I. Introduction – *"In a nutshell"*

MODULE I

1. **What is "urban"? Proposed definitions and related issues**: Urbanization can be co as a multidimensional process that manifests itself through rapidly changing human popu and changing land cover. Cities can be seen as complex social ecological systems as they much more than a particular density of people or area covered by artificial structures.

2. **Major urban-related trends with ecological implications:** Urban areas are expand than urban populations; Urban areas modify local and regional climate; Expansion of bui areas depend heavily on natural resources, with negative effects on habitats, biodiversity ecosystem services; Urban land expansion is occurring faster in areas adjacent to biodive hotspots and in biodiversity-rich coastal zones; Most future urban expansion will occur ir limited economic development, and thus limited resources to invest in the protection of biodiversity, conservation and restoration.

3. **Patterns of urban growth and its relationship with biodiversity hotspots:** Rural population is expected to plateau or decline in the next decades in respect to urban popu There will be an expansion of cities, in particular regional to mid-sized cities. Urban grow take place primarily in Asia (China and India) and in Africa (Nigeria) and it will expand into farmland, forests, savannas and other ecosystems.

I. Introduction – *"In a nutshell"*

MODULE I

4. **The discipline of Urban Ecology as a bridge between Humanities, Engineering ar Natural Sciences**: Urban ecology emerged as a subdiscipline of ecology in the early 1970 ecologists have recognized that human settlements were legitimate subjects of ecological Urban ecologists can be engaged in basic research focused on understanding the structure function of urban environments, or in applied research that is focused on solving importar environmental problems. The science of urban ecology is a unique field of study that integ several disciplines because of a mutual interest in understanding the ecological foundatior and towns.

5. **The concept of "novel" urban ecosystems, and its criticisms:** As humans urbanize, ecosyst taken from their historical "natural" configuration through a hybrid state, into a novel (eve resilient) system, or collapse. Some changes will result in hybrid systems retaining some or characteristics as well as novel elements, whereas larger changes will result in novel syster comprise completely different biotic (e.g., species composition) and abiotic conditions (e.g use, climate, pollution). Criticisms to the concept of novel ecosystems (e.g., no clear thresl among historical, hybrid and novel; limited interest of people in conserving, and restoring ecosystems).

GLOBAL CHANGE AND EVOLUTION OF HUMAN-MODIFIED ECOSYSTEMS

(6 CFU - ECOLOGY)

MODULE II

MODULE II

Unique ecological conditions of urban ecosystems

II. Unique ecological conditions of urban ecosystems

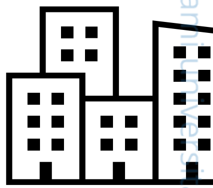
- The relation between plants and animals and their surroundings in urban contexts, and thu **establishment of ecological patterns, is not understandable without understanding the pr of urbanization**, and how urban growth and densification proceed.

- **Human impacts through using the land for different purposes** and changing the frequency interventions and disturbances in quality and quantity, **extends the influencing area that produces the conditions of urban ecosystems.**

- With the replacement of the vegetation cover by paved surfaces and buildings, the **urban s not only decreases the former surface but introduces new surface materials** (e.g., asphalt, plates, glass, etc.) that are not biologically active. **These materials cover the soils and chan functions** by having completely different thermal characteristics and influences on hydrolog processes. **Human activities introduce new matters, nutrients, and pollutants into the nat system of the water cycle and change the air quality.**

MODULE II

A new world is created — the City.
This is not only a new physical, but also a new ecological environment



II. Unique ecological conditions of urban ecosystems

This module discusses the <u>physical conditions</u> that influence and determine the ecological condit within cities, mainly urban climate, land-use change, impacts on soils, and hydrology.

MODULE II

II. Unique ecological conditions of urban ecosystems

Characteristics of the environment within cities

- **Urban climate**: 'urban heat island' effect, the elevated temperatures compared to the city's surroundings;
- **Altered hydrology**: negative impacts on surface waters, increased stormwater runoff, and reduced groundwater formation;
- **Degraded soils**: impacts of pollution
- **Changes in biodiversity (MODULE IV)**: altered species composition, species homogenization, altered within-species genetic diversity, invasive species.

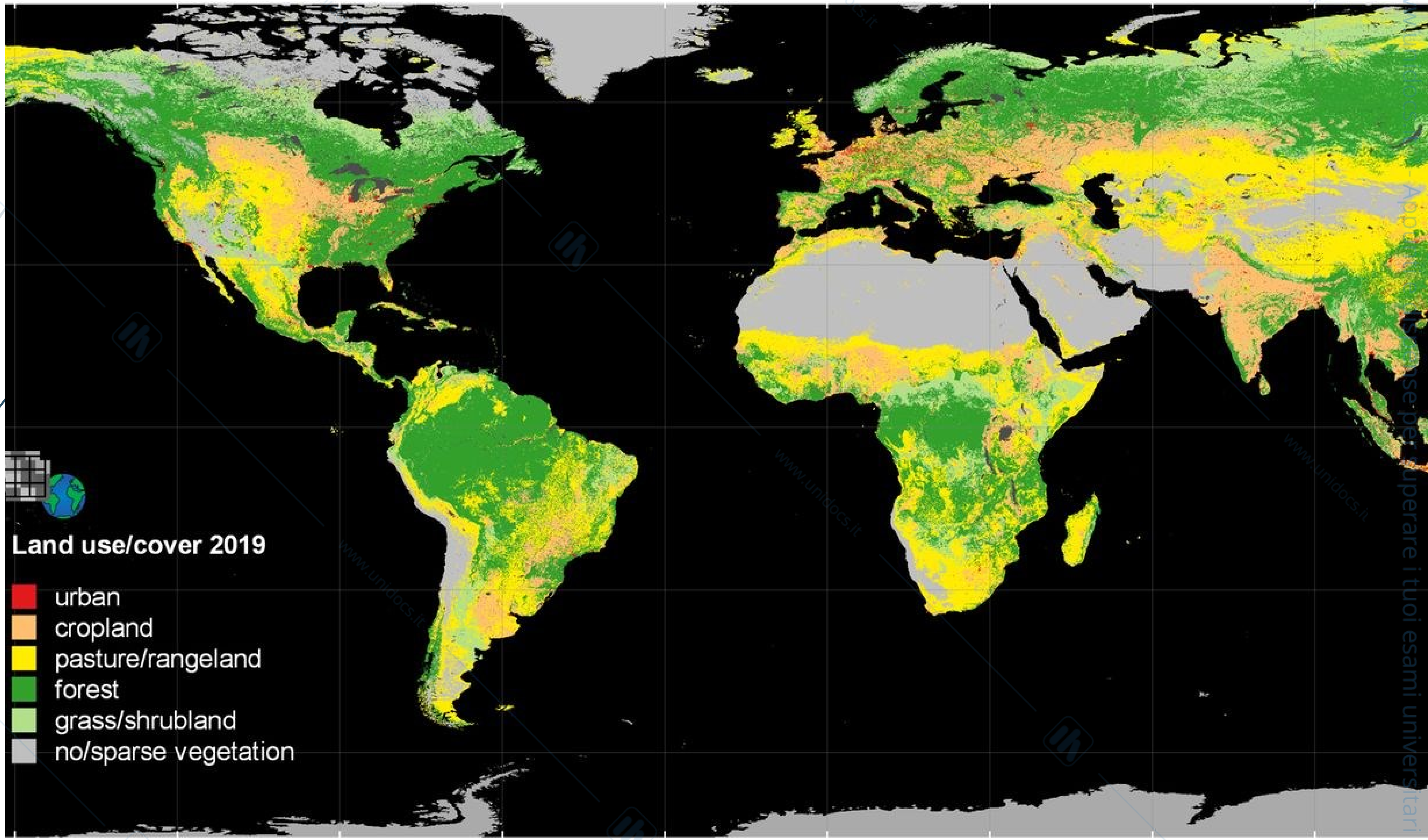
MODULE II

These distinctive characteristics of the city are a consequence of the fundamental changes t happen to the land when urban areas are developed, and natural areas are replaced by bui surfaces.

