

Part I

Introduction

Frank Schwartz, Antje Katzschner, and Michael Schmidt

Overview

Undoubtedly, Ho Chi Minh City is not just the biggest city in Vietnam, but also its economic centre. With its regional location as hub in Southeast Asia, its airport, harbour and the intersection of main roads, the metropolis is well connected within the domestic as well as the most important international markets.

Located downstream of the Saigon-Dong Nai River with a relatively flat terrain, the city traditionally has a strong relationship to water. It is located at the north-eastern fringe of the Mekong Delta and its southern part is connected to the east sea. Major parts of the city are situated on low-lying marshy lands that are crossed by a complex network of canals and rivers. These topographic and geographic conditions make the city extremely sensitive to various flood sources.

The city's core area covers about 2095 km² and inhabits 7.7 million people, which means a population density of about 3666 person per km² (Labaeye et al. 2012). In fact, the city has already developed into Vietnam's first mega city with the benchmark of ten million inhabitants according to UN-definition. This is not only due to its migrants population but because the urban spatial growth of the city has already transgressed its administrative borders. The greater agglomeration

F. Schwartz (✉)

Laboratory of Urbanism and Planning, Luebeck University of Applied Science, Lübeck, Germany

e-mail: frank.schwartz@fh-luebeck.de

A. Katzschner

Department of International Affairs, Universität Hamburg, Hamburg, Germany

e-mail: antje.katzschner@uni-hamburg.de

M. Schmidt

Department of Environmental Planning, Brandenburg University of Technology Cottbus-Senftenberg, Cottbus, Germany

e-mail: michael.schmidt@tu-cottbus.de

consists of eight different provinces and has 18.3 million inhabitants (SIUP South/MoC 2007; GSO 2011). More than 70 % of the population of the region is below the age of 35, a fact that is clearly indicating the potential natural growth of the future. During the next years the city's population will grow with an average annual rate of 3.5 %, which means that by 2025 the core city is expected to host more than 10 million inhabitants and the HCMC region about 25 million people (SIUP South/MoC 2007; UPI).

Due to its role as the country's economic centre, the most significant driver of the population growth within the Ho Chi Minh City metropolitan region is migration: It is by far the most attractive destination of the country's migration streams (GSO 2011). For example, about one third of the total population of Binh Duong has migrated from other parts of the country to the HCMC region within the last decade (Marx and Fleischer 2010). The main originating provinces of migrants are the regions of the Mekong Delta, North Central and the Red River Delta, which are main agricultural centres of Vietnam. As in other countries of the region, the most important reasons for migration are economic ones: The decision to migrate is generally driven by the prospect to earn higher incomes than in the countryside. Further, it is an evidence for the shifting from an agricultural economy to an industrial and service oriented economy which centres are located in urban areas.

Today the HCMC region accounts for almost 70 % of the country's export revenue growing rate and contributes 40 % of its GDP. The region's average income is nearly 30 million VND per year, which is more than 2.5 times the national average. Until 2025 the city's economy is expected to grow at a rate of 7 % per year (PricewaterhouseCoopers 2009). A similar development is happening in the regions surrounding the municipality's boundaries, particularly in the provinces located east and southeast to Ho Chi Minh City. Those provinces are rapidly industrialising, are showing similar grow rates like the core city and are even receiving more foreign direct investments by now. Together with the gradual improving of the regional infrastructure—e.g. the envisaged international new airport Dong Nai—the whole metropolitan region is gradually emerging as an economic and logistic hub of the whole south-east Asian region. National and local policy makers aim to accelerate the economic development through a shift from a labour intense production to the division of functions focussing on service, commerce, education and high-tech industries.

Although Ho Chi Minh City has to fight with similar problems like other rapidly growing mega cities such as traffic congestion, environmental degradation, excessive population growth due the massive influx of rural migrants or the overburdening of technical and social infrastructure, the whole economic development can be regarded as a success story. However, there are significant threats to further increasing prosperity and the most important one is certainly related to the threats of global climate change. The exposure to sea-level rise, to the increasing frequency and intensity of extreme weather events and the tremendous task to potentially inhabit several hundred thousands of climate change refugees from the Mekong delta and other coastal regions put several severe challenges to the path of future urban development of Ho Chi Minh City.

Given all this, it was certainly a good decision of the German government to support a trans-disciplinary research consortium of urban planners, architects, construction engineers, traffic experts and social scientists to identify ways towards more sustainable urban development and to actively assist the local policy makers in terms of implementation.

A comprehensive documentation of all research carried out in the MC HCMC project can be found on the project homepage: <http://www.megacity-hcmc.org/>.

