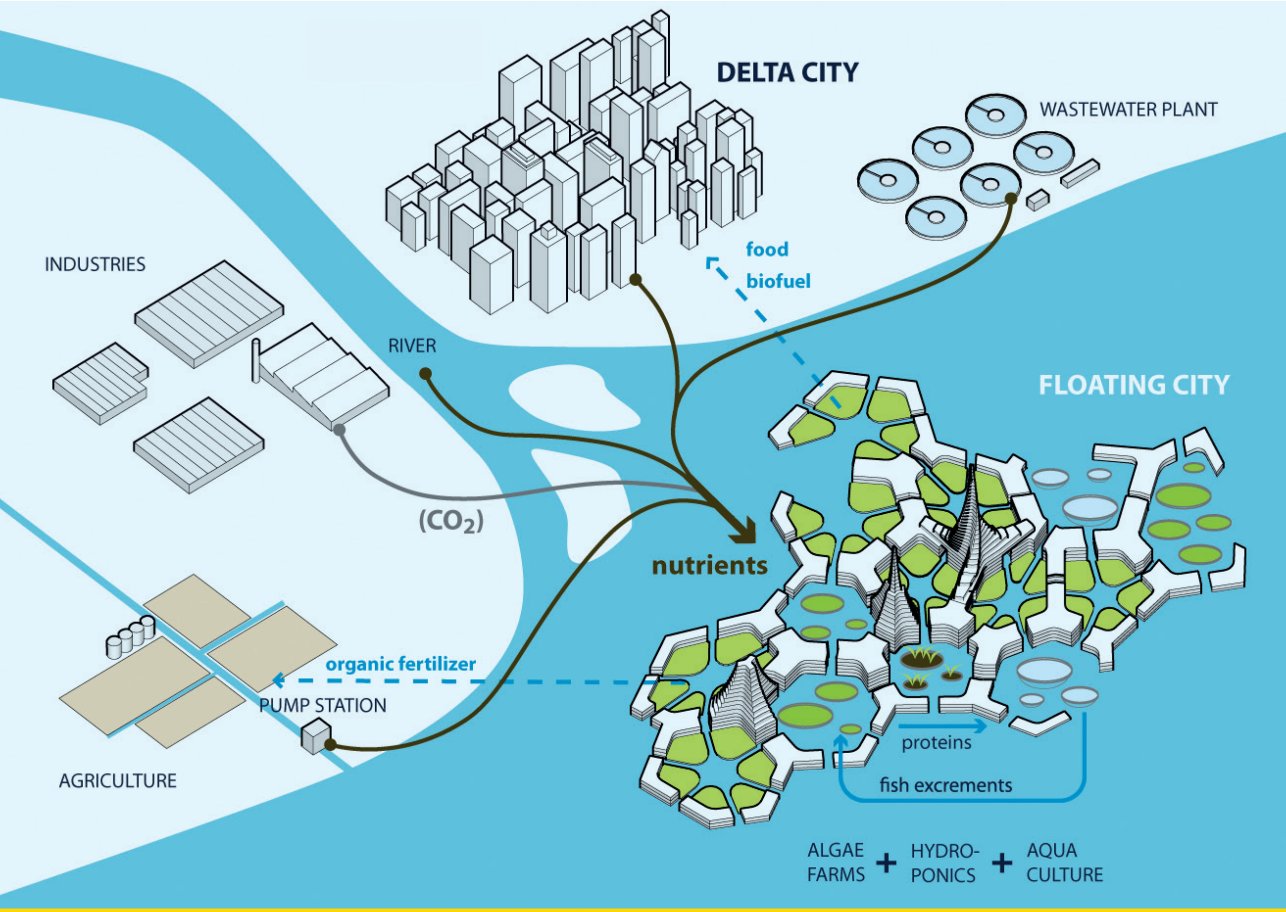
Adaptive urban development

A symbiosis between cities on land and water in the 21st century

Rutger de Graaf



Inaugural Lecture

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Colophon

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Inaugural Lecture **Rutger de Graaf**

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Contents

01. Introduction

"You could not step twice into the same river; for other waters are ever flowing on to you." - **Heraclitus**

Cities in delta areas are constantly changing. Driven by social processes and physical processes they constantly adapt to the new reality and create new possibilities at the same time. Today, change in delta areas seems to take place much faster than ever before. This book is about adaptive urban development in delta areas and elaborates what kind of strategies and technologies can be used to adapt urban areas to important challenges in the 21st century such as resource scarcity, flood damage, land availability and climate change. The process of urbanization in delta areas is taken as the overarching theme for the analysis that is presented in this book.

1.1 Urbanization in delta areas

Most of the largest cities in the world cities are located in areas that are vulnerable to flooding such as coastal plains and river plains, as figure 1.2 demonstrates. More and more people are moving to these vulnerable areas as cities continue to grow. Until 2100, 5.0 billion people will move to cities, this equals more than 150,000 people every day.[1] The largest proportion of these new city dwellers will live in vulnerable floodplains. It is estimated that in 2050, half of the world population will be living within 100 kilometres from the coast.[2]

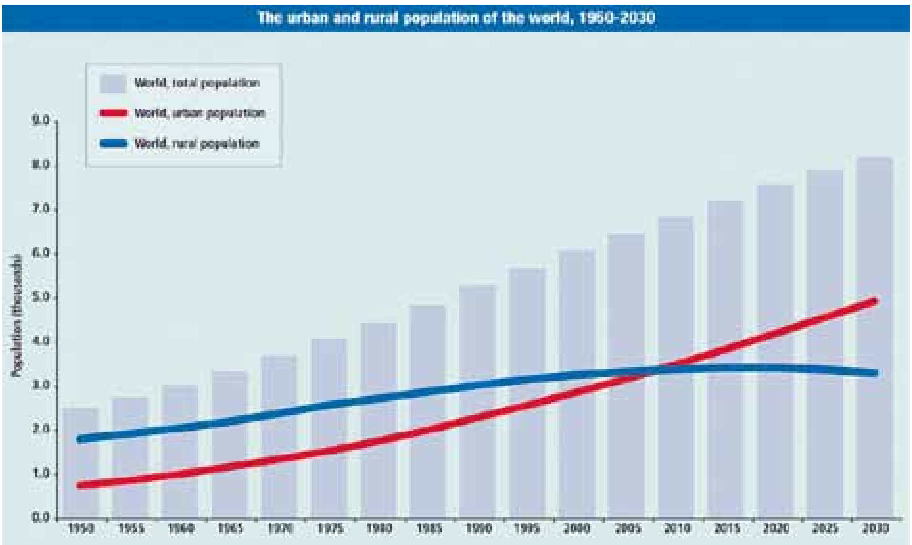

Figure 1.1:
Predicted global urbanization, in 2030 the urban population will be 5.0 billion people [3]

Traditionally, humans have settled in delta areas for a number of good reasons. In these areas, reliable water resources are available and waste can be easily disposed to the river which transports it downstream. The abundance of fertile land provides good opportunities for agriculture. The resulting food surplus makes a significant part of the population available to produce other goods and services that are valuable to the economy. These goods can be transported easily to other cities all over the world because good connections by water transport are available.
It is therefore not surprising that most of the largest cities in the world are located in delta areas. On the other hand, urbanization in delta areas has also created several problems. The first cities in delta areas were mostly built on slightly elevated places in coastal plains, such as sand ridges, dunes or hills. This provided strategic and military advantages but also protected the city against the frequently occurring floods. Mechanization of agriculture and the transition from a rural economy to an industrialized, and later service economy, has driven many people to cities. As cities continued to grow, they were forced to expand into marshlands and locations with a lower elevation compared to the historic city centre. As a result, the flood damage increased which often led to the construction of dikes to protect the buildings and people.

