Spatial Indicators for Assessing Climate Risks and Opportunities within the Urban Environment of Ho Chi Minh City, Vietnam

1. Introduction

This paper describes the research results in the development of spatial indicators for assessing both climate risks and opportunities for the southern Vietnamese city of Ho Chi Minh City (HCMC). The assessment is based upon a shared spatial framework, utilising an urban structure type approach. The key urban environmental impact indicator of imperviousness is provided as an example. The proposed system represents a thematically integrative method, for ultimately compiling domain specific GIS- applications, analytical models and thematic assessment methods. Climate change resilience and exposure indicators are used to generate spatial sector-specific analyses. Through the utilisation of planning recommendation maps, the comprehensive aim is to develop, designate, and incorporate climate change mitigation and adaptation potentials into the urban decision-making and planning processes. The research is envisaged to contribute to and promote an increase in the city's resilience to climate-related vulnerabilities and the overall sustainability of structures. The main objective is to advance and disseminate knowledge and inform decision-makers and the general public about the climate change risks, aiding the appraisal of adaptation options, increasing capacities to respond to climatic stress, to implement necessary adaptation measures and to strengthen the sustainable responsive capacity of the urban system.

2. Ho Chi Minh City: Development and climate challenges

Climate change impacts are predicted to be unevenly distributed and represent real and urgent challenges to cities situated within the inter-tropical low elevation coastal zones throughout Southeast Asia. These threats are especially acute in the numerous rapidly emerging megacities of the sub-region. HCMC provides an example of such an emerging Asian coastal megacity facing the double challenge of rapid urbanisation and climate change. Located northeast of the Mekong Delta and only fifty kilometres inland from the South China Sea, the city has undergone unprecedented urbanisation during the last twenty years (Figure1).

Within Vietnam, a decisive political shift occurred in the late 1980´s, with the Doi Moi reforms, which enabled significant economic realignment with the overall aim of improving living standards. They were targeted at agriculture, the expansion of consumer goods production and the increase in foreign trade. For Vietnam, the opening up of its markets, the shift to an export-driven economy and economic globalisation led to remarkable economic growth and a reduction in poverty levels. The economic growth has to the greater part been urban-based and manifested in the rapid urban growth of HCMC beyond its juridical limits, via both in-migration and the incorporation of already densely populated rural areas into its administrative boundaries. According to the 1989 census HCMC had a population of just over three million (Drakakis-smith & Dixon 1997). However, since the early 1990´s, the population of HCMC has grown quickly to an official current population of over seven million inhabitants and is still growing, with an estimated additional two million unofficial migrants. While concurrently the settlement area has been seen to more than double. The city has now become Vietnam´s largest urban settlement, an important port city for Southeast Asia and beyond and contributes the dominate share to the national gross-domestic product. However the concentration of population and economic activity in combination with its rapid formal and informal expansion into flood-prone areas make HCMC particularly vulnerable to out-paced unsustainable development and the impacts of climate change (Storch & Downes 2011).

HCMC has undergone massive transformations and is currently feeling the full impact of urbanisation pressures.