II. Unique ecological conditions of urban ecosystems – Land use and surface c

MODULE II

World map of land use and surface cover 2019



https://www.kit.edu/kit/english/pi_2021_044_global-land-use-more-extensive-

II. Unique ecological conditions of urban ecosystems – Land use and surface c

MODULE II

Land use and surface cover

- **Definition**: **land use is the process whereby land is involved in human activity**. Th process can be driven by individuals, groups, or the whole community. The result i piece of land that can be typified, representing a **land-use type**. Land-use types re different anthropogenic activities in a certain area.
- **Land uses can be diverse, small-scaled, intensive, and affect not only on the targ urban area but also the surroundings areas** through urban noise, air pollution, etc
- **Land uses consist of a mosaic of different land-use types, which accommodate ba human needs** for facilities in the residential, industrial and commercial, education other social institutions, and recreation sectors. Urban areas can also harbor large of agricultural, forest, and unused land.
- The visible results of land use are the characteristics and elements of vegetation a built-up structures on the surface. **This physical material at the surface of the Eart called surface cover.**

II. Unique ecological conditions of urban ecosystems – Land use and surface c

MODULE II

The processes of land use create new urban morphology

- **The physical urban form can only be interpreted by understanding land use as a continuing process**, as land is involved in human activities and produces surface-c patterns.
- **Urban structural or morphological units and types can be distinguished by their characteristic pattern of built and open spaces**. **Vegetation cover** is a component almost all urban land-use types and **is responsible for the ecosystem services**.
- **Land-use types represent** the basic elements, which form **the tools for undertaki applied urban ecological research and urban nature conservation**.
- **Ecosystem services**, that is 'the benefits people obtain from ecosystems' **are relat land use and surface cover**. **Spatial planning and regulations that influence the s pattern and intensity of land use can have huge implications for the ecology of c**

II. Unique ecological conditions of urban ecosystems – Land use and surface c

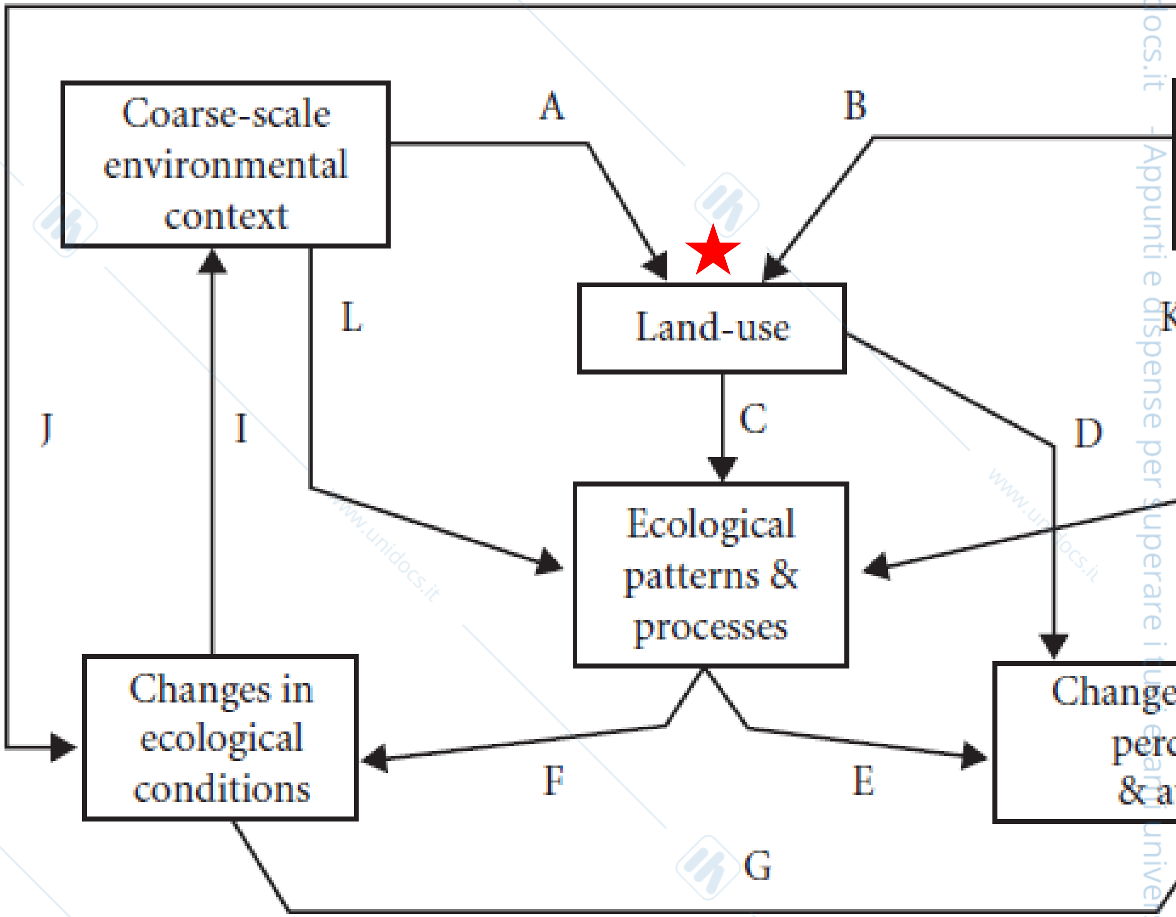
MODULE II

Conceptual scheme for integrating ecological and social systems in urban environments

Land-use is influenced both by societal and environmental processes and patterns.

In turn, land-use influences ecological patterns and processes in cities, which themselves lead to changes in ecological conditions and environmental context.

Changes in ecological conditions may affect human perceptions and attitudes and influence the formulation of policies, which have an impact on land-use.



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II. Unique ecological conditions of urban ecosystems – Land use and surface c

For the analysis of ecological conditions of urban land, a detailed characterization of land use is required. **Two complementary approaches can be used to analyze the urban spatial pattern and its relationship with the e processes**, allowing urban planning to identify areas in need of protection or restoration:

- **Biotope mapping:** a biotope can be seen as a variable-scale environmental unit of a landscape (e.g., a tract of open grassland or wetland, characterized by certain conditions and populated by a characteristic biota). **Biotope mapping is the process of identifying existing habitats and landscap units and it is related to vegetation mapping** through comprising not only the vegetation structure but the whole area, including water and urban fabric.