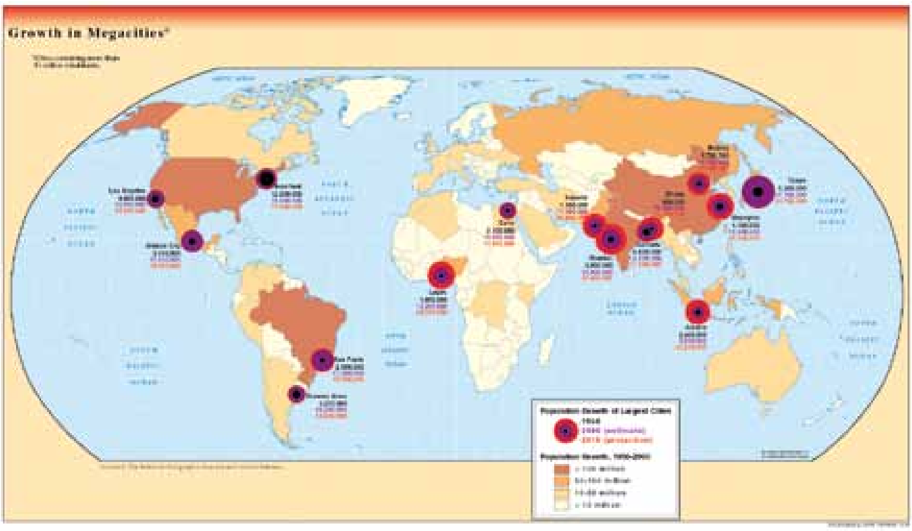

Figure 1.2:
Most of the world largest cities are located on the coast and are growing rapidly (Source: Di Cartography Centre (2000) [4]

How much space do the global cities cover together? In literature there is a huge variation of estimates of the global urban area, depending on the measurement method, the data collection method but also on the definition of what an urban area is. An area can be classified as urban by a minimum size of a settlement, a minimum population density or by measuring a certain light intensity from satellites. The areal extent of urban land cover generated by GLC00, MODIS, and GRUMP are 308,007, 726,943, and 3,524,109 square kilometres.[5] NewGeography[6] estimates the total amount of urban area at 1.2 million km^2, whereas the EDRO website[7] estimates the total amount of urban area 5.2 million km^2. In this book an estimated size of the total urban area of 2.0 million km^2 will be used.

1.2 Urbanization and flooding

While dikes have proven to be quite effective in protecting cities against flooding they also have a drawback. Dikes stop the natural sedimentation process in river plains. In a natural situation, with each flood a layer of sediment is added to the soil. As a result, the land rises with the same rate as the river. After dikes have been constructed, no sediment deposition takes place any more in the river plains behind the dikes. Instead all sediments are deposited between the dikes or transported downstream. The land no longer keeps up with the rising level of the river bed, increasing the potential flood damage of the river plain behind the dike. Moreover, the land behind the dikes is often drained to create more favourable conditions for agriculture and urban development. The increased particle pressure in the soil causes the land begins to subside, creating even larger differences between the river level and the land level. Due to these processes, many delta cities are partly located below the level of the river or sea and experience serious flood risk as a consequence.

The continuing urbanization process in flood prone areas has led to a large increase in capital and population in vulnerable areas. As a consequence, flood risk has increased dramatically. A flood that today would cause a huge damage and loss of life would have caused much lower damage 100 years ago. The main reason is that both the population and the amount of capital in the affected area were much lower at that time. Also the number of extreme floods has risen as figure 1.6 shows. The average global flood damage is now around 19.2 billion US$ a year.[8] The average number of deaths due to flooding amount to 7508 people per year. These numbers continues to rise as the conventional way of urbanizing in delta areas continuous. Figure 1.3 shows that the global damage due to natural catastrophes, including flooding, has risen dramatically over the past decades. The number of natural catastrophes has also risen sharply as figure 1.4 demonstrates. Looking to the future flood damage is expected to increase to 48,6 billion US$ per year 2100 only as a result of income growth and population growth not taking into account the expected effects of climate change.[8] Urbanization in vulnerable coastal plains and river plains will continue and more buildings and infrastructure will be constructed in these areas. Moreover, climate change and sea level rise will even make flood plains more vulnerable to flooding. The OECD has investigated how many people will be exposed to flooding in 2070.[9] Figure 1.6 shows that in particular in China and India the number of people that are exposed will increase. The increase is caused by socio economic development such as rising living standards and urbanization, but also by the expected impacts of climate change.

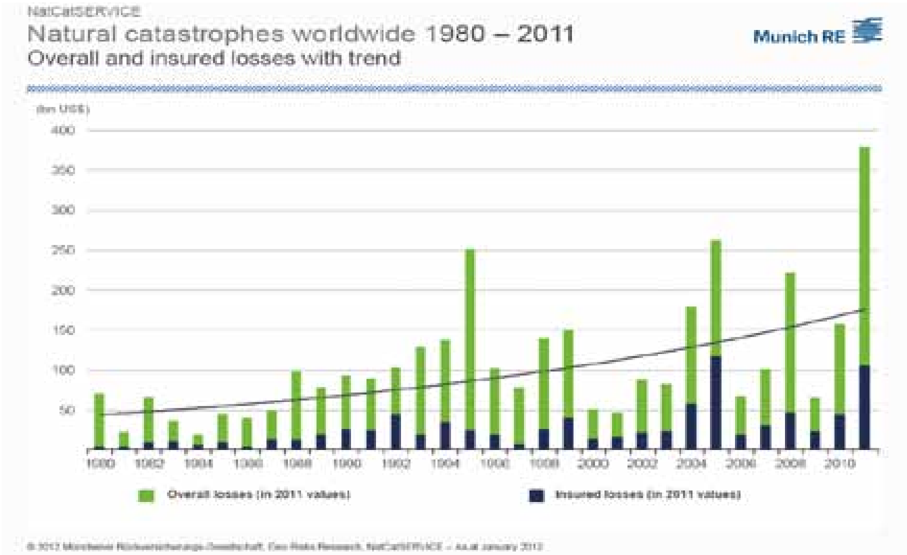

Figure 1.3:
Trends of economic losses (in billion US$) due to natural catastrophes (Munich Re 2012)

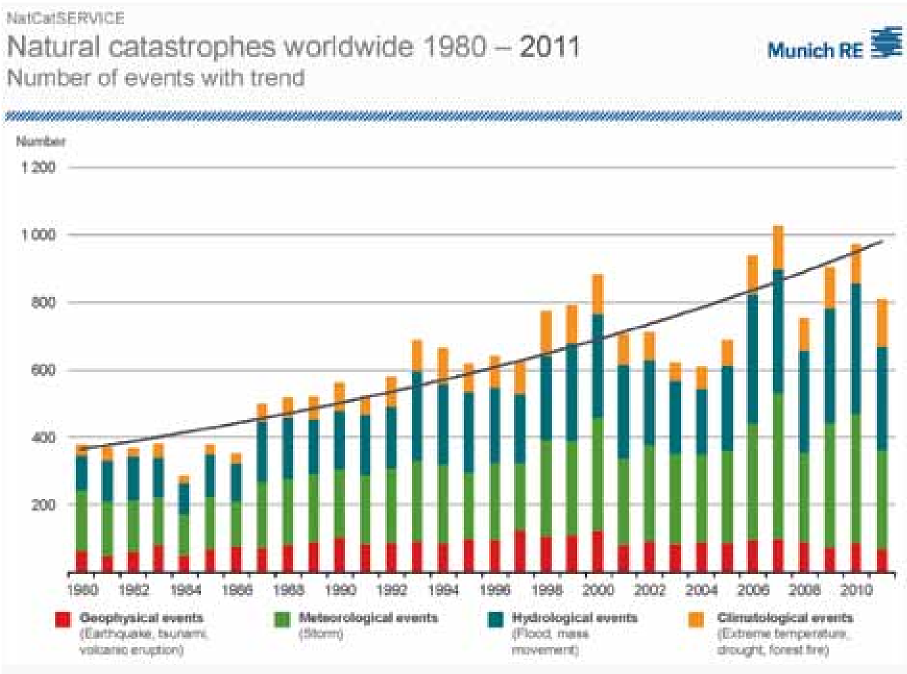

Figure 1.4:
Number of natural catastrophes worldwide (Munich Re, 2012)