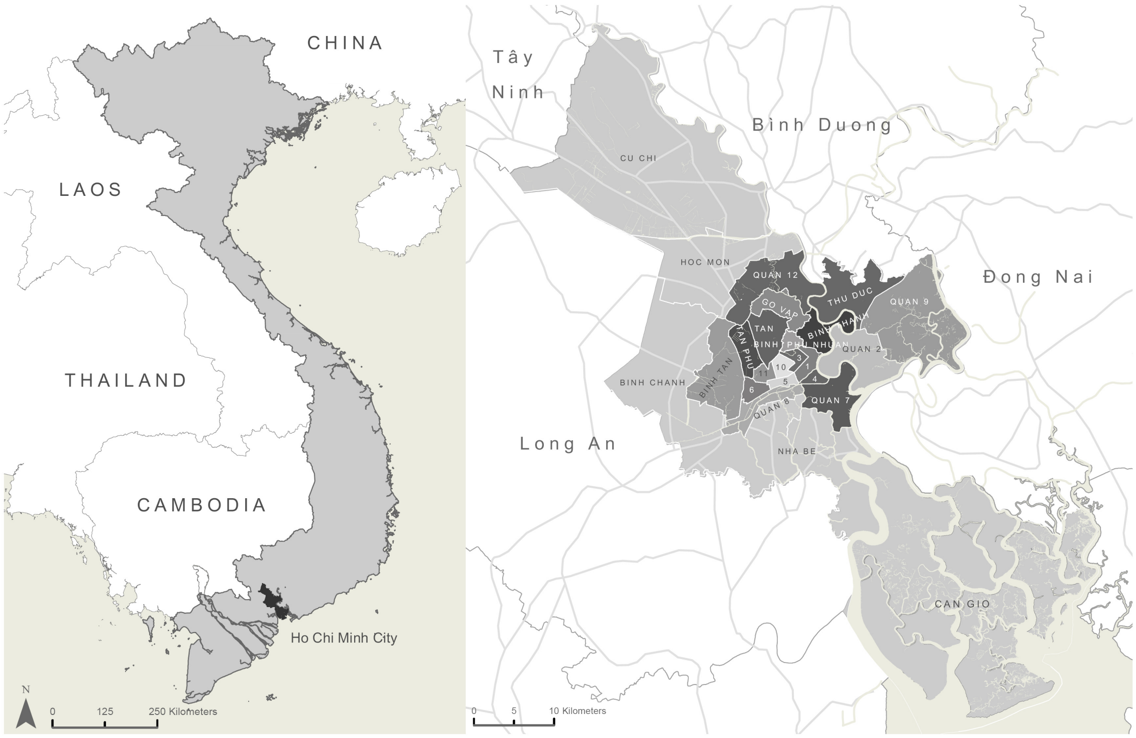

Figure 1: Map of HCMC: Left: The location of HCMC administrative region in Vietnam. Right: The administrative region of HCMC, with its urban districts highlighted.

The city's location and its haphazard growth over the last two decades, has affected the types of climate hazards to which it is currently being and likely to be exposed to in the future. HCMC already experiences significant annual variations of weather extremes. Simultaneously the city's rapid, precarious and unsustainable development has led to a higher sensitivity and lower adaptive capacity to climate change risks. This already poses a significant threat to the physical and social fabric of the city. The result is an increasing overall vulnerability to climate risks, widening inequalities and an altered urban risk divide. Together with its large population, economic assets, and the dominant role it plays in the national economy, the city has been considered a hotspot of vulnerability to the impacts of climate change (DasGupta et al., 2007; ADB 2010; Birkmann et al., 2010; Carew-Reid 2008).

Recent recognition of the potential impacts of climate change has heralded awareness of the need for action. While a multitude of initiatives, interventions and measures in the spatial planning for climate change have already been identified, considered and partially undertaken in the major cities of the Global North, the inherent complexity of the rapidly emerging megacities of the Asian present a somewhat different challenge. Here the focus on climate risks and opportunities remains relatively uncharted. Furthermore, although considerable research has already been undertaken, little is known about synergies between mitigation and adaptation potentials. Additionally, complex inter-linkages exist between both the effects of climate change and the rapid urbanisation process itself. For HCMC, the challenge of climate change has added a distinct and significant new dimension to the urban sustainability and development conundrum.

Fast growing and rapidly expanding cities such as HCMC have intrinsic and characteristic development patterns, which are already affected by current climate change impacts and together with future impacts will lead to a multitude of adverse secondary and cumulative development challenges over the coming decades. The unprecedented urbanisation and precarious growth situation of HCMC over the last 20 years has had a downside of environmental degradation which has led to an increase in the exposure to climate-related risks. Originally founded on relatively higher grounds, the city has densified through the infilling of open spaces or the redevelopment and extension of existing building footprints. However of greater concern has been HCMC's rapid increase of both planned and informal expansions into its lower-lying and former wetland surroundings. The expansion has caused the degradation of valuable multifunctional natural areas in the urban periphery, channelling natural waterways, sealing surfaces to differing degrees, creating impermeable surfaces and increasing surface run-off. This has lead to the creation of more hardscape features and the loss of space for water, including natural detention and retention areas and the alternation of the natural drainage systems and urban hydrograph. The result is the growing susceptibility and exposure to risk for both populations and assets in existing settlements, which were once significantly less exposed, as well as the addition of new risks situated in recent developments in low lying areas. Here physical infrastructure, urban structures, land-use planning, and the size of informal settlements are the main factors determining the magnitude and spatial distribution of climate change impacts and associated risks.

In recent decades urban flooding in HCMC has become one of the most pressing issues. HCMC is exposed to multiple flood risks. These risks to the existing urban area are already a major issue, with a significant part of the city already experiencing frequent flooding. The city witnesses severe disruptions on a regular basis with multiple consequences (Storch et al., 2009). The occurrence of localised urban flash and pluvial flooding (water not being able to enter the drainage system or ejected from the drainage system), following high intensity or prolonged heavy rainfall leading to overland flow and ponding, is a common occurrence on many streets. Flood events occur individually but more commonly in combination with high tides and fluvial flooding events. High water levels in the receiving watercourses of HCMC caused by tides and overburdened or blocked drainage and sewage systems exacerbate the flood risk. The occurrence of inner urban flood events is not a new phenomenon for HCMC though the increasing frequency with which they are occurring and their rising impact to the city over the last 20 years may be attributable to climate change (Phi 2007; Storch et al., 2009).