- **Urban morphology-type survey:** **urban structural types or urban morphology units and t (UMTs) are the product of past and present human land-use activities and can be distinguished b their characteristic pattern of built and open spaces.** UMTs have characteristic physical features a are distinctive according to the land uses. Physical properties and human activities are assumed to key factors that largely determine the ecological properties of urban areas. **Urban morphology uni can be delineated from a survey of aerial photographs and grouped into a number of types.**

MODULE II

Niemelä et al. 2011

II. Unique ecological conditions of urban ecosystems – Land use and surface c

The distinction of urban structural types (or UMTs) is a suitable basis for the spatial analysis of cities for urba

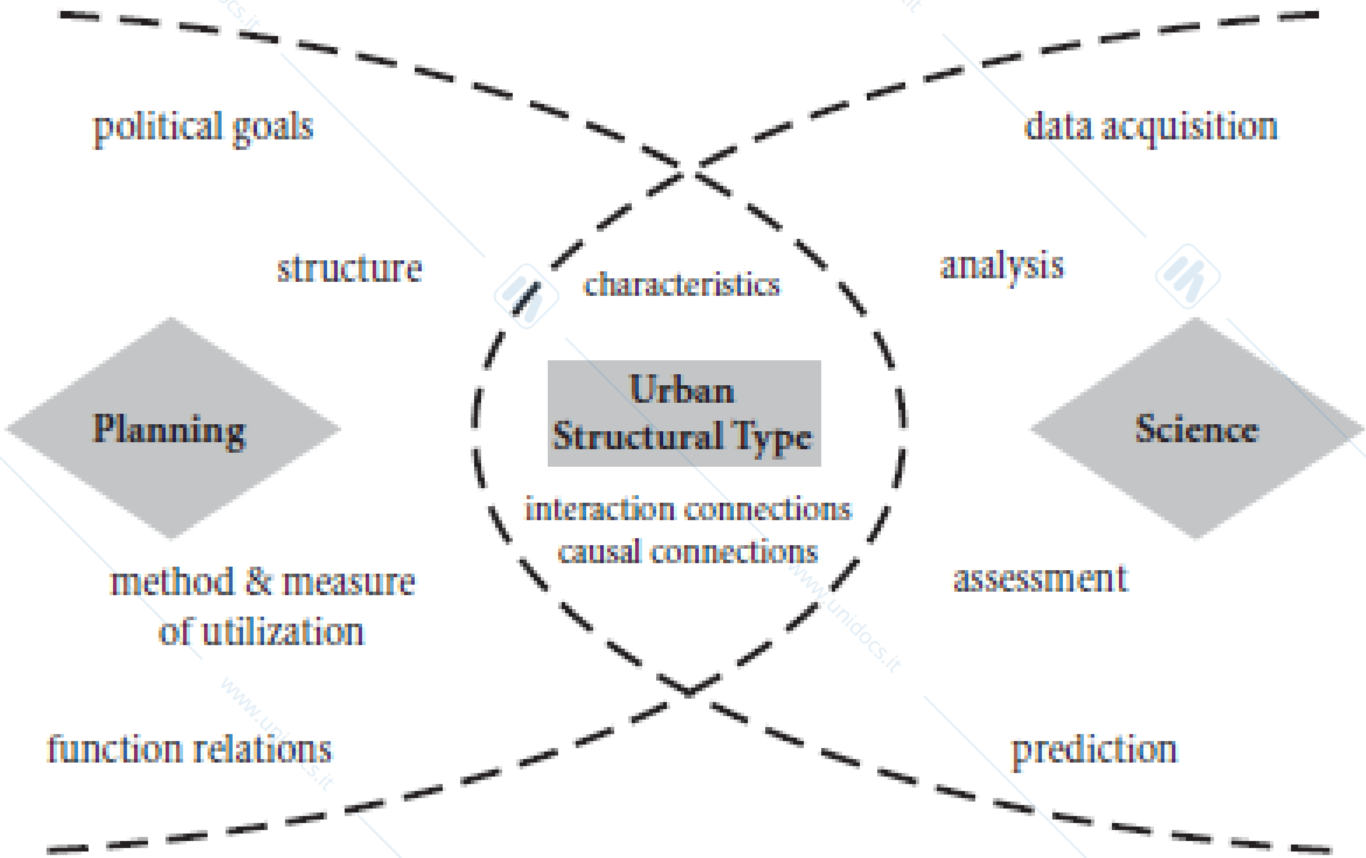


Figure 1.1.2 Urban structural types as a bridge between the science of urban ecology and urban planning (Breuste 2006)

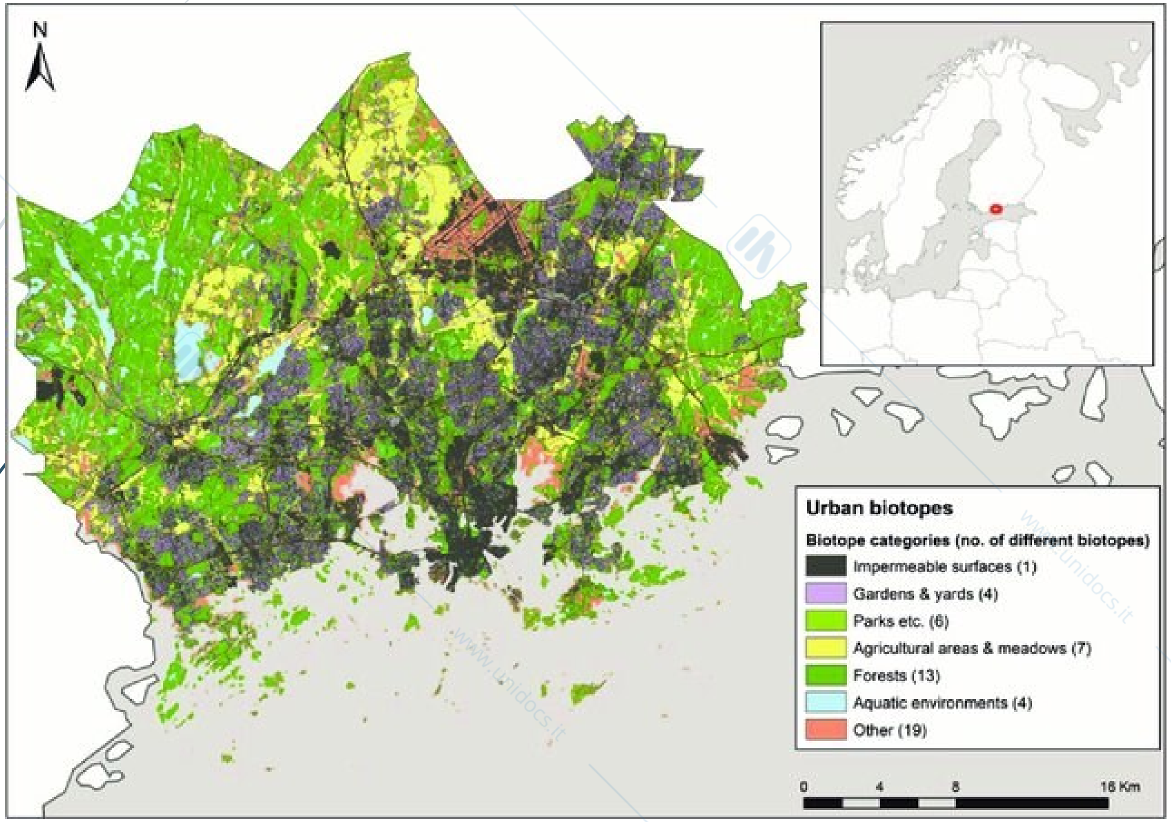
MODULE II

Niemelä et al. 2011

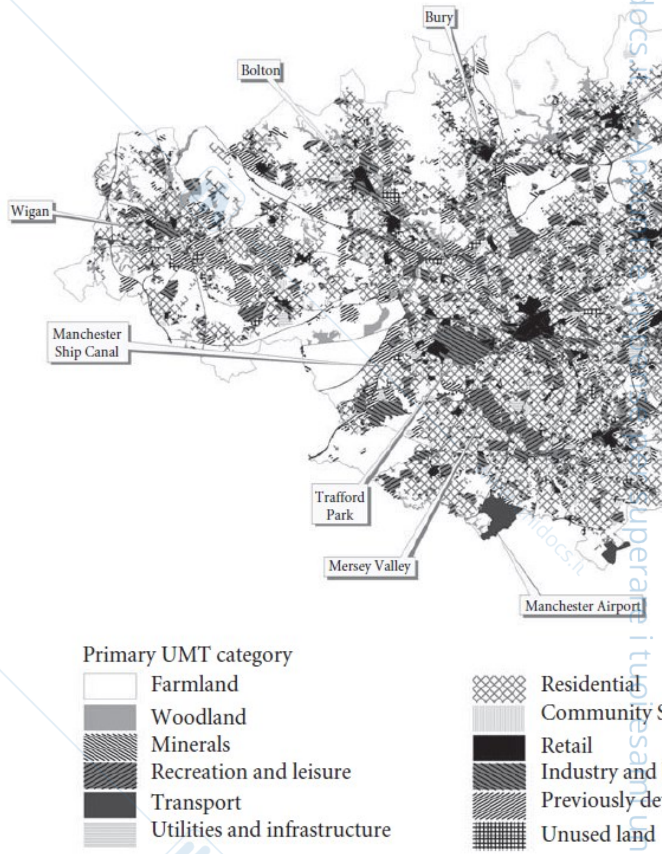
II. Unique ecological conditions of urban ecosystems – Land use and surface c

