Towards understanding the hydro-climatic implications of urbanization in the GFDL global climate and earth system modeling framework

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The environmental significance of land-use/land-cover changes, of which urbanization is an extreme case, is well recognized but understood in a limited way. How urbanization affects regional and global climate and how urban areas respond to climate change at time scales from seasonal to decadal are critical areas of research. However, to date, most global climate models that are used to investigate impacts of land-use/land-cover changes on the climate do not include an urban representation. Moreover, the effect of urban expansion on climate of near-by areas has not been characterized in any existing urban representations. In order to answer these questions, the Geophysical Fluid Dynamics Laboratory (GFDL) is developing a high-resolution global climate model with an urban representation that can simulate interactively both changes in urban environments and feedbacks of urban changes. In this study, efforts towards urbanizing the GFDL land model LM3 are described. Historical simulations with the urbanized GFDL LM3 are presented to demonstrate how growth of urban areas has affected the near-surface climate in recent decades over the continental United States.

Changes of temperature and humidity in areas of city sprawl under climate change conditions

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The contrasting climate between urban and rural areas is a serious consideration in the context of climate change. Differences in the local response to large-scale changes could have significant repercussions for most of the population. However, Global Climate Models are only able to provide very limited information on future urban climate. In this study, we investigate the combined effects of urban expansion and changes in greenhouse gas emissions on the future climate of Sydney, Australia. We use a regional climate model at very high resolution (2 km) to dynamically downscale a Global Climate Model and simulate the climate of the region for both present and future climate conditions. The model is coupled with an urban canopy model to incorporate the interactions between urban structures and the atmosphere while preserving the physical consistency of the model. Changes in temperature and vapor pressure are examined as a means of determining changes in the population exposure to heat stress due to the combination of urban expansion and greenhouse gas. Daily maximum and minimum human heat stress are estimated using hourly values of temperature and vapor pressure. Our results indicate that new urban areas are likely to experience higher heat stress conditions at night in the future, with changes that are substantially larger than in the rural counterparts. During the day, urban structures seem to compensate the climate change effects on heat stress through vapor pressure differences. Overall, urban areas tend to enhance the climate change signal during the cooler hours of the night by contributing to temperature increases, whereas vapor pressure deficits induced by urban surfaces dominate over temperature during the day. This work emphasizes the need to include explicit representation of urban effects and to consider variables other than temperature to assess climate change impacts on urban population.

Modelling the relative impact of land-use change and global climate change on the climate in cities

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It is known from global climate ensemble projections that both global warming and the increasing extreme weather conditions including heat waves and pluvial flooding will put increasing pressure on the livability of cities. At the same time, urban heat island intensities are expected to increase because of the unrestrained urban expansion, which makes cities the 'hotspots' of climate change. This not only implies severe health hazards for the many urban dwellers, it also leads to increased energy consumption, damage of city's infrastructure, and hypothecates the urban environmental health.

We investigate the relative impact of urban land-use change and global climate change on the increased temperatures and extreme precipitation in cities at the second half this century. Therefore, urban-climate simulations with COSMO-CLM coupled to TERRA_URB at 2.8km resolution over Belgium are cascade-nested in EC-EARTH (GCM) for the climate of the recent past (2000-2010) and for future climate projections (2060-2070). The regional climate model accounts for urban land-use change for Belgium towards 2060 based on projections with 'Ruimtemodel Vlaanderen'. We further address the synergy between urban heating and global climate change. Hereby, we investigate how the frequency and intensity of heat waves (+), the local changes in atmospheric radiative transfer by greenhouse gases (-), changes in precipitation (+/-), but also the urban expansion (+) and increased cooling demands (+) affect heat island intensities in Belgium. In order to account for urban climate with a broad-risk assessment approach, we investigate the relation between urban heat island intensities and the frequencies of circulation weather types or the percentiles from the temporal temperature distributions.

Assessment of three dynamical urban climate downscaling methods

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A new high-resolution dynamical downscaling strategy to examine how rural and urban areas respond to change in future climate, is presented. The regional climate simulations have been performed with a new version of the limited-area model of the ARPEGE-IFS system running at 4-km resolution coupled with the Town Energy Balance scheme (TEB). In order to downscale further the regional climate projections to a urban scale, at 1km resolution, a stand-alone surface scheme is employed in offline mode. We performed downscaling simulations according to three model set-ups: (i) reference run, where TEB is not activated neither in 4-km simulations nor in 1-km urban simulation, (ii) offline run, where TEB is activated only for 1-km urban simulation and (iii) inline run, where TEB is activated both for regional and urban simulations. The applicability of this method is demonstrated for Brussels Capital Region, Belgium. For present climate conditions, another set of simulations were performed using European Center for Medium-Range Weather Forecasts global reanalysis ERA40 data. Results from our simulations indicate that the reference and offline runs have comparable values of daytime and nocturnal urban heat island (UHI) and lower values than the inline run. The inline values are closer to observations. In the future climate, under and A1B emission scenario, the three downscaling methods project a decrease of daytime UHI between -0.24 °C and -0.20 °C, however, their responses are different for nocturnal UHI: (i) reference run values remains unaltered, (ii) for the offline runs, the frequency of present climate weak nocturnal UHI decreases to the benefit of negative UHIs leading to a significant decrease in the nocturnal UHI over the city, (iii) for the inline run, nocturnal UHIs stays always positive but the frequency of the strong UHI decreases significantly in the future by 1°C. The physical explanation is put forth.

How many days are required to represent the urban climate statistics?

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Evaluating the effect of adaptation and mitigation measures is important for urban development strategies. This can be achieved using high resolution numerical models. However, they are computationally expensive, thus simulating a 30-year climate period is challenging. An approach can be to simulate only a subset of days from the 30 years. Identifying the number of days which are sufficient to represent the urban climate is the aim of this presentation.

The presented statistical dynamical downscaling method is applied to simulate the urban climate of Hamburg. It utilises 30-year time series from 27 weather stations in Northern Germany and The Netherlands. For some meteorological quantities measured at these stations, the frequency distributions have been analysed. These are compared with artificial frequency distributions built with bootstrapping and a lower number of days. For comparing these distributions, a skill score following Perkins et al. (2007) is further developed, now taking into account the relationship between the quantities. The results of this statistical dynamical downscaling method indicate that the statistics of the urban climate of Hamburg can be simulated with a much lower number of days than the 30-year time series.

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The effect of future climate change on indoor thermal environment of a natural ventilated urban apartment in Taiwan

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The effects of global warming and climate change would lead the future weather more severe in terms of temperature. As buildings are built by complying nowadays building energy conservation regulations, they are vulnerable in facing the future weather change, especially for those operating in natural ventilation mode. To this end, this paper firstly adopted a statistical downscaling method, i.e. morphing method, to construct local hourly future weather data. This method uses either by shifting or stretching on the certain weather elements of the existing hourly local typical meteorological year (TMY) via calculating the differences between nowadays and the future projected weather base on the selected general circulation models (GCMs). SRA1B scenario suggested in IPCC AR4 was used to study the impact of weather change on the effectiveness of passive building design strategies. Probabilities of each year's thermal comfort achieved by means of natural ventilation were therefore identified by superimposing future hourly weather data onto the bioclimatic chart. Furthermore, to understand the indoor overheating problem of residential space, we simulated a typical natural ventilated four room's apartment via EnergyPlus with 2000 to 2100 weather data to obtain hourly indoor thermal condition. CEN standard EN15251 thermal comfort model were used to assess each room's overheating occurrence frequencies and their overheating severities. Due to different occupied hours, living room and bedrooms were discussed independently under three future time slices, which are 2020s, 2050s, and 2080s. In comparison with the baseline case (1998-2013), for the future three time slices, the overheating frequencies slightly increase from nowadays 0.03% to 0.48%, 2.23%, and 5.39%, respectively for living room; and from nowadays 0.68% to 0.5%, 1.86%, and 4.15% for bedrooms. However, the growth rate of overheating severities exponentially increase by 210%, 1213%, and 3360% for living room; and are -34%, 299%, and 877% for bedrooms. It indicates that spaces using during daytime are much more vulnerable to overheating problems both in terms of occurrence probability and the severity in the future climate context, which may cause natural ventilation ineffective and need mechanical cooling to maintain indoor thermal comfort.

Summer climate departure in mid-latitude cities: health impact, mitigation and adaptation

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Climate departure refers to the time after which climate parameters shift beyond historical values. Because climate variability and changes increase the frequency, intensity, and duration of heat waves, this study focuses on summer climate departures leading to heat-related urban mortality. Heat waves are especially deadly in large cities owing to the heat island effect, the production of anthropogenic heat, and the aging population. Twenty-seven Earth System Models of the Coupled Model Inter-comparison Project phase 5 were applied to different Representative Concentration Pathways (RCPs 2.6, 4.5, 8.5), using historical and modeled data from 1950 to 2100, including the following variables: daily maximum, minimum, and mean near-surface air temperatures; relative humidity; and wind speed. The predicted times at which the temperatures of recent heat waves will become normal summer temperatures depend on the scenarios for greenhouse gas emission, from stabilization to unconstrained growth. The tropics will be affected first, but summer climate departures will be more lethal in mid-latitude cities. Nine mega-cities were selected from Western Europe, North America, and Eastern Asia, based on a literature review of high temperatures and mortality from 1980 to 2010. Climate departure times and potential health impact were analyzed as a function of population characteristics, urban surface properties and heat island effects, anthropogenic emissions, temperature thresholds, and risk exposure. Summer climate departures in mid-latitude cities prompt for a substantial reduction of greenhouse gas emissions and implementation of mitigation strategies, such as increasing urban surfaces reflectance and vegetation, and for strengthening adaptation measures in public health actions to prevent the lethal impact of extreme heat events.