Additionally the city is already particularly affected by a significant rise in inner city temperatures caused by the effects of an urban heat island over the city, demonstrated by a distinct difference between the city's inner core and the vegetated surroundings, which has consequentially caused air quality to deteriorate and decreased the thermal comfort of inhabitants. During the dry months energy shortages and power outages caused by the increasing demand for cooling are a common occurrence.

The current challenges HCMC faces provide an indication of the possible consequences of climate change. Many of the current and foreseen climate related impacts directly interact with the urban area of HCMC. These can be termed the primary climate change impacts. These however further interact with the current urban development patterns and cause secondary climate change impacts along the chain of causation and result in long-term development challenges. Many of the occurring flood events provide good examples of the interactions between unsustainable urbanisation processes and the impacts of climate change *i.e.* increased soil sealing, the increase of urban run-off, the overwhelming of the existing drainage system and the occurrence of pluvial flooding. Even in the absence of climate change and with no future improvements to the existing drainage system, increased urbanisation is likely to lead to higher run-off amounts, which then would in turn lead to an increased stress to the urban drainage system. This may ultimately lead to the increased occurrence of flood events.

Climate change will undoubtedly influence the development path HCMC in coming decades. However, besides from presenting increased exposure to hazards, the impacts of both urbanisation and climate change create a multitude of opportunities to reassess the current development pathway and consider how the future growth of HCMC can be more efficiently managed. An opportunity to identify synergies and minimise trade-offs is presented. As such the assessment of the urbanisation and climate change impacts present a very dynamic window in which to steer future development and effect urban change. While the very nature of both phenomena stress a need for a new emphasis to be placed upon the forward planning of HCMC over next decades.

Since many of the main impacts of climate change exhibit a land use dimension, such as the increased frequency of urban flooding events or the intensification of the already existing urban heat island effect, planning and land use controls can be seen as the most appropriate adaptation management strategy. A downscaled and spatially explicit indicator framework based upon urban structure types integrating environmental, social, and economic indicators was developed. It is envisaged to function as a switchboard for adaptation and mitigation responses. Furthermore, it can contribute to sustainable development objectives, strengthening the existing urban governance, mitigating spatial disparities, minimising the risk divide within the city, and ensuring climate preparedness. The framework will provide a basis for the assessment of future development, planning options founded on the basis of strong scientific findings and indentify those solutions of how best to respond to climate change while minimising the associated hazards. The resulting framework will support urban governance with climate change solutions, advancing knowledge about current and future hazards, elements at risk, and the different types of vulnerabilities present.

3. Urban structure type mapping for spatial indicators

The current spatial pattern and settlement structures of HCMC are integrated into a system that is affected by a number of internal and external pressures. The potential impacts of climate change on the city, its settlements, population, and infrastructure should be assessed within the context of the urban system's complexity. Urban risk is complex but displays distinct spatial dimensions being highly locality and scale dependant. This spatial component of climate risk is critical for advancing understanding about climatic risk on the one hand and potential management options and challenges at the urban level on the other. Climate risks arising from climate variability, climate change, and urbanisation are spatially heterogeneous across HCMC. Here adaptation planning requires site-specific information. However few studies have attempted to expose the spatial heterogeneity of climate risk at smaller spatial scales such as a mega urban region (Preston et al., 2007; Rosenzweig et. al 2000). More often than not, a methodological void is seen between the regional climate change modelled, and the local urban development scenarios, which hinders the effectiveness of urban impact assessment methods.

Over the entirety of the HCMC administrative area, vulnerability to the effects from climate change varies considerably from settlement to settlement and even within settlements. The location, present urban structure types, dominant building types, social-economic characteristics and existing institutional capacity are all key factors that affect the ultimate vulnerability and adaptive capacity of a settlement in the urban context (Storch et al., 2009). Furthermore, the exposure to and sensitivity for climate change related risks and impacts are a result of unsustainable physical processes, such as building construction, urban planning, infrastructure provision or transportation, as well anthropogenic processes, such as lifestyle choices, that lead to vulnerabilities. Hence the fundamental motivation for downscaling climate change impact assessments to the urban scale lies in the understanding that every region exhibits its own unique urban development issues and paths as well as inherent resilience options and adaptation potentials. However, as Preston et al., (2007) states, achieving spatial integration in such assessments, is non-trivial due to issues of data scarcity, quality compatibility and scale. The necessary downscaling for the impact and vulnerability assessments in our approach is obtained from the detailed mapping of the current HCMC urban structure types.

