Understanding Ho Chi Minh City's Urban Structures for Urban Land-Use Monitoring and Risk-Adapted Land-Use Planning

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Abstract This chapter outlines an urban structure type approach used to portray, classify and understand the settlement patterns and urban structures of the current and emerging landscapes of Ho Chi Minh City. An important prerequisite for establishing much needed efficient and proactive, as well as rapid, adaptation planning strategies is the spatial and rational characterisation of the current urban fabric according to vulnerability relevant features. In our work an understanding of urban settlement patterns and urban structures allowed for the capturing of the highly dynamic spatiotemporal social and structural changes associated with rapid urbanisation processes. The aim was an integrated assessment of the underlying the inherent urban resilience based on coherent and credible indicator sets. The approach provides a common spatial framework at

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the resolution of the urban block for data integration various thematic and scientific disciplines at the same spatial scale. The scale provides a clear instrument to generate portfolios of block-specific core indicators, move across scales, run scenarios and aggregate to larger planning horizons, ultimately useful to determine hotspots for administrative interventions and to assist prioritising in spatial planning decision-making.

Precarious Growth and Shifting Patterns of Risk

Urban growth, particularly in the form of rapid spatial expansion is a recent phenomenon common to a large number of cities in Southeast Asia. By its nature urbanisation causes changes in land-use to both the existing urban and peri-urban environments which often leads to an increase exposure to hazards but also an increase in the number of assets exposed, i.e. by a growing number of people, buildings and infrastructure potentially exposed to events. Significantly for the emerging megacity of Ho Chi Minh City, formerly known as Saigon and often abbreviated as HCMC, population growth and associated urban development have led to an increased exposure to climate and hydro-metrological hazards. HCMC is considered a hotspot of vulnerability to the impacts of climate change (Nicholls 1995; Dasgupta et al. 2007; Nicholls et al. 2007; Carew-Reid 2008; Webster and McElwee 2009; ADB 2010; Birkmann et al. 2010; Fuchs 2010; Fuchs et al. 2011; Hanson et al. 2011).

The urban districts of HCMC, making up the inner core, are particularly dense, with an average population density >28,000 pers./km^2 and highs of 45,000 pers./km^2. Historically, this high-dense development of the inner core was principally a manifestation of the necessity to adapt to the dominant flood risk situation of the city (Bolay et al. 1997; Bolay and Ngoc 1999). Figure 1 demonstrates the role that the geographic setting played historically in the location of both the French colonial city of Saigon—clearly recognisable from its grid-like planned streets—and the historical Chinese influenced city of Cholon founded in 1979. Historically two separate cities located apart in what are now districts 1 and 5 of HCMC, they later merged. Clearly also visible and marked on the map are the extensive low-lying tidal and freshwater and waterways to the south, east and north of Saigon.

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 (Downes et al. 2013; Downes and Storch 2013). Yet recently, great concern has been raised at the city's rapid expansion into the lower-lying and former wetland surroundings (Downes and Storch 2014). The vast majority of HCMC's administrative area is distinctive due to its low altitude and general flat topography. The terrain elevation varies from 4 to 32 m AMSL in the

Fig. 1 Early HCMC (1892) Photograph of a map entitled "Saigon et ses environs 1892" translated to Saigon and its environment dated 1892 on display at the central post office in HCMC (authors own)

north-northeast, to the southern coastal lowlands at 0 to −1 m AMSL. In total, 70 % of the whole urban area of HCMC is below 2 m AMSL. Furthermore, 98.8 % of the southern rural districts of Nha Be and Can Gio are below 2 m AMSL, whilst in contrast, for the two northern rural districts Cu Chi and Hoc Mon, the figure is 38.3 % (Downes et al. 2011).

In disparity to the underlying conditions, between the years 2005 and 2011, the highest rates of population growth were seen the peri-urban districts and rural of HCMC (Downes et al. 2013). These urban growth trends are similar to those recently experienced in many higher income urban areas on the rapidly urbanising Asian continent, with central districts of HCMC, experiencing little, no or declining population growth, whereas the peripheral districts (peri-urban and rural) experiencing much stronger growth over the same time.

Storch and Downes (2011) assessing the exposure of HCMC to flooding by coupling urban development and sea-level rise scenarios highlighted that socio-economic development and resultant urban expansion into low-lying areas will be the main driver of both current and future increased exposure to flooding compared to the influence of sea-level rise. Storch and Downes (2011) showed that, currently 160 km^2 or 32 % of the current built-up area is exposed to flooding. This is likely

Fig. 2 Photograph of a localised flash flood event following heavy rainfall in Nguyen Duy Trinh Street, District 2 of HCMC on the 1st October 2012. The cause of the serious flooding was two separate rainfall events of 60.6 mm and 76 mm respectively coinciding with a high tide event of up to 1.5 m (authors own)

increase up to 360 km^2 or 48 % when solely considering planned urban development up until the year 2025.

Flooding in HCMC has become one of the most pressing issues (Storch et al. 2009, 2011; Downes and Storch 2013). 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 is currently incised by a dense network of rivers and canals of around 8000 km in length, which account for 16 % of the total area. These waterways are affected by a semi-diurnal tide, subjected a high-tide level as high as 1.5 m AMSL. Often coincident with annual rainfall peaks a significant percentage of the city's neighbourhoods regularly experiences floods, due to a combination of tides, heavy monsoon rains and storm surge floods. 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 (Fig. 2). The dimensions of flooding are constantly changing due to the on-going rapid urbanisation.