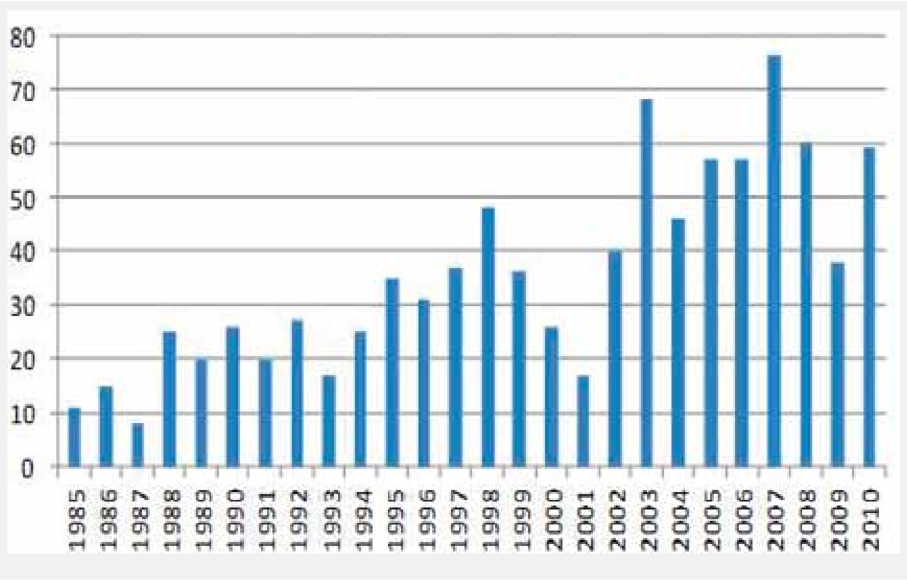

Figure 1.5:
Total number of extreme floods worldwide (Dartmouth Flood Observatory, 2012)[10]

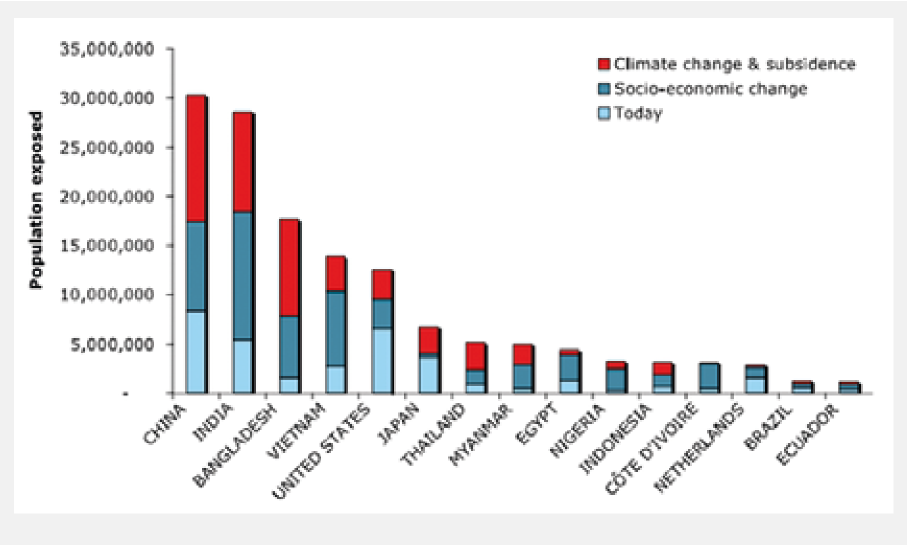

Figure 1.6:
Top 15 countries by population exposed to flooding today and in 2070 (Nicholls et al (2007) and OECD, Paris)

1.3 Urbanization and land scarcity

Next to increasing flood risk, urbanization in delta areas also increases land scarcity. Urbanization converts agricultural land into urban areas. One effect of growing delta cities is therefore the reduction of productive agricultural land. At the same time, these growing cities require more agricultural land to supply food and other resources to the rising number of inhabitants with increasing living standards.

Modern cities can only survive by an agricultural system that is based on massive input of energy, water and artificial fertilizer. For example, an amount of 10 kJ of fossil fuels is needed to produce and deliver 1 kJ of food to a consumer in the US.[11] Such a food supply system can only exist with relatively cheap fossil fuels, which soon will no longer be available. Biofuels are often mentioned as sustainable alternative to fossil fuels. However, biofuels require large amounts of land and water and compete with food crops for these resources. The growing market for biofuels therefore leads to an even a greater demand for agricultural products and drives up food prices.

Figure 1.7 shows that humanity now uses 1.5 times the resources than the globe can provide in a sustainable way. This means that the natural resources are being depleted faster than they are replenished. It is estimated that in 2050, the equivalent of 3 planets are used to supply the world population with their needs. This means population growth and the rise of welfare associated with urbanization leads to an enormous lack of space, in particular in delta areas where most of the urbanization takes place.

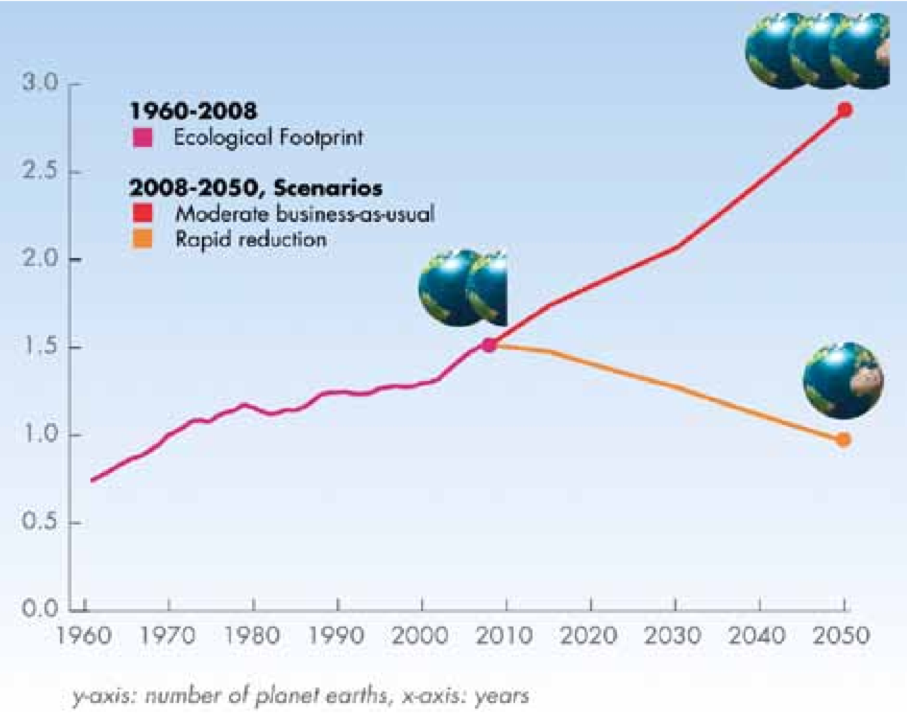

Figure 1.7:

Ecological footprint of the world population.[12]

The large ecological footprint is mainly caused by cities, because this is the place where most resources are consumed. Cities cause 70% of humanities ecological footprint[12]. Delta cities generally also have a large ecological footprint. Figure 1.8 shows the ecological footprint of various delta cities. The figure demonstrates that the area needed to sustain these cities is much larger than the city itself.