Assessing climate change in cities using UrbClim

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The urban heat island effect, in which air temperatures tend to be higher in urban environments than in rural areas, is a well-known and widely studied phenomenon. During heat waves, the urban heat island is known to exacerbate the impact on population health. Including urban heat island effects in the formulation of heat warnings and climate change adaptation plans is therefore essential and part of a sustainable urban development in general.

An important difficulty often encountered with typical numerical climate models is the limited resolution and long integration time, making them difficult to use when studying urban and intra-urban variations especially in the context of climate change. In this contribution, we will present a new urban climate model, further referred to as UrbClim, designed to cover agglomeration-scale domains at a spatial resolution of a few hundred metres. Despite its simplicity, UrbClim is found to be of the same level of accuracy as more sophisticated models. At the same time, the urban boundary layer climate model is faster than high-resolution mesoscale climate models by at least two orders of magnitude. Because of that, the model is well suited for long time integrations, in particular for applications in urban climate projections.

Within the EU RAMSES and NACLIM projects, the UrbClim model has been set up for a large number of cities : Antwerp, Lisbon, London, Bilbao, Berlin, New York, Rio De Janeiro and Skopje. We will present results and comparisons for these cities as well as detailed validations against air temperature measurements. Furthermore, a coupling was established between UrbClim and CMIP5 ensemble climate projections employed by the IPCC allowing the assessment of the urban heat island effects under future climate conditions, both for the near (2025 - 2045) and far (2081 - 2100 future).

Investigating the urban climate characteristics of two Hungarian cities with SURFEX/TEB land surface model

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Regional climate models are sufficient tools for estimating future climate change of an area in detail, although most of them cannot represent the urban climate characteristics, because their spatial resolution is too coarse (to date 10-50 km) and they characterize the urbanized areas as natural surfaces. At the Hungarian Meteorological Service (HMS) the externalised SURFEX land surface scheme including the TEB urban canopy model is used to describe the interactions between the urban surface and atmosphere on few km spatial scale.

In our study, the atmospheric condition is provided to the SURFEX by the ALADIN-Climate regional climate model adapted at the HMS. SURFEX is applied in a stand alone mode, thus the urban surface processes do not affect the atmospheric model. In the first step of our research a detailed validation is achieved to understand how the urban scheme modifies the climate model's results, and what the sensitivity of the SURFEX is to the biases of ALADIN. Model experiments are conducted for a 10-year period in the past for two Hungarian cities: Budapest is the capital with 2 millions inhabitants and the smaller Szeged is located at the flat southern part of the country. Temperature, wind results and certain fluxes provided by SURFEX and ALADIN are investigated and compared with measurements.

The focus of the presentation will be put on these results. However, the overall aim of the research is to provide climate change scenarios for Hungarian cities to help decision makers in preparing scientifically reasoned adaptation and mitigation strategies.

Near Future Weather Data for Building Energy Simulation in Summer/Winter Seasons in Tokyo Developed by Dynamical Downscaling Method

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Climate change phenomena, such as global warming and urban heat island, is proceeding. Mitigation and adaptation measures are the two approaches used when we deal with the global warming. For the mitigation in the construction sector, buildings are required to improve their energy efficiency to reduce CO2 emissions, which is the main cause of the global warming. Further, the adaptation of building designs to the climate change is needed to keep building indoor environment comfortable in the future. During the design processes, energy simulations are often used to calculate energy consumption of buildings and evaluate indoor environment. In these simulations, it is common to use regional weather data made from observations, which is based on current or past weather events. However, most buildings have been used for several decades during which climate conditions have gradually changed. Therefore, the development of weather data for the future is very important for the both of the mitigation and adaptation measures for the climate change.

In this study, we attempt to construct a near-future weather data for the building design using numerical meteorological models. Future climate data projected by Global Climate Models (GCMs) is available. Although GCMs can predict the long-term global warming, they cannot illustrate the details of local phenomena due to their coarse grid resolution (~100 km). Therefore, we input GCM data to a Regional Climate Model (RCM) as initial and boundary conditions and downscale the GCM data based on physical modeling with the RCM. This process is called dynamical downscaling. The RCM uses a nested regional climate modeling to analyze local climate in high resolution (~1 km). The future weather data produced by this method is expected to present the global climate change and local phenomena such as urban heat islands.

In this paper, we employ the Model for Interdisciplinary Research on Climate version 4 (MIROC4h) as GCM and the Weather Research and Forecasting (WRF) model as RCM. MIROC4h has a relatively high grid resolution among GCMs and its atmospheric horizontal grid size is about 60 km. In the WRF simulations, the target area was the Kanto region, or Tokyo and its surrounding area. We used four levels of nested regional climate modeling: where the first and fourth levels have horizontal spatial resolutions of 54 km and 2 km, respectively. We first dynamically downscaled current weather data projected by MIROC4h in August and January for a 10-year period (2001-2010) and compared results to observations to confirm the accuracy of dynamically downscaled MIROC4h data. Next, we downscaled near-future weather data projected by MIROC4h in August and January for a near-future period of 10 years (2026-2035) to confirm the climate change information of the weather data. The weather data, output of the climate models, included statistical error, or bias. Because the bias can become problematic when the obtained weather data is directly used for building energy simulations, we corrected the bias of the weather data by a statistical manipulation using statistical values of observations and results of current WRF simulation. We then constructed prototypes of near-future standard weather data for building energy simulations in summer/winter seasons in Tokyo by selecting average monthly weather data over multiple years. The weather data represents the near-future weather conditions and is expected to present both of the global climate change and local phenomena.

Modelling the impact of climate change on heat load increase in Central European cities

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The expected global climate changes are supposed to increase the heat load in urban areas. In order to plan and undertake the mitigation actions in particular cities, it is necessary to recognize the possible range of heat load increase, in terms of both its magnitude and spatial extent. Therefore, not only land use but also land form influences should be included. The present study shows preliminary results of an international project aimed to evaluate the expected heat load increase in four Central European cities (Krakow, Poland; Bratislava, Slovakia; Brno, Czech Republic and Szeged, Hungary) using the non-hydrostatic MUKLIMO_3 model developed by DWD (Deutscher Wetterdienst) for micro-scale urban climate and planning applications (Sievers 2012, 2014). All four cities have the spatial structure typical for post-communistic urban areas. Additionally, Krakow, Bratislava and Brno are located in large river valleys, in concave land forms, while Szeged is located in a flat area. In order to allow comparison of modeling results between the cities, the model setup uses standardize classification of land use properties based on local climate zones (Stewart and Oke, 2012) derived from remote sensing images (Bechtel and Daneke, 2012). The comparative analysis allows to study spatial patterns in urban heat distribution. The climatological changes in urban heat load are evaluated in terms of expected increase in the number of days with maximum air temperature exceeding 25 centigrade. The 30-year climatological indices are calculated using the cuboid method based on meteorological data from a local reference station for the recent climatic period and regional climate projections for the future climate signal.

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URBAN TOURISM IN SOUTHERN EUROPE: assessing present and future climate conditions

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Although tourism in Southern Europe is often assumed to be synonymous with beach tourism, cities are far from being just the gateway to a given region or country. In fact, city tourism is one of the rising markets of international tourism and, in association with market trends such as an aging world population and a growing interest in culture, it is expected to increase even further. Urban climate is a non-negligible asset that these regions have in common.
It is, thus, important to provide a comprehensive interpretation of the weather conditions experienced by tourists in some of the most visited southern European capitals during the summer. Besancenot's weather type method was selected and applied to Barcelona, Rome, Athens, Lisbon and Zagreb in order to assess these cities climate suitability for tourism activities. The weather type method was preferred on behalf of some of its advantages, namely the possibility to integrate a measure of comfort (using a thermophysiological index - PET) and to incorporate nuances, taking into consideration: a) tourists stated preferences; b) tourists revealed preferences; and c) the possibility of adjusting thresholds to the predominant tourist activities taking place in urban areas. The frequency of occurrence of the different established classes (eight different classes, numbered in descent, from the most favourable to the least favourable), each defined by the combination of 5 different variables (number of sunshine hours, cloud cover (at 12.00h), maximum daily air temperature, precipitation, wind speed) and a comfort index provides a weather-type pattern, which will be crossed with the seasonal tourist demand, in order to understand whether it influences visitors' arrival.