The urban expansion of HCMC has caused the loss and 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 caused the creation of more *hardscape* features and the loss of space for water, including natural detention and retention areas and

Table 1 Documented land-use change in HCMC (2000–2010) (DoNRE 2012)

	2000		2005		2010	
Criterion	ha	%	ha	%	ha	%
Agricultural land	130,720	62	123,517	59	118,052	56
Agriculture	91,139	70	77,955	63	72,143	61
Forestation	33,472	26	33,858	27	34,117	29
Aquaculture	4149	3	9765	8	9441	8
Salt marsh	1959	2	1471	1	1943	2
Other agricultural land			468	0	408	0
Non-agricultural land	74,294	36	83,774	40	90,868	43
Residential land	16,686	22	20,521	25	23,666	26
Public land	19,602	26	28,535	34	32,974	36
Religious land			400	1	410	1
Cemetery	998	1	925	1	951	1
Rivers & lakes	36,163	49	33,250	40	32,813	36
Other non-agricultural land	919	1	143	0	54	0
Unused land	4414.50	2.1	2263.70	1.1	635.5	0.3
Total land	209,501.80	100	209,554.50	100	209,554.90	100

the alternation of the natural drainage systems and urban hydrograph. Table 1 highlights the officially documented land-use changes in HCMC between the years 2000 and 2010. In the 10-year period agricultural land was seen to decrease by 6 % while non-agricultural land increases by 7 %. The result is the growing 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.

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 minimize 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.

Risk-Sensitive Adapted Land-Use Planning as an Appropriate Response

Typically the vulnerability assessment of urban areas to current and future impacts is based on three key factors: the level of regional exposure to climate variability and extremes, the current sensitivity of the urban system and their adaptive capacities of the elements at risk (Fig. 3). If the main interest lies in planned adaptation, undertaken with urban development in mind and related to land-use planning, the assessment of potential impacts is more practical. Urban populations are usually less vulnerable to many types of hazards (Peduzzi et al. 2012). The level of construction, and the built structures and critical infrastructure present, their locations and densities provide or take away safe havens. For example instead of providing shelter, a building or groups of buildings may actually escalate the risk, for example increasing surface run-off in the case of urban flooding, increasing thermal stress in the case of the urban heat island effect, flying corrugate roofing material in the case of a typhoon or poorly construction building in the case of an earthquake. Furthermore the geographical patterns of the expansion of a city have a direct relationship with its environmental quality, particularly water flows, flooding and urban thermal stress.

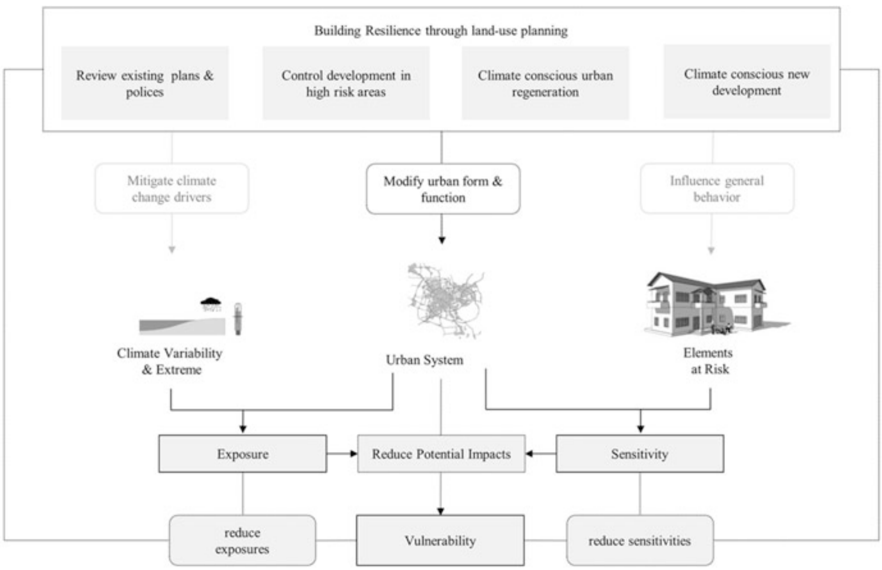

Fig. 3 Restrictive relationship between land-use planning mechanisms for enhancing urban resilience (authors own)

A key question for urban policy and planning is how to direct these changes in ways that minimise environmental impacts and risks. Since many of the main impacts of climate change in HCMC additionally 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 (Storch et al. 2011; Storch and Downes 2013). This may even be necessary in the face of a short-term cost to economic growth.

The spatial component of climate risk is critical for advancing the understanding about climate risk on the one hand and potential management options and challenges at the urban level on the other. Here adaptation planning will require site-specific information. A wreath of literature has demonstrated the importance of a real and up-to-date spatial and rational characterisation of urban areas according to vulnerability relevant features for comparative analysis. However, for HCMC currently only sparse information is available about the size, structure and spatial distribution and the dynamics of change to both its natural and built environments (Downes and Storch 2014). At the city level where adaptation requires place-based approaches (Adger and Kelly 1999; Cutter 1996; Turner et al. 2003; Walker et al. 2004; Bulkeley 2006; Bulkeley and Kern 2006), the HCMC authorities are overburdened with the social, economic and environmental challenges that are typical for the management, public servicing and resource allocation of an emerging megacity. Yet the city's authorities responsible for planning are very much aware of the gravity of risk the city is facing and their moral responsibility for risk reduction. There is also considerable agreement that a change in the current system of planning and urban management is needed.

The importance of effective land-use planning as a strategy for adaptation (Campbell 2006; Wilson 2006; Hallegatte 2009; Roggema 2009; Wilson and Piper 2010; Storch et al. 2011; Wamsler et al. 2013) and for better understanding of the relationship between future urbanization and disaster risks is known (Burby 1998; Godshalk et al. 1998; Burby et al. 1999, 2000; Sudmeier-Rieux et al. 2013). Our research has been carried out in collaboration with DoNRE. Ultimately, DoNRE has the most crucial policy tools available for embedding adaptation to climate change, which is the task of determining the overall land-use and spatial zoning (DoNRE 2012). Land-use planning and plans can influence the location, type, design, quality and timing of development (Table 2). Through on the one hand, the maintenance of protective features of the natural environment that lessen or absorb the potential impacts of climate change such as water retention areas, protective mangrove forests, and cold air generation areas should, and on the other hand, zoning instruments in land-use plans that designate development in both safe and suitable locations, land-use planning can build resilience and reduce episodic and regular risks prevalent in HCMC.