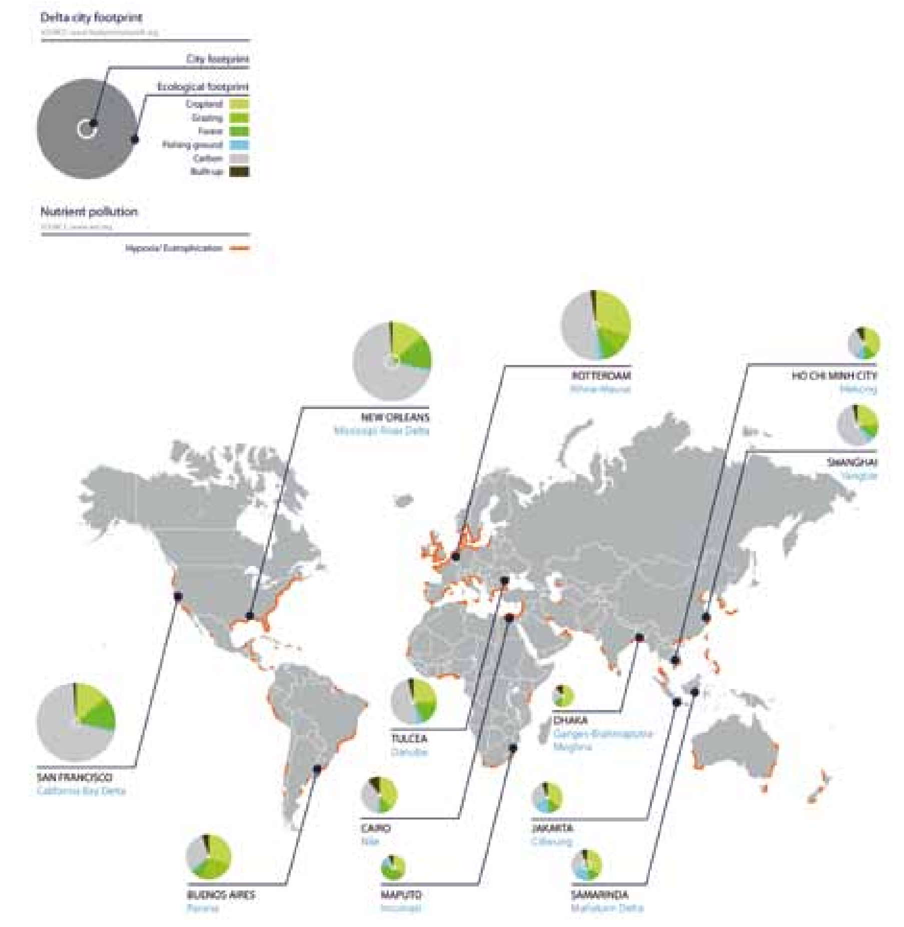

Figure 1.8:

The ecological footprint drawn to scale of various delta cities (DeltaSync, 2012)[13]

1.4 The impact of urbanization on the urban water system

Next to flood problems, urbanization also alters the natural water cycle and creates urban water management problems. Figure 1.9 shows that the urban water system consists of components that are closely related. Therefore it is important to apply a systems perspective when investigating problems in the urban water system. Traditionally, urban runoff is transported out of the city as quickly as possible. For this purpose, predominantly combined sewer systems have been implemented in most Dutch cities and other delta cities. In these systems, stormwater is transported with wastewater in the same pipe. During heavy rainstorms the capacity of the sewer system is not sufficient to transport all runoff. In that case, combined sewer overflows (CSO's) take place. This leads to the emission of diluted wastewater and sewage sludge to the urban surface water, decreasing the water quality of the urban surface water. To deal with this problem currently separate systems are mostly constructed in new urban areas to transport stormwater runoff and wastewater. In existing urban areas disconnection of paved surfaces from the sewer system takes place to prevent CSO emissions to the surface water system. More water storage capacity is created to prevent pluvial flooding.

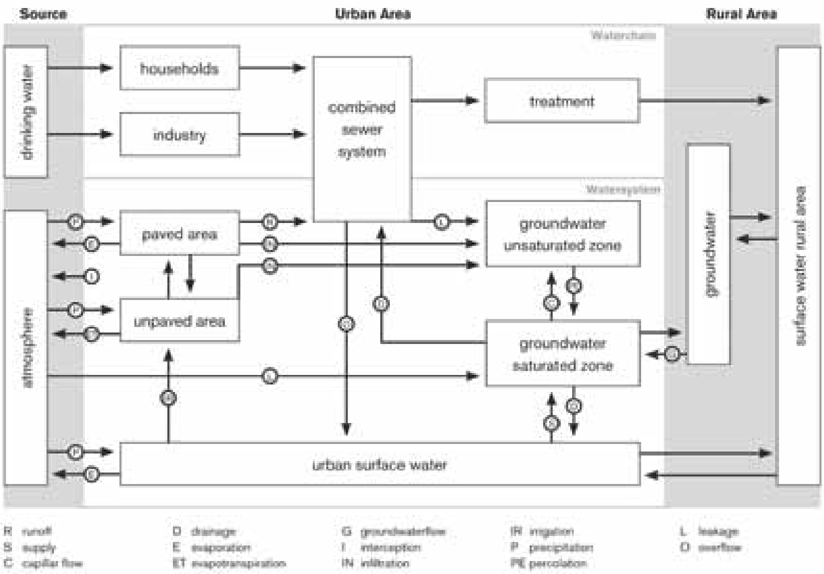

Figure 1.9:
Schematization of the urban water system with a combined sewer system[14]

In general, urbanization converts permeable natural soils into paved surfaces and roofs while vegetation is removed. This process decreases evaporation, decreases infiltration whereas runoff is increased. Due to the high amount of runoff, urban pluvial flooding and erosion of natural streams takes place. Urban runoff is also polluted due to building materials, traffic pollutants and other sources. Even at low levels of urban development, the discharge of urban runoff by centralised collection and transportation systems has detrimental effects on aquatic ecosystems.[15] Reported effects on receiving waters include: flooding, erosion, sedimentation, temperature rise, dissolved oxygen depletion, eutrophication, toxicity, and reduced biodiversity.

1.5 Scarce water resources and land subsidence

As cities in delta areas grow and industry develops, often the available surface water is no longer sufficient to deliver the rising water demand. Either the available quantity is no longer sufficient, or the decreasing water quality causes a water shortage. The extraction of groundwater resources is often the next step. Located in deeper layers, groundwater resources are not yet impacted by the effects of urbanization. A combination of water extraction from the groundwater and reduced water infiltration due to urbanization leads to a situation where groundwater extraction takes place at a rate that exceeds the natural replenishment. The groundwater table decreases and the pore pressure in the soil particles increases, leading to land subsidence. Excessive water use for irrigation has caused massive water extraction from groundwater layers and rivers. As an example, an equivalent of 130 million people in China and 175 million people in India are being fed with grain irrigated with water that is being pumped out of aquifers faster than it can be replaced.[17] Overexploitation of groundwater resources in delta areas has also led to land subsidence and saltwater intrusion in many delta cities such as Jakarta, Bangkok, Shanghai and Venice. In Jakarta, Indonesia, land subsidence of 20 cm to 200 cm has been reported in various locations and land subsidence rates of more than 10 cm a year are not uncommon.[18] As a result, large parts of the cities have subsided below the sea level. The flood risk in such cities increases as a consequence.

Due to overexploitation of water resources in delta areas, some rivers no longer reach the sea anymore because all water is extracted for irrigation and drinking water extraction. Examples are the Colorado River and Rio Grande in the United States and the Yellow River in China. In other rivers such as the Nile in Egypt and the Indus in Pakistan, the discharge has considerably dropped.[19] Because river flow is severely reduced or even eliminated, salt water intrusion threatens several coastal areas. The productivity of these areas decreases, which further puts food production under strain.

Figure 1.10:
Situation in Jakarta, Indonesia. The housing area on the left has subsided below sea level and is only protected by a low flood wall (picture: Piet Dircke, 2012)

1.6 Nutrient problem of delta cities

Nitrogen is available in large quantities in the atmosphere. It is used to produce artificial fertilisers through ammonia synthesis (Haber Bosch process). Industrial ammonia synthesis is vital for global food production to sustain the current size of human population. However, it has led to radical changes in the environment, including water and air pollution and a loss of biodiversity due to a huge increase in ammonia production.[20] The use of artificial fertilizer and extraction of water for irrigation has huge impacts on the ecosystems in river basins. The excessive use of fertilizers leads to eutrophication of water systems which is characterized by an abundance of nutrients that can lead to excessive growth of phytoplankton and algae, which leads to oxygen depletion destroying aquatic life in affected areas. Notwithstanding the excess of nutrients in delta areas due to eutrophication, the depletion of nutrients in particular phosphate is a serious risk for the food security of cities. Nutrients such as phosphate are nitrate are critical to food supply. Currently, the global food supply depends on artificial fertilizers. The production of most fertilizers is based on mining of finite reserves of rock phosphate. Proven phosphate reserves are sufficient for 100 years of economic use.[21] At the same time, local urban nutrient sources, in particular local wastewater streams are hardly used.