Following the assessment of the climate suitability of these cities during a baseline period (2000-2010), the same methodology will be applied to 2020 and 2050, making use of projections of temperature and precipitation drawn from an ensemble of 9 regional climate model (RCM) simulations based on the International Panel on Climate Change (IPCC) – Synthesis Report on Emission Scenarios (SRES) A1B emission scenario. This will allow to assess whether these destinations will still be adequate for the practice of tourism activities by mid XXI century. With this research, we expect to question claims of southern Europe's cities declining attractiveness during the summer, under climate change scenarios.

Integrated approach to assess vulnerability of urban natural resources under emerging climate change scenarios

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Warming of climate system is unequivocal and these changes will lead wide ranging impacts on different regions and sectors. Low lying coastal cities are more vulnerable to changing climate and strengthening the resilience capacity of urban systems to ensure sustainability calls for an immediate action. Managing the natural resources solicitously under changing climate is the most crucial responsibility and recognition of urban studies on climate change has increased in recent times. However, projection of climate change and its sectoral assessment at the city scale is a difficult task and need to be addressed in an integral manner, especially for the cities in developing countries. In this perspective, this study took an initiative to conduct a research with a study area of India's fourth largest metropolitan city and one of the fast growing urban centers in South Asia viz, Chennai Metropolitan Area (CMA). The methodological framework emphasized the integrated approach of assessments under present and future climate conditions.

This integrated methodology considers the exposure, sensitivity and adaptive capacity of the system for the vulnerability assessment of natural resources and was carried out in four phases viz, climate change analysis, urban system analysis, impact assessment and vulnerability assessment. Climate change analysis revealed the present and possible future climate exposure over the study area. 60 years of climate data were used to sketch the changes in climate variables over the past period and high resolution climate change scenarios of about 25 km from PRECIS (Providing Regional Climate for Impact Studies) were used to study the changes in future climate of the study area. Urban system analysis divulged present sensitivity and adaptive capacity of the study area. Both primary and secondary data such as ground measurements, census data, and satellite images were used to study principal components of urban system such as population characteristics, land use, green cover and microclimate of the city. Impact assessment elucidated the present and future sensitivity and adaptive capacity of the study area. The impact of climate change on water resources, heat waves and thermal comfort level under present and future climate change scenarios and inundation due to future sea level rise were studied in this phase. Vulnerability assessment portrayed the city's current and future vulnerability based on its exposure, sensitivity and adaptive capacity. The study used index based approach; an outcome based vulnerability measurement which included identifying the indicators, normalization and spatial mapping for current and future climate scenarios. A total of 18 indicators were identified to construct the present and future vulnerability index of CMA through three composite indices namely Exposure Index, Sensitivity Index and Adaptive Capacity Index and mapped spatially. It indicated the poignant tendency of increasing over all vulnerability under future climate change scenario. This assessment disclosed the influence of exposure and sensitivity with total vulnerability and the need to enhance the adaptive capacity of CMA. The spatial maps of vulnerability at zone level would help in providing the overview of consequences and this has particularly support the city administrative and decision makers at all stages in order to identify the vulnerable zones under changing climate. The zones experiencing high exposure and high sensitivity or/and high exposure with low adaptive capacity should be preferred on priority for undertaking climate change adaptation measures.

Characteristics of heat wave impacts for major cities in the US under current and future climate conditions

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The occurrence and duration of severe weather events is one of the indicators of climate variability and change. Heat waves have direct impacts on human health and daily activities in urban areas, especially when high pollution levels accompany elevated temperatures. We use the Weather Research Forecast (WRF) model at 12 km horizontal resolution with downscaling from the Community Climate System Model (CCSM) to simulate recent (years 2001-2003) and future (years 2048-2050) climate for nine major cities (Denver, CO; Fargo, ND; Dallas; TX; Chicago, IL; Boston, MA; New York, NY; Washington, DC; Atlanta, GA; Miami, FL) in the central and eastern United States. The future climate scenario was derived using the IPCC A1B scenario. The nine cities were chosen on the basis of their location in different climate zones based on the Koppen climate classification system, and the synoptic weather pattern during summer. We use and compare heat indices that combine temperature and humidity from WRF output to identify and analyze the heat waves in the nine cities and compare their occurrence and duration under these two different climate scenarios. We analyze meteorological parameters, during the heat wave episodes, such as boundary layer height, cloud conditions, and flow patterns in terms of backward trajectories to characterize pollution levels at these cities in association with the heat waves. We hypothesize that differences in these parameters characterize differences in the heat waves across cities. Differences in wind patterns between recent and future climate simulations also result in changes in potential regional sources of air pollution in these cities.

Impact of urban form on sunlight availability for urban farming in Asian cities at different latitudes

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Urbanization process in Asia is increasing at an unprecedented rate. New towns are built in the cities' outskirts occupying farmlands and therefore making urban population more dependent on food produced farer or from overseas.

Increasing local self-sufficiency in terms of food and energy in residential areas is one of the key measures to reduce greenhouse gases emissions as well as to mitigate and adapt to climate change. Therefore, the integration of farming areas as part of the urban tissue should be considered as one of the design parameters for new residential districts in Asian cities.

The objective of the study is to quantify the sunlight availability in a series of densities and urban morphologies located at three different latitudes and sky conditions in Asia: Singapore (1.3°N), Hanoi, Vietnam (21°N) and Beijing (39.9°N). Local food self-sufficiency are then assessed according to the sunlight requirement for some common species of fruits and vegetables. Two scenarios are considered for urban farming technologies on the ground and building facades, conventional and a combination of conventional and 'vertical' technologies.

Three typical residential typologies are considered: point block (25 cases), slab block and complex block (16 cases each). Each typology is assessed in terms of solar access and daylight autonomy (DA > 10klx) by using a density parameter: plot ratio and two interrelated geometry parameters: site coverage and building height. The residential area under study is 520 x 520m2.

Results show that for equatorial latitudes, the impact of density and therefore the decrease of sunlight availability is lower than in higher latitudes, however food self-sufficiency is only achieved with plot ratios (PR) lower than 2. In higher latitudes the obstruction of surrounding buildings in higher densities, considerably reduce the food self-sufficiency both on the ground and facades. The influence of facade orientation and the position of the farming areas on the ground is also analysed.

The study provides the basis for future environmental and energy assessments as well as for the elaboration of general guidelines in terms of density and urban form to achieve the required sunlight for the integration of farming areas in cities at different latitudes, especially in the East Asia region.

Impacts of a future city master plan on thermal and wind environments in Vinh city, Vietnam

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Vietnam (the Socialist Republic of Vietnam) is a rapidly developing country, and the recent growth rates of the economy and population are about 6 % and 1.2 %, respectively. The expansions of urban areas are progressing in the country. Under such a situation, in Vietnam, many city master plans have been proposed in these days. Recently, Nikken Sekkei Civil Engineering Ltd. proposed a city master plan for Vinh city, the capital of Nghe An Province, located in the northern part of Vietnam. The proposed city master plan targets the year of 2030 with a population of 900,000, and the total planning area covers approximately 250 km2.
In this study, we conduct future projections of the thermal and wind environments in June (hottest month), 2030 in Vinh city by introducing the proposed city master plan. The future projections are carried out using a regional atmospheric model, Weather Research and Forecasting (WRF) (Skamarock et al., 2008), combined with a pseudo-global warming method proposed by Kimura and Kitoh (2007). In particular, the changes in the local thermal and wind environments in three urban districts, i.e., central business district (CBD), existing urban district, and new urban district, by introducing the city master plan are quantitatively investigated. Additional cases with the changes in green coverage ratios (30 %, 50 %, and 60 %) and urban structures (northern-concentrated, southern-concentrated, and decentralized types) are designed, and the effects of the modifications of the city master plan on the future thermal and wind environments in Vinh city are also studied. Furthermore, the human thermal comfort in each urban district (CBD and existing and new urban districts) is assessed by using a thermal comfort index, Wet Bulb Globe Temperature (WBGT), calculated based on the results of the WRF projections.

Vulnerability to heat waves: impact of urban expansion scenarios on urban heat island and heat stress in Paris (France)

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Heat-wave risk in cities is determined both by regional climate evolutions and by cities size and shape change, because they can impact heat island effect. Land planning and urban transport policies, due to their long-lasting impact on cities shape, can therefore play a role in heat-wave risk mitigation. However, the link between these policies and resulting change in urban heat island is far from direct, and not yet clearly understood. Using Paris urban area as a case study, we show that evolutions towards a denser city could indeed lead to increased heat wave exposure when compared with urban sprawl evolutions. However, this increase depends strongly on the way heat-wave risk is measured, and on the indicators used to characterize heat island effect. Using an interdisciplinary modeling chain, including a socio-economic model of urban expansion and a physically-based model of urban climate, air temperature in the city during heat waves is simulated for five prospective scenarios of Paris urban area expansion and development. These scenarios differ in terms of land planning policies simulated, but are otherwise similar (e.g. in terms of total population evolution). Their impacts on urban heat island and population heat stress are evaluated and compared through different indicators. The urban heat island is always higher at night and hits preferentially the small area of the city centre, whereas it more widely affects the residential areas during the day. However, the concentration of population in the historic centre and the first suburbs makes these districts quite vulnerable. This is especially the case for the compact city scenario, whereas the greening strategies allow to mitigate urban heat island and consequently to insure better thermal comfort. The efficiency of such strategies is however strongly dependent on water availability for evapotranspiration of plants. Finally, it should be kept in mind that the method and choice of indicators are crucial in the process of adaptation strategies analysis.