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Introduction to Ho Chi Minh City

Antje Katzschner, Frank Schwartz, Bao Thanh, and Michael Schmidt

Climate

With an average temperature of 27–28 °C and maximums of up to 40 °C, the HCMC region has a typical tropical wet and dry climate. Because of the aftermath of climate change the average temperature is constantly rising and is expected to be about 1.4 °C higher in 2050 than in the baseline period of 1980–1989 (ADB 2010). But that does not take in count the urban heat island effect, which is accountable for the fact that dense urban areas are up to 10 °C warmer than rural areas (Thi Van et al. 2009). That effect is also expected to increase in future times due to the rapid urbanisation and economic development.

Viet Nam features monsoon tropical climate with annual mean temperature varying from 12.8 to 27.7 °C. Average annual rainfall ranges from 1400 to 2400 mm. Each year, on average, the country is affected by six to eight typhoons or tropical cyclones.

A. Katzschner (✉)

Department of International Affairs, Universität Hamburg, Hamburg, Germany

e-mail: antje.katzschner@uni-hamburg.de

F. Schwartz

Laboratory of Urbanism and Planning, Luebeck University of Applied Science, Luebeck, Germany

e-mail: frank.schwartz@fh-luebeck.de

B. Thanh

Sub-Institute of Hydrology, Meteorology and Environment (SIHYMETE), Ho Chi Minh City, Vietnam

e-mail: baothanh56@gmail.com

M. Schmidt

Department of Environmental Planning, Brandenburg University of Technology Cottbus-Senftenberg, Cottbus, Germany

e-mail: umweltplanung@tu-cottbus.de

Climate Change in Vietnam

Water Resources

Taking into account only perennial rivers and streams over 10 km in length, Viet Nam has about 2360 rivers and streams with an average density of 0.6 km/km². There are nine major river systems in Viet Nam. The largest system, Mekong River, enters Viet Nam before draining into the East Sea. Annual flows of all rivers in Viet Nam average 835 billion m³. Groundwater reserve is 50 billion m³/year (SIHYMETE 2011).

Climate Change Manifestation

Temperature: Over the past 50 years (1958–2007), annual average temperatures increased by about 0.5 to 0.7 °C. Temperatures for winters and northern climate zones increased at faster rates compared to summers and southern climate zones, respectively.

Rainfall: Annual average precipitation over the last nine decades (1911–2000) does not show a clear trend across regions and time periods. Instead, both upward and downward trends can be seen. Northern climate zones have seen a decrease in annual rainfall, in contrast to southern zones. On a country-wide basis, average precipitation fell by 2 % during the last 50-year period (1958–2007).

Cold fronts: The number of cold fronts affecting Viet Nam has decreased significantly over the last two decades. However, anomalous events have occurred more frequently recently, with most notably the damaging cold surge which lasted for 38 days in the North of Viet Nam during January and February 2008.

Typhoons: In recent years, typhoons with higher intensity tend to occur more frequently. Typhoon tracks show signs of moving southwards (see Fig. 1), with abnormal movements while storm seasons tend to end later (SIHYMETE 2011).

Sea level: Observations by tidal gauges along the coastline of Viet Nam show that the mean sea level rose at a rate of 3 mm/year (during 1993–2008). Over the past 50 years, sea level at Hon Dau Oceanographical station has increased by about 20 cm as can be seen in Fig. 2.

Impacts of Climate Change

Impacts on Water Resources

Climate change will impact river stream flow volumes and temporal and spatial distribution. The impacts of climate change on annual flows, flood flows and low

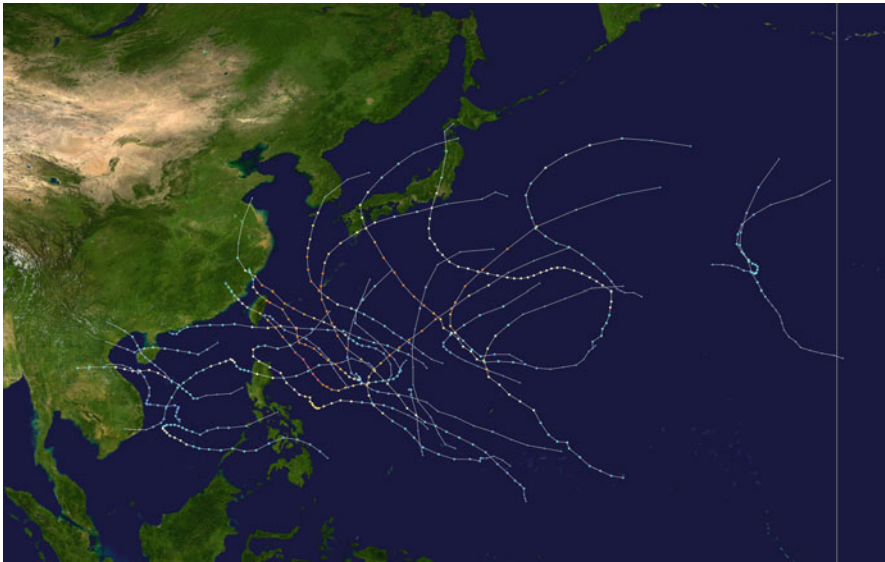


Fig. 1 West Pacific Ocean typhoon tracks in 2007 (own depiction by SIHYMETE 2013)