The development of an adaptation planning framework based on an urban structure type approach acts to downscale climate change impacts and embraces HCMC´s urban complexity (Storch et al 2011). Within our study, the classification and mapping of urban structure types, forms the basis for the classification of spatial indicators. Spatial indicators are defined as characteristics of the urban system which can be measured and used to provide indirect or proxy information of other parameters such as climate risks and opportunities which are not directly observable (Cutter et al 2003).

As a prerequisite, climate change related urban adaptation decisions require the rational characterisation of the current urban landscape according to vulnerability relevant features. In addition to providing an up-to-date assessment of the current land-use pattern, the urban structure type approach acts as the central integrating component for the identification of ameliorating opportunities and as an adaptation planning framework for HCMC. The approach allows for the spatial linking of an indicator concept, which represents a method to integrate the biophysical aspects of exposure to climate change risks with the social-economic aspects of climate change sensitivity of people, localities and environmental information (Pauleit & Duhme 2000; Thinh et al 2002; Gill 2008). Through the assessment of impacts, an estimation of the possible damages that might arise to the urban system and its assets from climatic stimuli can be undertaken (Blum & Gruhler 2009; 2010). In general there are two elements that define the potential risk: first, the probability of the occurrence of the events and second, the elements at risk. Events to be included are heat waves, heavy rainfall events, floods, etc., while elements at risk are not only assets, such as houses, urban infrastructure services or economic losses, but also human health and livelihoods.

In order to accurately define the current urban components and their characteristics, the digital version of the official land-use map 2010 at a scale of 1:25,000 provided the common spatial geometry to which a ´current land-use` map for the year 2010 was compiled (see Figure 2). Current land-use was determined from an urban structure type classification for the entire HCMC urban area. This involved the visual interpretation of high resolution panchromatic satellite imagery captured in primarily 2009 and 2010.

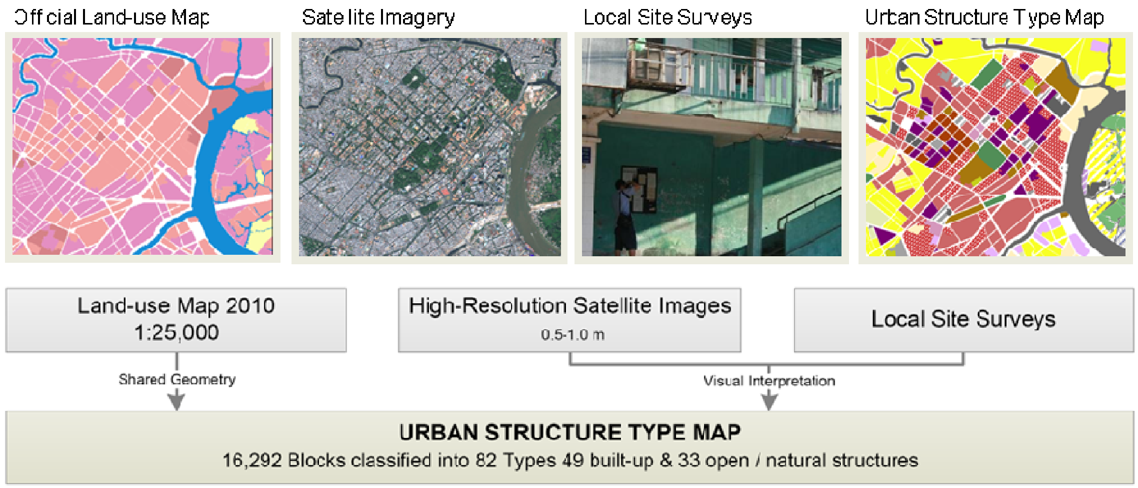

Figure 2: Urban structure type classification based on the visual interpretation of satellite imagery and local site surveys.

Table 1: Classified urban structure types for HCMC 2010, defining current land-use.

Utilisation category	No. of sub-division into urban structure types	No. of blocks	Surface Area (km²)	Percentage utilisation category	Percentage of total HCMC surface area
Urban structure types (in total)	82	16.292	2114,9	-	81,7
Residential	25	6717	445,9	100	21,1
Shophouse-based	12	6346	424,8	95,3	20,1
Villa based	4	107	8,4	1,88	0,40
Apartments	5	103	5,0	1,12	0,24
Central Business Dist.	2	160	7,4	1,66	0,35
Public & special use	20	772	52,0	100	2,43
Industrial & commercial use	4	828	56,6	100	2,67
Green & open spaces	33	7995	1173	100	55,5
Remaining street and surface waters	-	-	388,1	-	18,3

In total eighty-two discrete urban structure types were devised and assigned to the 16,292 blocks in the common spatial geometry of the official land-use map 2010. The classification was sub-divided into the utilisation categories of residential, public and special use, industrial and commercial use, green and open spaces and the remainder of street and water networks. Table 1 provides an overview of the classification, while Figure 3 below provides a selection of some of the commonly occurring urban structures within HCMC. While the official HCMC land-use plan itself displays only the pure designation of land-use utilisations. The inherent qualities, *i.e.* environmental significance or the exposure or resilience of areas or structures, the urban structural densities or the real utilisation are not illustrated.