Bamboo Structures: A perspective for Climate Change Mitigation

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The exponentially growing population, fast expanding cities, depleting resources and accelerated pace of development has led to various unprecedented changes in the earth's environment. The present rapid development of infrastructure in the form of buildings has heavily relied on brick, concrete and steel which are very energy intensive materials having high carbon footprint. If the unchecked growth of utilization of these materials continues for the target of achieving 26 million houses in India, it will be a sure recipe for an ecological disaster. Hence, it's time to evolve the strategies for achieving sustainable growth, fulfilling the needs of the people in general and addressing the climate change concerns in particular.

The present paper brings out the potential of a ubiquitous grass, bamboo, for addressing the housing issues for the masses in the light of advancing climate change. A typical bamboo plant production potentials is around 2 – 20 t/ha/yr depending on the fertility of land; compressive strengths around 20 – 100 MPa and tensile strength around 100 – 300 MPa. This suggests great potential to produce annually equivalent renewable bamboo to replace steel, concrete, aluminum and plastics. India has over 120 species of bamboo with different potential applications, but Indian Standards with specific guidelines need to be developed for utilizing this material with confidence.

The paper presents the experimental results of the various load bearing elements like beams and columns made of bamboo composites which could be of great utility for the various upcoming housing projects. In the background of the high rate of urbanization, the proposed usage of bamboo as a constructional material would decisively infuse sustainability and would be of substantial use for mitigating the climate change

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The Impact of future urbanization on summer climate of Israel

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Israel's population is projected to increase significantly through the middle of the current century, requiring further expansion of the built environment. This study examines the impact of future urban expansion on local near-surface temperatures using a future land modification scenario based on the national development plan (TAMA35). The Weather Research and Forecast model was used to simulate the present (August 2010) and future (2050) climate at 1-km resolution. The future simulation incorporates the projected changes in the urban area of Israel to account for the expected urban expansion. Analysis of the temperature changes revealed that future urbanization will lead to nighttime warming of up to 3.5 °C across all Israel's geo-climatic gradient, whereas no impact was detected for daytime temperatures. At the national scale, the averaged warming due to TAMA35 urban expansion is 0.4-0.8 °C; the same magnitude as the projected climate change for Israel. The reduction in albedo, increased heat storage capacity during the day, and the longwave emission of the stored energy during nighttime are the key mechanisms causing the warming over areas undergone urbanization. Spatially, temperatures differences show an evident north-south and east-west gradient, suggesting local conditions play a significant role in determining impact of future urban expansion. The results presented here illustrate the need to incorporate climate models as tool for quantifying the consequences of a specific land use strategy, and identifying the places where planning intervention is needed.

Urbanization Effect on Temperature and Humidity in Nanjing, China

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Nanjing is an important economic, scientific and technological center in east China, so it is of great significance to research the effect of urbanization. We collected station climate data, NCEP/NCAR reanalysis data and urbanization statistics data, basing on the aggregative indicator method combined with Back-propagation (BP) artificial neural networks, observation minus reanalysis (OMR) method and urban observation minus rural observation (UMR) method to study the urbanization process and its effects on temperature and humidity. The correlation between environmental change (temperature and humidity) and urbanization process had been discussed in this study.

(1) Basing on the urbanization statistics from 1985 to 2010, we used BP artificial neural networks to calculate the weighted value of urbanization indexes. The results showed that civilian car ownership made the biggest contribution to the comprehensive level of urbanization, urban population made the least contribution. All kinds of urbanization comprehensive indexes continued growing year by year, especially after 2000 in Nanjing.

(2) Daily average surface air temperature and humidity data from meteorological stations in Nanjing during 1980~2009 and the National Centers for Environmental Prediction and National Center for Atmospheric Research (NCEP/NCAR) reanalysis were used to investigate the rapid urbanization effects on temperature and humidity change. The result showed that urbanization made 45.07% contribution to urban warming and 26.8% contribution to relative humidity decreasing.

(3) The correlation between temperature and humidity variation and urbanization comprehensive indexes was remarkable, especially in Nanjing. During all the seasons of the year, correlation was most significant in winter and the least significant in summer. Urbanization process and the minimum temperature were notable related, especially in winter. The correlation between urbanization process and humidity was remarkable only in Nanjing. To some extent, OMR and UMR method could both reflect the effects of urbanization on temperature and humidity variation, and OMR method had a better performance.

Urban Climate Adaptation Impacts: A multi-scale assessment to examine modeling robustness

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Recent projections indicating the U.S. will add about 300 million inhabitants through the end of the current century emphasize the considerable conversion of existing land covers to new urban land uses. California, the most populated state in the U.S., is among the states where a significant portion of end of century urbanization is anticipated. To examine climatic impacts of projected urbanization, multi-year, multi-member, continental scale simulations at medium resolution (20km grid spacing) are conducted with the WRF model coupled to a single-layer urban canopy scheme. Guided by medium-range resolution results, additional high-resolution experiments (2km grid spacing), positioned to coincide with the California area projected to undergo greatest urban expansion (i.e., Central Valley region of the state), are performed for several summer seasons to identify result dependence on resolution, an essential determinant of modeling robustness. Results demonstrate qualitative resolution-independent agreement: greater near-surface temperature benefits due to cool compared to green roofs deployment. However, changes in simulated convective mixed layer characteristics, and consequently, a much shallower planetary boundary layer depth, illustrate a key concern associated with diminished daytime turbulence due to both adaptation strategies that extend to air quality concerns: identical emissions of pollutants (e.g., particulate matter [PM]) will be confined to a smaller volume, thereby decreasing daytime perceivable air quality. In addition to emphasizing the need for integrated assessment incorporating biophysically induced urban impacts, I argue in favor of examining scale dependency of simulated outcomes to comprehensively address tradeoff assessment of various urban adaptation approaches.

An urban model for analysing thermal effects dependent on spatial parameters

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Global warming is changing the urban climate and influencing human society. A report from Royal Netherlands Meteorological Institute (KNMI, 2013), showed that the temperature will rise globally by 1,0 -2,3°C in 2050 and 1,3 – 3,7 °C in 2085. To strategically deal with this issue, our research project aims at city planning incorporating climate change. KNMI has developed four scenarios to investigate the relation between land use planning and urban climate (KNMI, 2014), which are based on global airflow and temperature changes. Analysis of variance for the four scenarios on the national level indicate significant effects by different categories of land-use types on neighbouring areas.

In our research, a model is developed that links thermal maps with a land-use maps on the urban level. For this study, Rotterdam is used as a case study because it is a delta city, and more than half of the habitants are vulnerable to climate change (City of Rotterdam, 2013). For the case study, we employ thermal data from Landsat and land use data from the municipality of Rotterdam for a representative part of the city. With this model we analyse which spatial parameters such as building density, green spaces, road material, etc. are dominant in determining the city temperature. Following the four KNMI scenarios are applied to study the effect of climate change. In the paper we will report on the main local effects and how undesired heating/cooling could be prevented in future city planning.

Isfahan's Urban Design Sustainability with Climate During Safavid Period.

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Iran has a hot, dry climate characterized by long, hot, dry summers and short, cool winters. The climate is influenced by Iran's location between the subtropical aridity of the Arabian Desert areas and the subtropical humidity of the eastern Mediterranean area. Therefore, sunlight and its effects were an important factor of Persian gardens structural design. Textures and shapes were chosen by architects to harness the light. Iran's dry hot climate makes shade important in gardens. Trees and trellises largely feature as biotic shade; pavilions and walls are also structurally prominent in blocking the sun. The climate also makes water important, both in the design and maintenance of the garden. This subject has been explained in the first section of this paper by focusing on Persian garden's types and specially its garden city.

In the continuation, the paper will explain the Isfahan Garden City designing process as Capital of Safavid Dynasty. The city has been designed and planning for enhancing citizens' health and well-being. Sustainability with the climate and specially water supply for new gardens are subjects that have been solved in Isfahan's urban design. This section has explained the methods by which Safavid's had used for attaining sustainable water, shade and urban spirit in hot and dry climate of Isfahan.

Finally, this paper classifies the principles of urban design and the city axis features to indicate the inventions and adaptation to climate. The result of the study shows that Isfahan's urban design principles has used in accordance with climate conditions during Safavid period which was created a state of longevity in the design of the city and its environment.

Climatic aspects in the first city plan of Tel-Aviv (1925)

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Our study examines the climatic aspects of the first city plan of Tel-Aviv (1925). This paper examines how the 1925 plan effected outdoor human thermal comfort in two periods: at the time of its implementation (1920-30s) and in the present (2010s). Additionally, the paper asks which of the two - shade or wind velocity – has greater influence on outdoor thermal comfort in the urban areas along the Israeli Mediterranean seashore.