MODULE II

Biotope map



Urban morphology type m



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II. Unique ecological conditions of urban ecosystems – Land use and surface c

MODULE II

Surface cover: built *vs.* green surfaces

- For urban ecological analysis, **urban morphology types need to be further characterized by s cover. Surface-cover is an important determinant of ecosystem process in cities, influencing such as climatic energy exchange and hydrology**.
- Surface-cover can be easily surveyed from remote sensed data (as aerial photographs or sate images). **The relationship between built and paved (i.e., 'sealed') spaces, and vegetated sur an important determinant of ecosystem process in urban areas**.
- **Soil sealing is usually used as general indicator of extreme physical anthropogenic influence** on ecosystems.
- The **vegetation cover** (as part of the surface-cover) **is a component of nearly all urban land-use types**. Some units are dominated by designed vegetation cover (e.g., parks), in others the vegetation cover is an additional decorative element (e.g., residential areas). Other vegetation covers establish spontaneously after finished or interrupted utilization of land over a longer time (derelict land).

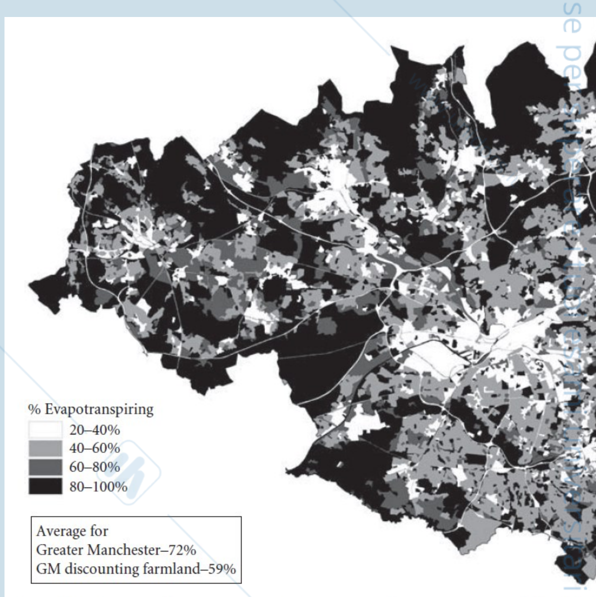


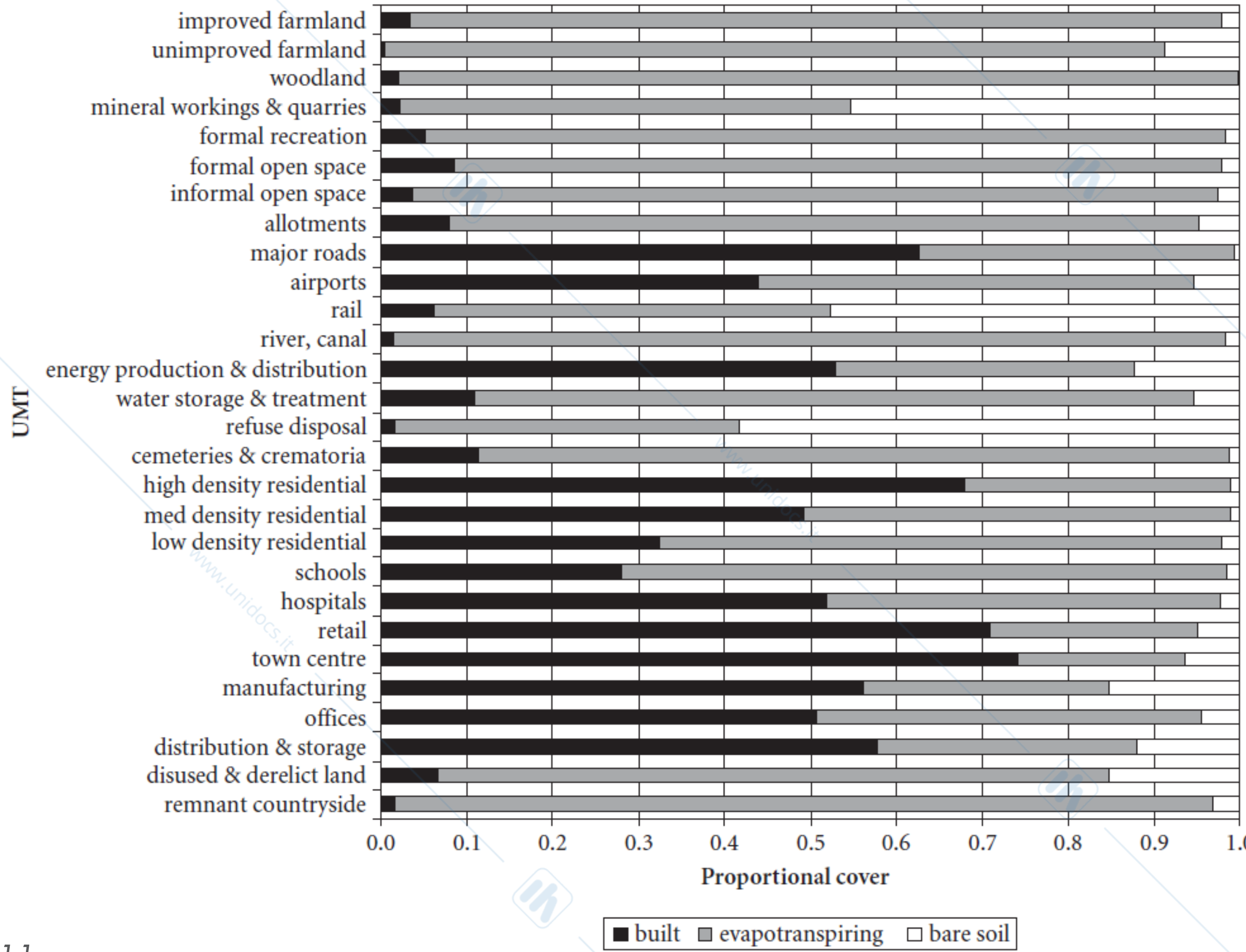
Figure 1.1.5 Proportion of evapotranspiring surfaces in Greater Manchester as estimated from UMT s the photo interpretation) (Gill *et al.* 2008). Used with permission from Elsevier

Niemelä et al. 2011

II. Unique ecological conditions of urban ecosystems – Land use and surface c

Differences in surface-cover between various UMTS grouped into three broad categories (built, evap and bare soil) for the UMT (urban morphology types) categories in the city of Manchester.

An example…



MODULE II

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II. Unique ecological conditions of urban ecosystems – Land use and surface c

MODULE II

Key impacts of replacement of vegetated surfaces by "sealed" surfaces

Soil and water regime (through 'loss' of the vegetation cover and physical change of the soil surface and the upper soil layer)

- partial or complete removal of the upper soil layer;
- decreased infiltration of precipitation water into the soil and thus reduced groundwater replenishment;
- renewal;
- increased evaporation;
- increased and accelerated rates of stormwater runoff;
- more frequent high levels in drains and streams with heavy rain and thaw.

