The main pollutants produced by human activities are sulfur oxides (particularly sulfur dioxide, SO2), nitrogen oxides (NO2), carbon monoxide (CO), volatile organic compounds (VOCs, mainly methane, CH4) and particulates 10 or 2. 5 (PM10 and PM2.5) is dust with a diameter of less than 10 µm and 2.5 µm, respectively, as well as dissolved substances.

Recent studies (Banting et al., 2005; Rosenzweig et al., 2006) show that the increase of green infrastructure in urban environments can contribute not only to the mitigation of microclimate problems, but also to a wide range of ecosystem services, such as the improvement of air quality (Currie and Bass, 2008; Speak et al..., 2012) or providing resilience to exceptional weather events (Berndtsson, 2010; Gregoire and Clausen, 2011).

## 4.2. Green infrastructures for air filtering

Urban vegetation affects air quality by removing its pollutants; The air purification effect can be produced aerodynamically, when the plant mass is interposed to the direction of the wind and deflects particles, or by absorption through stomatal openings during the physiological processes of photosynthesis and transpiration of plants (Chapparo and Terradas, 2009). In vegetated areas, the presence of CO2 is reduced because excess carbon is stored as biomass during photosynthesis (McPherson and Simpson, 1998). In a recent study (Davies et al., 2011), it was estimated that home gardens allow to store the emission of about 0.76 kgC m-2. The presence of urban green infrastructures modifies the physical distribution of airborne pollutants, as they act as obstacles that exert a frictional force on the atmosphere (Britter and Hanna, 2003).

In plants, the absorption of air pollutants occurs mainly through the opening of the stomata (Winner, 1994) and takes place during the physiological processes of plant photosynthesis and transpiration. These are passive processes, by which gases dispersed in the atmosphere enter the plant. Once in plant tissues, some of the dissolved air pollutants such as NOx and SOx are absorbed by an active biochemical reaction (Baldocchi et al., 1987) and are used for plant metabolic processes.

Dust components (PM10-2.5) are removed from the atmosphere by electrostatic deposition at the cuticle of the particles (Prajapati, 2012), and are partially absorbed, rented through runoff or re-suspended in the air. Recent studies have shown that the creation of new green infrastructure in urban areas significantly reduces airborne pollutants, indirectly contributing to increased environmental health and well-being of citizens (Nowak et al., 2006). Green roofs have been shown to efficiently remove these particles.

The ability to reduce dissolved gases and PM is attributed to the increase in impact surfaces due to the coverage of plants that produce scrubbing effects (Petroff et al., 2008). This is a relatively new area of study and a clearer understanding of the air filtering capacity of these green infrastructures is likely to come in the near future (Currie and Bass, 2008).

## 4.3. Minimizing the urban heat island

The effect of the urban heat island consists in the increase of temperature in urban areas compared to the surrounding rural areas (Phelan et al., 2015) due to human activities and to the higher absorption of solar radiation by artificial materials (asphalt and cement). Vegetation can play a key role in the overall temperature regulation of cities, since, through evapotranspiration, air temperature can be reduced. Phelan et al. (2015) documented the increase of vegetation in urban areas as a possible remedy for urban heat islands. By placing a vegetation canopy surrounding and around built structures, the first observed effects are temperature mitigation and reduction of energy costs associated with air conditioning, especially during the summer.

The indirect cooling effect of vegetation structures is determined by a great capacity to protect against thermal radiation, lowering primarily the temperature of the building surface (Wong et al., 2003a). This benefit is a direct consequence of the albedo modification of walls and roofs. Buildings with waterproofed, friable substrates generally have a low albedo, which means a higher absorption of solar radiation.

This results in a more intense surface cooling. During the summer, this leads to an increase in the heat island effect, an increase in energy consumption for indoor artificial cooling and the emission of pollution. In European cities, more than 90% of the roofs are dark-colored and the roof surface under sunlight reaches temperatures around 80°C, with a negative impact on the duration of the waterproofing (Santamouris, 2014). Alternatively, the adoption of green covers enhances the conversion of solar energy into transpiration (cooling), as well as plant growth. This is particularly the case in the summer, given the direct relationship between plant transpiration and solar radiation and temperature. Consequently, thermal isolation is produced both by the plant cover and by the substrate.

*The use of plants instead of air-conditioning to save money*

Urban areas tend to have a lower level of humidity than the surrounding rural areas due to the absence of vegetation and the increased absorption of the sun's energy caused by asphalt or concrete surfaces. This also explains why the inner areas of the city are often warmer than their surroundings. This phenomenon, known as the urban heat island effect, can have serious consequences for vulnerable people, such as people with chronic illnesses or the elderly, particularly during heat waves. The humid air generated by natural vegetation helps to counteract this phenomenon. Humidity levels could also be artificially increased with electricity to evaporate the water, but this would cost significantly more than the use of natural vegetation (around 500,000 € per hectare). Working with nature and the use of green infrastructure in an urban environment, through the incorporation of parks, green spaces, green terraces/murbs and fresh air corridors, is generally a much cheaper and versatile option to help mitigate the effect of the urban heatwave. It can also help absorb $CO_2$ emissions, improve air quality, reduce rain runoff and increase energy efficiency.

## 4.4. Financing of urban agriculture initiatives

The private sector also plays an important role in investing in urban agriculture, especially in the development of innovative "green" technologies. On the other hand, urban agriculture projects are complex and are often perceived as a risk by investors, especially in the early stages of development. Specific financial instruments (risk-sharing practices) can help reduce the risks associated with urban agriculture projects. Consequently, the European Commission and the European Investment Bank (EIB) are implementing various options to facilitate funding to support investments related to natural capital, including urban agriculture projects.

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