URBAN GREEN TRAIN

URBAN GReen Education for ENTteRprising Agricultural INnovation

Urban Green Train Modules and Resources (IO2)

Module 2:

Resource use from a challenge perspective

Erasmus+

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MODULE 2 “Resource use from a challenge perspective”

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INTRODUCTION

This module and the related educational resources have been developed within URBAN GREEN TRAIN (URBAN GReen Education for ENTteRprising Agricultural INnovation) a project funded by the European Union and the Italian National Agency for the ERASMUS+ Programme. The aim of URBAN GREEN TRAIN ERASMUS+ project (2014-1-IT02-KA200-003689) is to encourage pioneering business oriented initiatives in urban agriculture based on knowledge exchange and mutual cooperation among different actors, as to meet the global demand for urban green innovation.

One of the main outcomes of Urban Green Train is a set of modules and resources (IO2) especially designed to be a useful toolbox for anybody looking to operate, directly or indirectly, in the world of urban agriculture.

The set includes **5 modules suitable for at presence and at distance learning, for a total duration of 150h.** The modules structure and content have been defined on the basis of an accurate analysis of the training needs of relevant key actors in urban agriculture, carried out by project partners in the their respective countries and illustrated in the publication "URBAN AGRICULTURE INITIATIVES TOWARD A MINDSET CHANGE" (IO1). URBAN GREEN TRAIN modules are the following:

Module 1: Introduction into urban agriculture concept and types

Module 2: Resource use from a challenge perspective

Module 3: Urban agriculture types/production systems and short food chains

Module 4: Networking and governance

Module 5: The world of business and urban demands

The URBAN GREEN TRAIN Modules and Resources (IO2) have been tested within a pilot international course offered from August 2016 to January 2017, both fully online and in a blended modality, to a wide range of participants from different European countries and professional backgrounds, through the e-Learning platform of the University of Bologna. Thanks to the feedbacks of pilot course participants and tutors, the modules and resources have been improved and finalised and made available in the present format to Higher Education Institutions and other private and public adult learning providers with the purpose of offering a complete and structured training pathway tackling all aspects relevant to new ways of doing business in agriculture.

URBAN GREEN TRAIN project is coordinated by the University of Bologna, Alma Mater Studiorum – Department of Agricultural Sciences (www.scienzeagrarie.unibo.it) and developed in cooperation with the following partners:

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- Vegepolys, Angers, France www.vegepolys.eu
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- Grow the Planet, Italy www.growtheplanet.com
- RUAF Foundation, The Netherlands www.ruaf.org

More info at: www.urbangreentrain.eu

MODULE 2 “Resource use from a challenge perspective”

Aims

This module aims at introducing participants to the relationship between urban agriculture and urban ecology. Strategies for improving the role of urban agriculture in reducing the city ecological footprint will be defined and critically addressed. Students will explore the different elements contributing to resource efficiency and waste management, as well as to the citizen’s wellbeing. At conclusion of the module, students will be able to identify and assess entrepreneurial opportunities and innovation possibilities for each challenge.

Structure

Module 2 contents have been organised as follows:

- 2.1 Urban Agriculture for biodiversity and ecology
    - 2.1.1 Urbanization and the loss of biodiversity
    - 2.1.2 Urban Agriculture and Green corridors
    - 2.1.3 Sustainable management of agricultural inputs
    - 2.1.4 Ecosystem services by ancient/new genotypes
    - 2.1.5 Management of polluted soils
- 2.2 Urban Agriculture for reducing the city ecological footprint
    - 2.2.1 Climate change mitigation: Local production and foodmiles
    - 2.2.2 Boosting freshness: Food waste reduction and environmental implications
    - 2.2.3 Environmental justice: Minimizing geographic tradeoffs by promoting localism
    - 2.2.4 Assessing the sustainability dimensions of UA
- 2.3 Urban Agriculture for resource efficiency and waste management
    - 2.3.1 RTG and green walls: low energy consuming building acclimatization
    - 2.3.2 Waste-to-resources: the potential uses of bio-waste
    - 2.3.3 Rainwater harvesting and greywater recovery
- 2.4 Urban Agriculture for improving city climate
    - 2.4.1 UA for improving city Climate
    - 2.4.2 Air filtering green infrastructures
    - 2.4.3 Minimizing the urban heat island
    - 2.4.4. Financing urban agriculture initiatives for improved city climate
- 2.5 Bullet points: remember the economic dimension

Learning objectives

Main learning objectives of Module 2 are the following:

TOPIC TITLE	TIME	LEARNING OBJECTIVES	LEARNING OUTCOMES
2.1 Urban agriculture for biodiversity and ecology	5.5	To introduce students to the relationship between cities and biodiversity To introduce students to the concept of green corridors To define how agricultural input may be sustainably managed To define the role of plant genotypic resources in providing ecosystem services To describe how UA can be practiced in polluted soils To link ecological issues in UA systems	Participants are able to: Describe the link between cities and biodiversity Define green corridors and identify them in a city plan Identify agricultural practices that respect ecosystems and biodiversity Plan and manage ecological agricultural systems
2.2 UA for reducing the city ecological footprint	4.5	To understand the environmental footprint of current urban food system To understand the relevance of food waste on cities environmental footprint To define food systems from a Life Cycle perspective in economic, environmental and social terms.	Participants are able to: Critically assess diverse food systems in terms of environmental, economic and social terms Plan and develop proximity agriculture projects
2.3 UA for resource efficiency and waste management	9	To understand energy efficiency at city scale To identify the energetic nexus between built environments and green infrastructures To comprehend the relevance of composting in efficient city management To define the water cycle in the urban environment and efficient water use associated with UA To define space and land as a resource in the urban environment	Participants are able to: Design and implement resource efficient UA projects
2.4 UA for improving city climate	5	To understand the link between urbanization and air pollution To relate green infrastructures with ecosystem services including air filtering and microclimate regulation	Participants are able to Design air filtering green infrastructure Design climate resilient UA
2.5 Bullet points: remember the economic dimension	1	To identify possible innovations for main module's subtopics	Participants are able to: Considered city related challenges and create UA business List of putative innovations

MAIN CONTENT AND RESOURCES

2.1 - Urban Agriculture for biodiversity and ecology

Introduction

This chapter will introduce students to the relationship between cities and biodiversity and the concept of green corridors. Within the chapter, it will be defined how agricultural input may be sustainably managed, the role of plant genotypic resources in providing ecosystem services, and how urban horticulture can be practiced in polluted soils. Furthermore, students will explore the links between ecological issues in urban agriculture systems. When completing the chapter, participants are able to describe the link between cities and biodiversity, define green corridors and identify them in a city plan, identify agricultural practices that respect ecosystems and biodiversity and plan and manage ecological agricultural systems.

2.1.1 - Urbanization and the loss of biodiversity

In the last century, people moved gradually from rural areas to cities and urbanized areas. Today, just over half of the world's population lives in urban environments. Food production sites have to be increasingly located near main consumption centres because the rate of urbanization is increasingly expanding. Consequently, urban agriculture is gaining importance all over the world and it is necessary to devise new strategies to ensure the food supply and food security of those who live in urban environments.
This chapter will address the following subjects:

- **Urbanization trends**. Since 2007, the urban population exceeded the rural population, leading to a marked growth of urban areas. Trends show that, in 2050, the urban population will constitute 70% of the total. Cities are growing mainly in world biodiversity hotspots.
- **World biodiversity hotspots and cities distribution.** Hotspots are global areas for conservation. Hotspots are characterized by exceptional levels of plant endemism (at least 1,500 species of vascular plants) and by serious levels of habitat loss (lost at least 70% of its original habitat). Worldwide, 34 biodiversity hotspots have been identified. Collectively, these hotspots are estimated to house high levels of biodiversity, including at least 150,000 plant species as endemics and 77% of the world's total terrestrial vertebrate species. The 34 biodiversity hotspots identified worldwide by Conservation International all contain urban areas. Cities containing rich biodiversity are numerous, and they are located in a multitude of geographic locations such as Brussels, Cape Town, Chicago, Curitiba, Frankfurt, Mexico City, New York City and Singapore, to name a few. Brussels, for example, contains more than 50 percent of the floral species found in Belgium. Cape Town is host to 50 percent of South Africa's critically endangered vegetation types and approximately 3,000 indigenous vascular plant species. Singapore has more than 10 ecosystems within its bounds and recent surveys have recorded more than 500 species of plants and animals new to Singapore, of which more than 100 are new to science.
- **Global biodiversity loss**. Across the world, ecosystems have continued to be converted for agricultural and other uses at a constant pace over at least the last century. Conversion has been slower in areas, such as Mediterranean forests, where most suitable land for agriculture had already been converted by 1950 and where the majority of native habitats had already been lost. Species extinction is a natural part of Earth's history. However, over the past 100 years humans have increased the extinction rate by at least 100 times compared to the natural rate. The current extinction rate is much greater than the rate at which new species arise, resulting in a net loss of biodiversity.
- **Cities growth and biodiversity.** Cities growth causes agricultural lands reduction, deforestation and habitat loss, reduction of open spaces, pollution and soil sealing, overall resulting in lower climate resilience, ecosystems fragmentation and biodiversity loss.
- **Urban ecosystems**. Urban ecosystems are artificial and offer specific habitat condition. Biodiversity in the urban environment is highly specific and varies in relations to human pressure and activities.
- **Biodiversity and ecosystem services.** Ecosystem is a way of describing nature's functioning and it consists of components (plants, animals, microorganisms, water, air etc.) as well as the interactions between these components. Functioning ecosystems are the foundation of human well - being and most economic activity, because almost every resource that humankind utilizes on a day-to-day basis relies directly or indirectly on nature. The benefits that humans derive from nature are known as ecosystem services. They can be divided into four categories: provisioning services, regulating services, habitat or supporting services, and cultural services.