Urban climate (through 'loss' of the vegetation cover and thermal and energetic effects due to human modifications (creation of new technical surfaces))

- increased thermal capacity and thermal conductivity of the sealing materials;
- increased air temperatures;
- increased particulates, and thus more frequent precipitation events;
- lower volume and shorter periods of snow cover;
- reduced humidity in temperate regions (not always true for arid regions).

Vegetation and fauna (through destruction of the vegetation cover and change of the local ecological conditions, intensive use by trampling and driving on)

- reduced, usually minimal colonization opportunities for plants
- lower oxygen and water supply for soil fauna, and decreased exchange of matter and gases between the soil and the near-surface air layer;
- depletion of the native flora;
- loss of levels of the food pyramid;
- loss of habitat;
- increasing isolation of populations.

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II. Unique ecological conditions of urban ecosystems – Land use and surface c

An example…

Table 1.1.2 The urban structural or land-use type of older areas of villas, compared to the city centre in Leipzig, show very different fo land-use (modified from Breuste 2009)

	old villa areas	city centre
		
Land-use	Residential	Residential plus commercial and offices
Urban morphology type	Single houses	Compact building blocks
Building cover	20–30%	More than 70%
Open space character	Extended open spaces	Small open spaces in courtyards, some squa
Vegetation character	High vegetation cover, esp. tree cover	Almost no vegetation cover
Cover of sealed surfaces	Below 40%	Above 90%

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MODULE II

II. Unique ecological conditions of urban ecosystems – Land use and surface c

Types of urban vegetation structures influenced or created by urban land us

Vegetation Group	Vegetation structure type	Main utilization	Main poten
A) Vegetation remnants of the original natural landscape	Woods and forests	Recreation, biodiversity	Timber produc
	Wetlands	Nature protection, biodiversity	Nature experie
B) Vegetation of the cultural landscapes formed by agriculture	Meadows, pastures	Agriculture	Recreation, bio
	Drifts, dry grasslands	Agriculture	Recreation, bio
	Arable land	Agriculture	
C) Ornamental, horticultural and designed urban vegetation spaces	Decorative green (flower beds, small lawn patches, bushes, hedges, etc.)	Decoration	Recreation, bio
	Accompanied green along traffic lines or as an addition to fill up the space between apartment blocks	Decoration	Recreation, bio
	Gardens/parks	Recreation, decoration	Biodiversity
	Allotment gardens (territorially organized in allotment garden estates)	Recreation	Biodiversity
	Urban trees	Decoration	Biodiversity
D) Spontaneous urban vegetation (areas)	Spontaneous herbaceous vegetation	None	Biodiversity, na recreation
	Spontaneous bush vegetation	None	Biodiversity, na recreation
	Spontaneous pre-forest vegetation	None	Biodiversity, na recreation

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MODULE II

II. Unique ecological conditions of urban ecosystems – Land use and surface c

MODULE II

Land-use and surface-cover dynamics in urban areas and their ecological implicatio

I. Urban growth/sprawl: Urban areas are becoming more dispersed—a process also called urba Urban sprawl has induced change to some important characteristics of urban form and land-us structure:

- Residential areas have grown faster on the urban fringe than in urban core areas.
- Commercial and industrial areas, as well as their infrastructure, have extended much faster than reside Again, this growth has been stronger on the urban fringe than in urban core areas.
- Green urban areas have grown on the urban fringe but declined in urban core areas.
- Farmland and areas classified as 'natural' have declined and become more fragmented

Some of the major environmental problems associated with urban sprawl:

- Loss of natural areas and biodiversity, fragmentation and degradation of remaining natural areas.
- Loss of farmland and productive soils.
- Negative impacts on hydrology: e.g., deterioration of surface water quality and increased stormwater ru
- Increase of air pollution, through more individual traffic; extension of the urban heat island effects.
- Increase of energy consumption.

II. Unique ecological conditions of urban ecosystems – Land use and surface c

Land-use and surface-cover dynamics in urban areas and their ecological implication

II. Urban densification: The densification or compaction of urban areas has been suggested as a to avoid or reduce urban sprawl. Densification means that available land within urban areas is b rather than on the urban fringe. Densification also means that inner urban open spaces are bui with negative consequences for ecosystem processes.

Urban sprawl is clearly undesirable from an environmental perspective because it increases th footprint. On the other hand, urban compaction, which has been proposed as a strategy to re urban sprawl, can have negative impacts on the quality of life and health of urban citizens.

MODULE II

Urban sprawl

vs.

Urban densification

II. Unique ecological conditions of urban ecosystems – Urban climate

MODULE II

The urban climate is strongly modified by human activities. Most meteorological var
(e.g., temperature, wind, air pollution) are influenced by urban conditions.

The urban climate differs from non-urban/rural conditions in various aspects:

- The urban area has a high aerodynamic surface roughness, which influences vertic turbulence and the wind field.
- It has a completely different radiation and heat budget due to the physical propert construction materials (e.g., heat capacity and thermal conductivity).
- It is normally highly three-dimensional and therefore a very complex surface for al exchange processes with the urban boundary layer.
- It is a significant source of emissions from traffic and industrial sites as well as thro heating and air conditioning in terms of greenhouse gases, pollutants, and direct h release.

II. Unique ecological conditions of urban ecosystems – Urban climate

Physical aspects of urban climate

In urban systems the solar irradiance is strongly influenced by the three-dimensional shape of the city, e.g., the [...] of streets, height and type of buildings, type and size of urban greens etc., which produce shadowing effects o[...] multiple reflections in the streets. The **urban radiation and heat budget** directly control the meteorological fie[...] temperature and wind in cities as well as the bioclimatic situation during the day.

MODULE II

The **radiation budget** of an area depends on the following parameters:

$$Q^* = E_{sd} - E_{su} + E_{ld} - E_{lu}$$

with Q* all net wave radiation

E_{sd}: shortwave downward solar irradiance
E_{su}: shortwave upward radiation (reflection)
E_{ld}: longwave atmospheric counter radiation
E_{lu}: longwave upward surface emission

II. Unique ecological conditions of urban ecosystems – Urban climate

Physical aspects of urban climate

The radiation budget of an area depends on the following parameters:

$$Q^* = E_{sd} - E_{su} + E_{ld} - E_{lu}$$

with: **Q*** net all wave radiation,
E_{sd}: shortwave downward solar irradiance,
E_{su}: shortwave upward radiation (reflection),
E_{ld}: longwave atmospheric counter radiation,
E_{lu}: longwave upward surface emission

- E_{sd}: Shading and exposure of the buildings and other structures greatly influence E_{sd} vertical distribution.
- E_{su}: The shortwave upward radiation depends on the surface material and its reflection characteristics.

The ratio of E_{su} / E_{sd} is known as **albedo** and describes the reflectivity of the surface. It varies between 0 (no reflection, black) and 1 (total reflection, white). Albedo values differ for typical rural and urban surfaces.

Table 1.2.1 Albedo of different surface types

Surface type	Albedo
Soil, dark wet	0.06–0.08
Soil, light dry	0.16–0.18
Stones	0.2–0.3
Forest, coniferous	0.05–0.15
Forest, deciduous	0.10–0.25
Grass, green	0.26
Rock, granite	0.12–0.18
Road, asphalt	0.05–0.15
Buildings	0.09
Concrete	0.15–0.37 ★
Urban, mean	0.15

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MODULE II

II. Unique ecological conditions of urban ecosystems – Urban climate

Physical aspects of urban climate

The radiation budget of an area depends on the following parameters:

$$Q^* = E_{sd} - E_{su} + E_{ld} - E_{lu}$$

with: **Q*** net all wave radiation,
E_{sd}: shortwave downward solar irradiance,
E_{su}: shortwave upward radiation (reflection),
E_{ld}: longwave atmospheric counter radiation,
E_{lu}: longwave upward surface emission

MODULE II

- E_{ld}: The longwave downward radiation is an important radiative energy source. In clear sky its mostly depends on air temperature and water vapor in the lower atmosphere. It does nc very much during the daytime because air is well-mixed by wind and turbulence.