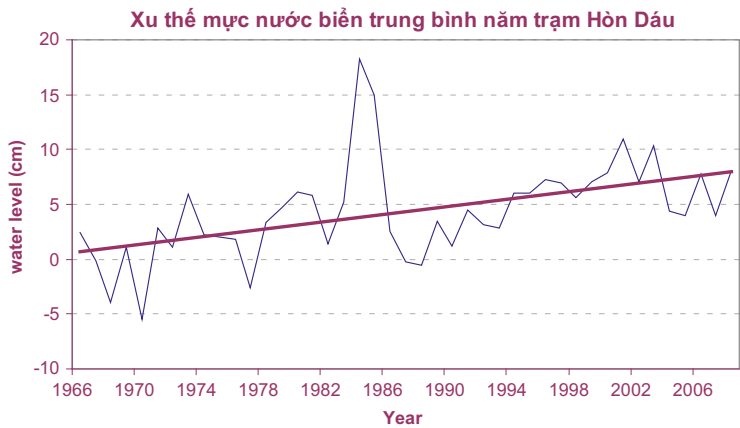


Fig. 2 Sea level changes at Hon Dau Oceanographical station (own depiction by IMHEN 2010)

flows in the future were assessed based on the rainfall-flow model and the above-mentioned climate change scenarios.

Climate change impacts on annual flows vary from one region/river system to another across Viet Nam’s territory. According to the medium climate change scenario B2, annual stream flows in the Red River Delta and northern North Central region will trend towards increases under 2 % for 2040–2059 and between 2 and

4 % for 2080–2099. By contrast, annual flows for regions south of the North Central region to the northern South Central region and the Southeast (Dong Nai River system) will trend towards varying decreases, slightly below 2 % for the Thu Bon and Ngan Sau Rivers, but significantly higher at 4–7 % for the Dong Nai and Be River systems for 2040–2059 and 7–9 % for 2080–2099.

Flood flows for most rivers are generally projected to rise by 2–4 % for 2040–2059 and 5–7 % for 2080–2099, albeit with a wide degree of variations between rivers. Flood flows for Thu Bon and Ngan Sau Rivers are likely to rise by less than 2 % for 2040–2059 and below 3 % for 2080–2099 (SIHYMETE 2011).

Post-2020, groundwater table may decrease significantly due to overexploitation and decrease in groundwater recharge during the dry season. In the South, if river flow decreases by 15–20 % in the dry season, the corresponding groundwater level may drop by 11 m below current levels. The groundwater level may drop even lower in areas not subjected to tidal activities (SIHYMETE 2011).

Impacts on Coastal Zones

Sea-level rise will increase flood area, intensity and duration. Recent research has indicated that a 45 cm rise in sea level would increase the annual flooded area to 18,346 km², affecting 44,210 km². A 100 cm rise in sea level would increase these figures to 40,000 km² and 56,000 km², respectively, with the worst affected area being the Mekong River Delta which would account for 90 % of the national flooded area. Rising sea levels may also lead to higher risks of salinization for freshwater rivers and aquifers, causing serious socio-economic damage. Coupled with increased storm intensity, the sea-level rise would additionally exacerbate coastal erosion.

Coral reef ecosystems are in danger of destruction. Reefs in shallow waters are most vulnerable to destruction by the concurrence of rising sea levels and strong storm waves. Seagrass: Large disturbances to the living conditions of seagrass caused by storms and sea-level rise threaten the reproduction and development of seagrass ecosystems. In 1997, typhoon Linda swept away 20–30 % of the Con Dao seagrass bed. Lagoons: Lagoon environments are very vulnerable to severe floods and rising sea level. Rising lagoon water salinity causes damage to aquaculture infrastructure, and the disappearance of rivulets in lagoons with adverse impacts on local aquaculture and fishing activities. Conservation areas: Viet Nam has 68 major wetlands and 15 marine conservation areas, 36 of which are set to be frequently flooded, 13 of these 36 will be severely inundated when sea level rises by 100 cm. Conservation areas such as U Minh Thuong National Park and Bac Lieu Natural Reserve will be completely submerged, thus affecting the conservation of endangered species in the area (SIHYMETE 2011).