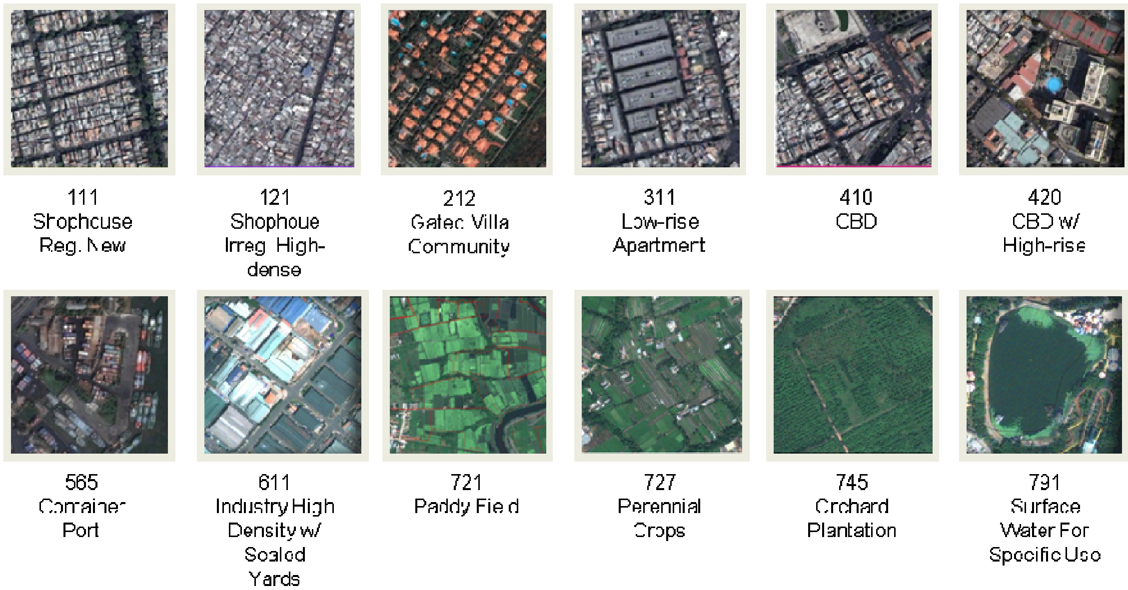

Figure 3: A selection of interpreted urban structure types based on satellite imagery and site visits.

Table 2: Density-, structural-, environmental- and socio-economic core-indicators derived from an urban structure type approach.

Bio-physical core urban structure type derived indicators	
Built Structural	Dominant building types; Construction material; Age; Structural assets; Utilisation; Roofing material and pitch
Density	Buildings (dwellings) (ha); Average no. of stories; Building volume; Floor space/population; Floor space ratio (FAR); Housing density/Gross floor ratio (GFR)
Environmental	(%) Impervious surface coverage built/non-built; (%) Greenspace (vegetation cover)
Social-economic indicators derived from census data	
Housing	Population/residential (living space) density; Average household size
Income	Household income
Demographic	(%) male/female; Age structure; (%) secondary/tertiary education

The urban structure type approach allows for the initial and further differentiation of the urban landscape on the basis of each structure's biophysical and socio-economic characteristics. As such the approach represents the urban system and displays a higher differentiation than commonly seen in official land-use maps. Moreover the approach attempts to spatially represent multi-disciplinary core indicators concerning environmental, social, and demographic aspects (Table 2). Features of built-up areas, impervious surfaces, real or actual land use, housing types, building density, population density and social status of urban areas can be assigned to every urban structural unit. Thus, the overriding framework obtains whole sets of biophysical and socio-economic indicators.

The approach also allows for additional indicators to be incorporated such as consumption indicators for energy and water requirements or adaptive capacity indicators such as urban greening potentials, solar potentials or runoff potentials for individual structures. Additionally, the approach allows for indicators for current broad issues relevant to many cities to be integrated. This presents a means access varied planning targets and goals. Issues include energy and the identification of potentials for micro- generation, potentials to address emissions from the building sector, low- and no-carbon potentials, water harvesting and recycling potentials of waste, the identification of potentials for turning waste from a cost into revenue, such as producing energy from waste. In relation to climate risks and opportunities, the subdivision also allows for a series of initial questions to be addressed (Table 3) such as; how robust or resilient are current urban structures in regards to their physical, social and economical conditions? How do different urban structure types contribute to environmental impacts on local conditions? And which potentials exist for the improvement of energy efficiency and the adaptation to climatic conditions in existing and future building structures?