- **E_{lu}: It is the most important radiation flux, which leads to significant differences between and rural sites. According to the law of Stefan-Boltzman E_{lu} is directly dependent on surfa temperature.**

$$E_{lu} = \sigma\varepsilon T_0$$

σ: Stefan-Boltzman-constant
ε: emissivity
T_0: surface temperature

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II. Unique ecological conditions of urban ecosystems – Urban climate

Physical aspects of urban climate

The radiation budget of an area depends on the following parameters:

$$Q^* = E_{sd} - E_{su} + E_{ld} - E_{lu}$$

with: **Q*** net all wave radiation,
E_{sd}: shortwave downward solar irradiance,
E_{su}: shortwave upward radiation (reflection),
E_{ld}: longwave atmospheric counter radiation,
E_{lu}: longwave upward surface emission

$$E_{lu} = \sigma\varepsilon T_0$$

MODULE II

Table 1.2.2 Thermal properties of materials used in rural and urban enviro

Material	Heat capacity $Jm^{-3}K^{-1} \times 10^6$	Thermal co $Wm^{-1}K^{-1}$
Sandy soil, dry	1.28	0.30
Sandy soil, saturated	2.96	2.20
Clay soil, dry	1.42	0.25
Clay soil, saturated	3.10	1.58
Asphalt	1.94 ★	0.75 ★
Concrete, dense	2.11 ★	1.51 ★
Stone	2.25	2.19
Brick	1.37 ★	0.83 ★
Clay tiles	1.77	0.84
Wood, dense	1.52	0.19
Water, still	4.18	0.57

The artificial urban surfaces warm-up most because of the thermal properties (heat capacity, t conductivity etc.) of the construction material used in urban systems, like concrete, bricks and Heat capacity and thermal conductivity of urban and non-urban material are very different.

<u>Heat capacity</u> indicates how much energy is needed to heat a cubic meter of a certain material by 1 degree c
<u>Thermal conductivity</u> is a property which indicates how easily heat can be transported within a material.

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II. Unique ecological conditions of urban ecosystems – Urban climate

Physical aspects of urban climate

A further important aspect is the **urban heat budget**, which makes the urban climate special. It describes **how gain from net radiation (Q*) is partitioned into the various heat fluxes**.
The heat budget for a surface can be written as follows:

$$Q^* + Q_H + Q_E + Q_S + Q_F = 0$$

Q*: net radiation
Q_H : sensible heat flux density
Q_E : latent heat flux density
Q_S : storage heat flux density
Q_F : anthropogenic heat flux density

MODULE II

If net radiation (Q*) is positive, as is normally the case during daytime, this energy is used fo heat flux (increase of air temperature) (Q_H), latent heat flux (evapotranspiration) (Q_E), and st heat flux (flux into the soil and building material) (Q_S). The anthropogenic heat flux Q_F incluc additional energy input produced by human activities (e.g., the energy released by combusti fuels, and electric heat from industry and traffic or through heating and air conditioning).

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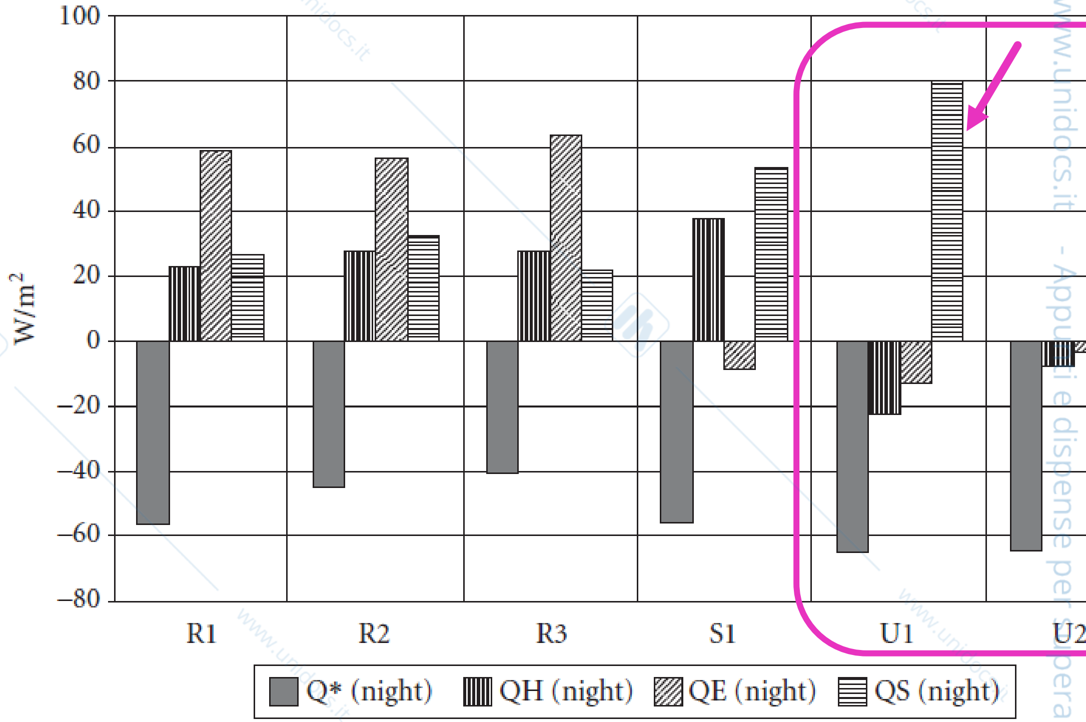
II. Unique ecological conditions of urban ecosystems – Urban climate

Physical aspects of urban climate

$$Q^* + Q_H + Q_E + Q_S + Q_F = 0$$

Q^*: net radiation
Q_H : sensible heat flux density
Q_E : latent heat flux density
Q_S : storage heat flux density
Q_F : anthropogenic heat flux density

Portioning of (night) heat budget for rural, sub-urban and



MODULE II

During night-time, rural and urban sites behave completely different. At the urban sites, the storage heat higher than the net radiation, indicating an over-compensation of net radiation, which enables a small sens even latent (Q_E) heat flux to be kept in the boundary layer atmosphere.

The source of energy for this compensation is the heat stored during daytime in urban construction mate acts like a battery, charged during daytime and discharged during night-time. Consequently, the decrease temperature in the urban system during night-time is much smaller compared to that in rural systems. Th characteristics of rural and urban energy budget are very important in explaining the **urban heat island e**