Table 2 Structural and non-structural land-use planning options and measures in response to increased flood risk

Land-use planning options	Description	Specific structural and non-structural land-use measure
Density control	Applying occupancy and density ceilings for permitted land uses	Limit occupancy load Ground Coverage (GCR) and Floor Area Ratios (FAR) in high population density exposed to flooding Desealing of impervious surfaces or change surface coatings
Site selection and development	Maintaining inappropriate land uses and development out of hazard areas	Avoid areas where development will increase the likelihood of risk or level of impact, including resettlement Maintain development out of risk and extreme-risk zones Flood proofing in medium to high risk zones
Design and building regulations	Application of appropriate building controls	Building controls in terms of elevation, high foundation walls, stilts, setbacks, minimum lot size, sealing degree, depending on risk levels Sustainable drainage systems, detention/retention ponds rainwater collecting and reusing, green roofs, facades, tree planting
Protection of critical infrastructure	Critical facilities are ensured of their functionality during disasters	Construct overhead service lines Protect water and sewer lines, extension and optimisation of runoff and sewer system Hard protection measure (i.e. dyke systems)
Open space preservation	Specific areas used for low intensity and low density use to minimise damage	Flood plains used only for urban agricultural use, avoid the development of additional settlement areas at risk of flooding Designation and maintenance of riparian vegetation, conserve and protect the existing natural or near-nature water balance, including afforestation Wetlands created as a means to absorb peak flows from floods: Establishment of suitable retention and detention areas

Density Information Matters for Risk-Adapted Land-Use Planning

Research and policy action on planning for adaptation of large cities is only now emerging (IPCC 2007). In HCMC there is growing consensus that adaptation is necessary both in the short and longer terms to address the current and future impacts of climate change. However a remaining key challenge for risk-adapted spatial planning is the provision of relevant information on exposed populations and assets at risk to planners and policy makers. Currently a significant lack of planning relevant information exists. While some institutional data exists to support the forecasting and assessment of climate change impacts, there is currently a lack of consistency across platforms, which restricts urban growth monitoring, plan compliance assessments, and the sharing of data between the different planning actors. To be useful for example for the Department of Natural Resources and Environment in HCMC (DoNRE), information needs to be at a relevant scale, credible and useful and available in a timeframe for taking action (Downes and Storch 2014). DoNRE, through their land-use planning, are required to consider the impacts of climate change; however, there are insufficient studies and city-wide assessments on the impacts of climate change to provide inputs into planning. For example the importance of information on urban densities (i.e. population, floor area ratio, coverage ratio, building) (see Table 2), is important for both mitigation and adaptation. Population density information is an important component of city planning, while floor area and coverage ratios ultimately determine the built-up densities as well the quantity nature and density of green and open space (Figs. 4 and 5).

As Hamin and Gurran (2009) discuss, mitigating climate change often requires a denser urban environment to reduce distances travels and building energy use, while adapting to an urban environmental to climate change often requires space available for stormwater management and urban cooling among other goals. At

Fig. 4 Photograph of the high dense urban core of HCMC of Nguyen Thai Binh Ward in district 1. High dense shophouse developments sit among apartment blocks (authors own)

Fig. 5 Photograph of the new residential area of Thao Dien Ward in district 2. Recent luxury villa and apartment extensions of the city into low-lying riparian areas of the city (authors own)

first glance this may present a density conundrum. However in rapidly growing cities such as HCMC, in areas less exposed to climate risks, a denser concentration of population, assets and infrastructure should be endorsed and effectively supported. This can contribute to reduce overall vulnerability. However if populations, assets and infrastructure are concentrated in vulnerable locations, without proper infrastructural or institutional frameworks, then densities ultimately create can increased risk (Dodman 2009). While densities in areas at risk should be strictly regulated, they also play an important factor in long-term investment decisions by planners and policy makers for adaptation-by preferring either central or de-centralised adaptation options in specific locations under certain current or target urban densities (Hallegatte 2009). Not surprisingly a lack of information has resulted in a failure to identify and implement policies and measures to address the risks posed. Furthermore, DoNRE notes that an additional formidable challenge is a general lack of targeted tools and methodologies to instruct and inform decision-makers and advance implementation at the local level.

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Urban Structure Type Mapping

Urbanisation is an extreme case of land-use change. In addition to the residing population, cities are defined by their geographical location and their built structures and densities—often the most apparent elements of physical and economic capital and development. The potential impacts of climate change on HCMC, its structures and its population, therefore should be assessed within the context of the urban systems complexity. Climate risks arising from climate variability, climate change, and urbanisation are spatially heterogeneous across HCMC being highly locality and scale dependant. Over the entire administrative area of HCMC the vulnerabilities to the effects of climate change can be imagined to vary considerably from settlement to settlement and even within settlements. The location, built urban structures, dominant building types, social-economic characteristics and existing institutional capacities are all key factors that affect the ultimate vulnerability and adaptation capacity of a settlement within the urban context.

As a prerequisite, urban adaptation decisions require the rational characterisation of the current urban landscape according to vulnerability and density relevant features. However, different approaches to assess urban vulnerability as well as density commonly require and utilise accepted discipline-specific spatial working bases. Individually these approaches often need high-resolution spatial demographic, structural, environmental and/or economic information at different scales. To conduct a truly trans-disciplinarily analysis of the urban system therefore additionally requires an adequate spatial explicit basis or platform capable of ensuing that the individual heterogeneous investigations can be resultantly trans-disciplinarily integrated. However achieving final spatial integration in such assessments is often non-trivial due to issues of data scarcity, quality, compatibility and scale.