Follow the slideshow below:

2.1.1 PPT Presentation

2.1.2 - Urban Agriculture and Green corridors

According to UN Secretary Ban Ki-moon (Secretariat of the Convention on Biological Diversity, 2012), the challenges of urbanization are great. Indeed, well-designed cities can sustainably accommodate large numbers of people in a relatively small amount of space, offering improved quality of life and allowing for greater resource efficiency. As seen in the previous chapter green infrastructures and corresponding ecological services are key factors for the liveability of cities. This chapter will address the theme of the positive role that cities can play regarding the preservation and promotion of biodiversity. Urban agriculture can become, through the construction of green (ecological) corridors within cities, a determining factor for improving both human well-being and environmental protection.
This chapter will address the following subjects:

- **Urban biodiversity, key messages.** Urban biodiversity is the variety and richness of living organisms and habitat diversity found in and on the edge of human settlements. Key messages: 1) Urbanization is both a challenge and an opportunity to manage ecosystem services globally. 2) Rich biodiversity can exist in cities. 3) Biodiversity and ecosystem services are critical natural capitals. 4) Maintaining functioning urban ecosystems can significantly improve human health and well-being. 5) Urban ecosystem services and biodiversity can help contribute to climate change mitigation and adaptation. 6) Increasing the biodiversity of urban food system can enhance food and nutrition security. 7) Ecosystem services must be integrated in urban policy and planning. 8) Successful management of ecosystem services and biodiversity must be based on multi-scale, multi-sectorial and multi-stakeholder involvement. 9) Cities offer unique opportunities for learning and education about a resilient and sustainable future. 10) Cities have a large potential to generate innovations and governance tools and therefore can and must take the lead in sustainable development.
- **Green infrastructures for biodiversity.** In cities, there are different kind of green infrastructures: intensive green roof, extensive green roof, urban gardens, and wild flowers in the flowerbeds.
- **Green corridors (definitions).** Ecological corridors help maintain a cohesion in otherwise fragmented ecosystems. Through the connection of fragmented habitats, the viability of animal and plant species is improved by enlarge habitats, dispersion of young animals, and re-use of empty habitats. Ecological networks consist of core areas, corridors and buffer zones. Corridors create a permanent connection between core areas. The core areas and connecting corridors are surrounded by buffer zones, which serve as a protection from possible disruptive external influences. Beyond the core areas and connecting corridors lies another area with land selected for sustainable use with preservation of several ecosystem functions.

Follow the slideshow below:

URBAN GREEN TRAIN 2.1.2 PPT presentation

2.1.3 - Sustainable management of agricultural inputs

Urban agriculture is gaining attention of the public, being considered a sustainable activity that reduces food miles, creates communities and sense of belonging, enables physical activity and overall improves well-being in the cities. Indeed, when plants are grown in the urban environment, a number of agronomic questions arises. Is it really more sustainable to grow plants in individual plots rather than in a farm? Is the product healthy? How can a non-trained urban farmer grow sustainably agricultural plants? How can resources (e.g. water, plant nutrients) be wisely managed? How can pests and diseases be controlled with no arm to the environment and the users?

These questions were addressed in the framework of the EU project HORTIS (Horticulture in Towns for Inclusion and Socialisation). The project, funded within the framework of the Lifelong Learning Programme (LLP-GRUNDTVIG) aimed at the dissemination of good urban agricultural practices, with the final goal to develop sustainable urban agriculture in European cities. Among the output of the project, a series of e-book was produced and is freely downloadable from the project website (www.hortis-europe.net).
The five e-books addressed the following topics:

- Sustainable Community Gardening in cities
- Sustainable urban garden management
- Urban garden cultivation systems
- Simplified soilless systems for urban vegetable production
- Eating closer to home: an urban consumer's manual

Please read at least one chapter of the enclosed e-book on sustainable management of the urban garden. After reading, perform the Assignment 2.1.3

2.1.3 Sustainable Urban Garden Management

Assignment 2.1.3: read the book chapter, answer the following questions and discuss with other participants

1. Which chapter did you read?
2. Can you please list at least five take-home messages that you learned from the chapter?

2.1.4 - Ecosystem services by ancient/new genotypes

Introduction

The present lesson will provide essential knowledge on the relevance of plant genetic biodiversity and the contribution that urban agriculture can play in ensuring preservation.

The following video, part of the movie documentary "God save the green" illustrates the features of a roof biodiversity garden in the city of Turin, Italy.

Watch the video at: https://www.youtube.com/watch?v=sSQgZ_3xk3U

Assignment 2.1.4. See the video and answer to the questions

1) Which ecosystem services may be provided by the green roof shown in the video (please rate them in order of relevance)?

a. Thermal regulation
b. Biodiversity promotion
c. Flood control
d. Food production
e. Therapeutical / antistress

2) Which are in your opinion the most important elements to take in consideration before creating a roof garden similar to the one shown in the video (please rate them in order of relevance)?

a. Weight load
b. Wind occurrence
c. Cultivar selection
d. Roof waterproofing
e. Roof accessibility
f. Safety fences

Agriculture and plant breeding

In recent years, a growing concern has arisen with regard to the adoption of commercial hybrids in agriculture. Cultivar selection has been associated with loss of traditional genotypes, insurgence of allergies and pathologies, and decrease resilience to environmental and climate changes. Indeed, plant breeding may not be considered a recent trend in agriculture, and is actually estimated to date back 9'000 to 11'000 years. Initially, early farmers selected food plants with particular desirable characteristics and used them as seed sources for subsequent generations, overall resulting in an accumulation of desired features over time. Starting from the experiments of Gregor Mendel, hybridization was introduced, leading to the current application of modern plant breeding, which encompasses a range of disciplines, including molecular biology, cytology, systematics, physiology, pathology, entomology, chemistry, and statistics.

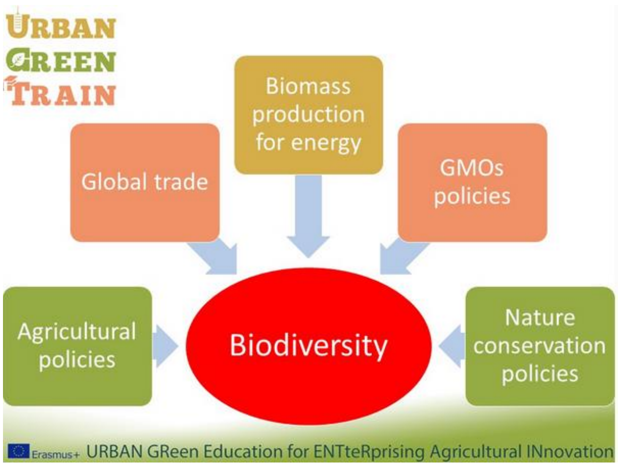
The major interactions between agriculture and global biodiversity appeared between the end of 19th and the beginning of 20th century, when a marked decline in extensively used grassland and pastoral land occurred, as innovation in agricultural technologies was established. Such intensification was accelerated in the second half of the 20th century through the adoption of common agricultural policies (CAP) and the globalization of agricultural markets. This resulted in increasing habitat degradation, overproduction of food products, intensification of farming practices, and the concentration of production into fewer, larger and more specialized agricultural farms. Only starting from the 1990s, CAP reforms started to recognize the environmental role of faming, integrating policies that valorized biodiversity promotion and preservation at farm level. The results of these agro-environmental schemes in achieving biodiversity conservation goals vary dramatically across Europe. Consistently, it has been shown that the effect of set-aside schemes on species richness and population density depends on the age of the set-aside area, the total area managed by set aside schemes and the intensity of agriculture.

Today, agricultural landscape covers 45% (180 million ha) of the European Union territory (EU27). Agricultural lands however differ considerably in term of biodiversity, according to soil condition, water availability, climate, slope and management factors. Consistently, the European Environmental Agency (EEA) in 2004 identified three types of so-called High Nature Value (HNV) farmland systems, which are respectively:

- Type 1: farmland with a high proportion of semi-natural vegetation;
- Type 2: farmland dominated by low intensity agriculture or a mosaic of semi-natural and cultivated land and small-scale features;
- Type 3: farmland supporting rare species or a high proportion of European or world populations.

Based on this classification, the maintenance of biodiversity depends directly on traditional types of agricultural land use, which are overall decreasing due to both farmland abandonment and intensification of land use. As HNV farmlands decrease, the survival of all those species adapted to their diversity of structures and resources becomes threatened.

The major pressure currently affecting farmland biodiversity are described in the figure below:



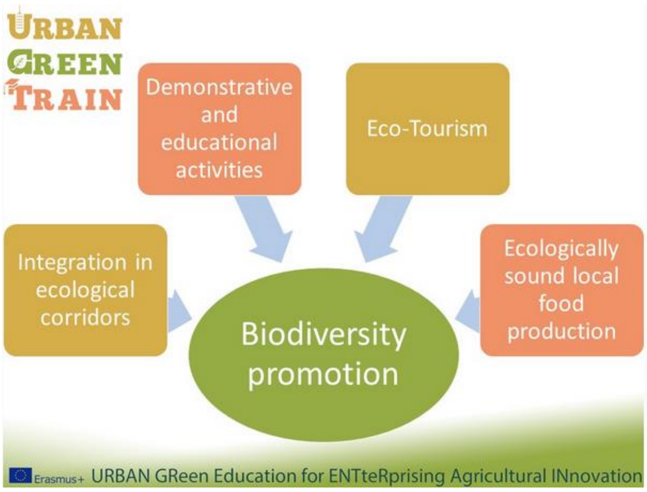
Main factors affecting biodiversity in global agricultural systems.

European and National legal and administrative schemes have been adopted to support biodiversity in agricultural and urban landscapes. These include, amongst other, the following:

- The establishment of nature reserves (European Natura 2000 network, comprising more than 25’000 sites and covering an area of 1 million km^2 (EU, 2007).
- Buying land and managing it for biodiversity purposes, as adopted in the Netherlands and UK.
- Supporting maintenance or restoration of natural habitats through dedicated funding opportunities (e.g. EU-LIFE+ program).
- Biodiversity conservation programs aiming at purchase of agricultural land, e.g. www.euronatur.org.
- Supportive measures promoted by private companies (e.g. IUCN project on Sustainable Agriculture and Steppe Biodiversity in Russia and Ukraine).
- Related supporting measures promoted by regional/national administrations for the promotion of local/regional market or tourism.

Moreover, eco-Labelling (e.g. organic or biodynamic production, especially for large retail food chains) and community-supported agriculture (for short-food chain) improve environmental sustainability of agriculture and promote biodiversity.

Consistently, in order to maximize the impact of agriculture in biodiversity preservation and promotion, the following activities may be addressed:



Agriculture and biodiversity.

Tutorial: How to conserve tomato's seeds

Please watch the following video about the use and maintenance of traditional genotypes in urban horticulture, from the EU project HORTIS:

Watch the video at: https://www.youtube.com/watch?v=u9Wotav21Tc

The role of urban agriculture on biodiversity preservation

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

1. It is located nearby or in proximity of urban centers, where biodiversity is of crucial relevance but also highly endangered;
2. It may represent both a risk and a promoter of urban biodiversity, according to its way of management;

3. It may raise awareness in urban citizens about the relevance of an environmentally friendly way of life;
4. It may constitute a biodiversity reservoir when traditional/local cultivars and species are grown.