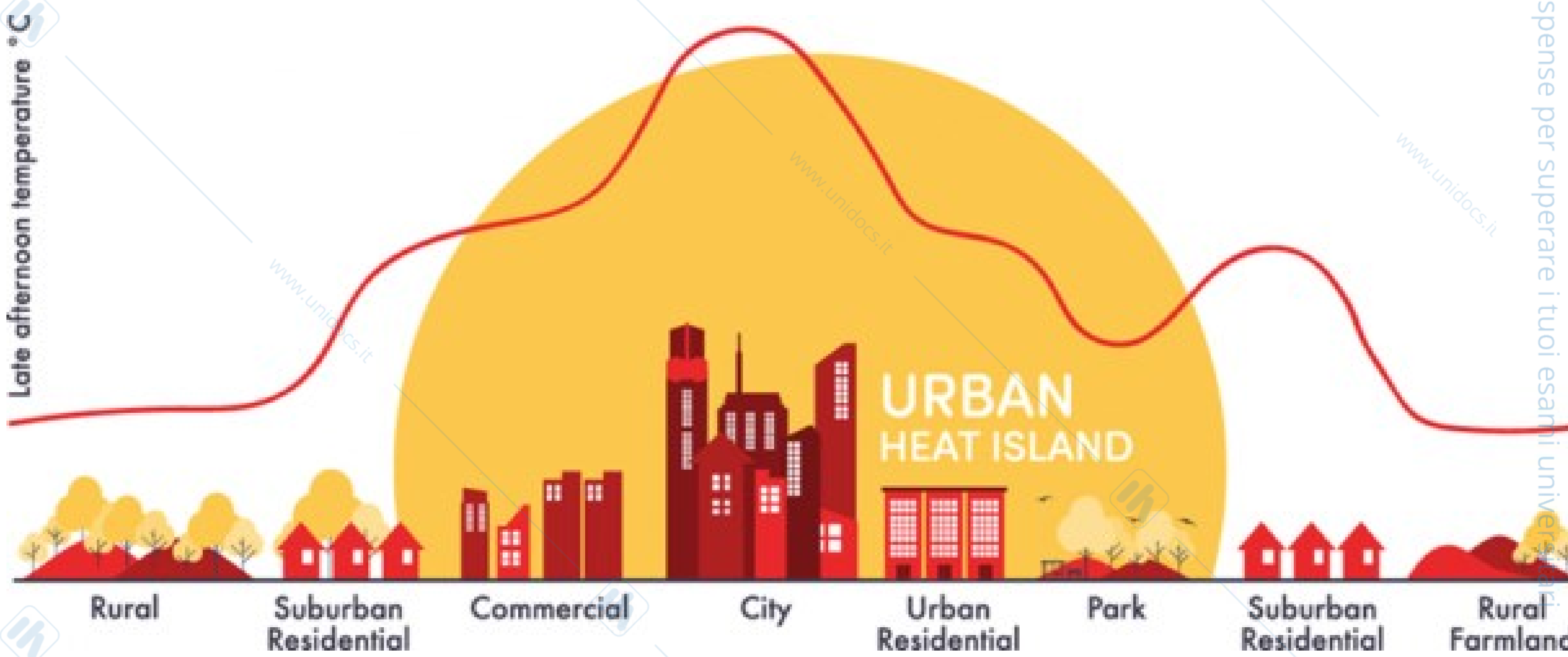
II. Unique ecological conditions of urban ecosystems – Urban climate

The urban heat island (UHI) effect

The UHI is a prominent feature of the urban climate. Daily or annual mean urban air temperatures are some degrees higher than the rural surroundings. This can be found in most cities of the world and is n
to summer conditions.

The heat island intensity correlates positively with the size of the city but is also strongly dependent on t
different construction types of buildings and especially the use of air conditioning in private and public b
(thus it can vary among similar sized cities).

MODULE II



II. Unique ecological conditions of urban ecosystems – Urban climate

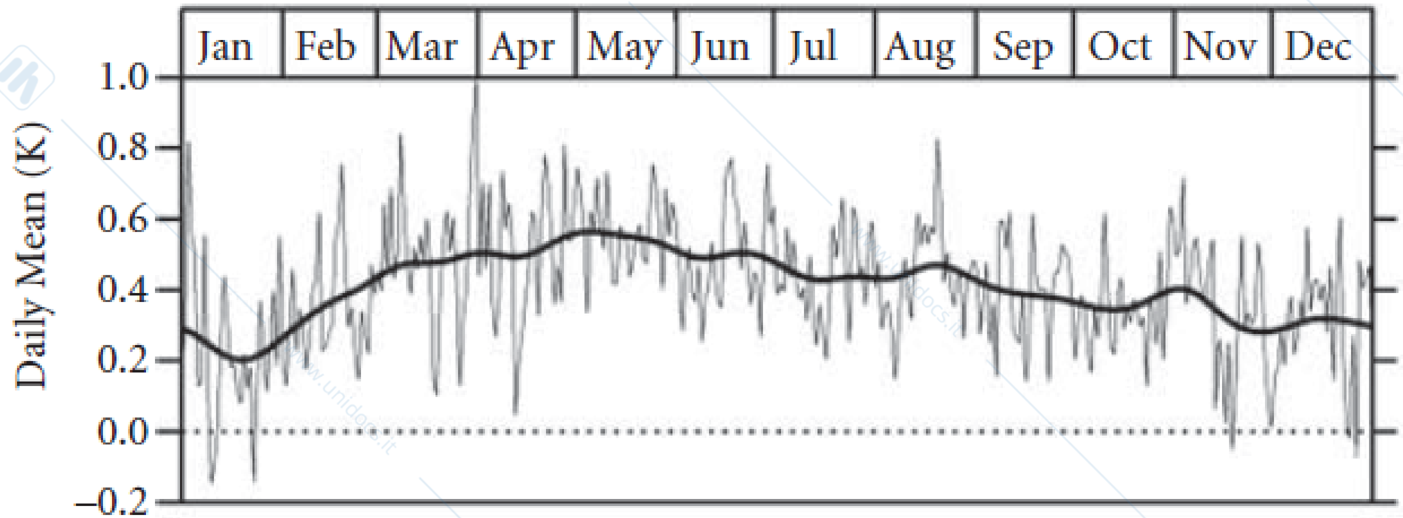
The urban heat island (UHI) effect

History of UHI: the observation of urban heat island goes back to the early nineteenth century. In 1820 Luke Howard analy temperature differences between the City of London and the rural surroundings over many years. He discovered that duri air temperatures were higher in London compared to the rural sites and that during daytime it was the opposite.

An example…

MODULE II

Annual dynamics of the urban heat island effect



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Annual dynamics of the urban heat island effect measured at an urban station in the city of Basel and a station few km away, for the period 1994–2002. The temperature differences between the urban and th station are shown. **In all months of the year, mean daily temp differences (ΔT) of the urban site were 0 higher than the rural one, indicating that the urban heat island is not dependent on seasonal effects.**

II. Unique ecological conditions of urban ecosystems – Urban climate

The urban heat island (UHI) effect

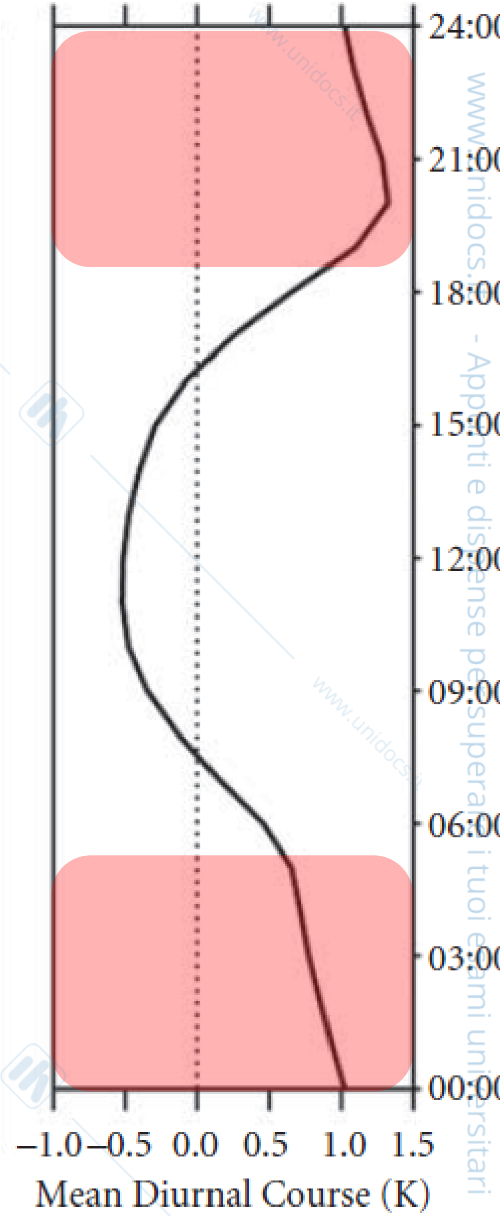
The urban heat island effect does not depend on the season, and it has distinct diurnal characteristics. During daytime it is mostly absent, while during the night-time air temperatures of urban sites remain at a significantly higher level compared to rural ones

MODULE II

Daily dynamics of the urban heat island effect

Diurnal dynamic over 24 hours as mean annual values measured at an urban station in the city of Basel and a rural station few km away, for the period 1994–2002.