To overcome this challenge, a spatially explicit indicator framework based upon the detailed mapping of the actual HCMC urban structure types (UST) was developed. UST mapping is currently a commonly used tool in many German cities to support effective and efficient urban planning (Heiden et al. 2012). The approach has been used in many cities to categorise the urban system into its distinct proportions of the major elements of urban heterogeneity—the built-up, the un-built up impervious and the pervious urban open and green spaces, as well as highlight the location of critical infrastructure.

The concept of UST was established in the late 1980s and early 1990s in Germany and has since been applied to a wide range of German cities as well as many other countries. The goal has commonly been to facilitate a deeper understanding of the relationship in the coupled anthropogenic-nature urban system (Downes et al. 2011; Li et al. 2011). UST's typically comprise built structures in a defined area (groups of building, or mixes of building types) and are normally characterised by a range of features that describe their physical properties (i.e. construction materials), their environmental characteristic (i.e. climatic and hydrological properties) and their functional properties (i.e. land use) (Pauleit and Duhme 2000).

The approach assesses the current land-use arrangements, existing plans and aids the development of new strategies. Centrally it addresses how the dynamic pattern of urban development can assist or hinder risk adapted non-structural adaptation in land-use planning and function as a switchboard for adaptation and mitigation responses through modifying the form and function of land. As well as providing an up-to-date assessment of the current land-use pattern and building stock, it necessitates the integration coherent and credible indicator sets providing a uniform methodological and spatial framework at the resolution of the urban block. This scale provides a clear instrument to generate portfolios of block-specific core indicators, move across scales, run scenarios and aggregate to larger planning horizons, ultimately useful to determine hotspots for administrative interventions at various levels and to assist prioritising in decision-making. For example in terms intervention and structural and non-structural land-use planning options and measures, adaptations can be undertaken at the household level such as increasing shading by planting trees, installing on site water retention systems. Alternatively adaptations measures may be undertaken at the larger planning block level. These could include providing additional green and blue infrastructure or public open space, installing sustainable urban drainage systems and greening public spaces. Table 3 highlights some additional key examples of adaptation methods at both the individual building and block level to reduce the impact of climate change for which a UST derived classification can be useful and assist decision makers with an inventory of both building types and UST.

Table 3 Key examples of adaptation methods at both the individual building and block level to reduce the impact of climate change in HCMC

Adaptation of buildings (individual building)	Adaptation of urban blocks (UST scale)
Elevation of properties—to protect from pluvial and fluvial flooding	Planting of moisture retaining species—to provide shading, cooling, evapotranspiration and a reduction in rainwater run-off
Demolition of properties—to remove flood risk in low-lying areas, to release productive land, to create land for water retention, and opportunity for green infrastructure	Construction of ponds and reservoirs—to increase evapotranspiration, increase bio-diversity and establish localised cooling
Installation of canopies—to increase shading and cooling within properties and externally	Construction of SUDS—to enhance water containment and reduce flooding
Installation of 'green roofs'—to reduce rainwater run-off, and evapotranspiration and to reduce UHI effects Installation of 'white roofs'—to increase albedo, and create conditions for localised cooling	Increase drainage capacity—to withstand more frequent and intense weather impacts, which in turn would prevent contamination of the surrounding environment and properties
Installation of passive ventilation—to aid cooling, improve air quality, reduce air-conditioning use and associated UHI, and improve internal temperature control	Construction and reinforcement of flood defences—(Hard)—embankments, walls, weirs, sluices and pumping stations (Soft) flood retention areas—to reduce rainwater run-off and protect key infrastructure
Installation and rain water capture systems—to decrease cost for water treatment, and rainwater run-off	Removal of non-porous sealing materials—to reduce rainwater run-off and flash flooding
Installation of solar panels (photovoltaic and thermal)—to reduce fossil fuel use and increase energy security	Development and conservation of green space—to reduce rainwater run-off, increase evapotranspiration and to reduce UHI
Provision of property flood gates, sand bags and pumps—to provide a fast flood defences which can be installed on demand by households	

Observed Building Archetypes

A survey and understanding of the observed building archetypes in urban, peri-urban and rural areas of HCMC provided the initial starting point for the evolution of the UST classification. Of relevance for adaptation, the attributes of, physical characteristics, building use and building age were considered. The building archetypes where categorised by building height, construction types (partly defined by national and HCMC-specific building codes), and their proximity to other structures (Table 4). Building heights ranged from low-rise (one or two floors), to mid-rise

Table 4 Categorisation of HCMC buildings by physical characteristics and utilisation

Categorisation	
Building height	• Low-rise: 1 or 2 floors • Mid-rise: 3–6 floors • High-rise: 7 floors and up
Construction materials & type	• Combustible building: built using lighter, stud-frame construction or wood joists on masonry bearing walls • Non-combustible building using steel or masonry and contrite frames
Proximity	• Detached: freestanding • Semi-detached: sharing a wall with another building • Terraced: sharing walls on both sides with adjoining buildings

(three to six floors) and to high-rise (seven floors and up), meanwhile, there were two main construction types, combustible buildings, which were built using lighter, nail, stud frame construction or wood joists on masonry bearing walls; and non-combustible buildings that use heavier steel and concrete frames. Buildings in HCMC could also be described by their proximity to each other: they can be detached (freestanding); semi-attached (sharing a wall with a neighbouring building) or attached (sharing walls on at least two sides with adjoining buildings). Finally buildings in HCMC were categorised by their age. This is a key factor because it correlates to the building standards and styles applicable at the time of the buildings construction and thereby strongly to the method and materials of construction.