2.1.5 - Management of polluted soils

Assignment 2.1.5: Please read the following paper and add a comment in the appropriate forum / discuss with other participants

2.1.5 Heavy metal accumulation in vegetables grown in urban gardens

2.2 - Urban Agriculture for reducing the city ecological footprint

Introduction

This module focuses on the ecological footprint of urban areas and food products and the potential contribution of urban agriculture to minimize the negative impacts. The ecological footprint (impact of human activities measured in terms of the area of biologically productive land and water required to produce the goods consumed and to assimilate the wastes generated) refers to the planet dimension of sustainability that seeks to ensure a livable future. Therefore, the ecological footprint accounts for the required resources to sustain a certain activity. In the case of cities, although representing less than 3% of the Earth's surface, cities largely contribute to the global environmental impacts. The current urban metabolism implies the consumption of several resources (food, water, energy or land) which are converted into wastes 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 environmental implications of the current metabolism. Such initiatives focus on reducing the consumption of resources and minimizing the emissions and wastes while promoting self-sufficiency, local production and circular metabolism (re-use, recycle, circular economy).

This chapter will address the following subjects:

- Climate change and food production
- Local production and food miles
- Environmental implications of food waste
- Sustainability assessment

The following slideshow introduces the topic and defines important concepts.

URBAN GREEN TRAIN 2.2 Intro PPT Presentation

Assignment 2.2. Please read sections 1 and 2 of the article (link below), which reviews the environmental implications of urban agriculture in terms of resources use and urban metabolism and add a comment to the discussion group / discuss with other participants.

URBAN GREEN TRAIN 2.2 (1) Urban versus conventional agriculture, taxonomy of resource profiles: a review

2.2.1. - Climate change mitigation: Local production and foodmiles

The sector that produces the highest amount of greenhouse gas emission at European level is food production. While agricultural production contributes to climate change (e.g., land use changes, resources consumption, fertilizers application, fuel consumption, food loss and waste), the effects of climate change to natural ecosystems such as desertification or soil erosion drastically affects agriculture and food production. The entire food supply-chain contributes to climate change, particularly in stages that involves transportation requirements. In the context of designing a sustainable future, local food movements have created alternative food networks to shorten the long distances while reducing the contribution to climate change. The concept of "avoided food-miles" has been used in the literature to evaluate the different environmental impacts of imported and local food supply-chains, mainly in terms of energy consumption and climate change. Even more, local food systems are also known as "km 0". The use of urban spaces for boosting local food production through urban agriculture initiatives can positively contribute to reduce the environmental impacts related to urban food consumption.

The following slideshow details the relation between climate change and local production by defining concepts and showing case studies.

URBAN GREEN TRAIN 2.2.1 PPT Presentation

2.2.2 - Boosting freshness: Food waste reduction and environmental implications

According to the Food and Agriculture Organization (FAO), around 30% of the food that is produced is wasted, accounting for 1.3 billion tons of food waste per year. According to figures from the European Commission, only in Europe 100 million tons of food waste are generated and this value can be increased up to 120 million tons by 2020 if no mitigation actions are implemented. Thus, food waste has become a hotspot for global food security. Plans and programs are being designed and implemented to promote the reduction of food waste generation at production and consumption stages. Local food production can positively contribute to this purpose by minimizing the supply-chain of food products.

The following presentation highlights main facts and figures of food waste and a video about the environmental implications of food wastage produced by UNEP.

2.2.2 PPT Presentation

Watch the video http://www.unep.org/newscentre/videos/shortfilms /MASTER99.mp4

Assignment 2.2.2.

Read the following article, answer the following questions, and discuss with other participants.

2.2.2 (1) Energy balance for locally grown versus imported apple fruit

- What supply-chains are compared?
- What environmental indicators do the authors use?
- What do the main results suggest with regard to consuming local products and environmental impacts?

2.2.3 - Environmental justice: Minimizing geographic trade-offs by promoting localism

The globalized food industry generates several environmental injustices, such as soil erosion, deforestation, biodiversity loss, water depletion or contamination. Furthermore, urban development has progressively created local environmental injustice since poor neighborhoods are linked to deteriorated environments with lower life quality. Local food movements seek minimizing the geographical trade-offs of the global food industry by developing alternative food systems. Furthermore, urban agriculture projects improve social justice and neighborhood restoration of cities.

Assignment 2.2.3. Read the following e-book that explores local food systems and alternative supply-chains employed in urban agriculture and discuss with other participants.

2.2.3 Eating closer to home: an urban consumer's manual

2.2.4 - Assessing the sustainability dimensions of urban agriculture

Urban agriculture systems seek to minimize the impacts of local food production to the three pillars of sustainability: environment, society and economy. Academics are currently working on developing assessment tools that evaluates sustainability from a global perspective. For example, life cycle tools have been developed for the environment (life cycle assessment), the economy (life cycle costing) and the society (social-LCA). In this unit, we will discuss around the way of assessing sustainability from a quantitative perspective.

Assignment 2.2.4. Read the following paper and participate in the discussion forum / discuss with other participants:

URBAN GREEN TRAIN [2.2.4 Techniques and crops for efficient rooftop gardens in Bologna, Italy]

Guide for discussion

- What are the environmental indicators considered? Would you include further environmental indicators in the assessment? Why?
- What is the concept of eco-efficiency? Is eco-efficiency an easy concept to communicate the results to the general public?
- What indicators could be used to evaluate the social dimension?

2.3 - Urban Agriculture for resource efficiency and waste management

Introduction

This chapter will enable students to understand energy efficiency at city scale, identify the energetic nexus between built environments and green infrastructures and comprehend the relevance of composting in efficient city management. Moreover, it will define the water cycle in the urban environment and efficient water use associated with urban agriculture, as well as space and land as a resource in the urban environment. When completing the chapter, participants will be able to design and implement resource-efficient urban agriculture projects.

2.3.1 - Rooftop greenhouses and green walls: low energy consuming building acclimatisation

Introduction

Why roof and wall plantations?
The reasons to include green wall or rooftop/lateral greenhouses to a building are multiple:

- Improved quality of life
    - Improve visual aspect (however, it mostly concerns the walls, or rooftop plantation without a greenhouse)
    - Reduce the noise level
    - Answer the social and environmental needs for a comeback of nature in cities by providing animals and plants species with a living environment
- Improved storm water management, as rooftop cultivation can temporarily stock some of the water, allowing reducing the storm water runoff.
- Local food production, mostly on existing or industrial buildings (it mostly concerns the rooftop plantation for practical reason)
- Reduce energy demand:
    - Green wall
    - Rooftop greenhouse
    - Vegetated double-skin facade

The last point is the subject of this course, and will be covered at length. The other points will be further developed in other sections of the course.

Scope of the lesson

The thermal effects of building greening and greenhouses will be covered, with a focus on green wall and rooftop cultivation. Due to the growing interest in building-based agriculture and nature-based solutions, the lesson includes greenhouses in/on buildings, as well as the vegetation of double-skin facades, which behave as lateral vertical greenhouses.
After a quick recapitulation of the different building greening systems, some basics of the physics behind heat transfer will be given. Only principal results relevant for the study of building energy will be exposed.

Cultivation systems

Rooftop cultivation systems

A wide panel of rooftop cultivation systems exist depending on their goals, from the simple decorative systems to the food production greenhouse. The diversity in scope leads to big variations in the installation complexity and cost. From a technical point of view, the different cultivation systems are distinguished by their thickness, mainly the substrate one. Finer substrates are simpler but cannot allow growing large plant, whereas even tall trees can be planted in thick (above 30 cm) substrates.

Intensive rooftop in Monaco (left), extensive rooftop in Dardilli France (middle) and semi-intensive rooftop in La Rochelle, France (right)

These differences will affect the energy transfers between the interior and the exterior of the roofs, as thicker substrate give more thermal insulation.

Green wall cultivation system

For the green walls, the possibilities are limited by the vertical geometry, and a distinction is made on the presence or not of a growing medium on the entire height.

Facade greening system (Kontoleon and Eumorfopoulou, 2010)

Living wall examples (intensive system) (Kontoleon and Eumorfopoulou, 2010)

Different methods of plants attachment to the structure of extensive living walls (Mazzali et al., 2013)

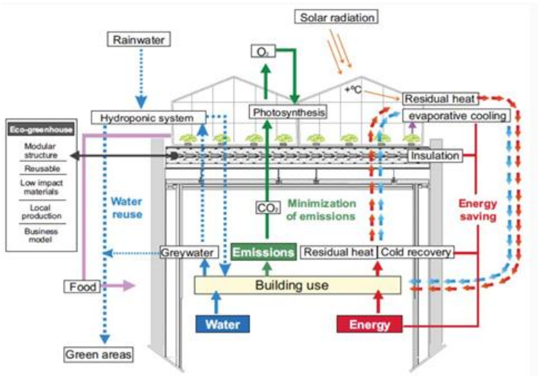
The plants, and particularly the leaves, allow reducing the insolation and the surface temperature. Hence, the reduction of the building cooling needs in summer. Moreover, and as for the roof, the presence of substrate or growing medium would increase the insulation.

Urban greenhouses on buildings

The greenhouse installed on the roof are more or less identical to the classical ones. As the primary objectives of urban greenhouses rely more on local food production to reduce the environmental footprint of food consumption, few data are available for building energetic gains.

Rooftop Greenhouse (nexuscorp.com)

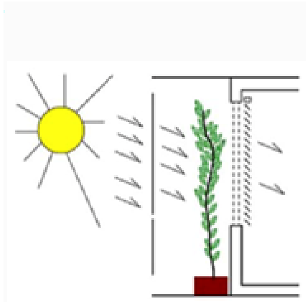
The difference with common greenhouses, and the advantage for building energy consumption, concerns the coupling with the underlying building. Indeed, the reuse of the energy from one part of the building to the other allows saving. The greenhouse could serve as an aide or as a complete HVAC system in summer for the underlying building. The latter heating system would be used to warm the greenhouse.



Conceptualization of RoofTop Eco.Greenhouse, with interchange of water, energy and CO_2 between the greenhouse and the building (Cerón-Palma et al., 2012)

Some buildings are constructed using so-called "double-skin" facade where the walls of the structures are doubled, on the exterior side, by a glass casing. The aim is to use the greenhouse effect to warm the intermediate space in winter, and then use it to temperate the inside air. In summer, the space of the double-skin facade is used to collect or evacuate the solar radiation absorbed by the facades by ventilating the air.

However, during hot summer, the cooling need increased and shadowing system can further increase the efficiency of the double-skin facade. In this context, the use of plants can be a cheap and efficient way to limit the load on HVAC system. The resulting system is very similar to a vertical greenhouse.



Scheme of the installation of plants in a double-skin facade (Zhou and Chen, 2010)

The cooling effects are mainly due to the reduction of sunlight reaching the interior wall by shading of the leaves. Moreover, the transpiration of the plants plays an important role in decreasing the air temperature.