Table 3: Vulnerability and resilience of urban structure types to different climate impacts.

Relative vulnerability of urban structure types to different 1st order climate impacts	
Extreme Heat	High / medium / low
Sea-level-rise	High / medium / low
Extreme rainfall	High / medium / low
Drought	High / medium / low

The urban structure type approach allows for the consideration of the effects of endogenous social and environmental change and permits the running of current and future development scenarios against the consideration of changes in the exogenous climate forcing. For example the impact of changing social structures and development of areas to the south of the present day city may be assessed to see its impact on hazard exposure and net vulnerability. In our indicator system, single indicators are not intended for use in an isolated manner, but from the urban structure type approach, multiple indicators can be used to generate spatial maps of the components of resilience, exposures and sensitivity. These maps can then be combined to generate net maps of vulnerability. This allows for a spatially explicit view of the consequences of development and (climate) change, which is highly attractive to stakeholders, as it provides a readily interpretable image of the potential consequences at the same scale as the official land-use map. Finally transferable guidelines incorporated into spatially explicit planning recommendation maps will be compiled.

4. Imperviousness as a key urban environmental impact indicator

One of the most significant environmental indicators for urban agglomerations is the extent and degree of impervious surface coverage. The level of imperviousness not only exerts a strong influence on the urban hydrology but also on urban climate. The amount of impervious surface coverage strongly affects the environmental quality of urban and surrounding areas. The extent of imperviousness correlates with both the urban heat island (UHI) affect (Katzschner 2011) and increased surface runoff (Pauleit & Duhme 1998; 2000; Haase 2009). Mitigating for the affects of both UHI and increased surface runoff are two of the major environmental challenges currently being faced by HCMC.

Urban areas are sealed to different degrees according to the related urban densities and structures present, leading to an alteration of the urban hydrograph and to a separation of atmosphere/hydrosphere and the pedosphere. Normally a large proportion of precipitation is quickly converted to surface runoff. Often the existing drainage and sewer systems in the fast growing cities do not have the capacity to cope with large surface runoff volumes following heavy rainfall events. Together with the superimposition of natural retention areas, the water balance is disturbed, so that a compelling need for dedicated site specific risk assessment and planning arises. The present management of precipitation and runoff waters in high density urban areas, such as HCMC, typically aims for fast and efficient removal. However, HCMC is a city currently in a precarious situation and exhibiting a growing sensitivity to water. The city has a high seasonal annual precipitation, high humidity and naturally high groundwater levels and owing to its location in a delta. The intensive industrialisation and urbanisation over the past decades has lead to a strong increase in water demand and contamination of all water resources. The result has been qualitative and quantitative overuse, water shortages and water stress (Arnold & Gibbons 1996).

Distinguished are built and un-built sealed areas. In both instances, the less water which can infiltrate results in higher and more dynamic surface run-off amounts. Therefore the sealing has direct infrastructural as well as ecological consequences. Areas which would normally allow for the infiltration, filtration and retention of rainwater are lost and superimposed and waters must be diverted to receiving water bodies and drainage systems. The groundwater recharge is hindered and surface runoff waters become exposed to contamination. Un-built and built urban structures in areas of high structural densities are furthermore absorbers of global radiation. The reflected long-wave radiation warms the atmospheric boundary layer over the city. This has distinct hydrological consequences, while in conjunction with the simultaneously increased emissions of aerosols within the city, the UHI leads to higher and more frequent rainfall events on the lay-side of the urban area compared to surrounding landscape.

To determine the current impervious surface coverage of HCMC, the visual estimation of the percentage of both built-up and non built-up sealed surfaces for each urban structure type was carried out using high resolution satellite imagery (Figure 4). From these estimations mean values were calculated for each urban structure type (Rujner et al 2010). These mean values were then calibrated utilising a building footprint map from the year 2005 in unaltered urban areas, adjusted accordingly and attributed to all blocks. Table 4 displays the sealing degrees for a selection of urban structure types of HCMC.

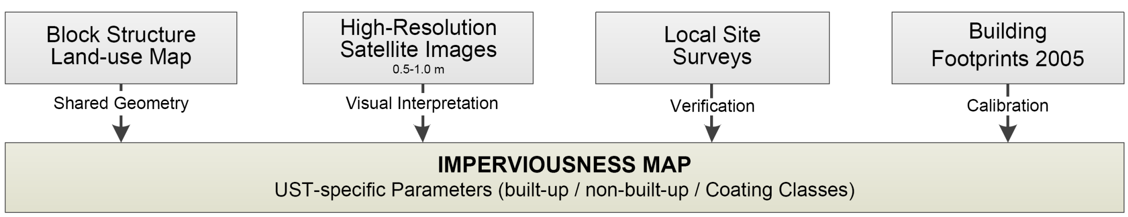

Figure 4: Determining and mapping imperviousness for HCMC:

Table 4: Imperviousness cover for selected HCMC urban structure types.