The undertaken classification was based in part on the Vietnamese standards (TCXDVN 353, 2005), but altered to include additional categories. In total 19 individual building archetypes were classed and subdivided into four groups. Variations of detached; semi-detached houses and terrace shophouses, and high-rise and low-rise apartment constitute dominate building typologies in urban districts while more traditional houses were seen built in the more rural districts. The majority of the urban houses are commercially constructed with modern material such as concrete, steel works and glass. Nevertheless, the rudimentary and temporary building typologies are built by their owners with locally available and collected materials. Figure 6 provides some examples of typical building archetypes seen in HCMC.

The Urban Structure Types of HCMC and Density Indicators

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 an UST map for the year 2010 was compiled.

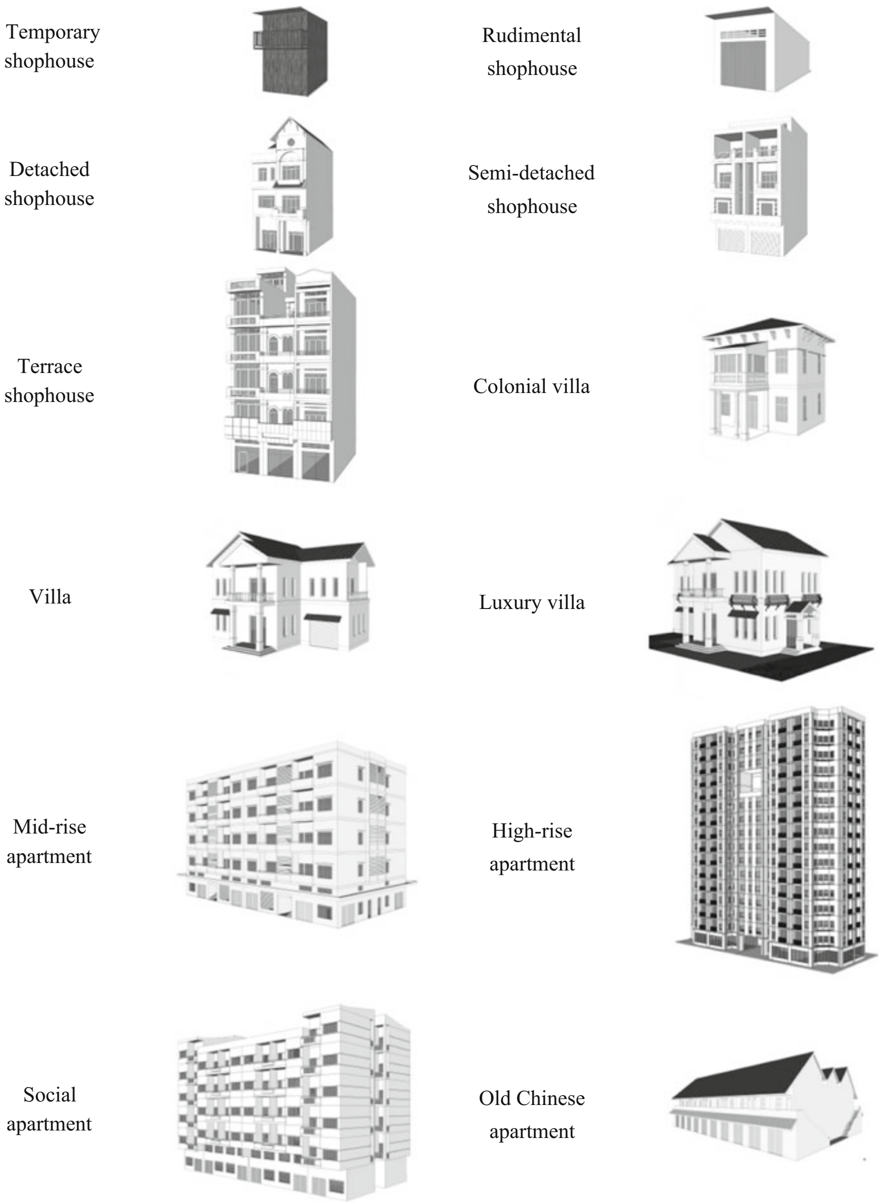


Fig. 6 Selection of observed building typologies in HCMC (not to scale) (authors own)

This involved the visual interpretation of high resolution satellite imagery captured in primarily 2009 and 2010. The basic housing archetypes in HCMC, each were conceptually divided into subtypes to generate UST that are reflective of different biophysical exposure or impact indicators. In total 82 differentiated UST were devised and assigned to the 16,292 building blocks in the common spatial geometry.

The classified UST were divided into four utilisation categories on the basis of their predominant utilisation, residential, public and special use, industrial and commercial use, green and open space and the remainder of street and water networks. Each utilisation categories was then additionally further sub-divided into UST classes and finally UST's. Table 5 provides an overview of the classified UST for HCMC.

Blocks were classified in to the utilisation category residential use if they were predominantly used for residential purposes. Residential blocks can therefore be of mixed use but overall exhibit residential character. As such they can include additional residential related buildings, public facilities, local open and green spaces and adjacent large fields. In total just over 21 % of the overall HCMC administrative area was classified as residential. The shophouse-based urban structures are the dominant structures in HCMC, accounting for 95 % of the seen

Table 5 Classified urban structures of HCMC in 2010

Utilisation category	No. of urban structure types	No. of blocks	Surface area (ha)	Percentage utilisation category	Percentage of total HCMC surface area
Urban structure types (in total)					
	82	16.292	170,960.5	–	81.7
Residential *(4 classes)*					
	23	6717	44,404.6	100	21.1
Shophouse based	12	6346	42,315.3	95.2	21.2
Villa based	4	107	844.7	1.9	0.4
Apartments	5	103	500.1	1.1	0.2
Central Business Dist.	2	160	744.5	1.7	0.4
Public, commercial & special use *(9 classes)*					
	20	772	5249.7	100	2.5
Industrial *(2 classes)*					
	4	828	5637.5	100	2.7
Green & open space *(9 classes)*					
	33	7995	115,668.7	100	55.2
Remaining street and surface water					
	–	–	38,539.5	–	18.4