Principles of thermal transfers

There are three modes of heat transfer:

•**Conduction**: This is the main mode of heat transfer in solid. It occurs because when a part of the body is hot, its molecules vibrate more quickly than the ones in the colder part of the body. Their kinetic energy is then conducted to adjacent part of the body - molecule by molecule until the kinetic energy (and thus the temperature) is homogeneous.

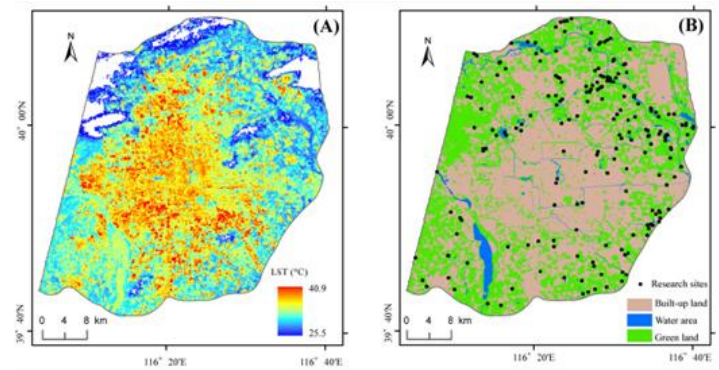
•**Convection**: In this case, the heat transport from molecules to adjacent molecule is coupled with a transport of the molecule by fluid movements. The overall heat transport is generally faster as the molecule velocity can be high. It mostly concerns fluids (liquid and gaseous). If the heat transport is the origin (the driving force) of the fluid movement, one speaks of natural convection. The fluid movement can also exist without the heat transfer, ones then speak of forced convection.

•**Radiation**: This mode of heat transfer concerns the heat exchange between surfaces at different temperatures. It is caused by the fact that every body emits electromagnetic energy, depending on the surface temperature and constitution. Energy is radiated from warm to cold surfaces, but contrary to the other two heat transport mode also from cold to warm surfaces.

Generally, all three modes occur when considering thermal transfers of a building. Buildings greening involves large modifications on the radiative and conductive transfers between the building and the exterior environment, whereas the convective heat transfers are less modified. For this reason, the present courses will focus on conduction and radiation.

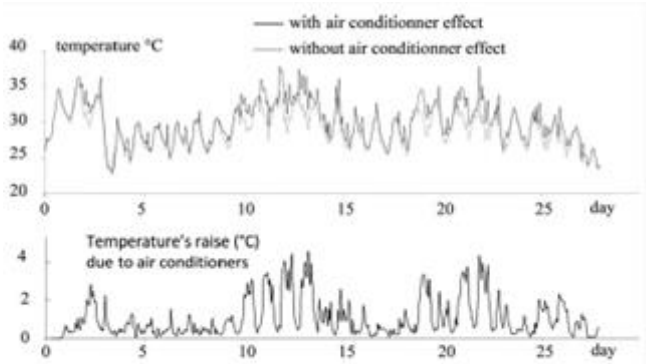
Interests of building greening

Due to human activities, the climate of urban areas is significantly warmer from the one in the countryside:



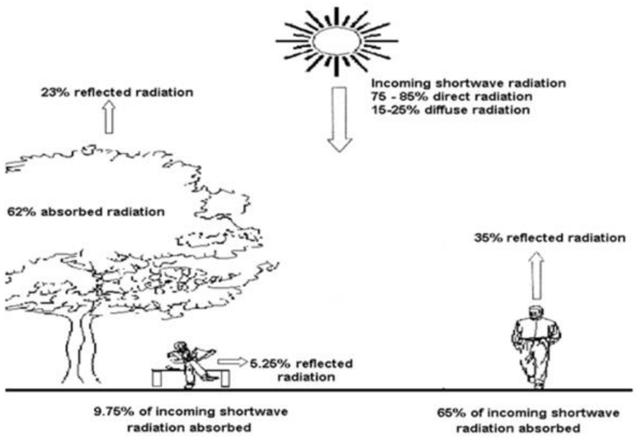
Land surface temperature (a), land cover (b), and location of 197 water bodies (b) inside the sixth ring-road of Beijing (Sun and Chen, 2012)

In summer, this lead to discomfort for inhabitants, with global climate change expected to increase the summer temperature and thus worsening the situation. Indeed, a doubling of the electrical consumption due to air urban heat island is cited by Santamouris (2014).
In developed (and developing) countries, this causes an increasing use of acclimatization in order for the buildings to remain comfortable for their occupant. Yet, air acclimatization involves heating the exterior air, thus worsening the situation. Moreover, the widespread use of fossil fuel to produce electricity involve the generation of large amount of greenhouse gas due to air-conditioning.



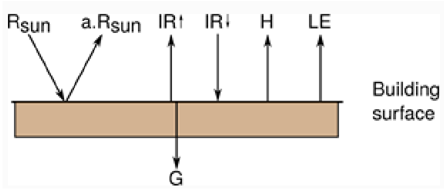
Mean temperature evolution within streets, and deference due to air-conditioning (Bozonnet et al., 2013)

In this context, building greening is a means to reduce the energy consumption of building by limiting the needs for air-conditioning. Moreover, some of the solutions described in the following could be interesting in order to limit the heat loss in cold conditions, hence reducing the energy consumption during winter.



Impact of the radiation reduction provided by trees upon the human radiant energy balance (Armson, 2012)

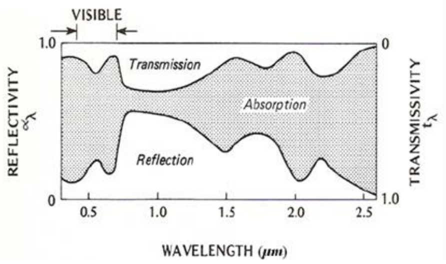
At the city or neighborhood, studies show that vegetation (either by trees or grassing) is very positive for the summer climate or a town. For example, Armson (2012) attributes to grassing a decrease of the surfaces temperature by 24°C.
Concerning buildings, the energy exchanges in summer can be described on the following sketch:



In order to reduce the cooling need in summer, that is the energy that pass through the roof and the walls (denoted G above), the input must be reduced, or the output must be increased.
As we will see below, plants and greening are efficient means to act on all the concerned heat fluxes.

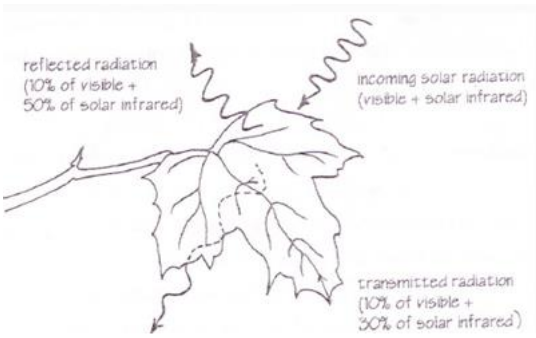
Radiative exchanges

The first approach to limit the heat input on a building is to reduce the amount of direct solar illumination that reaches the roof and the walls by shading, or increasing the albedo of these surfaces, that is the amount of reflected solar light.
For the wavelengths emitted by the sun, the leaf optical properties are described on the following figure:



Relation between wavelength and the reflexivity, transmissivity and absorptivity of green leaf (Armson, 2012)

The transmission, that is the part of the radiation that pass through the leaf, is limited and a large part of the incoming radiation is reflected.

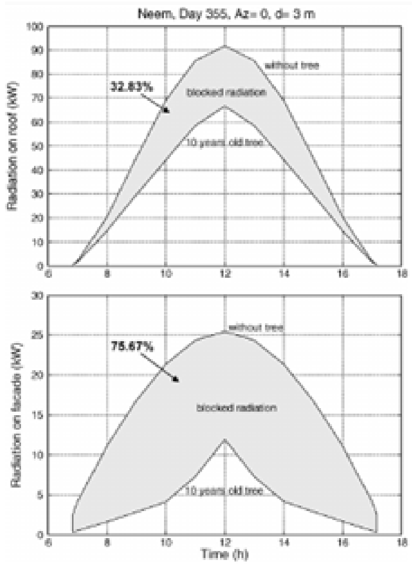


Radiative balance of a green leaf (Armson, 2012)

The radiative balance of a leaf is depicted on the above figure. Less than the third of the incoming radiations are transmitted, that explains the wide use of trees to provide shade.

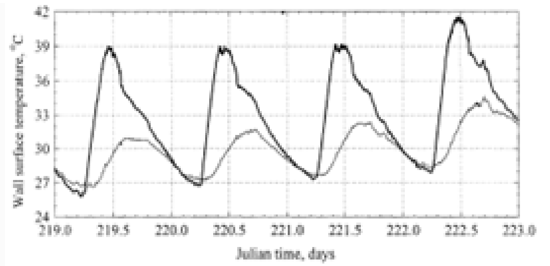
Shading: prevent solar radiation to reach building

The first mean to reduce the energy input on a building is to prevent the energy input by solar radiation. To achieve that, it is common to use trees in order to shade building.



Tree shading on a building on a roof (up) and on south wall (down) (Gómez-Muñoz et al., 2010)

Numerous studies have been produced to confirm that shade reduce the exterior wall temperature.



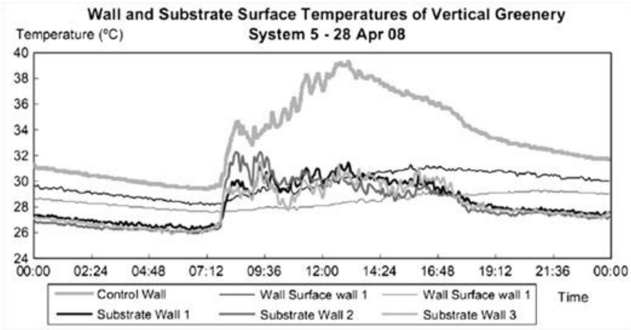
Wall surface temperature in the shaded (thin line) and unshaded (thick line) area (Papadakis et al., 2001)

The gains on the cooling load vary depending on the climate and latitude and most of the studies are located on low latitude cities where the expected gain is higher. Literature gives some example of energy saving for cooling load: 3.23 and 6.46 kWh m^{-2} in California (Akbari and Konopacki, 2005).
The same principles also apply for green walls or green roof are described by Pulselli et al. (2014). As expected, the shading effect is strongly linked to the LAI (Leaf Area Index, which is the leaf surface for m^2 of ground (or wall or roof)).
There is a linear relation between the LAI and the shading effect (Wong et al., 2009), and for very low light transmission factor (achievable with dense crop), the energy losses can be reduced by 40% (Wong et al., 2009). However, this is interesting for a building energy point of view as leaves insulate the buildings from the sunshine in summer when cooling is needed, but deciduous plants lose their leaves in fall and winter when sunshine is an appreciated heat influx.
Nonetheless, the shading effect of green roofs and walls is difficult to differentiate from the effect of the albedo variation induced by leaves.