Code	Urban Structure Type Name	Number of blocks	Sealing degree built-up	Sealing degree non-built-up	Sealing degree adjacent streets	Total Area
			in %			in ha
Residential						
111	Shophouse Reg. New	100	70	11	100	451
112	Shophouse Reg. New Community	62	60	16	100	394
113	Shophouse Reg. Alleyways	592	75	15	100	2071
114	Shophouse Reg. w/ Yards	153	44	15	100	2028
121	Shophouse Irreg. High-dense	425	78	14	100	1602
122	Shophouse Irreg. w/ Yards	794	57	10	100	4462
123	Shophouse Irreg. Scatt. (Peri-urban)	815	28	8	95	7001
124	Shophouse Irreg. Clust./Line. (Peri-urban)	741	30	10	90	5513
125	Shophouse Irreg. w/ lar. Fields (Peri-urban)	2342	5	5	80	17219
131	Shophouse w/ Indust.	222	74	15	100	1257
132	Shophouse Irreg. w/ Reg.	23	69	14	100	356
211	Villas	26	30	14	100	276
212	Gated Villa Community	49	17	20	100	392
221	Villas in est. UST	16	55	20	100	151
311	Low-rise APT <9 Floors	37	84	8	100	153
312	High-rise APT >9 Floors	29	61	20	100	219
Public & special use						
410	Central Business District	103	72	10	100	534
420	Central Business District w/ Highrise	57	73	20	100	214
511	Campus	141	35	49	100	563
512	High-dense	63	74	20	100	110
531	Religious and Worship Site	79	46	40	100	172
540	Hospital & Health Centre	48	62	30	100	168
550	Administration/Public Offices	100	60	30	100	233
563	Airport/Heliport	1	10	20	100	833
565	Harbour/Port Container	25	10	80	100	550
572	Place of cultural arts	76	39	25	100	395
Industrial & commercial use						
611	Indust. High Density w/ sealed Yard	213	75	20	100	1075
612	Indust. High Density Unsealed Yard	205	60	7	100	1125
621	Indust. Low Density w/ lar. Sealed Yard	44	35	35	100	228
622	Indust. Unsealed Yard	368	29	10	100	3232
Green & open spaces						
711	Forested Park	13	5	10	100	136
712	Mixed Park	20	5	10	100	462
7--	Agriculture (721-753)	7291	1	0	50	109617
761	Municipal Solid Waste Site	4	10	15	65	139
762	Wastewater Plant	13	5	85	65	162
771	Unsealed Grassland	41	10	20	100	117
780	Cemetery	128	7	50	100	402
791	Surface Water for Specific Use	141	1	0	65	1216

According to the Department of Natural Resources and Environment (DONRE), on the basis of the current HCMC urban development master plan for 2025, the available agricultural land (121,000 ha in 2008, ca. 58% of the total area) will reduce to 83,000 ha, with 38,000 ha rezoned as construction land and becoming available for new developments (VNNEWS, 2010). Alongside this ongoing urbanisation comes the loss or deterioration of the valuable surrounding multi-functional green and open spaces, which as mentioned are not only important for agricultural production but also for the regulation of the urban water balance and climate of HCMC.

As urban structure types are assigned to the block geometry of the official land-use plan, it is also possible to depict future land-use planning situations. Imperviousness of over three time-periods (current, 2010-2015 and up to 2025/30) could be considered. The urban structure type indicators were available at the necessary spatial resolution for the representation of the results at a scale of 1:25,000. The current expanse of built-up land derived from the urban structure type map and future urban development scenarios taken from the land-use plan up to the year 2010 and from the draft land-use plans 2010-2015 to 2025/30 are portrayed in Figure 5. For future scenarios, a range of likely UST´s with respective imperviousness values were included to fill areas designated to demonstrate new developments. The results aggregated to the entire urban area show that currently approximately 16% of HCMC is imperviously covered. This percentage is seen to increase to 21% and 32% respectively with the implantation of the future development plans. These changes alone provide interesting insight into the significance of urban development on future urban hydrological conditions and the role that rapid urbanisation processes can play as drivers of future flood and thermal stress risk. With the implementation of the future development plans up to 2025/30 the impervious coverage will be seen to double for the entire urban area of HCMC. This action will significantly increase the amount of surface-runoff, which is presently a major cause of urban flood episodes.