1.7 A parasitic metabolism

The metabolism of current cities resembles the behaviour of parasites. The cities use food, energy, and various other resources from surrounding areas and areas elsewhere. Moreover they are growing rapidly by taking up productive land. In the cities, the imported resources are used and changed into material waste, CO_2, heat and wastewater. These waste streams are not used in a productive way. Instead the waste products and their negative effects are disposed to the surrounding areas. The parasitic behaviour of cities is characterized by linear resources flows that lead to depletion of resources and accumulation of negative effects of urbanization in ecosystems. Therefore, there is an urgent need for cities in general and delta cities in particular to transform into productive cities that live in balance with the rural surroundings and the ecosystem. The metabolism of such cities should be characterized by cyclic resource flows and productive use of waste streams to reduce the impact on ecosystems.

1.8 Overview of the problem and an outline of the solution

Urbanization in delta areas causes an increasingly severe flood problem. The process is also heavily constrained by the availability of space, food, energy and other resources. Moreover, conventional urbanization leads to degradation of land and ecosystems. Increasing the efficiency of agriculture is needed but will not be enough to keep up with the rising demand for food, biofuels and carbon capturing. In addition to increase the agriculture production, often more water extraction, more fertilizers and more energy is needed. This will again increase rather than decrease the ecological footprint of cities. Therefore, the problem that is caused by the parasitic behaviour of delta cities needs to be addressed both in the delta cities itself, and in their future expansions. What is needed are cities that:

→ Increase land availability rather than create land scarcity
→ Decrease flood risk rather than create flood risk
→ Produce energy, food, water and nutrients instead of only consuming resources and producing waste
→ Have positive impact on ecosystems and create ecological habitat rather than degrade ecosystems

This is the outline of productive cities with a cyclic resource metabolism, also called *adaptive urban development* in this book. It will be discussed in more detail in the next chapter.

02. Adaptive urban development on land: transforming existing cities

“You never change things by fighting the existing reality. To change something, build a new model that makes the existing model obsolete.” **- Richard Buckminster Fuller**

Adaptive urban development is the design, construction and continuing evolution of urban areas to anticipate and react to changes in the environment and society. These changes include both processes within the city itself and external developments. The previous chapter presented four general objectives of adaptive urban development. These four general objectives are used in this book to discuss adaptive urban development on land (this chapter) and adaptive urban development on the water (next chapter). Concrete examples are given about the urban development process in Rotterdam and other delta cities. After discussing the four objectives, this chapter will elaborate on the feasibility and knowledge gaps. Finally the realization process in will be discussed.

2.1 Increase land availability

One of the main objectives of adaptive urban development is to solve the scarcity of land in delta areas in general and delta cities in particular.

Urban densification

Urban densification is an important strategy to increase the land availability in delta cities. Cities that are denser make more efficient use of space and other resources.[22] As the distances become smaller in cities that become denser, less energy is needed for transportation of goods and people. It also increases the walkability of a city and makes public transport more competitive. The inhabitants will be less dependent on cars and it will be more likely that people will walk or take the bike.

Urban densification, however, also has some disadvantages. Due to urban densification there will be a higher amount of paved areas in a city. The result is a faster rainfall runoff process which will lead to more frequent pluvial flooding. Increasing the amount of conventional water retention capacity is difficult in such circumstances because space is lacking. Therefore, urban water management innovations, such as green roofs, water squares, urban floodplains, stormwater infiltration and water retention under buildings are needed to achieve sufficient water storage in high density cities. Another important objective of urban water management innovations is to contribute to a better living quality of delta cities for citizens and companies. In Rotterdam, this is illustrated by the title of the municipal Waterplan 2:' working on water for an attractive city.'

Figure 2.1 a & b:
Urban floodplain along the Westersingel in Rotterdam during normal circumstances (left) and intensive rainfall. An example of realizing water retention capacity while space is scarce (Source: Rotterdam Climate Proof).

Multifunctional use of space on the land
Multifunctional space is the use of urban space for more than one function to increase the efficiency of land use. Integration of urban planning with flood control strategies is a key component of multifunctional use of space in delta cities. A good example of such a strategy is the development of superlevees in Japan (figure 2.2). Due to the high value of buildings and infrastructure along the rivers in Tokyo and the importance of land ownership, it is not possible to demolish an urban area to construct a levee. Therefore, superlevees can only be created in combination with urban renewal projects. During the planning of an urban renewal project along the river, the river manager is involved and a superlevee is integrated in the urban renewal plan. Characteristic for this type of planning is the long term perspective. One segment of superlevee will have no impact on its own in reducing the flooding probability of the city. This reduction will only be materialized if multiple segments of superlevees are created and if these segments are connected in order to form a superlevee riverfront. This will take decades to accomplish. The example of the superlevee therefore demonstrates the value of integrating water management and urban planning, and the use of a long term perspective to transform a city in order to make it flood proof. In Rotterdam, currently a roof park levee is created. It is a combination of a levee, a green roof and a shopping centre.

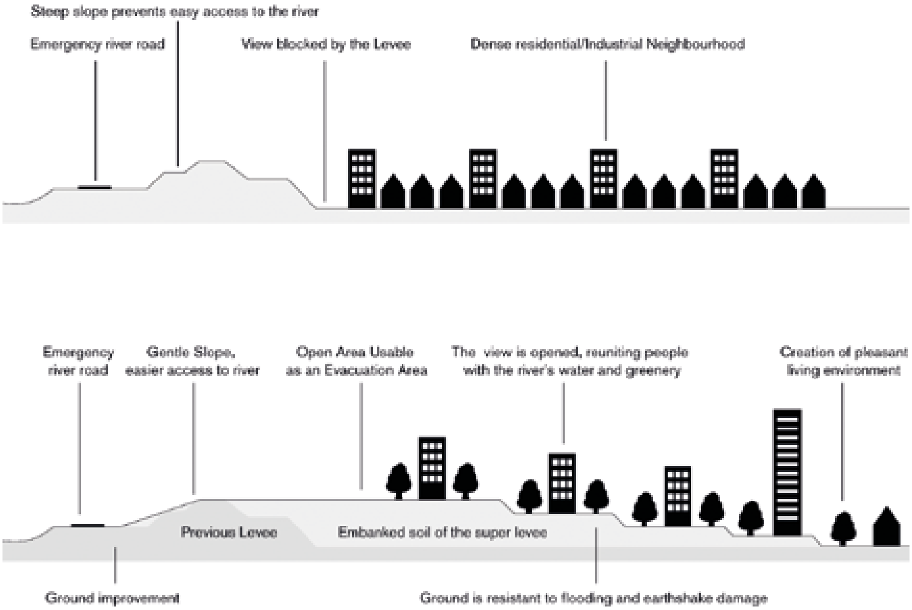

Figure 2.2:
Illustration of a conventional dike (top) and superlevee (bottom)[23]

Figure 2.3:
Illustration of the roof park which is integrated with a levee near Marconiplein, Rotterdam[24]

Multifunctional use of space on the water

Since space is scarce in cities, also the water surface should be used in a multifunctional way. An example of multifunctional use of the water surface is the construction of floating buildings. Floating urbanization enables multi-functional use of space in densely populated areas, without further increasing flood risk. During floods, floating constructions increase the flood coping capacity of an urban area. No damage to the construction will occur because floating buildings will adapt to the rising water level. In addition, these buildings may serve as emergency shelter during flooding. Because floating houses can be relocated, they are also flexible and reversible, which is a benefit to deal with uncertain future developments such as climate change.