Albedo

Apart from the solar insulation, the exterior surface temperature of surfaces depends on the albedo, that is the part of the sun radiation that is reflected by a surface. In cities, the historical use of low albedo materials is one of the main causes of the urban heat island effect.
For this reason, new building constructions tend to use high albedo materials in order to increase the reflection of the sunlight and thus a reduction of the surface temperature. As depicted earlier, this involves a reduction of the conductive heat transfer through the walls and roof.

Measurements of the albedo as well as air 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 is hardly modified by surface behavior. The mean temperature reduction is around 0.3 K for a 0.1 albedo point increase (Santamouris, 2014).
The gains on cooling load of high albedo surfaces are of the order of 10 to 40% in summer, for a loss between 5 and 10% on heating (Santamouris, 2014). For southern California, the saving on air-conditioning consumption is between 40 and 70 Wh m^{-2} day^{-1} depending to the building type (Akbari et al., 2005).
As depicted by the above figures, the use of vegetation can induce a limitation of the surface temperature. The plant species and LAI have a great influence on the surface temperature.

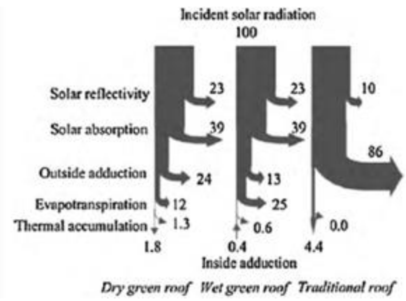


Wall and substrate surface temperature for different revegetation system (Wong et al., 2010)

For an air temperature of 33°C, Simmons et al. (2008) reports a roof surface temperature of:
• 68°C for black roof
• 42°C for white roof
• between 31 and 38°C for green roof
However, the gain for green surfaces is not entirely due to the radiative properties, but for a large part to the evaporative cooling (Santamouris, 2014).

Evapotranspiration

Live plants absorb large amount of energy by their leaves, but maintain their temperature by transpiration, that is by converting the liquid water into vapor. The needed energy is taken from the leaves and the surrounding air, allowing for their temperature to drop.
As a consequence, the revegetation surfaces are colder than surrounding areas. Usually, around 30% of the incoming sun radiation is converted by transpiration (Tilley et al., 2012). As plants involve a shading similar to artificial systems (Pérez et al., 2011), the temperature of the supporting walls and roofs can be far below the one of conventional surface. The surface temperature for a green roof can be up to 8°C below the one of a cool roof.



Comparison of the energetic exchange of the dry or wet green roof with a traditional roof, summer case (Lazzarin et al., 2005)

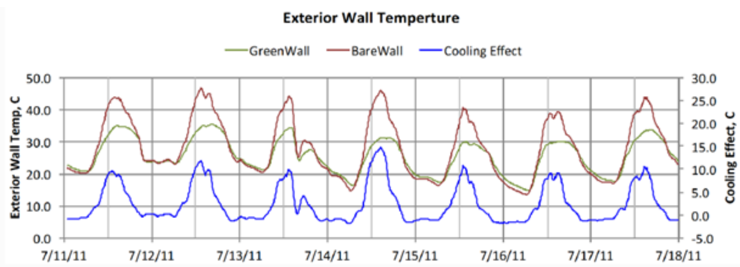
However, this effect exists only as long as the plants transpire. When subjected to water stress, biological regulation prevents the plants from losing too much water and the transpiration is reduced. For these reasons, the cooling effect of the green wall/roof heavily depends on the availability of water in the substrate.

Depending on the plants and their development, between 40 and 80% of the solar radiation can be reflected and absorbed (Wong et al., 2010). A test performed in southern USA by Pérez et al. (2011) states that only 15% of the incoming solar radiation pass through a *virginia creeper* crop, 18% through *Honeysuckle*, 41% through *Clematis* and 20% through *Ivy*. More than the species, the LAI and the cover thickness play a major role in the final heat inflow (Kumar and Kaushik, 2005).
Moreover, the transpiration involves a modification of the air water content and relative humidity (Pérez et al., 2011). The resulting microclimate is benefic as it is closer to the human comfort zone than the initial air. However, the influence of buildings greening on urban heat island effect is limited to a cooling of approximately 1°C at 60 cm from the wall (Wong et al., 2010) because of the wind effect.
At last, not only buildings greening allows to reduce the building incoming heat, but the creation of a colder and moister climate is beneficial for the air-conditioning. Indeed, colder air at the hot source allows the thermodynamic refrigeration cycle to run with a higher efficiency (Getter and Rowe, 2006).

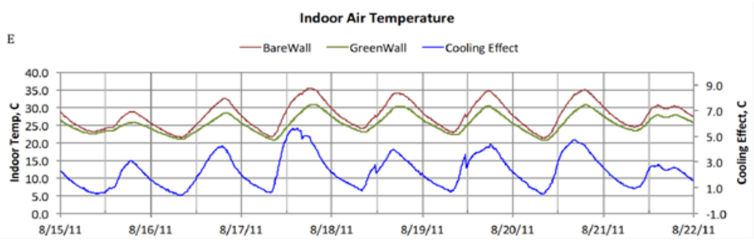
Effect of Green Walls and Rooftop Cultivation

The first effect of the green walls/rooftop cultivation is to reduce the surface temperature by the principles explained before. This will involve a reduction of the conductive heat flow inside buildings. Apart from the plant parameters (thickness, LAI…), the effect of the vegetation depends on building parameters:
• Geographic position, as shading effects increase for low latitude;
• Localization, as little gain is expected for already shaded buildings;
• Exposure, better prospect for the south wall or roof than for the north wall;
• Climate, as evaporative cooling has better potential for hot and mostly dry ambient air.
Consequently, a wide range of cooling effects can be found in the literature, and a proper inclusion of green walls/rooftop cultivation effects on building remains to be made.
As stated before, the average mean cooling effect on the surface temperature depends on the latitude. A mean cooling effect of 5 to 10°C along the summer can be expected for 40° degree of latitude, with a maximum cooling around 15°C (Tilley et al., 2012, Pérez et al. 2011).
The cooling effect is greater when the latitude decrease or the climate drier. Indeed, for approximately the same latitude, the mean 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° degree of latitude) the gain is “only” 30°C because of a higher relative humidity of the air.

The west wall is hotter than the east one due to thermal inertia: during afternoon, the east wall begins to cool, whereas the west wall is already warmed by the warm air and the reflection on other buildings.
Obviously, the cooling effect depends on the plants activity and is maximum around noon or at the beginning of the afternoon.



Exterior wall temperature (Tilley et al., 2012



Indoor air temperature (Tilley et al., 2012)

If the variations of exterior surfaces can be important thanks to the insulation and the building structure inertia, the variation of the interior air is limited. Moreover, the indoor conditions are generally controlled by HVAC systems that are designed to avoid them.
In these conditions, the mean reduction of interior temperature involved by walls or roof greening is limited to more or less 4°C (Getter and Rowe, 2006; Tilley et al. 2012). However, small temperature variations can reflect large variations on the air-conditioning system, and a 0.5°C temperature decrease can correspond to an 8% saving on the electrical consumption for cooling (Getter and Rowe, 2006).

Influence of irrigation and water demand

The effect of vegetation strongly depends on the irrigation level. Indeed, if the water available to the plants decreased, plants reduce their transpiration. This involves an annulation of the cooling effect of the transpiration.
For this reason, the vegetated surfaces are colder just after irrigation. For example, grass is 3.5°C colder just after irrigation (Chatzidimitriou and Yannas, 2015). Moreover, the moist soil induces a supplementary insulation (Wong et al., 2003).
During summer, the water needed for irrigation can be difficult to justify because of the pressure on the water stocks. If not properly irrigated, the efficiency of the green wall and rooftop plantation to decrease temperature is thus limited (Virk et al., 2015).
For a LAI between 3 and 4, the water consumption is between 0.5 and 2.6 liters by square meter by 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 sun radiation. For warmer and drier climate, the evaporation can represent greater amount of water. Marasco et al. (2014) measured up to 15.4 liters by square meter by day in New York and Takebayashi and Moriyama (2009) up to 18 liters by square meter by day in Japan.

Cultivation system as an insulating layer

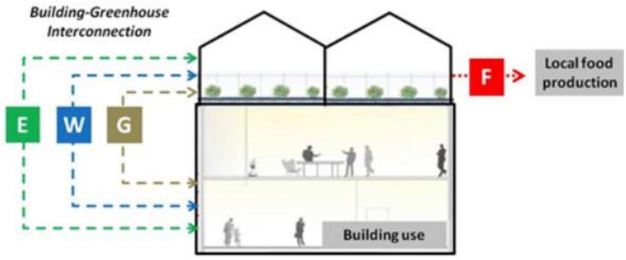
The energy inputs through the building structure are limited by green wall and rooftop cultivation, not only because of the surface temperature but also because of the insulating effect of the cultivation system.
Indeed, cultivation systems represent added layers on the wall or roof that increase the structure thermal resistance. The thickness of such layer depends on the vegetation system, from some millimeters for living walls formed of felt layers to up to one meter of substrate for extensive root plantations.
As common substrates have a low thermal conductivity, they represent good insulation layers. The gains on electrical consumption depends on the initial structure of the building and its preexisting insulation.
Minke and Witter (1982) (via Bass and Baskaran (2003)) estimated that a rooftop cultivation system made of 20 cm of substrate and 20 to 40 cm dense grass has an equivalent thermal resistance as 15 cm of rock wool. And a substrate layer approximately 50 cm can reduce the cooling peak consumption by 25% (Bass and Baskaran, 2003).
Measurements show that 40 cm of substrate allows an increase of the R-value of the roof from 1.72 to 2.20 (Wong et al., 2003), which represent a decrease of nearly 30% of the heat flux. Castleton et al. (2010) quoted an increased of the R-value from 1.7 to 2.4, inducing an annual saving of 6% for cooling and 0.5% for heating. In both cases, the classical insulation remains necessary.

Modifications of the R-value involves a reduction of the heat transfers between exterior and interior, thus reducing the cooling load in summer and the heating load in winter.

Greenhouses interest

Rooftop greenhouses

For Mediterranean climate, Cerón-Palma et al. (2012) stated that closed or semi-closed greenhouse would be efficient to design low-input, low-emission greenhouse production systems. The aim is to reduce energy consumption for heating during the cold season and to recycles the drainage water from irrigated crops (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.