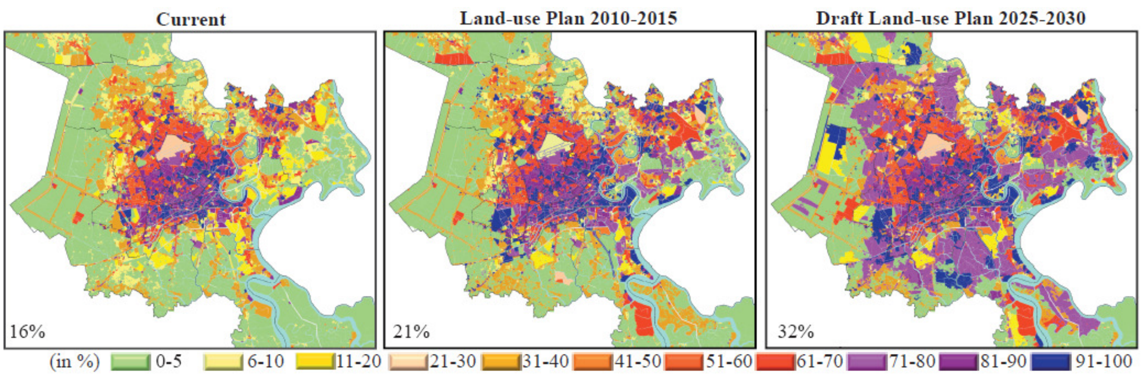

Figure 5: The current imperviousness and future imperviousness for HCMC's urban development scenario.

Summary and outlook

HCMC is a future megacity in the making, it is a city in rapid transition; rapid urbanisation driven by socioeconomic development (including population and economic growth) and question marks have been raised over the sustainability of this transition. The city´s vibrant growth, expansion and the future impacts of climate change present huge physical and economic challenges and have notable implications for future governance. Well-governed, -designed and -constructed cities have the potential to be amongst the most resilient and most sustainable places to reside. However, for HCMC with its inherent development issues and hazard portfolios, where physical and social infrastructure is inadequate or weak and unsuitable to meet the future challenges of climate change, there is very real threat that if not suitably addressed it will undoubtedly be among the worst.

Over the coming decades, in light of the underlying demographic structure of Vietnam, the strong rural-urban pull of HCMC and the government's own development targets, a significant amount of further urban development will be required. As the built environment has a design life of over 80 years and settlement patterns and urban form often display even greater longevity, the legacy of these developments will continue to impact the environment and ultimately shape the spatial pattern and long-term vulnerabilities of the urban system for decades to come. Hence in addition to the urgency to develop cities in a more liveable and sustainable manner, there is a need for anticipatory decisions to be undertaken to steer cities like HCMC towards low-risk development which would have potentially high benefits over the coming decades. These challenges should not blind us to opportunities. There is a need for spatial indicators to measure progress, linking climate change opportunities and threats with urban structures. The current sustainability paradigm is part of an attempt to transform HCMC inline with the demands of more challenging future conditions. For the process of sustainable adaptation to climate change, adaptation options will depend greatly on the adaptability of the urban system with spatial land use planning a key criterion for effective strategies to deal with future challenges and steer development towards a low carbon and resilient urban future. Due to the complexities of rapid urbanisation however, transformations will take time.

Planning responses are required that on one hand adapt the city to climate change and on the other maintain or enhance the current urban environmental system without hindering development. An important prerequisite for establishing efficient proactive and rapid adaptation planning strategies is the spatial and rational characterisation of the current urban fabric according to vulnerability relevant features. This paper outlines an urban structure type approach as a tool for the integrated assessment of urban resilience. The approach provides a common spatial framework at the resolution of the urban block for data integration and to compile existing vulnerability concepts from various thematic and scientific disciplines at the same spatial scale. This provides a clear method to generate portfolios of block-specific core indicators, move across scales, run scenarios and aggregate to larger planning horizons, ultimately useful to aid decision-making.

Adaptation is unrealisable without improvements in the usability of scientific results for decision-making and their integration into the planning process. By identifying and estimating the local risks arising from climate change, the results will support the HCMC administration to establish a well-founded database with reliable information. On the basis of such data, maps incorporating planning advice in reference to measures (restrictions, bans, conditions, and development objectives) will be transferable end products. Utilising the adaptation planning framework approach outlined above, the overall aim is the interlocking of the planning recommendation maps: multi-functionality of the landscape. In this respect, the same area may contain significant unsealed surfaces, or exhibit an infiltration, retention and/or evaporation potential. In addition, the same or an adjacent area may also render itself suitable for a heat sink, roof greening, for the development of retention water bodies or even for the protection of riparian buffers. In such a way spatial indicators based on an urban structure type approach aim to advance and disseminate knowledge and inform decision-makers and the general public about the climate change risks, to increase their capacity to implement necessary adaptation measures, and to strengthen the resilience of the HCMC urban system.

Acknowledgements

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