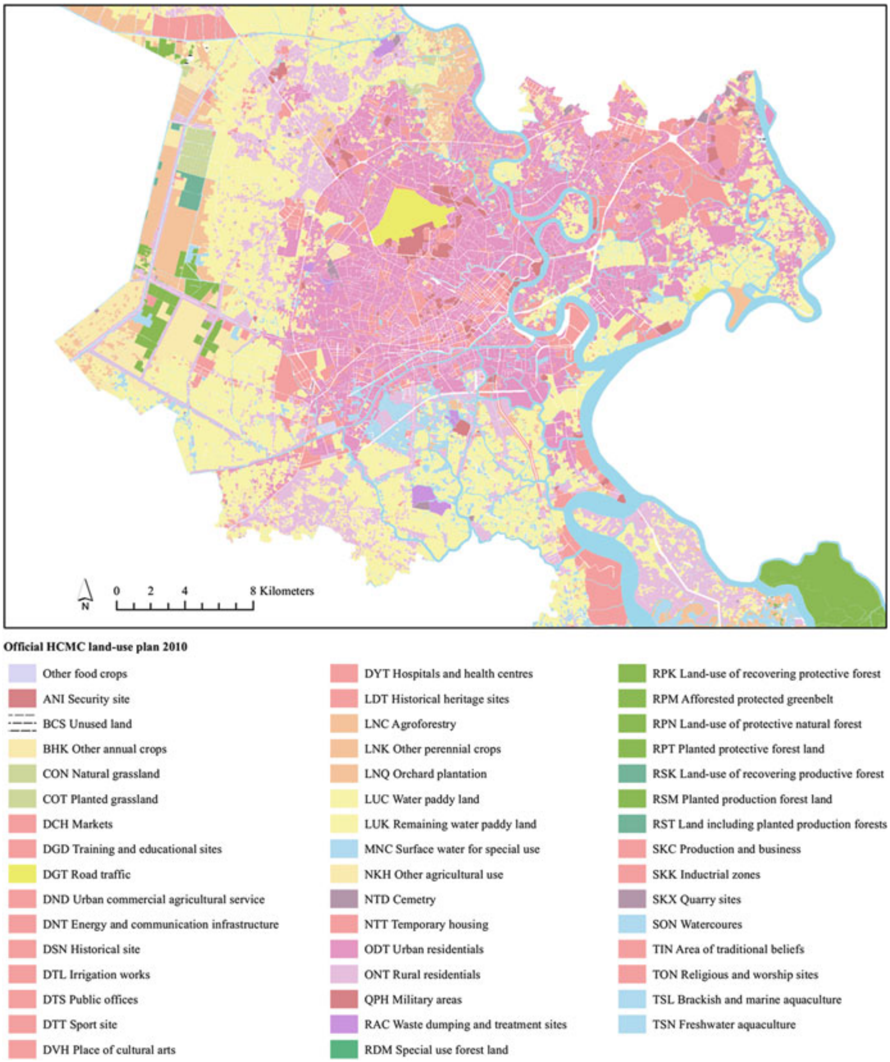


Fig. 7 Land-use plan 2010 from DoNRE (authors own)

residential UST. These were divided into 12 specific subtypes to reflect the broad variety of their structures observed in HCMC.

As the UST classification allowed for the differentiation of the urban landscape on the basis of each UST's biophysical and socio-economic characteristics, the approach displays a higher differentiation than commonly seen in official land-use maps (Figs. 7 and 8). 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

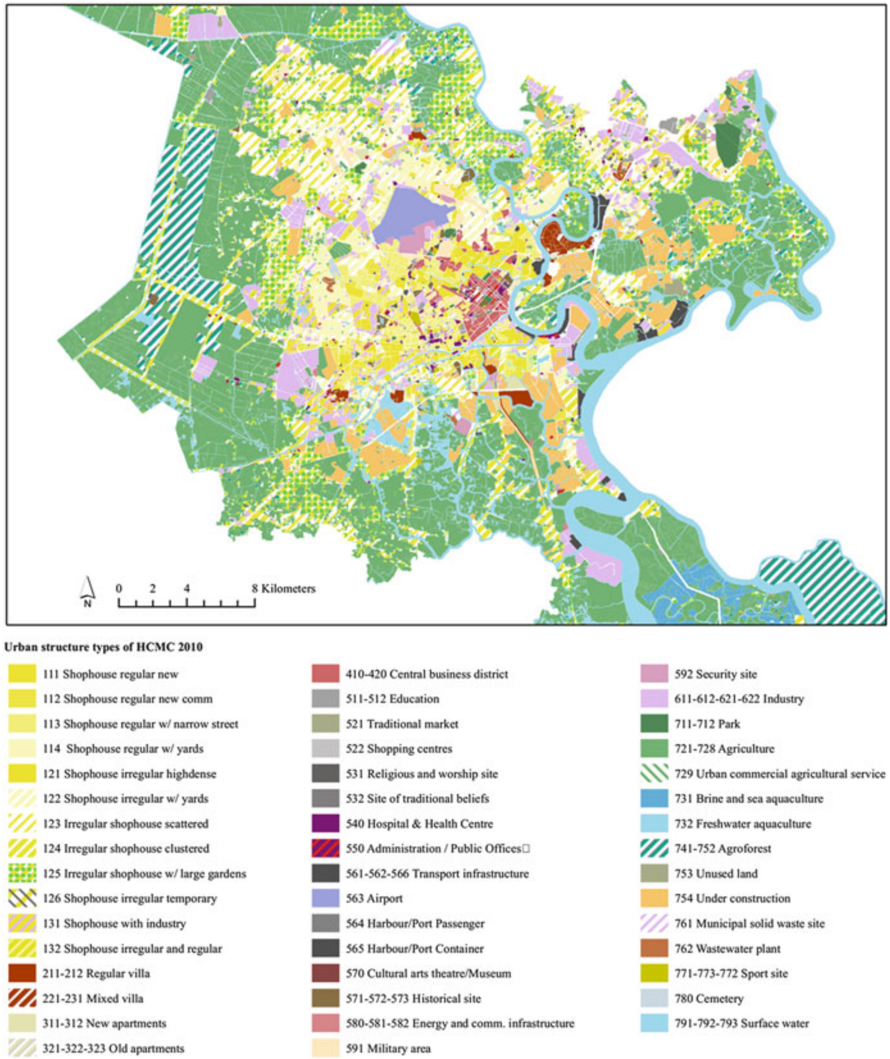
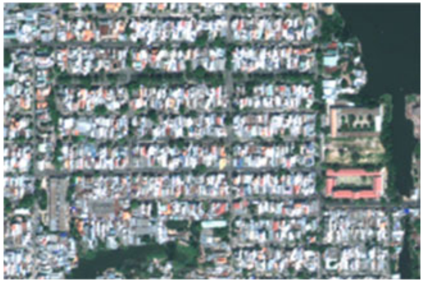