The city of Tel-Aviv provides an ideal case study to examine these issues. Tel-Aviv was established in 1909 and grew rapidly. In 1925, the city had 34,000 inhabitants and there was a demand for a city plan. The task was given to Professor Patrick Geddes, who planned a city for 100,000 inhabitants that would spread along the Mediterranean seashore and would be suited to local environmental conditions. Geddes planned a grid of main streets, where the wide commercial streets stretched from north to south parallel to the sea. As a result, the main streets of Tel-Aviv were shaded most of the summer days but blocked from the sea wind. The plan was implemented during the late 1920s and 1930s.

To examine the thermal comfort at street level during the 1920's and 30's, a series of summer and winter climatological measurements were taken in the years 2010-13 and compared to historical climatic data from the 1920-30s. The historical city structure was then reconstructed virtually and the climatological measurements for 2010-13 were fed into the RayMan model to produce thermal comfort data (PET). The results show that in both summer and winter, solar radiation has a greater effect on thermal comfort than wind velocity. Consequently, the 1925 urban plan created improved thermal sensation in the main streets of Tel Aviv, mainly by the reduction of solar radiation.

Urban heat islands in the future Hanoi City: Impacts on indoor thermal comfort and cooling load in residential buildings

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In Hanoi, Vietnam, a long-term urban development plan, namely Hanoi Master Plan 2030, was implemented in 2011. In the master plan, the population is projected to increase from 6.7 million in 2010 to 9-9.2 million by 2030. It is expected that the dramatic expansion of the city brought by the master plan would induce significant impacts on its urban climate, thus lead to the increase in cooling load in buildings during the summer months. In order to minimize the negative impacts, the master plan proposed a large and centralized urban green network comprising green belts and green buffers. However, the urban heat island (UHI) mitigation effects of the above green network have not been assessed scientifically in the master plan.

This study is composed of two sub-topics. Firstly, this study investigates the UHI effects in Hanoi under the present land use conditions as well as under those conditions proposed by the master plan through numerical simulations, specifically meso-scale urban climate modelling using Weather Research and Forecasting (WRF). Further, an UHI mitigation strategy with improved urban green network is proposed and the resulting UHI effects are also assessed. Secondly, the indoor thermal comfort and cooling load of a typical urban house is assessed in different climatic zones under the weather conditions of each scenario (i.e., current condition, master plan situation and mitigation scenario), respectively. The climatic zoning is derived from the cluster analysis based on the simulation results of the master plan condition.

The results of urban climate simulation show that even after implementing the master plan, the peak air temperature in the urban areas remains at the same level of 41°C. However, at night, the expansion of built-up areas largely increases UHI intensity and raises air temperatures in the planned built-up areas by up to 2-3°C. The centralized green spaces currently proposed in the master plan was thus insufficient to minimize the UHI impacts. In contrast, the newly proposed green network which equally distributes the urban forest in the city was more effective in the reduction of UHI intensity in the city (up to 1°C). Moreover, the new green network could reduce the amount of areas that experience the peak nocturnal air temperature by 56.5%.

The building simulation was conducted for the typical urban house using TRNSYS. The typical urban house was determined through the classification of building drawings based on the total floor area and room arrangements. Further, the computational model was validated with the results of field measurement conducted in a typical urban house of Hanoi in the summer month of August to September 2014. Empirical validation of the simulation model showed the satisfactory results in term of air and operative temperature (RMSE≤0.33°C, R2≥0.89). The further simulations are then carried out by using the spatial average of weather data from each climatic zone in three scenarios, respectively. Based on the above analysis, the impact of UHI effects on the indoor thermal comfort and cooling load in the typical urban house would be discussed. The indoor thermal comfort is evaluated under the assumption that the occupants will adopt natural ventilation when the indoor operative temperature is lower than the upper limit of adaptive thermal comfort criteria. The cooling load is then estimated when the indoor operative temperature exceeds the adaptive comfort level.

It was found that the average cooling load of typical row houses in urban areas is higher than that in rural areas. The increase of ambient air temperature due to the implementation of the master plan would likely cause an increase in the cooling demand, especially in the newly developed urban areas. This would force the occupants to use air conditioning more, thus result in a considerable increase in energy consumption for cooling in the future. Meanwhile, the newly proposed green network would more effectively moderate the increase in cooling load in residential buildings due to future urban development.

Thermal impact of blue infrastructure: Casestudy Cheonggyecheon, Seoul (Korea)

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Seoul, the capital of the Republic of Korea, is influenced like many other large cities by the urban heat phenomena. The urban heat phenomena are typical for a metropolitan area that is significantly warmer than its surrounding rural areas due to human activities.

Special geographical and political conditions are combined with a high population density, remarkable high-rise buildings and small open spaces are characteristic for Seoul. The city of Seoul (9.8 Million inhabitants) is located in a valley surrounded by mountains in the north and south. Furthermore, in 1972 a restricted development zone (RDZ) precinct was established by the government. This is essentially a Greenbelt that has a size of 1,567 km². This greenbelt is more than two times larger than the city of Seoul. Seoul has an area of 605 km². All urban development within the RDZ has been prohibited during the last four decades.

After the full urbanization of the Seoul during the late 1980s several new towns where established outside the Greenbelt. Several push-and-pull factors have followed and influenced the rapid urbanization of the capital region of Korea. Currently more than 23 Million inhabitants are living in the Seoul Metropolitan Area (SMA). This has become one of the biggest urban agglomerations in the world.

The greenbelt has had a significant impact on the whole of the SMA. Due to the containment by the greenbelt, an intensive urbanization has occurred within the constrained Seoul City. This has resulted in a limited number of green areas and water bodies in the Seoul. The number of green spaces per inhabitant is one of the lowest in the world. Next to the 600m wide Han-River that flows from east to west through the central part of the city, there are no open streams or water bodies.

Therefore, the establishment of new green or water bodies in the Seoul City is of great importance. One of the most remarkable projects is the redevelopment of a 5.84 km long and 24 m wide two-tier expressway to a river stream.

We will investigate the micro-climate changes and urban-scale cooling load reduction which has resulted from the so called Cheonggyecheon water stream. This stream is located in central Seoul and runs from the northern central business district into the Han-River. After the Korean war (1950-1953) the Cheonggyecheon river was for more than 50 years covered with pavement and concrete overpass structures. The reconstruction of the expressway was carried out from 2002 to 2005. To estimate the thermal impact of the expressway into a water pathway remote sensing analysis (Landsat 7 ETM+) was undertaken. 20 Landsat-7 ETM+ images from 2000 till 2014 were used to compare the land surface temperature (LST) distribution during the time the expressway was there and through to the reconstruction and the establishment of the river stream. A built-up area of two km width surrounds the new water pathway and this was used as a reference area. The investigation could show that the establishment of the Cheonggyecheon stream forced a considerable thermal impact, i. e. an average decrease in the land surface temperature by seven degrees Celsius.

The results indicate that the cooling benefits of the restored stream areas are promising in the locations.

Simulating the extent of the moderating influence of green space distribution on future urban climates

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How a city thermally responds to weather directly impacts the health of its citizens. A changing climate, with higher temperatures and more frequent extreme events, together with growing and aging urban populations, motivates the need for better urban design. Thus, an understanding of the role of open space and vegetation to mitigate heat related health risks is valuable to urban designers and policy makers. However, these professionals may often be challenged to introduce extensive urban green space in urban (re)design projects as it competes against conventional and tangible urban real estate development benefits. Therefore quantifying how specific green space layout and distribution characteristics may positively influence local and city wide climate is helpful to show benefits that are just as tangible. In this work, an urban climate simulation process and its results are described and illustrated by means of a case study in China that identifies the spatial influence of different green space scenarios. The simulation process described herein allows multiple city and green space forms to be evaluated for different climate zones to develop climate responsive design rules for green space area ratios, distribution and layout. In particular, the process allows the scoring of green space integration in city design by evaluating the relative temperature modification or offset provided by its introduction.

A meteorology coupled urban climate simulation process is first described. The simulation process uses Open Source Computational Fluid Dynamic tools to simulate city wide wind exposure for a proposed large scale city (re)development. These wind simulation datasets are coupled with typical annual hourly meteorology data and a separate detailed solar exposure model and surface energy balance solver to predict the hourly climatic response for a given weather period. The computational solver and surface energy balance model also includes vegetation as porous moisture sources, so that the appropriate latent heat sink due to evapotranspiration, and solar shading effects can be modelled. Ultimately the process takes city geometry, vegetation plans and hourly meteorology data as input and delivers hourly surface and near surface temperature maps. Using the simulation process, a city redevelopment case study is evaluated under varying green space distributions for a number of different climates in China. Correlations between green space mitigation scenarios and the urban thermal response are presented and summarized in the findings.