In delta cities there are currently two main fields of application of floating urbanization. The first is floating urbanization in port areas that have lost their commercial function. These are often the shallowest ports that are closest to the city centre. As new deep sea ports are developed to accommodate modern ships, the industrial activity moves away to these new ports leaving old ports vacant. Waterfront development and floating urbanization present a solution to give a new economic function to these areas. At the same time, urban sprawl is prevented by achieving multifunctional use of space and urban densification. The second application of floating urbanization in delta cities is multifunctional use of water retention areas. To adapt to more frequent extreme weather events, delta cities need to develop a higher amount of surface water to increase their water retention capacity. Because property value and land costs are generally high in delta cities and in particular in densely built areas, it is necessary to also use these new water surfaces in a commercial way. Floating urbanization is a potential solution to this problem. Part of the newly constructed water can be sold to future residents or project developers to construct floating buildings. This method enables the municipality to reclaim part of the costs of developing surface water for water retention. Various municipalities in the Netherlands, including Delft, Amsterdam and Rotterdam have already sold water plots or are currently in the process of selling water plots. Next to floating urbanization in abandoned pot areas and water retention surfaces, floating urbanization can also create a possibility to expand on the sea. In the next chapter, this option will be discussed in more detail.

Figure 2.4:
Floating urbanization plan
for the Maashaven, Rotterdam
(DeltaSync, 2010)

Next to floating urbanization, another function of urban surface water that can be promoted is water based public transport. Cities such as Venice have already applied this concept for a long time. Historically, also Dutch cities used urban water systems intensively for transportation. In the Netherlands, water was the most important mode of transportation until the 19th century. In that period, the train became more important and many canals were filled in, because of hygienic problems and water pollution. However, in many cities the main water infrastructure is still present. In addition, many Dutch cities have plans to restore the historic water systems. This creates opportunities to use the water system again for water based urban transport.

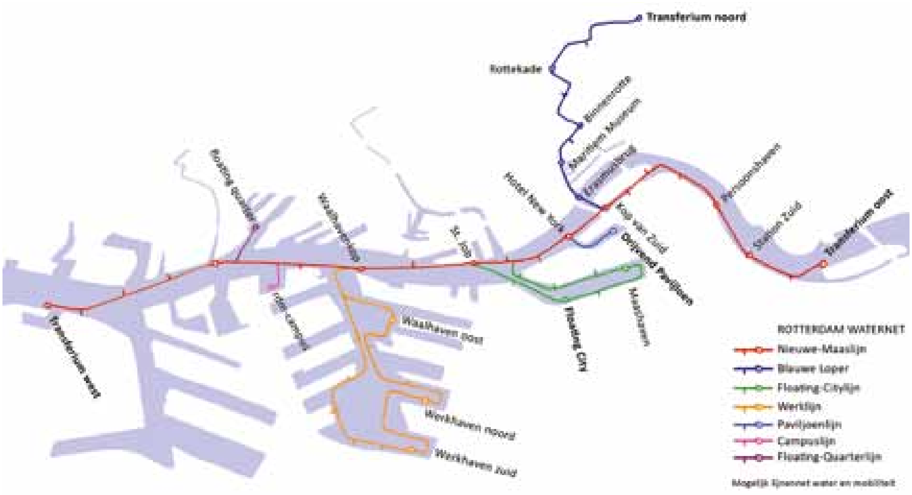

Figure 2.5:

A plan for a water based transport network for Rotterdam (DeltaSync, 2010)[25]

2.2 Decrease flood risk

Urbanization in flood plains usually increases flood risk because it leads to an increase in invested capital and people in an area that is threatened by floods. How can we urbanize in such a way that flood risk is not increased or even decreases the flood risk of surrounding area? One technical solution is flood proof urban development. Multiple technical measures are available to construct buildings and infrastructure in such a way that damage is reduced.[1]

Wet flood proofing

Wet flood proofing or wet proof construction is a building method that allows temporary flooding of the lower parts of the building. To prevent damage, preferably water resistant building materials are applied. Alternatively, materials can be used that can be easily repaired or replaced.

1 Section 2.2 is based on DeltaSync(2012) Technologies and concepts for flood proofing hotspot buildings. Research developed under the EC FP7 project FloodProBE: technologies for the cost-effective protection of the built environment.

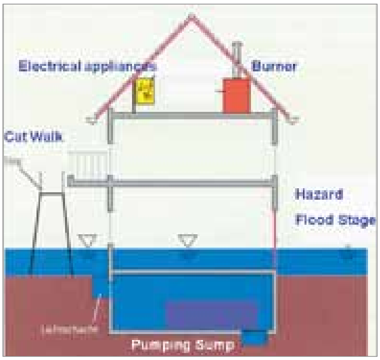

Figure 2.6:
Wet proof method scheme with temporary escape ways (E. Pasche, 2008).

Figure 2.7:
Combination of mobile walls and cat walks in Hamburg, Germany (E. Pasche, 2008).

Dry flood proofing
With dry flood proofing or dry proofing, water is prevented to enter the building. The building is made waterproof by treating the facades with coatings, using resistant materials or building materials with a low permeability. Openings in the facades can be closed with flood shields, panels or doors.

Figure 2.8:
Door barrier (Leven met water, 2008).

Figure 2.9:
Pohkit Goh: 'Flood House' (Architecture.com, 2011).

Elevation of buildings
Another method to protect a building from floods is to elevate the entire building above the expected flood level. To enable the continuing functioning of such a building, the connection to infrastructure should be secured against flooding as well.

Methods to elevate a building a couple of buildings are building on stilts and building on mounds.

Figure 2.10.
Office building on stilts in Amsterdam,
The Netherlands (Fghbank, 2012).

Figure 2.11:
Buildings on stilts in Trondheim,
Norway (Allshesaysis. blogspot.com, 2010).

Floating and amphibious constructions

Floating and amphibious structures allow the vertical building movement with the changing water level while fixing the building at the horizontal location by a mooring system. While floating structures have water constantly present at the location, amphibious structures are founded on the ground and have the ability to start floating as soon as a flood occurs.

Figure 2.12:
Floating houses in Utrecht,
The Netherlands (W. Lindemans, 2009).

Figure 2.13:
Floating Pavilion under construction in Rotterdam,
The Netherlands (Deltasync, 2010).

Figure 2.14:
Amphibious dwellings in Maasbommel, The Netherlands (beeldbank.rws.nl, Rijkswaterstaat/Rens Jacobs, 2004).

Figure 2.15:
Amphibious house in New Orleans, Louisiana, USA (DeltaSync, 2012).

Temporary and permanent barriers

By constructing either temporary or permanent barriers, buildings can be protected against flooding. Temporary barriers are installed if a flood is predicted while permanent barriers such as dikes or flood walls are permanently installed around a building.

Figure 2.16:
Multiple examples of temporary flood barriers

Figure 2.17:
Dutch dike along the Waal (beeldbank.rws.nl, Rijkswaterstaat, Ruimte voor de Rivier/Martin van Lokven, 2010).

Figure 2.18:
House with dike in Vicksburg, Mississippi, USA (Huffington Post, 2011).

Design considerations of flood proofing measures for hotspot buildings

For floods with a low flood level of less than 1 metre, wet proofing, dry proofing, stilts, mounds or temporary barriers are the most suitable solutions. For dry flood proofing, in that case, only the lowest 1 metre of the building has to be made flood proof. Temporary barriers are only useful if the flood can be predicted. They are most suitable for short floods, for instance with a duration of days or weeks, and a relatively low flood level. A mound is a good solution for low flood levels. In that case the costs for ground displacement are relatively low. For a flood with duration of weeks or months this solution seems appropriate.

Wet proofing is a possible solution when short periods of floods are expected and the expected frequency of flooding is comparably low. Permanent barriers may be a good strategy for flood levels lower than one floor that occur frequently. Also in case floods cannot be predicted, permanent barriers can be a preferable option. For high flood levels that exceed 3 metres, floating and amphibious constructions can be useful options. Contrary to most other flood proofing technologies, the costs of these technologies hardly increase with the flood depth. Floating and amphibious building can adjust easily to changing water levels. Both technologies are most appropriate for longer flood duration. With stilts it is possible to de-sign and construct a building above the expected flood level. Stilts can be applied for different flood durations and flood levels. However, elevation on stilts creates multiple use of space. It is therefore more appropriate if the expected flood levels are higher than one floor. In that case the ground floor can be used for another function such as parking. Figure 2.19 summarizes the design considerations as a function of flood duration and flood depth.