Fig. 8 The compiled UST for HCMC (please note that for readability some UST have been grouped) (authors own)

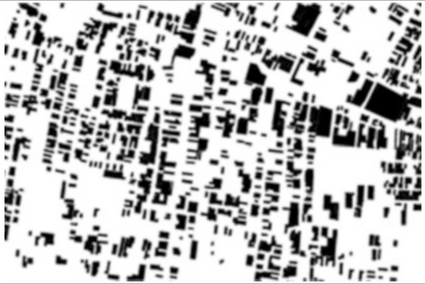
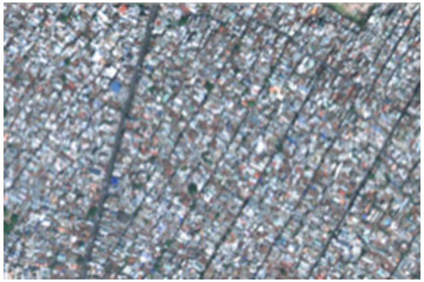
densities or the actual real utilisation are not illustrated. Table 6 provides an overview of the calculated median land-use block densities of coverage ratio, floor area ratio, and number of stories, population density and building volume for a selection of residential UST. Further to this, Fig. 9 shows a selection of compiled density related UST derived indicators mapped for HCMC.

Table 6 A selection of calculated density related indicators for some residential UST in HCMC

			Coverage ratio (GCR)	Floor-area ratio (FAR)	Average number of floors	Population density (ha)	Building volume (m^3/ha)
Shophouse regular			0.54	0.89	1.8	408	32,401
Shophouse regular narrow streets			0.72	1.33	2.0	579	39,943

(continued)

Table 6 (continued)

			Coverage ratio (GCR)	Floor-area ratio (FAR)	Average number of floors	Population density (ha)	Building volume (m^3/ha)
Shophouse regular with yards			0.22	0.25	1.2	99	7648
Shophouse irregular			0.72	1.14	1.8	620	34,101
Shophouse irregular temporary			0.70	0.82	1.3	507	21,134

Villa			0.23	0.37	1.5	70	13,758
High-rise central business district			0.63	1.93	2.6	241	50,473