During night-time, the urban air temperatures were up to 1.4 K higher than the rural ones, while during daytime the urban temperatures were up to 0.5 K lower than the rural.



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II. Unique ecological conditions of urban ecosystems – Urban climate

Biological aspects of urban climate

Vegetation in cities is directly influenced by differences of urban climate, in respect to rural surroundings. Air temperature is directly related to e.g., plant phenology. Phenology is a highly sensitive indicator of any mo
air temperature on a year-to-year basis. Temporal shifts in phenophases (beginning of pre-spring or full-spring
are influenced by both the general global climate change and the local urban climate effect. **Many studies hav
shift in start dates of phenophases for urban agglomerations around the world. In nearly all cases, flowering
urbanized areas started earlier than in adjacent rural areas.**

MODULE II

Urban climate with pronounced local urban heat island effect is amplifying the general trend of global warming, and it significantly prolongs the vegetation period in urban areas.

II. Unique ecological conditions of urban ecosystems – Urban climate

Chemical aspects of urban climate

- **Urban areas are an important source for emissions and pollutants**. The urban atmosphere has a unique m specific gasses compared to a non-urban atmosphere. **Urban areas contribute significantly to global CO_2 a emissions.** Vehicle emissions and other anthropogenic and industrial activities are also source of important and pollutants.
- **Urban aerosol has become an important political and health issue**. Particulate matter (PM) or particle poll describes the mass of aerosol particles (a mixture of solid particles and liquid droplets found in the air) with aerodynamic diameter <10 µm (PM_{10}) or <2.5 µm ($PM_{2.5}$). Even smaller particles (ultrafine, <0.1 µm) are im Since these particles can penetrate the lungs, and the ultrafine particles into the blood system or even the system, they can affect other organs and are related to health hazards (e.g., heart disease, disorders of the system, lung cancer).

MODULE II

Table 1.2.3 Mean concentrations of air pollutants in rural and urban areas for Germany

Pollutant	Rural areas	Urban areas	Maxima (urban)
CO	< 0.5 mg m^{-3}	0.5–5 mg m^{-3}	30 mg m^{-3}
SO_2	5–15 µg m^{-3}	10–75 µg m^{-3}	1600 µg m^{-3}
Total suspended matter (TSP)	25–30 µg m^{-3}	75 µg m^{-3}	1200 µg m^{-3}
NO	5–15 µg m^{-3}	40–120 µg m^{-3}	1200 µg m^{-3}
NO_2	10 µg m^{-3}	40–80 µg m^{-3}	450 µg m^{-3}
CH	20 ppb C	200–600 ppb	up to 30 000 ppb C
O_3	50–75 µg m^{-3}	25–50 µg m^{-3}	300 µg m^{-3}

Niemelä et al. 2011

<u>II. Unique ecological conditions of urban ecosystems</u> – Urban climate

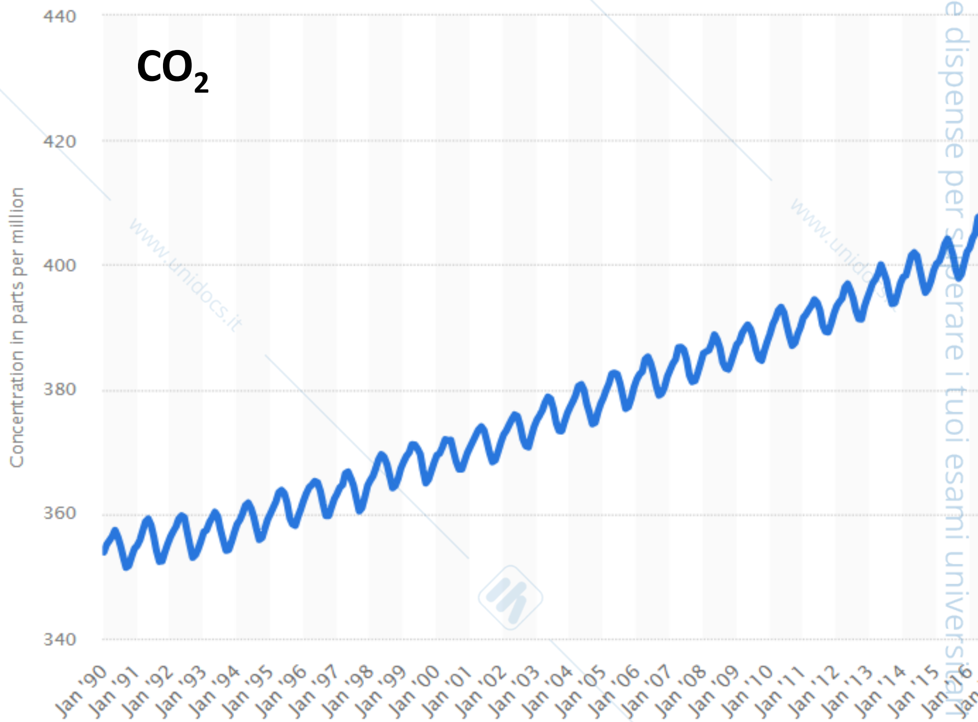
Chemical aspects of urban climate

CO_2: Main CO_2 concentrations in urban and rural areas are influenced by the global background concentration and the in between vegetation and atmosphere through photosynthesis and respiration. Due to the long lifetime of CO_2, the global c are well mixed by atmospheric circulation and **the global background value is growing by roughly 2 ppm per year (currently** Quantifications of CO_2 emissions are mainly estimates of fossil fuel consumption. Little is known about measured concentrat areas. The daily variations are a result of anthropogenic, biogenic, and meteorological influences.

MODULE II

NO_2: NO_2 is another pollutant which is greatly increased in urban areas. This is mainly traffic-related. Emissions are generally highest in urban rather than rural areas. Levels vary significantly throughout the day, with peaks generally occurring twice daily due to rush hour traffic.

Urban atmosphere has a significantly higher level of CO_2 and NO_2 concentrations compared to mean global conditions, due to the increased local emissions by traffic, industry, and heating.



II. Unique ecological conditions of urban ecosystems – Urban climate

Impacts of urban climate on human health

Two important issues of urban climate influence the health of people: **heat stress during summer conditions a** **pollution. Due to the urban heat island effect, heat stress for human beings is enhanced and air pollutants al** **higher concentrations both in summer and in winter.**

MODULE II

- Bio-climate is an important factor for human wellbeing, and integrates all meteorological v such as air temperature, air humidity, wind speed, shortwave solar radiation, and longwave terrestrial emission. All these variables influence the human heat budget. Humans have to body temperature of 37 °C under all climatic conditions, and this value only allows small de **Thermal stress can lead to adverse effects for human health as shown in numerous epide studies, in which the thermal environment has been related to thermal-related mortality**

- **Air pollution in cities is the result of complex interactions between natural and anthropog conditions. Poor air quality in cities is a serious environmental problem, especially in dev countries.** Emissions from motor traffic are a very important source of air pollution throug world. During transmission, air pollutants are dispersed, diluted, and subjected to photoch reactions. In many cases, there are additional sources of air pollutants such as burning foss burning waste, industrial processes, and many more.