Integrated rooftop greenhouse. Energy (E), water (W) and CO_2 are exchanged between the building and the greenhouse (Esther Sanyé-Mengual, 2015)

The study conducted in Barcelona by Cerón-Palma et al. (2012) on an integrated greenhouse concludes that the considered rooftop greenhouse has a higher environmental impact (by 17 to 75%) than a multi-tunnel greenhouse, as well as a 2.8 fold higher economic cost. However, when considering the entire supply chain up until the consumption point, the rooftop greenhouse displays a 42% saving on ecological costs and a 21% saving on economic costs.
A comparison between the conventional supply chain and RTG local supply chain showed that RTG tomatoes grown in Barcelona could replace the traditional tomato production location, thereby avoiding 441 g of CO_2 eq and 12 MJ of energy consumed per kg of tomato. At the building-greenhouse system level, Ceron-Palma et al. (2011) performed a preliminary energy modeling results and showed that the introduction of residual heat from the greenhouse into the building on an ideal winter day could substitute 87 kWh of the heating demand.
If the primary objective on the economic and ecological are fulfilled, the advantages for the underlying building energy consumption is not demonstrated for such conditions.
Caplow and Nelkin (2007) used a more classical greenhouse on a building in New York. The greenhouse was provided with evaporative cooling pads, and the cold air can be used to cool the building. Moreover, the greenhouse also provided insulation in summer by eliminating some sunlight gains. In summer, when the structures are combined, elimination of solar gain through the building’s roof is estimated to eliminate 37 kWh per day from the cooling demand, with the consumption of approximately 3.9 metric tons of watery.
In winter, the thermal losses through the building roof are reduced by the greenhouses because this surface is also the floor of the greenhouse, with an intermediate temperature between the building indoor temperature and the exterior one. In winter, Caplow and Nelkin (2007) estimated the heating loads at 366 kWh for the greenhouse and 7 kWh for the building. Overall, only 6 kWh per day are saved.
From the perspective of traditional energy conservation, the potential annual savings are approximately equal to the entire cooling load of the building, 44 MWh, because this load will be met by the low-energy forced ventilation / evaporative cooling systems in the greenhouse if the structures are integrated.

Vegetated double-skin facade

The use of plants in double-skin facade is an efficient means to reduce the solar energy input in a building. Fang et al. (2011) cited that 60% of the incoming solar radiations are absorbed by plants (*Tillandsia usneoides* for a building in Shanghai). This is coherent with finding by Stec et al. (2005) that gives a decrease between 50 and 70 %. Their efficiency can be superior to classical blind.

Tillandsia usneoides plant curtains used by Fang et al. (2011)

This involves an important reduction in the interior wall temperature variation during a hot day. Stec et al. (2005) measured a temperature amplitude of 5-30°C with plants instead of 10-60°C without.
The air temperature is slightly reduced, and Fang et al. (2011) reported a 2.3°C decrease inside the double-skin facade for a plant's density of 750 g m^{-2} in double-skin facade for hot climate (Shanghai). However, this can lead to significant decreases of the air-conditioning system load. Chan et al. (2009) cited a decrease of 26% of the annual cooling energy compared to standard double-skin building with reflective glass. This is coherent with 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. Indeed, the plant density and grow process cannot be finely controlled by occupants. Moreover, the maintenance of the plant and cultivation system (irrigation, collection of fallen leaves…) is costly and a specialized task. At last, choosing the plants is difficult due to the environmental and the low maintenance pressures (Fang et al., 2011).

2.3.2 Waste-to-resources: the potential uses of bio-waste

Introduction

In Europe, over than 75% of people live in cities. The main consequence is the great consumption of raw materials to build the city and the great production of wastes exported out of the city. The city can be considered as an urban ecosystem with a linear metabolism, which can be compare to an entry/exit model of materials.

Follow the slideshow below:

2.3.2 (1) PPT Presentation

In Europe, the dwellers currently use 16 tonnes of material per person per year, of which 6 tonnes become waste. In 2010, total waste production in the EU amounted to 2.5 billion tons. From this total only a limited (albeit increasing) share (36%) was recycled, with the rest was landfilled or burned, of which some 600 million tons could be recycled or reused (European Commission, http://ec.europa.eu/environment/waste/compost/).
All this waste has a huge impact on the environment: (i) pollution, (ii) greenhouse gas emissions and (iii) losses of materials (http://ec.europa.eu/environment/waste/pdf/WASTE%20BROCHURE.pdf).

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

It is necessary to change the urban metabolism to a circular model by turning waste into a potential resource of ‘secondary raw materials’ in the objective of an efficient and sustainable way. The development of this type of strategy is one key to a circular economy of the city. The main actions of waste management policy are to improve waste prevention (change consumer behaviour) and waste recycling and to limit incineration to non-recyclable materials and the use of landfilling.

Optional material: for further information

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

Type of urban wastes

Municipal waste (collectivities and households) represents one-third to a half of the urban waste excluded demolition rubble. Municipal waste is composed of household waste, and other waste similar to waste from households (commerce, offices and public institutions). Their management depends on public policy and budgets. Bio-waste represents one-third of the municipal wastes. Each person in Europe is currently producing, on average, half of tonne of such waste.

Follow the slideshow below:

2.3.2 (2) PPT Presentation

Bio-waste is defined as biodegradable (i) garden and park waste, (ii) food and kitchen waste from households, restaurants, caterers and retail premises, and (iii) comparable waste from food processing plants. It does not include forestry or agricultural residues, manure, sewage sludge, or other biodegradable waste such as natural textiles, paper or processed wood. It also excludes those by-products of food production that never become waste (European Commission, http://ec.europa.eu/environment/waste/compost/).

Ways of recycling bio-waste

A number of EU legal instruments address the issue of treatment of bio-waste. Currently, the main environmental threat from bio-waste (and other biodegradable waste) is the production of methane from such waste decomposing in landfills, which accounted for some 3% of total greenhouse gas emissions in the EU-15 in 1995. Landfilling is the worst waste management option for bio-waste with negative impacts by landscape deterioration and local water and air pollution from the generation of methane and effluent. The Landfill Directive (1999/31/EC) obliges Member States to reduce the amount of biodegradable municipal waste that they landfill to 35% of 1995 levels by 2016 (for some countries by 2020) which will significantly reduce this problem.

Optional material: for further information, please read the following publications

http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32008L0098
http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31999L0031

The most significant benefits of bio-waste management would be the production of renewable source of energy and recycled compost that contribute to enhanced resource efficiency and soil quality. Composting is the most biological treatment used for green waste and woody material.

Follow the slideshow below:

2.3.2 (3) PPT Presentation

For further information we recommend to watch the following video on biogas production

Watch the video at: https://www.youtube.com/watch?v=B660d2c-RkA

Watch the video about industrial composting and identify the conditions for success in composting.

Watch the video at: https://www.youtube.com/watch?v=QBSGuUq2D9E

Potential uses of bio-wastes for plant production

Compost is used in agriculture, for landscaping, to produce growing media and constructed soil and for land restoration. EU legal instruments regulating the use of bio-waste are presented in the “Green Paper, on the management of bio-waste in the European Union" (http://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A52008DC0811)

Follow the slideshow below:

URBAN GREEN TRAIN 2.3.2 (4) PPT Presentation

The popularity of rooftop gardens and urban gardens initiated by associated community groups or urban gardeners increases the demand of urban soils. Urban gardeners and farmers want information about the quality of the soil and its contaminants contents to have healthy food and landscapes.
There are solutions to improve urban soil fertility. Among them, introducing high amounts of organic matter (until 40% in volume) is an important issue to favor long-term soil fertility (Vidal-Beaudet et al., 2012; Cannavo et al., 2014). Indeed, organic matter provides serious soil benefits: physical fertility (soil structuration for a better water retention and air circulation), chemical fertility (nutrient reservoir, cation exchange capacity), and biological fertility (carbon, mineral and energy resources for soil organisms). Organic matter composition is generally controlled and standardized. In France, the NF U 44-051 gives confines about its composition: organic matter and dry matter contents, trace metal, hydrocarbon and micro-organisms content limits. Among available composts, the green waste compost is the major one used in peri-urban and urban areas, due to high amounts of plants pruning produced by towns.
If the soil is contaminated or in the case of rooftop or soilless gardens, it is necessary to bring a new substrate with appropriate properties and performance recommendations defined by the green space project.

Using topsoil from agricultural parcels for urban greening is currently controversial due to the decrease in arable surface area. An alternative idea for protecting these natural resources consists in reusing waste materials in order to construct functional soils (Séré et al., 2008). Cities are continuously being renewed through the demolition of older structures and produce demolition wastes, such as bricks, concrete, track ballast and excavated soils. These debris are regularly hauled outside of cities and only a fraction is being recycled (Marshall and Farahbakhsh, 2013). In 2009 for instance, civil engineering activities were estimated to have generated 250 millions of tons of waste in France. Compost materials and green wastes stemming from garden and park maintenance are also generated within cities and massively exported out of urban areas to produce compost or energy. Some of these materials could be associated to build soils adapted to the urban environment. Such soils have to be able to support plant growth, tree development and light traffic. Thus, they need to display adequate bearing capacity, agronomic properties, and drainage capacity. Moreover, they must comply with environmental restrictions to prevent pollutant release into the underlying aquifer.

URBAN GREEN TRAIN Watch the video at: https://www.youtube.com/watch?v=QBSGuUq2D9E

Assignment 2.3.2. Answer to the following questions:

Watch the video about industrial composting and identify the conditions for success in composting.

Identify the element concentrations to verify for using bio-waste as compost.
Try to determine the standards of a good compost.
Identify the functions and ecosystem services of the compost for UA.

2.3.3 Rainwater harvesting and greywater recovery

Introduction

By the 2050, 66% of the world population will live in urban areas. The main consequence is the progressive soil sealing due to expansion of urban areas. Water cycle in the urban area is considerably different compared to natural areas. Indeed, because of important impervious areas, the main water flow in urban area is runoff and consequent flooding. Then, water infiltration is only possible when planted soils are present, whereas it is the main water flow in natural soils. Thus, one major challenge is to favour water retention and/or infiltration by increasing greening areas such as green roof or parks and gardens.
People living in cities are more and more hoping for green spaces for their well-being. Indeed, urban vegetation can provide various services such as:

- human benefits (health, social tie)
- natural equilibria benefits (biodiversity, thermal regulation, air quality, water circulation and soil protection)
- economic benefits (construction promotion, plant waste repurposing, urban agriculture, territory attractiveness).

Cities develop greening and renaturation strategies whose success depends on the quality and functions of the soil supporting plants and the water quality for plant growth.
In order to reconcile urban extension and demographic population to water runoff and more urban green spaces, innovative solutions in terms of water management are required.
The objective of this lesson is to present the possible alternatives for water management, and the key elements to take into account for an efficient water use in urban areas.