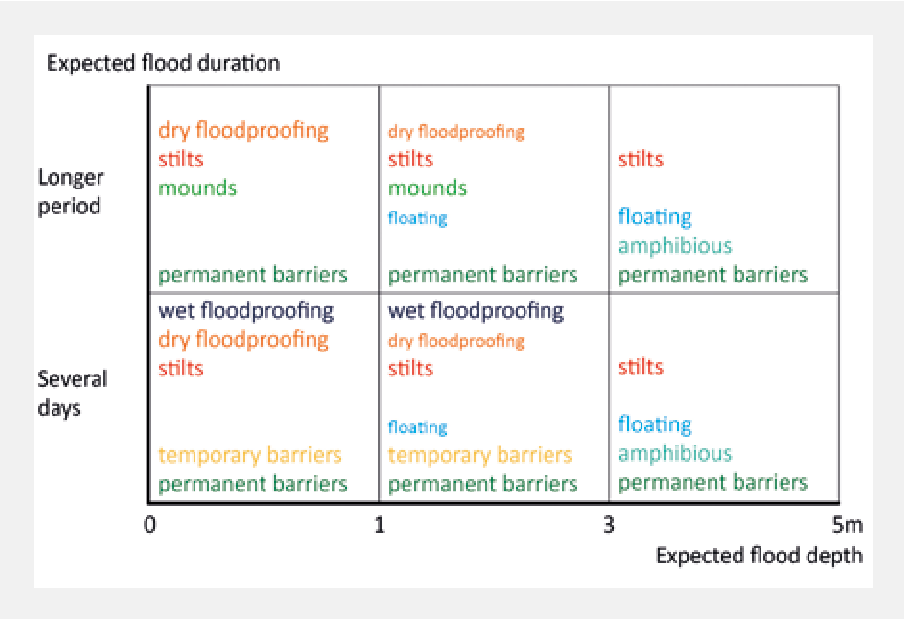

Figure 2.19:
Flood proofing concepts for hotspot buildings (DeltaSync, 2012)

Critical infrastructures and hotspot buildings
Multiple technical measures are available to protect ordinary buildings from flooding. However, to secure the functioning of entire urban areas during a flood, it is key that also critical infrastructures are protected. Critical infrastructures such as electricity networks, water supply, communication and transportation are vital for the continuing functioning of urban areas during floods. Hotspot buildings within these networks include power stations, water treatment plants, control centres of public transport, waste water treatment plants, fire fighting stations and hospitals. The availability and functioning of hotspot buildings is needed to maintain daily life as normal as possible during floods but is also required for fast and effective recovery after flood disasters. The flood vulnerability therefore largely depends on the degree in which both high value assets and critical urban infrastructure are affected, either directly or indirectly.

In the FP7 project FloodProBE the feasibility and cost effectiveness of flood proofing vulnerability hotspots has been studied. A result of the research is shown in table 2.1. This table presents and overview of feasible and unfeasible flood proofing concepts for different types of hotspots.

Table 2.1:

Flood proofing concepts for vulnerability (R= retrofit, can be applied on existing building) (DeltaSync, 2012)

	Wet proof	Dry proof	Stilts	Mound	Floating	Amphi-bious	Temporary Barriers	Permanent Barriers
Drinking water treatment	×	√R	×	√	√R	√	√R	√R
Sewage water treatment	×	√R	×	√	√	√	√R	√R
Substations, surface	×	×	√	√	√	√	√R	√R
Substations, building	×	√R	√	√	√	√	√R	√R
Substations, underground	×	√R	×	×	×	×	√R	√R
Energy storage	×	√R	×	√	√	√	√R	√R
Hospitals	×	√R	√	√	√	√	√R	√R
Fire stations	×	×	√	√	√	√	×	√R
Police stations	×	×	√	√	√	√	×	√R
Communication centres	√R	√R	√	√	√	√	√R	√R
Food distribution	×	√R	√	√	√	√	√R	√R
Financial buildings	×	√R	√	√	×	×	√R	√R
Airports	×	×	√	√	√	√	√R	√R
Bus station	×	×	√	√	√	√	×	√R
Train station platform and tracks	×	×	√	√	×	×	×	×
Metro station underground	×	√R	×	×	×	×	√R	√R

2.3 Produce resources

To deal with the challenge of energy scarcity and to reduce the negative impact of cities on the environment it is key that cities abandon the linear resource flows. To move towards cyclic resource flows cities will have to use their internal sources of water, energy and nutrients first before they extract resources from other areas. This does not mean a city should become an isolated completely self supporting system. However, cities should use their internal resources in an optimal way.

Using the urban water system as a source

Urban water systems can be valuable source of water, energy and nutrients. Rainwater, for instance is a resource that is often not utilized in most cities, instead it is mainly converted into wastewater in combined sewer systems. However rainwater has many opportunities of application. For example it can be used for flushing toilets or to irrigate green spaces. In a city there are usually many impermeable surfaces that can be used to collect rainwater in storage systems, for example in underground tanks. The extraction of external water resources can be reduced by applying this strategy. Figure 2.20 shows how in the Tokyo Dome, Japan, rainwater runoff is captured and used in the building.

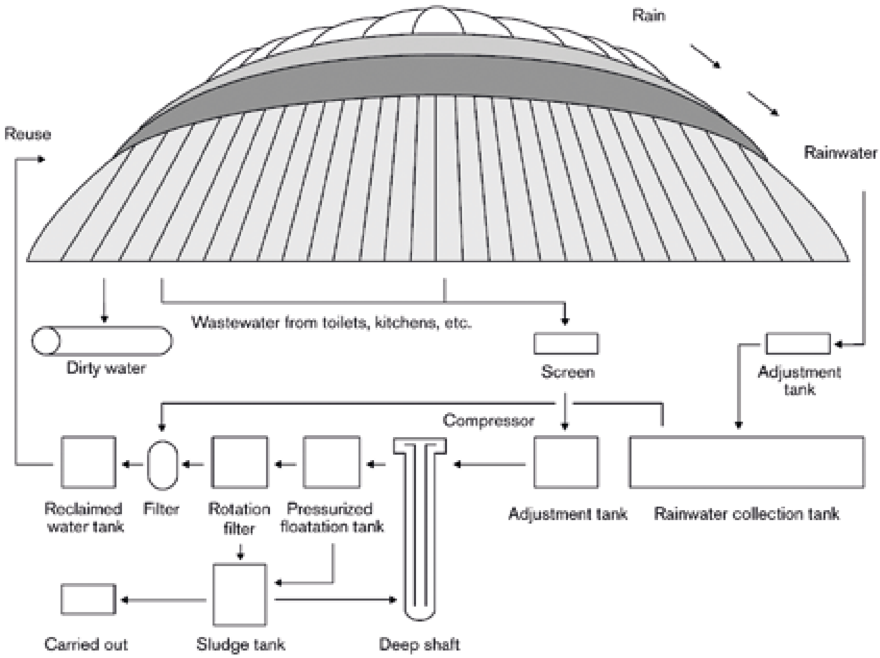

Figure 2.20:

Scheme for capturing and using of rainwater in Tokyo Dome, Japan[26]

Instead of transporting rainwater runoff as quickly as possible outside the city by sewer systems, water can also be infiltrated to the groundwater, adding to the groundwater storage of the city. In many cities this is now widely applied and a wide variety of technologies is available for this purpose such as bioretention systems, raingardens, permeable pavements, planter boxes but also infiltration of rainwater to deeper groundwater layers by Aquifer Storage and Recovery (ASR). In Australia landscape architecture, water management and transition management have been combined in a new discipline of Water Sensitive Urban Design (WSUD) which is now commonly used across Australia to reflect a new paradigm that aims to achieve that water environment and infrastructure service design and management opportunities are being considered in the earliest stages of the decision making process that is associated with urban planning and design. The concept of WSUD is a holistic urban water management approach that encompasses all aspects of integrated urban water cycle management, including water supply, sewerage, and stormwater management. The objectives of WSUD include:

- → Reducing potable water demand through water efficient appliances, rainwater and greywater re-use.
- → Minimising wastewater generation and treatment of wastewater to a standard suitable for effluent reuse opportunities and/or release to receiving waters.
- → Treating urban stormwater to meet water quality objectives for reuse and/or discharge to surface waters.
- → Preserving the natural hydrological regime of catchments.