Urban greening with avenue trees along the roadside: an adaptation for mitigation of air-pollution induced climate change in developing countries

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Canopies of urban vegetation are efficient absorbers of re-suspended dust. Plant leaves can capture dust on both the surfaces but more on the upper surface. Deposition of air-borne or re-suspended dust on the leaf surfaces is a snowballing process which starts fresh once the rain washes out the dusts from the leaves. This is supported by the observation of approximately 10 fold difference between the winter and monsoon maxima for dust load. The inter species variations in dust interception efficiency of plants is attributed to the differences in morphological structure. Leaf surface characters like presence of trichomes, stomata and surface roughness help in capturing dust particulates. Moreover, plant canopy shapes also account for differences in dust interception potential of plants. Such observations point towards the need for suitable species selection while considering urban greening with an aim to reduce the pollution load.

A simple technique for improved particle filtration efficiency of vegetation barriers

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Well positioned vegetation barrier (VB) have been suggested as one of the green infrastructures that could help filter particles (pollutants) from our air, thereby improving air quality. However, the filtering capacity of VB has been less well studied. A detailed knowledge of this would help in configuring VB for maximum benefit. The aim of this study is to optimize VB as a mitigating measure for worsening near-road air quality. Hence, this study made use of a Computational Fluid Dynamics (CFD) model, ENVI-met to investigate the Particle Size-removal Efficiency (PSE) of VB of different dimensions, under different wind condition. A new technique to ensure maximum benefit of VB was developed and evaluated. Preliminary results show VB has both positive and negative effects on near road air quality depending on prevailing wind condition: The so-called "positive effect" (i.e. positive PSE) due to filtration capacity can be split into two aspects i.e. VB enhances and prevents further reduction and increase of pollutants downwind respectively. Likewise, the so-called "negative effect" (i.e. negative PSE) due to blocking and aerodynamic effects of VB is also divided into two aspects i.e. VB prevents and enhances further reduction and increase in pollutants downwind respectively. Result from our new technique shows negative impact of vegetation barrier can be prevented in all cases by placing VB behind a 'Distance of Maximum Concentration, (DMC)'. Further investigation on the role of leeward VB on PSE of downwind VB indicates positive influence irrespective of wind parameter and barrier dimension.. Finally, recommendation was given for appropriate application of this study.

Capability of urban woody plants to reduce particulate matter content in Tehran megapolis

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Urban green space, particularly urban forests are known to provide important ecosystem services. Improvement of air quality, especially reduction of particulate matter content of the air is among the most important services of urban vegetation. Tehran city is one of most polluted urban ecosystems of the world. This study compares five tree species (Morus alba L., Platanus orientalis L., Ulmus minor Mill., Cupressus sempervirens L. and Pinus brutia Tenore) that are commonly cultivated in Tehran megapolis for their capability to capture fine particles, particularly PM10 and PM2.5. Plant sampling was carried out during 2012 vegetative season and about 300 leaf samples were collected in 10 stations. Particulate matter content of air was obtained from air quality monitoring stations of Tehran municipality. According to our results, significant amount of particulate matter was deposited by urban woody species. The capability of tree species to capture air particles was compared statistically within and among the stations. Significant differences were found between woody species tested and their capability in different stations. We found significant correlation between particulate matter on leaf surface and different parameters including leaf surface morphological traits, cultivation pattern, concentration of particulate matter in the air and season time. All of these relationships were analyzed and discussed. Elm tree showed better capability mainly due to its rough and uneven leaf surface. There was a positive correlation between particulate matter content of air and leaf surface. We concluded that plant species, leaf morpho-functional traits, cultivation pattern along with local conditions should be considered for designing urban green space with the air refinement perspective.

Impacts of urban spatial structure on air quality: an integrated modeling approach

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Urban air pollution remains a key challenge when defining measures to reduce health impacts and for achieving sustainable development. In most cities, road transport is clearly identified as the main source of atmospheric pollutants. In spite of continuously improving vehicle efficiency standards, pollution levels have not improved in Europe as much as hoped over the last decade, due to the progressive growth in traffic levels and general urbanization (European Environment Agency, 2011). The situation will remain critical if policy measures at local, national and European level are not implemented.

In this context, urban planning might potentially be a component of air pollution mitigation strategies, due to its actions on modal choice, travel distances and dispersion of pollutant emissions in the city. Environmental approach in sustainable urban planning is however often limited to energy consumption issues, because the goals are ambitious and aim to reduce by a factor of four greenhouse gases emissions in the next 40 years. To deal with energy consumption issues, a compact city shape, based on efficient public transport and journey restrictions, is often considered as a good solution for sustainable urban development. However, the impacts of urban densification policies on air quality are not discussed, whereas the concentration of pollutant emitting activities in dense urban areas can lead to high population exposure to degraded air quality (G. Siour, 2012). The question is what are the determinants, in terms of urban layout, of a better urban air quality.

The modeling of future air quality, belonging to the field of physical chemistry of the atmosphere, is often limited to the implementation of anthropogenic emissions scenarios applied to the current urban structure, or to simple city evolution scenarios, using chemistry-transport models. These scenarios do generally not take into account the economic and energy constraints that govern the evolution of the city (size, structure around transport axes, sprawl ...) nor the urban traffic flow resulting from the balance between households budget, the supply of public transport and the urban area structure.

Here, we use an interdisciplinary four step modeling chain to analyze the effects of urban structure evolutions on air quality, using Paris urban area as a case study. We link an urban economics based transport-land use interaction model, a traffic congestion simulation model and a pollutants emission model to the chemistry-transport model CHIMERE (Siour, 2012; Menut et al, 2013). This enables to compare air pollution levels across the city in several prospective city development scenarios.

The implementation of biofiltration systems, rainwater tanks and urban irrigation in a single-layer urban canopy mode

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Urban vegetation is generally considered as a key tool to modify the urban energy balance through enhanced evapotranspiration (ET). Given that vegetation is most effective when it is healthy, stormwater harvesting and retention strategies (such as water sensitive urban design) could be used to support vegetation and promote ET. This study presents the implementation of a vegetated lined bio-filtration system (BFS) combined with a rainwater tank (RWT) and urban irrigation system in the single-layer urban canopy model Community Land Model-Urban. Runoff from roof and impervious road surface fractions is harvested and used to support an adequate soil moisture level for vegetation in the BFS. In a first stage, modelled soil moisture dynamics are evaluated and found reliable compared to observed soil moisture levels from biofiltration pits in Smith Street, Melbourne (Australia). Secondly, the impact of BFS, RWT and urban irrigation on ET is illustrated for a two-month period in 2012 using varying characteristics for all components. Results indicate that (i) a large amount of stormwater is potentially available for indoor and outdoor water demands, including irrigation of urban vegetation, (ii) ET from the BFS is an order of magnitude larger compared to the contributions from the impervious surfaces, even though the former only covers 10% of the surface fraction and (iii) attention should be paid to the cover fraction and soil texture of the BFS, size of the RWT and the surface fractions contributing to the collection of water in the RWT. Overall, this study reveals that this model development can effectuate future research with state-of-the-art urban climate models to further explore the benefits of vegetated biofiltration systems as a water sensitive urban design tool optimised with an urban irrigation system to maintain healthy vegetation.

Impacts of urban heat island mitigation strategies on surface temperatures in downtown Tokyo

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Annual mean air temperatures in downtown Tokyo have increased about 3 degrees Celsius in the past 100 years due to global warming and urban heat island (UHI). Also, the frequency of heat stroke outbreaks in Tokyo tends to increase in recent years. We have therefore investigated the impacts of UHI mitigation and adaptation strategies such as making highly reflective pavements, creating green and water spaces, etc.

As part of the investigations, we performed thermal infrared (TIR) remote sensing in downtown Tokyo on three different extremely hot days: Aug. 7, 2007, Aug. 19, 2013, and Aug. 19, 2014. The TIR measurements were carried out in the daytime (12-13 local time: LT) and the nighttime (around 21 LT) under similar weather conditions, using a long-wave infrared (8-14 um wavelength) camera (NEC Avio; TS7302) installed on a helicopter. The helicopter was flying at Flight Level 20 (2,000 ft: 610 m). This allows horizontal spatial resolution of data from the thermal imaging camera to be significantly high (approximately 2 m) in spite of airborne TIR measurements. Daily maximum air temperatures on those days reached 32-34 degrees Celsius. Sea breezes prevailed over downtown Tokyo.

An area of the measurements in 2013 includes the area of 2007. To evaluate impacts of recent UHI mitigation strategies in downtown Tokyo, we analyzed changes in the image-derived surface temperatures between 2007 and 2013. The results show that daytime surface temperatures in 2013 are relatively high in the greater part of the area, compared with the ones in 2007, nevertheless, lower surface temperatures can be observed in some redevelopment areas where new buildings were constructed between 2007 and 2013. This appears to be due to green and water spaces created in the redevelopment areas through the UHI mitigation strategies, indicating some measures for UHI mitigation are effective.