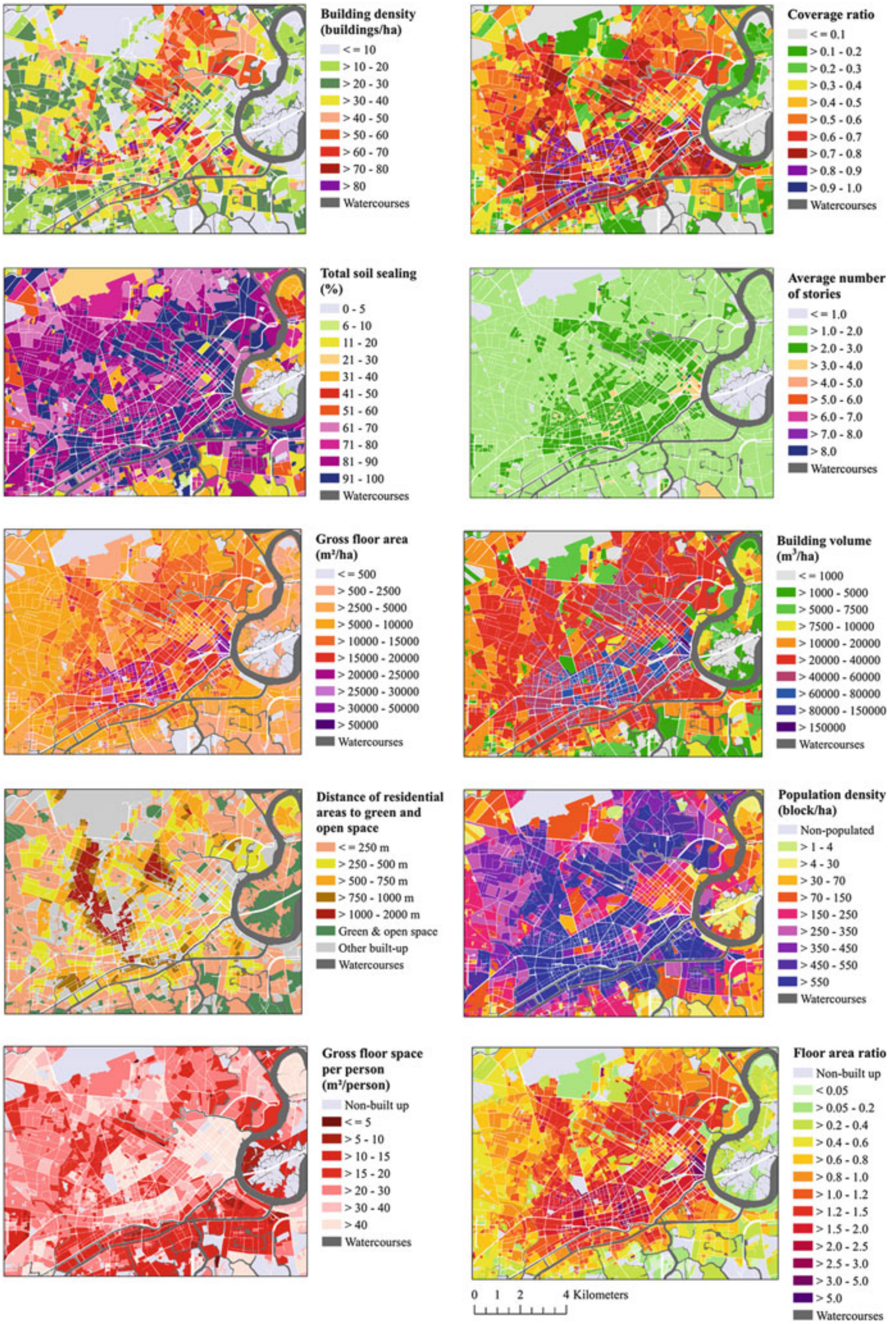


Fig. 9 Selection of ten compiled density related UST indicators mapped for the centre of HCMC on the block geometry of the official land-use plan (authors own)

Summary and Outlook

For HCMC, the rapid pace of urbanisation over the past two decades has placed a huge burden on the local authorities. They have had to contend with simultaneously planning for new developments, while at the same time carry out urban up-grading and improvements of existing areas. Ultimately urban resilience and exposure are dependent upon the choices that are made regarding which structure types to build, their location and arrangement, and the local urban context. The exposure and resilience pattern of each individual development therefore helps to determine the ultimate vulnerability to climate change for the entire urban region. 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 HCMC for decades to come. The need to focused support and guidance in formulating suitable adaptation policies and spatially explicit zoning regulations is apparent and it is therefore of highest importance to plan in an integrated manner from the outset. Yet 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 of our work in the development of planning recommendations have supported the HCMC administration to establish a well-founded database with reliable information and to significantly expand the existing evidence base to assist a shift in both policy and practice within the land-use planning and climate change adaptation domains. A basic requirement for the development of our planning recommendations was the description of HCMCs urban fabric based on core indicators. Figure 10 shows selected pages from final documentation of HCMC's UST detailing the mapping criteria, spatial distributions and densities of each classified UST (Downes and Storch 2015). The handbook has been made available to the city administration in both English and Vietnamese.

In our work, the compiled density related UST derived indicators were not used in isolation as presented in this chapter, but multiple indicators were used to generate spatial maps of exposure and sensitivity. These maps were then 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 (Storch and Downes 2011). The exposure to environmental hazards, the mapping of public infrastructure, and official plans and demographic data came to life when visualised and mapped. Not only UST, but general high risk areas became apparent when mapped, reviling patterns and hotspots across geographic locations (Downes and Storch 2015).

Fig. 10 Extracts from the final documentation of HCMC's UST (Downes and Storch 2015)

Finally transferable guidelines incorporated into spatially explicit planning recommendation maps were compiled. It could be argued on the basis of our results, the spatial distribution of built-up land must optimised to create more green and open space within existing settlements and focus on a patchwork of greening along transportation and floodplains (ribbons and corridors), rather than large expanses solely at the urban periphery. These open spaces must be so designed and distributed to be able to achieve multiple goals, agricultural production, stormwater management, flood protection. Currently the larger blocks of green space are limited to the low-lying flood prone urban periphery where they act as a natural greenbelt or foodbelt. These have essentially been able reinforce the seen internal settlement containment (Downes and Storch 2014). A future HCMC's form, distribution of land-uses and UST's best suited to the needs of both adaptation and mitigation will be one where the available land resources achieve multiple goals. Though, several methods based on indicators and other information have been proposed to evaluate vulnerability and disaster risk issues, the UST approach in our work proved successful in spatially representing core indicators. Features of built-up areas, impervious surfaces, real or actual land use, housing types, building density, population density and the social status of urban areas were assigned to every urban structural unit. In a further step, the UST approach also allows for additional indicators to be incorporated into the framework such as consumption indicators for energy, water and waste requirements or adaptive capacity indicators such as urban greening potentials, solar potentials or runoff potentials for all for individual structures. This presents a means to access the future multitude of varied planning targets and goals (Viguié and Hallegatte 2012).

In conclusion, the UST approach as applied in our work, concretely linked climate change impacts to the urban environmental in a downscaled and multi-scale manner while proving a substantial area-wide data basis for urban monitoring and through the drafting of planning recommendations assured the integration of climate change adaptation and into the existing planning framework. On this basis, spatially explicit planning strategies and recommendations that anticipate climate change risks and development scenarios and contribute to the development of resilient settlements within HCMC were developed. Spatial indicators and planning recommendations based on an UST approach aimed to advance and disseminate knowledge and inform decision-makers about the climate change risks, to increase their capacity to implement necessary adaptation measures, and to strengthen the resilience of the HCMC urban system. A challenge going forward is to provide a more comprehensive and integrated platform that is widely shared and updated by the administrative stakeholders and importantly the public.

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