Impacts on Agriculture

Climate change is set to raise aggregated temperature, with a declining number of days below 20 °C and an increasing number of days above 25 °C. Rising temperatures would increase the crop growth rate, and thereby shorten plants' growth cycle. A 1 °C increase in temperature would correspond to a shortening of the growth cycle by 5–8 days for rice, and 3–5 days for potatoes and soybean (SIHYMETE 2011).

Outputs for both spring and summer crops tend to fall, most noticeably in the Red River Delta. Spring crop output for the region may drop by 12.5 % by 2050 and 16.5 % by 2070, while in the Central and Southern regions, output may fall by 10 and 8 % by the respective years. Across the country, summer crop output may decrease albeit at a lower rate of around 2–4 % by 2050, and 3–6 % by 2070 (SIHYMETE 2011).

Impacts on Energy and Transportation

As temperatures rise, energy consumption in climate-sensitive sectors will also increase as more power is needed for electric fans, air conditioners, industrial cooling processes, and agricultural irrigation and drainage pumps. Recent research by the Institute of Energy under the Ministry of Industry and Trade shows that for every 1 °C increase in summer temperatures, energy demand increases by almost 1 %, particularly in residential, commercial/institutional sectors. The percentage increase is the highest between 9 a.m. and 4 p.m., rising 2.2 % above power consumption for other times of day each year.

Transportation infrastructure is damaged or destroyed as storms and floods grow in both frequency and intensity. Between 2001 and 2005, extreme weather events cost the transportation sector VND 2571 billion in damages. If sea level rises by 100 cm, 11,000 km of roads would be submerged.

Geographic Location of Ho Chi Minh City

HCMC is built mostly on low-lying marshland that is part of the large river delta. About 60 % of the main cities area is located only one meter above sea level. 40–45 % of the land is 0–1 m, and 15–20 % is 1–2 m in elevation (ADB 2010). That means that large parts of the urban fabric can potentially be affected by the aftermaths of flooding and landslides. The problem is exacerbated by the fact that the land is sinking continuously because of decreasing groundwater levels.

Due to its geographic location, HCMC is regularly affected by flooding caused by high tide, heavy rainfall and storm surges. Nearly half of the city's

322 communes and wards are experiencing floods, what means that 110,000 hectares of land and about 971,000 people—which is 12 % of the HCMC population—are regularly affected by floods (ADB 2010). The sea level rise is expected to be 3 mm/year (World Bank 2010) or 25 cm until the year of 2050 (ADB 2010). The regions low-lying southern areas at the river delta are facing the highest risks of sea level rise, where the provinces of Tien Giang, Lang An and Southern and Western HCMC are located. The construction activities in marshland and riverbeds are causing an increasing pace of the rising river levels. Due to these facts, about 70 % of HCMC's agricultural land and 50 % of surface and groundwater treatment plants are at risk of salinization and flooding (ADB 2010; see Rujner and Goedecke 2016). The ongoing climate change will have the effect that storms and storm surges will be more frequent and intense. And also the monsoon rainfall will become more intense (ADB 2010). The problems of rising sea and river levels and the increasing amount of rain falls due to climate change will lead to the situation that only land that is more than 3 m high will not be regularly exposed to floods.

The rapid urbanisation of the last decades is tightening future aftermaths of floods. Between 1989 and 2006 the impermeable surface area of HCMC has been doubled (Tran and Ha 2007). Upstream and downstream the agglomeration grew into unsealed areas such as forests, agricultural lands, green spaces and the wetlands and increased the vanishing of natural flood prevention systems by the construction of roads and buildings. Due to that process, the regions soil have lost its infiltration and evaporation capacity which is the main reason for an increased surface runoff during heavy rainfalls and flooding. The expansion of HCMC also did not consider the topographic conditions so that at some points the city grew into low lying lands and wetlands, which once contributed to the natural water retention capacity of the region. The storage capacity of the city's water network has also been reduced by construction activities that are occupying riverbeds, narrowing floodplain areas and altering the natural flow of rivers.

Urban areas are hardscapes, sealed to different degrees according to the related urban structures present and normally a large proportion of precipitation is quickly converted to surface runoff. Often the existing sewer systems in the fast emerging megacities of Southeast Asia, like HCMC, do not have the capacity to cope with large surface runoff volumes following strong tropical rainfall events. To assess and illustrate the inter-linkages between dynamic urban development processes and the feedback on the urban climate itself, our information management strategy is strongly focused on parameters describing the urban structure and their functional properties. Our research results document that the spatiotemporal processes of urban development, alongside climate change, are the central driving forces for climate-related impacts within HCMC urban system. In line with the administrative urban development plan up to 2025 one third of the existing agricultural land—mainly in the low-elevated urban fringe—will be lost and its natural functions significantly altered. As our developed indicator-based Planning Information System reflects these future land-use changes in the urban environment, the research results go beyond traditional climate related impact assessment.

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