In addition, we pick out hot spots where strategies for lowering temperatures should be required. The TIR images projected on Google Earth show higher surface temperatures on intersections and the northern parts of streets running from east to west. To clarify the causes of those hot spots, relationships among surface temperatures, sky view factors, etc. are investigated. Also, we analyze thermal environment around venues of the 2020 Summer Olympic and Paralympic Games.

Watering practices and urban thermal comfort improvement under heat wave conditions

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Increasing heat-wave risk due to regional climate evolutions, exacerbated with urban heat island effect, is a major threat for the inhabitants of many cities. However, relevant urban planning choices and adaptation policies can help limit population vulnerability.

Adding more vegetation to urban environment is often proposed as a potential tool, as it enables to regulate the microclimate by evapotranspiration. But the efficiency of such strategies tightly depends on water availability for green areas, so that this raises the fundamental issue of water supply for irrigation.

Using Paris urban area as a case study, we build several contrasted scenarios of possible city evolutions until 2100. Urban climate is simulated for each of them, which enables to evaluate both urban heat island (UHI) and heat stress under heat-wave conditions in 2100. To understand the characteristics and efficiency of different irrigation practices, three vegetation watering alternatives, as well as a scenario of pavement watering, are studied and compared. Using different indicators of UHI and heat stress, an optimized water-use scenario is finally proposed.

The effect of irrigation on air temperature during heatwave conditions

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In conventional urban areas, the majority of rainfall is exported out of the environment through the stormwater drainage system. This loss of stormwater is balanced by importing potable water, which is used for irrigation and gardening watering. Stormwater runoff can reduce urban moisture availability, leading to reduced evapotranspiration and increased sensible heat flux, which may cause higher urban air temperatures. This is particularly relevant in Australia, which has experienced extended dry periods and heat waves over the last two decades, especially in the major southern cities: Perth, Adelaide, and Melbourne. The ongoing drought has placed pressure on potable water resources and led to water restrictions and irrigation bans. These compounding consequences of drought: water restrictions, xeric gardening practices, and reduced health of urban vegetation, further exacerbate urban warming and energy demands. Reintegrating stormwater into the urban environment, may help to modulate the effects of urban warming, while also improving stream ecology and conserving valuable potable water resources. However, the climatological implications of water scarcity, stormwater reintegration, and changing irrigation practices, for urban climate are often ignored in urban scenario and mitigation modelling research.

The objective of this research is to understand the cooling potential of irrigation on local-scale air temperature in a mixed-residential environment. The analysis is conducted using the Town Energy Balance (TEB) model. We used TEB's built in irrigation scheme to test the cooling potential of a series of irrigation regimes during a heatwave case study. Hypothetical scenarios (where large volumes of water were used) suggest the average maximum cooling associated with irrigation during the 2009 heatwave was up to 3.7 °C at 3pm, and 1.1 °C at 5 am. It was also found that night-time irrigation (11pm – 5am) was more effective than daytime irrigation (11am – 5pm) at reducing exposure to adverse heat health conditions (daily average air temperature > 34 °C). Overall, irrigation and stormwater reintegration (processes which also have ecological benefits) show potential to cool daytime local-scale climate in suburban areas during heatwave conditions.

Rain Water Catchment Design Applied to Educational Centers in Mexico

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Rain water is a constant resource that is not well approached. We know that most of the major cities have periods of rain which have become random because of the climate change. In Mexico, this causes a problem of imbalance in the relationship between the rain water falls and the adaptation from the cities to manage this misunderstood resource. This problem raises when the drainage facilities got covered by garbage in the streets, which is another problem in Mexico. This causes flooding in cities and an unhealthy environment. So, Why not apply a design to take advantage of this situation instead of continue with this matter?

Water Catchment has been an ancient practice of our Mayan forefathers. They used to live in a peninsula with calcified water, so they need to create a system to take advantage of the rain water, the same that actually is used in some houses in this peninsula and have become a very useful practice along Mexico.

By the other side, most of the schools and public government institutions along Mexico have a lack in water for human use. The water use in this institutions is simple and defined by use in restrooms, green areas irrigation and cleaning.

There are many filter water systems, some of them may be used to rain water applied to this use in institutions. Then this study expect to look for the appropriated system for rain water catchment in public institutions which will be economically feasible, environmentally sustainable and socially applicable in Mexico.

Keywords: Rain Water, Catchment, Educational Centers

Passive irrigation of street trees to improve tree health and support urban cooling

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Urban vegetation is commonly identified as a key measure for mitigating urban heat and improving human thermal comfort. Trees are particularly effective as they act as a conduit for water loss from the soil to the atmosphere via transpiration and they provide shade. However, to be most effective, trees need a healthy canopy and be actively transpiring. At times, high rainfall runoff and limited infiltration from extensive imperviousness may reduce water availability in urban areas, and when combined with drought conditions and water restrictions, leads to a water deficit. This compromises the ability of trees to transpire at maximum rates and provide cooling. Further, high heat loads and greater vapour pressure deficits (VPD) in urban areas places greater evaporative demand on trees. Limited water availability can compromise tree canopy health, leading to leaf loss and reduced shading potential.

In partnership with the City of Monash local government authority, we explored the role of passive irrigation on soil water availability and water use of street trees in Melbourne, Australia. Two different passive irrigation kerbside treatments were retrofitted adjacent to established trees (Lophostemon Confertus) to divert stormwater runoff from the road directly to the root zone of the trees in a bid to increase soil water availability. The study aims to explore the effectiveness of the passive irrigation design, changes in soil moisture, and subsequent variations in tree water use. Over the 2013-14 Austral Summer (prior to treatment installation) and over the 2014-15 Summer, we established an extensive field campaign to observe the effects of the passive irrigation treatments. Soil moisture was monitored at each tree where the passive irrigation kerbside treatments were installed, along with several control trees. Tree water use was measured using sap flow sensors. Meteorological variables were also observed at the site including air temperature, VPD, solar radiation, mean radiant temperature, wind speed, soil temperature and CO2 concentrations, in order to consider their influence on tree water use.

Results will be presented for the 2013-14 and 2014-15 Austral Summers, with a particular focus on extreme heat conditions when air temperature can exceed 40 °C in Melbourne and VPD is high. Results will demonstrate the effectiveness of the passive irrigation treatment designs on soil water availability and tree water use. The results from this study will help inform the roll out of passive irrigation treatments to support tree health throughout Melbourne. The important dynamics of tree water use under changing soil water and meteorological conditions can help inform urban land surface schemes in which modelling the latent heat flux proves particularly challenging.

CCMA8: UHI mitigation strategies IV : vegetation management processes

The urban tree as a tool to mitigate the urban heat island in Mexico City: a simple phenomenological model

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The urban heat island (UHI) is a kind of thermal pollution in cities, although it is mainly a nocturnal phenomena also appears during the day in Mexico City. This pollution may affect the human thermal comfort which possibly influence human productivity in the spring-summer period. This heat excess is compensated by air conditioning systems implying an extra energy consumption and a feedback to the UHI. A simple phenomenological model based on the energy balance was developed to generate theoretical support of the UHI mitigation in Mexico City focused on the latent heat flux change by increasing tree coverage. Although it was necessary to establish an UHI update, hourly data of the urban energy balance components were generated in a typical residential/commercial neighborhood of Mexico City, and then parameterized using easily measured variables (air temperature, humidity, pressure, visibility). Transpiration and canopy conductance was measured every hour in four tree species using sap flow technique and parameterized by the envelope function method. Averaged values of net radiation, energy storage, sensible and latent (QE) heat flux were around 449, 224, 153 and 72 Wm-2, respectively. Daily tree transpiration ranged 3.64–4.35 Ld-1. Reducing air temperature by 1°C in the studied area using Eucaliptus camaldulensis (QE=48.0 Wm-2) required 138 trees ha-1 while a reduction of 2°C by Liquidambar styraciflua (QE=102 Wm-2) needed 67 trees ha-1. However, it is possible to establish more than four species to support biodiversity. This results shows that the simple reforestation of the city cannot mitigate UHI adequately, but requires to choose the most appropriate tree species to solve this problem. Also it is imperative to include these types of studies in the urban development planning and failure to do so, the UHI would be a dangerous problem in the future due to the rapid and anarchic growth of the city.

Evaluating climate-related ecosystem services of urban tree stands in Szeged (Hungary)

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In the context of climate change, it is more and more important to form and evaluate the different urban climate adaptation strategies in a planning-oriented manner, so as to implement them easily in urban environmental management processes. One solution for that can be the evaluation of ecosystem services of urban trees and green spaces. This recently developed methodology focuses on the contribution of the environmental functions of the ecosystems to human well-being. Some of these services can be expressed in monetary value, which makes it easier to compare the significance of these attributes to other goals in urban planning. In our contribution, we present the results of an individual-based evaluation of two climate-related ecosystem services (carbon sequestration, air pollution removal) of the tree stands of the centre of our city of Szeged (Hungary), by the adaptation of a targeted model developed in the U.S. (i-Tree Eco). The baseline tree cadastre database was made and is maintained in strong correspondence with the urban environmental management company of the city. The calculalations are based on allometric relationships between measurable parameters of tree size and condition and state indicators of the referring services (e.g. leaf area, total biomass). Our results highlight the importance of tree condition, which may strongly affect service provision (huge parts of the stands in good condition belong to non-indigenous species). Therefore, tolerance of urban circumstances (determined e.g. with this type of analyses) should be taken into consideration during species selection. Meanwhile, old trees in good condition have a distinguished role from the point of view of climate-related services as well (besides biodiversity aspects). The total economic value of the two investigated services are comparable with the planting and maintenance costs. The presented results on a per-tree basis can form a base for developing spatial-based assessments methodologies, in order to fulfil the requirements of the policy objectives on mapping ecosystem services on a national level (EU Biodiversity Strategy 2020).