Urban water hydrology

In a natural landscape, soil and vegetation naturally absorb 90% of rainfall through infiltration into the ground and evapotranspiration. In a city, asphalt, pavement and roofs rapidly shed water, creating huge volumes of fast flowing runoff. Developed areas create over 500% more runoff than natural areas of the same size. Runoff increases loading of contaminants and more treatments are required to reuse the water or to water discharge.
The solutions for urban water management is water capture using open-pit or buried storage basins or infiltration using porous pavements with innovative porous asphalt.

Green infrastructures can facilitate water management at neighbourhood scale:
-leaves trees reduce water runoff by rainfall interception;
-green roofs temporarily store rainfall and favour evapotranspiration;
-field water infiltration decreases water volume and reduces peak flow.
In general, runoff increases when vegetation areas decrease, and decreases if green roofs exist. In highly dense infrastructure areas, green roofs are an efficient way to decrease runoff.
Water infiltration in soil depends on physics soil properties: soil structure, granulometry, soil hydraulic conductivity.

Follow the slideshow below:

URBAN GREEN TRAIN 2.3.3 (1) PPT Presentation

Green roof potential for water runoff control

The origins of green roofs began thousands of years ago. The most famous green roofs were the Hanging Gardens of Babylon. Modern green roofs are made of a system of layers placed over the roof to support soil medium and vegetation. This 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 roof: intensive roofs, which are thicker, with a minimum depth of 12.8cm, and can support a wider variety of plants but are heavier and require more maintenance; extensive roofs, which are shallow, ranging in depth from 2 cm to 10 cm, lighter than intensive green roofs, and require minimal maintenance; semi-intensive roof have intermediate characteristics.
The growing media used in the green roofs can have different functions (vegetation support, filter), properties (water retention capacity) and composition.

Follow the slideshow below:

URBAN GREEN TRAIN 2.3.3 (2) PPT Presentation

Greywater

Greywater is all wastewater generates in households or office buildings from streams without faecal contamination. Source of greywater include sinks, showers, baths, clothes washing machines, dishwashers. Toilets wastewater of any kind are called sewage or black water to indicate it contains human waste. However, under certain conditions traces of faeces might enter the greywater stream via effluent from the shower or washing machines.
Generally, greywater is safer to handle and easier to treat and reuse onsite for toilet flushing, landscape or crop irrigation or other non potable uses. The application of greywater reuse in urban water systems provides substantial benefits for the water supply subsystem by reducing the demand for fresh clean water and for the waste water subsystems by reducing the amount of wastewater required to be conveyed and treated.
Greywater composition mainly depends on geographic origin, building category, occupants' activity. Most greywater is easier to treat and recycle then black water, because of lower levels of contaminants. If collected using a separate plumbing system from black water, it can be directly used. If stored, it must be used within a very short time or it will begin to putrefy due to the organic solids in the water. It cannot be used to drink. The treatment processes that can be used are biological systems (constructed wetlands, living walls, bioreactors) or mechanical systems (sand filtration).
In France, if greywater treatment is operated and is appropriate, its reuse is possible for toilet flush supply, green spaces irrigation and outside surfaces cleaning.
Main advantages of using greywater for irrigation are preservation of water resources and supply nutrient; main inconvenient are salinity, accumulation of metals, presence of pathogens.

Follow the slideshow below:

URBAN GREEN TRAIN 2.3.3 (3) PPT Presentation

Store water basin for road water runoff

Water fluxes in urban areas are different compared to natural areas. Road rainwater runoff (vector of contamination) is a necessity. One possible solution is retention/infiltration in store water basins.
Store water basins can have several roles: rainwater flow regulation, groundwater recharge, depuration. At the base, they present impermeable soil that improves water infiltration, surmounted by a sediments layer.
Properties of the sediment layer are:
- fine texture
- high organic matter content
- high water retention capacity
- low infiltration capacity
- hydrophobic behaviour

Organic matter content affects hydraulic conductivity at saturation; the higher is OM content, the lower is K_s.

Follow the slideshow below:

2.3.3 (4) PPT Presentation

Assignment 2.3.3. Follow the slideshow below and think about the request:

2.3.3 (5) PPT Presentation

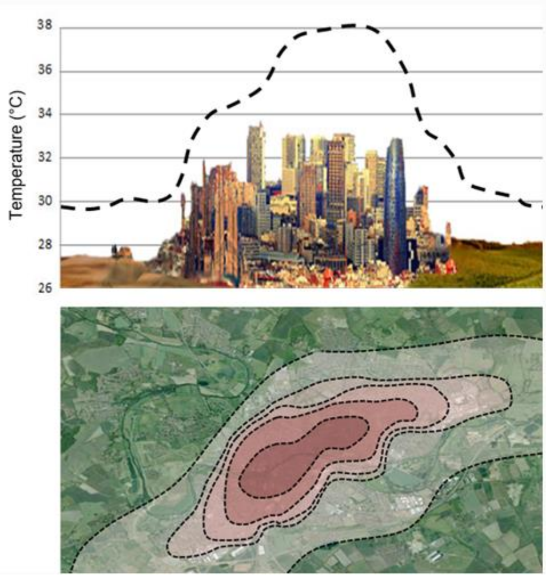
2.4 - Urban Agriculture for improving city climate

Introduction

This chapter will enable students to understand the link between urbanization and air pollution and to relate green infrastructures with ecosystem services including air filtering and microclimate regulation. When completing the chapter, participants are able to design air filtering green infrastructure and climate resilient urban agriculture experiences.

2.4.1 UA for improving city Climate

The last decades are characterized by a continuous, intense and complex process of urbanization, and today almost 54% of the world population inhabit urban areas while three quarters of European citizens live in metropolitan regions (WHO, 2015). Consistently, the reconciliation between the development of our cities with the respect and protection of the environment is becoming an important challenge. Cities are composed by structures and extensive interventions of anthropogenic origin, which make them poles on environmental problems (Naishi et al., 1998). Much of a city's soil tends to be sealed with impervious materials and surfaces that do not absorb water and increase the occurrence of runoff. Furthermore, most of the structural materials that are used in such environments are generally characterized by low albedo (a measure of the reflectivity of the surface), a fact that intensifies the conversion and storage of the incident thermal radiation to sensible heat when compared to the surrounding countryside. Therefore, the urban surface layer tends to be hotter than the rural one (Naishi et al., 1998; Britter & Hanna, 2003).
This effect is exacerbated in cities where green infrastructures are scarcely present. In other words, as green transpiring surfaces are substituted by impermeable soil cover, the water available for evaporation is reduced, affecting the flow of latent heat. Therefore, especially in absence of precipitation, the value of Bowen ratio (sensible heat flux / flow latent heat) becomes quite high (Bonafè, 2006).
When isothermal curves are plotted on a surface weather map, the result is a profile that looks like the topographic contours of an island.



Graphical representation of the heat island effect on the skyline of a city (on the top) showing the differences of temperature between country and city during the afternoon. The temperature in downtown may exceed in measure of 8 to 10 °C the surrounding countryside. Below, a simulation of the typical surface weather map from which it is possible to observe the Urban Heat Island (UHI) effect

This is the reason why the urban surface layer is also called "heat island" (urban heat island or UHI) (Naishi et al., 1998). In highly populated cities, the higher temperature is related to both an increased energy consumption for building air conditioning and an effect of the pollution associated with road traffic such as emission of pollutants, including sulphur dioxide, carbon monoxide, nitrous oxides and suspended particulates (Henderson et al., 2007). Pollution effects may be exacerbated in climates with a distinctively hot season (White et al., 2001; Koppe, 2004). Air pollution has become a problem since the beginning of industrial revolution. Transports, industrial activities, domestic heating and waste incinerations are the main sources of air pollutants. Major pollutants produced by human activities are sulphur oxides (particularly sulphur dioxide, SO_2), nitrogen oxides (NO_2), carbon monoxide (CO), volatile organic compounds (VOC, primarily methane, CH_4) and particulate matter 10 or 2.5 (PM_{10} and $PM_{2.5}$) constituted by dust of diameter lower that 10 µm and 2.5 µm, respectively, as well as dissolved substances.
Recent studies (Banting et al., 2005; Rosenzweig et al., 2006) point out that increase of green infrastructures in urban environments may contribute not only to the mitigation of the microclimate problems but also to a

wide range of ecosystem services, such as improving air quality (Currie& Bass, 2008; Speak et al., 2012) or providing resilience to exceptional meteorological events (Berndtsson, 2010; Gregoire & Clausen, 2011). In this section, the environmental functions provided by urban agriculture and, more generally, urban green infrastructures will be introduced, with a particular view on the role they can play on urban atmospheric quality and microclimate.

Assignment 2.4.1 Please read the following article and make the comprehension test

2.4.1 UA as green infrastructure: the case of New York City

1. Most of the city surface is permeable to water and allows quick drainage of rainfall

☐ true
☐ false

2. The urban environment is generally hotter than the surrounding countryside

☐ true
☐ false

3. Green infrastructures mitigate the city climates through plant transpiration

☐ true
☐ false

4. PM_{10} stands for:

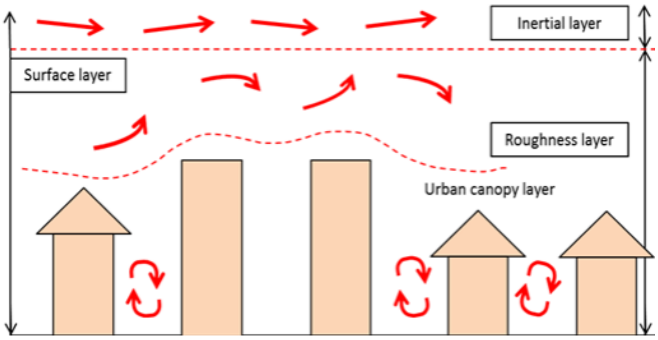
☐ dust of diameter bigger than 10 mm
☐ dust of diameter lower than 10 mm

5. The main causes of the urban heat island are (please mark correct ones):

☐ green infrastructures
☐ road traffic
☐ wind canyoning
☐ air conditioning

2.4.2 Air filtering green infrastructures

Urban vegetation affects air quality by eliminating air pollutants; the air purification effect can be caused aerodynamically, when the plant mass stands in the way of the wind and retains particles, or by absorption through stomata openings during the physiological processes of plant photosynthesis and transpiration (Chapparo and Terradas, 2009). Plants area sinks of CO_2 because they store excess carbon as biomass during photosynthesis (McPherson and Simpson, 1998). In a recent study (Davies et al., 2011), it was estimated that domestic gardens would enable storage of about 0.76 kg C m^{-2}. Consistently, the presence of urban green infrastructures has a physical modification on the distribution of the airborne pollutants, as they act as obstacles that exert a frictional force on the atmosphere (Britter and Hanna, 2003). Within the urban air profile, the urban canopy or roughness layer is the layer of air closest to the surface in cities, extending upwards approximately to the mean building height.