Urban green belt outdoor thermal evaluation via leaf area index

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With the widespread of urban living area and due to the urban heat island effect, people in urban outdoors is experiencing more severe heat stress than in rural area during summer period. Street trees can enhance pedestrians' thermal comfort mainly by providing sun shade via its leaf canopy to reduce human body's solar radiant exposure. Urban green belt is an important greening strategies in fighting with urban heat island effect in Taiwanese major metropolitan area and has been promoting for years. It is a consecutive urban open space allocated alongside the street with tree greening to serve as recreation purpose. However, tree planting location and tree selection would significantly influence the space users' thermal perception. As the density of a tree's leaf would crucially affect the amount of radiation received underneath, this study aimed to identify the minimum required leaf density in terms of leaf area index (LAI) for tree planting selection to provide pedestrian sufficient thermal comfort in summer under hot and humid climate context of Taiwan. Correlation model of solar radiation reduction rate with LAI had been established and was used for calculating radiation received underneath tree's canopy. In assessing hourly thermal condition, local typical meteorological year (TMY3) data containing hourly weather elements including total horizontal radiation, dry bulb temperature, relative humidity, wind velocity, and cloud cover, was used as outdoor climate conditions. These weather data together with the model estimated reduced solar radiation by trees were afterwards used for estimating the physiological equivalent temperature (PET). The outdoor thermal comfort PET range of Taiwan suggested by T.P. Lin was adopted as criteria in assessing overheating occurrence frequencies and overheating severities under various LAI values, thus to reversely identify the appropriate monthly LAI needed for ensuring thermal comfort. The results show that a minimum of LAI 2.0 is required to maintain outdoor thermal comfort in hottest July to ensure the overheating occurrence probability less than 5%. Other suggested values of minimum required LAI in June, August, and September are 1.44, 1.85, and 1.30, respectively. These results could be serve as a tree selection reference in planning or designing urban green belts in the viewpoint of outdoor thermal comfort.

How Do Green Roofs Mitigate the Urban Heat Island Effects under Heat Waves?

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Green roofs (GRs) are widely recognized effective in the mitigation of rooftop surface and near air temperatures at the building-scale due to their passive cooling function. This study investigates the mitigation of the Urban Heat Island (UHI) effect of GRs at the city-scale via numerical simulations using the Weather Research and Forecast (WRF) model coupled with the Princeton Urban Canopy Model (PUCM). The WRF-PUCM is set up in the Greater Beijing Region (GBR) during a heat wave period (July 1– July 5 2010) to assess the impacts on air temperature (T2) and humidity(Q2) at 2 m AGL (above ground level) and wind speed (U10) at 10 m AGL of GRs by varying their coverage in the urban area. Results indicate that (1) T2 and U10 significantly decrease whereas Q2 remarkably increase with GR implemented and (2) all the variations in T2, Q2 and U10 demonstrate strong linear correlation with the increase of GR coverage. The investigation also reveals that the mitigation of UHI results from the combined effect by GRs in the surface energy balance and regional advection: GRs dissipate more available energy vertically by latent heat flux and consequently prohibit the advective heating of urban area from its surrounding region under heat waves. This study underlines the effectiveness of GRs in the mitigation of UHI effect at the city-scale and shed light in employing the WRF-PUCM framework to support detailed analysis and diagnosis of the UHI phenomenon.

Evaluation of greening scenarios to reduce Paris city vulnerability to future heat waves

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Climate projections predict an amplification of global warming, potentially exacerbated in urban areas by the urban heat island effect. More frequent extreme events such as heat waves may have severe public health, ecological, and economic consequences as cities concentrate population. Among the measures aiming at improving thermal comfort or energy demand in the context of heat waves, a sustainable adaptation strategy, urban greening, is evaluated, based on urban climate simulations across the Paris area.

The modelling of urban climate under various greening scenarios relies on the Town Energy Balance model (TEB, Masson 2000) and its most recent developments. These include an improved parameterization of building energetics (BEM) and the Vegetation module which now encompasses parameterizations for better accounting for low vegetation in urban canyons (Lemonsu et al. 2012), for simulating green roofs (de Munck et al. 2013) and for representing watering practices. This study, which is a component of the MUSCADE project, is realized by running simulations with climate forcings and a dynamic urban heat island generator. This simulation configuration allows greening scenarios to be evaluated for a short heat wave event (2003) as well as for a 10-year period in order to determine the mean impacts of a summer-orientated strategy at the scale of an entire year. Simulation results are analyzed in terms of energy consumption, outdoor thermal comfort and level of water resource induced by watering.

The scenarios tested consist in an increase in ground-base vegetation (with various greening rates) or an implementation of green roofs on compatible buildings, or the two combined, with the option of watering green roofs or not in summer. Results show that increasing the ground cover has a stronger cooling effect than implementing green roofs, and even more so when the greening rate and the proportion of trees are important. The green roofs are however the most effective way to reduce energy consumption, not only in summer but also on an annual basis, mainly due to their insulating properties.

Green infrastructure and ecosystem services to tackle climate change in Chilean cities.

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Considerable literature has described ecosystem services of urban green spaces. However, only some of them are especially important for climate change mitigation and adaptation in urban environments. First, the paper presents and discusses the arguments in favor of urban green infrastructure and ecosystem services provision as key components of resilient urban ecological systems to climate change. Second, the developed analytical framework is applied at two spatial scales (1) green infrastructure was mapped and analyzed in six Chilean cities, and (2) riparian corridors in Santiago were analyzed in terms of their current and potential contribution for tackling climate change by evaluating three key ecosystem services (a) cooling effect, (b) routes for non-motorized transport, and (c) flood mitigation.

Evaluation of CO_2 Reduction Effects of Buildings with Green Roofs by Using a Coupled Urban-Canopy and Building-Energy Model

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In recent years, global warming has become more serious, and it is now an urgent priority to reduce energy consumption and CO_2 emissions. In particular, energy consumption for cooling in the summer continues to grow every year, and thus it is highly important, from the perspective of measures to address global warming, to reduce cooling demand in residential and living spaces. On the other hand, increasing temperatures due to urbanization (i.e., the urban heat island phenomenon) is becoming more serious in urban areas, and the loss of comfort and increase in cooling demand in urban spaces have become serious problems. Therefore, improving the thermal environment in urban areas is an important issue linked to both the global and urban environment.

Rooftop greening is one measure for improving the urban thermal environment. Although vegetation is known to be effective for reducing temperature via transpiration, there is only limited leeway for on-ground greening in urban areas, and thus in recent years rooftop greening has garnered particular attention. Therefore, this research focused on rooftop greening in office building districts, and its purpose was to evaluate the effectiveness of such greening in mitigating heat island conditions and reducing CO_2 emissions, while taking into account the amount of water needed for evapotranspiration.

In this research, a coupled urban-canopy and building-energy model (CM-BEM) was used to carry out simulation-based evaluation of the effectiveness of rooftop greening in mitigating heat island conditions, and reducing CO_2 emissions due to a decreased need for cooling energy. The rooftop greening assumptions were set to 3 levels of 0%, 50%, and 100%. Next, the amount of water needed for evapotranspiration was calculated from the latent heat flux, which in turn was obtained from the results of calculating the roof surface heat balance. In addition, the effect of rooftop greening in reducing CO_2 emissions was clarified based on its effectiveness in reducing demand for cooling energy, and this was done by calculating CO_2 emissions produced when the needed amount of water is supplied by watering using tap water.

The main results of this research were as follows:

(1) The heat island mitigation effect of rooftop greening was evaluated. The results showed that, under the calculation conditions of this research, the temperature reduction in the case of large-scale adoption of rooftop greening was a maximum of about 0.13°C. The relationship between this temperature reduction effect and evapotranspiration was also clarified.

(2) The CO_2 reduction effect of rooftop greening was evaluated. In particular, when evaluation was carried out in this research taking into account both CO_2 reduction due to cooling energy and CO_2 emissions due to watering, it was shown that the former is clearly greater in terms of direct effects due to the reduction in surface temperature, and a CO_2 reduction effect can be achieved in buildings where rooftop greening is adopted.

(3) In addition to the standard conditions assumed in this research, calculation conditions were also assumed in which the roof insulation performance and evaporation efficiency of the rooftop greening area were varied, and the same examination was carried out. The results showed the relationships, under each calculation condition, between water amount, heat island mitigation effect and CO_2 reduction effect.