Graphical representation of the urban profile effects on friction induced in the lower troposphere re-elaborated by Oke (1987) and Britter and Hanna (2003)

The mechanical impact of channeling and recirculation of the air turbulence, when combined with emissions of pollutants, leads to a high pollution risk within the urban canyons (Jeong & Andrews, 2002; Kastner-Klein et al., 2004). Indeed, inside the canyon profile there is an accumulation of pollutants due to a vortex recirculation. Only a little leakage of flow allows air renewal and in these particular atmospheric conditions causes concerns related to the health of the inhabiting population (Kastner-Klein, 2004).

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

Dust components of the airborne aerosol ($PM_{10\text{-}2.5}$) are removed from the atmosphere via electrostatic deposition on the leaf cuticle (Prajapati, 2012), and successively partially absorbed, washed through runoff or re-suspended in air. Recent studies showed that the creation of new green infrastructures in urban areas significantly reduces airborne pollutants, contributing indirectly to the increase of the environmental health and the wellbeing of citizens (Nowak et al., 2006). Green covers have shown to efficiently remove particulate matter.

The capacity for reducing dissolved gasses and PM is attributed to the increased impact surfaces provided by plant canopy that result in increased depuration effects for turbulence impact and interception (Petroff et al., 2008). This, however, is a relatively new area of study and clearer understanding of the air filtering capacity of such green infrastructures will likely come in a near future (Currie and Bass, 2008).

Assignment 2.4.2. After reading the lesson, answer to the following question

Select the correct answers:

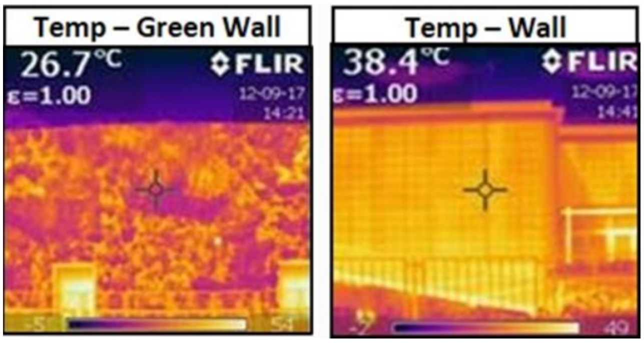
☐ Plants absorb oxygen during photosynthesis

☐ Inside urban canyons, pollutants build up causing contamination risks

☐ Air quality may be improved by urban green infrastructures through deposition of dust particles (e.g. PM 10-2.5) on plant leaves.

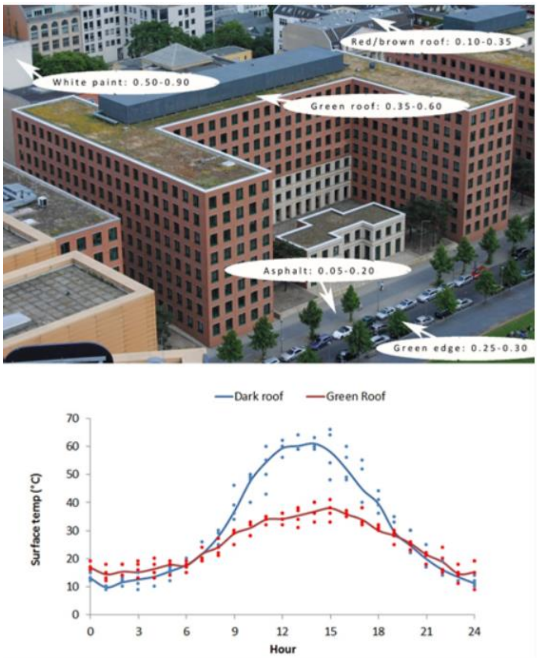
2.4.3. Minimizing the urban heat island

The urban heat island effect consists of temperature rise in urban areas as compared to the surrounding rural countryside (Phelan et al., 2015) due to human activities and to higher absorption of solar radiation by artificial materials (asphalt and cement). Vegetation can play a key role in contributing to the overall temperature regulation of cities, since, through evapotranspiration, air temperature can be reduced. Phelan et al. (2015) reported the increasing of vegetation in urban areas as a possible remedy for urban heat island. In recent years the adoption of greened infrastructures for their energy and ecological functions has become an established governance policy. By placing a vegetated canopy over and around built structures, the first observed effects are temperature mitigation and reduction of the energy cost associated with air conditioning, especially during summer.



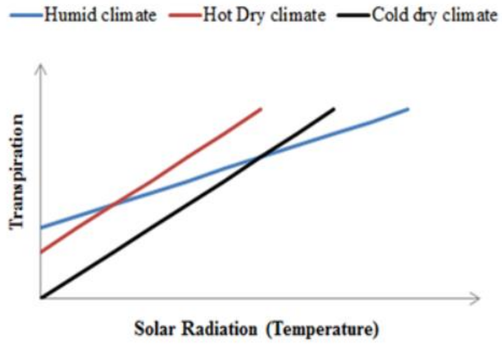
Analysis conducted with a thermal imaging camera by the CNR of Bologna (Italy) showing temperature differences between a green and a concrete wall cover.

The indirect-cooling effect given by vegetated structures is determined by a great protective capacity against thermal radiation, lowering in the first place the temperature of buildings' surface (Wong et al., 2003a). This benefit is a direct consequence of the albedo modification of walls and roofs. Buildings with dark impervious roofs have generally a low albedo, which means higher absorption of solar radiation.



Different albedo effect on the building surfaces. On the top, albedo values of different elements of the urban landscape. Below, surface temperatures of conventional and green roofs, measured during an experimental trial at the Department of Agricultural Sciences at the University of Bologna, Italy (Unpublished data, 2015). Temperature values measured with a thermal sensor PT100 (Rhopoint Components, East Grinstead, United Kingdom)

This translates into a more intense surface heating, especially if compared with a vegetated canopy. During summertime, this leads to an increase of the day-night heat island effect, energy consumption for indoor artificial cooling and pollution emission. In European cities, more than 90% of roofs are dark in color and the surface of the cover under the sunlight reaches temperatures around 80°C, with a negative impact on the duration of waterproof insulation (Santamouris, 2014). Alternatively, the adoption of greened roofs promotes the conversion of solar energy to transpiration (cooling), as well as the growth of plants. This is particularly the case during summer, given the direct relationship between plant transpiration and solar radiation and temperature. Consequently, from both the vegetated cover and the adopted substrate a thermal insulation is provided.



Graphical representation of the relationship between solar radiation, temperature and plant transpiration

Using plants instead of air conditioning – and saving money

Urban areas generally have a lower humidity level than the surrounding countryside due to the absence of vegetation and the increased absorption of energy from the sun caused by dark asphalted or concrete surfaces. This also explains why inner city areas are often many degrees warmer than their surroundings. This phenomenon, known as the urban heat island effect, can have serious consequences for vulnerable people, such as those who are chronically ill or the elderly, particularly during heat waves. The moist air generated by natural vegetation helps to counter this phenomenon. Humidity levels could also be artificially increased using electricity to evaporate water, but this would cost significantly more than using natural vegetation (around €500,000 per hectare). Working with nature and using Green Infrastructures in an urban environment, for example by incorporating biodiversity-rich parks, green spaces, green roofs and walls and fresh air corridors, is generally a much cheaper and more versatile option to help mitigate the urban heat island effect. It can also help to absorb CO_2 emissions, improve air quality, reduce rainfall runoff and increase energy efficiency.

URBAN GREEN TRAIN [2.4.3 Building a green infrastructure for Europe]

Assignment 2.4.3: After reading the lesson, please complete

The urban heat island effect causes higher __________________in urban areas as compared to the surrounding countryside.

Vegetation reduces surface temperature by direct shading effect, due to the greater ________________(as compared with dark impervious surfaces) that result in greater solar reflection.

During summer, higher temperatures and solar radiation results in greater plant _______________________.

2.4.4. Financing urban agriculture initiatives for improved city climate

The private sector also has an important role to play in investing in urban agriculture and, more generally, in developing innovative ‘green’ technologies. Nevertheless, UA projects are complex and are often perceived as risk by investors, particularly in the early stages of development. Specific financial instruments (e.g. risk-sharing practices) can help reduce the risks associated with UA projects. Accordingly, the European Commission and the European Investment Bank (EIB) are implementing a number of options to establish a financing facility to support natural capital-related investments, including UA projects.

Assignment 2.4.4: Please choose a project topic (either among the two listed below or another one) and collect the required information to fill the table in order to propose a business project to a potential donor:

	Current constrains		**Project improvement**	
Topic	Financial	Environmental	Direct	Indirect
Rooftop Garden vs building climatisation	Energy cost (e.g. Euro m^3 year^{-1})	Environmental footprint (e.g. kg CO^2 released)	Thermal insulation (e.g. T° C reduction in summer)	Inhabitants wellbeing (e.g. leisure, health cost during heat waves)
Indoor green wall in office	Sanitary cost (e.g. health costs)	Volatile Organic Compounds (VOCs) (e.g. Wolkoff, 2013)	Air filtering (e.g. quantity of pollutants filtered by plant canopy)	Workers wellbeing (e.g. reduced health costs; social corporate responsibility)

2.5 - Bullet points: Remember the economic dimension

Remember the economic dimension

2.1 <u>Urban agriculture for biodiversity and ecology</u>
- UA is gaining importance to ensure food supply and food security in an urbanizing environment;
- Urban sprawl/urbanisation: loss of productive farmland as a challenge for farms to cope with in a profitable way; mainstream agriculture (bulk production of crops and livestock) often unprofitable;
- Green infrastructure and biodiversity issues are able to create UA business fields (for farms, but also for public and private initiatives);
- Consider city-related challenges, like polluted soils, aerosols, etc., when producing food.

2.2 <u>Urban Agriculture for reducing the city ecological footprint</u>
- Climate-smart production systems via local production, circular metabolism, and self-sufficiency;
- Local production can reduce food miles and mitigate ecological impacts by simultaneously offering promising business strategies (local food systems, Community Supported Agriculture, direct marketing arrangements, etc.);
- Food waste reduction at the production as well as at the consumption stage is able to cause economic influences on the farm, but also food system level;
- Reduced ecological footprints are able to create UA business fields (for farms, but also for public and private initiatives), like extensive.

2.3 <u>Urban Agriculture for resource efficiency and waste management</u>
- Waste-to-resources, ‘rainwater harvesting’, and greywater recovery hold different economic potentials

Assignment 2.5: Please shortly present ideas (1 short paragraph each) how
- waste-to-resources;
- rainwater harvesting;
- greywater recovery are able to result in positive economic trade-offs in UA.

>> More details are following in the final module 5, which focuses on the economic dimension of urban agriculture.