Urban wastewater streams contain high amounts of phosphate and nitrates that could be used as fertilizer for agriculture. On the longer term, this is crucial because the proven reserves of phosphate are finite. Instead of burning wastewater sludge, nutrients should be recovered and cities can become a net producer of useful fertilizers for agriculture. The cycle can be closed even more by encouraging urban agriculture with locally produced fertilizers. Many cities now see a fast increase of urban agriculture. In Rotterdam there are already 14 locations for urban agriculture. This development can assist in making cities less dependent on external food supply and at the same time create a market for locally produced fertilizer.

Next to using urban water systems as a source for water supply and nutrients, they can also function as a source of energy. Possibilities include the use of wastewater for biogas production, recovering heat from wastewater streams by heat pumps, and using the urban groundwater and surface water systems as a source of heat. In the Paleiskwartier in 's Hertogenbosch a pond is used to collect solar energy in summer. Heat from this pond is stored in an aquifer thermal energy storage, and is used in winter for heating the houses, offices and apartments in the area. The required surface water area per house is 70 to 90 m^2 to collect enough heat.[28]

Figure 2.21 a&b:
Capturing, treatment and infiltration of rainwater runoff from roads in Melbourne (left) and Perth (right) Australia.

Figure 2.22:
Paleiskwartier Den Bosch, a shallow pond is used as heat collector for the nearby apartments. (Photo: E. Aparicio, 2008).

2.4 A positive impact on ecosystems

Using nutrients, CO_2 and other waste in a productive way will reduce the impact of cities on the environment. The urban metabolism will have a more cyclic character, less waste will be disposed to the surrounding area and fewer resources will be extracted. However, cities can also themselves be a valuable part of an ecosystem and create habitat. In cities the biodiversity can be even higher than in rural areas with monocultures of agricultural crops. Urban water systems can form a connection between different nature areas as they offer a migration route for fish and other animals. A good example is the Blue Connection (Blauwe Verbinding) in Rotterdam. This is a water connection of 13 kilometres between Barendrecht, a new landscape park in Albrandswaard and the south of Rotterdam. At the same time the connection has recreational functions and serves as water retention storage. Next to urban water systems, also buildings can be used to create habitat by the development of green roofs and green walls.

2.5 Feasibility and knowledge gaps

In this chapter many possibilities have been discussed for cities to become more flood proof, reduce land scarcity, produce resources and create ecological habitat. Most of the possibilities were illustrated with practical examples of realized projects. However, for flood proof urbanization, most of the examples were limited to individual buildings. There is a lack of knowledge how these technologies and concepts could be used to develop an integral concept for flood proof neighbourhoods or cities. Scaling up flood proofing technologies beyond the scale of an individual building is an important field of research for the coming years. Such a study should also take into account critical infrastructures and hotspot buildings within these infrastructures. Flood proof buildings are not sufficient to make a flood proof city as critical infrastructures should also function during a flood to maintain daily life. Also the interdependencies between different critical infrastructures play a key role.[29] A system to evaluate and select different flood proofing options for critical infrastructures should also be developed.

Although technologies and concepts are available for delta cities to transform into adaptive cities, the actual implementation remains limited to small scale pilot projects with small overall impact on the urban system. Therefore, more knowledge is needed what the required skills, capacities and development methods are that cities would need to transform successfully into cities that are less vulnerable to flooding, produce resources, create ecological habitat and deal with land scarcity. An international classification of delta cities in different stages of development and research on strategies to progress from one stage to the following stage are needed. Also more insight needs to be built on which capacities are needed for cities to implement adaptation measures. An international research network with climate adaptation centres in delta cities worldwide would be useful to facilitate joint research, knowledge exchange and capacity building.

2.6 Research agenda

In this chapter, knowledge gaps have been identified for adaptive urbanization on land. These knowledge gaps will be addressed in the coming years. Within the research centre RDM Sustainable Solutions which is a part of Rotterdam University of Applied Sciences, these gaps of adaptive urban development will be studied in close collaboration with government organizations, NGO's and entrepreneurs, SME's and large companies. For this purpose a four years research agenda for adaptive urban development and water management has been developed that includes the following topics.[30] This agenda fits in the overarching strategic plan of the research centre.[31]

Table 2.2

Adaptive urban development on land research projects that will be executed in the coming years to address knowledge gaps that were discussed in this chapter

Project	Knowledge gaps
Protecting Vulnerability Hotspots in Critical Infrastructure	Large scale strategies for protecting hotspot buildings and critical infrastructures
Innovative flood proofing	Integral concepts of flood proof neighbourhood development
Innovations in urban water management	Contribution of innovative water management concepts on system wide change
Rotterdam as entrepreneurial water and adaptation showcase	Development methods and strategies to transition to stages of development of water cities
Organising adaptation capacities in delta cities	Required skills and capacities to organise climate adaptation processes
Climate change adaptation delta centres	Comparison between transition processes in delta cities with regard to climate adaptation

2.7 Realization process: Rotterdam and other delta cities

What determines if innovations are applied and eventually become mainstream practice? Recent research gives an outline of important factors.[32]

Including innovations in spatial development

First, innovations should be included in spatial development processes. For this purpose, water managers and spatial planners should collaborate in long term vision development. A study on Rotterdam Watercity 2035 shows that cooperation between disciplines can lead to a change in perception in which both disciplines became convinced of the benefits of cooperation.[33] To successfully integrate flood control and urban planning, the role of water managers in spatial development processes should change from a reactive role at the end of the spatial development process toward a role where the water manager takes more initiative. By taking this approach, water resources and flood control interests can be included much earlier in the spatial development process. In the Netherlands, Waterboard De Stichtse Rijnlanden has taken such an initiative by developing a spatial plan for a flood proof urban district. This district includes multiple flood proofing concepts such as wet flood proofing, dry flood proofing, amphibious housing, floating housing, developing flood shelters and building on stilts.

Stakeholder receptivity

A second factor that determines if innovations are applied is stakeholder receptivity. Jeffrey and Seaton[34] defined receptivity as "*the extent to which there exists not only a willingness (or disposition) but also an ability (or capability) in different constituencies (individuals, communities, organisations, agencies, etc) to absorb, accept and utilise innovation options.*" For mainstreaming of new professional practices and alternative technological options, four attributes are required according to the receptivity framework:

- → Awareness: being aware that a problem exists, and that alternative options are available
- → Association: associate these options with the stakeholders own agenda and objectives
- → Acquisition: being able to acquire, implement, operate and maintain the alternative options
- → Application: having sufficient legal and financial incentives to apply the alternative options

Receptivity means that stakeholders need to be open to the concepts that are developed by change agents in envisioning processes. In Rotterdam, water management traditionally received little priority. Urban planners discovered that water had the potential to make the city more attractive to citizens and companies.[35] This created a willingness to include water innovations in urban planning. Solutions that were developed in the Rotterdam Watercity 2035 process were seen as a potential contribution to the urban challenge. As a result, politicians were willing to support the vision. The waterboards saw the vision as an opportunity to realise their water retention objectives in an urban environment where space for water retention is scarce. As a consequence, many ideas that were developed in Rotterdam Watercity 2035 were eventually included in official water management policy and are now being implemented in practice.

Figure 2.23:
Rijnenburg during normal operation: plan developed by a waterboard for a flood proof urban district (DeltaSync/Waterboard Stichtse Rijnlanden, 2011)

Figure 2.24:
Rijnenburg during extreme weather event: plan developed by a waterboard for a flood proof urban district, (DeltaSync/ Waterboard Stichtse Rijnlanden, 2011)

Improving innovations

Innovations in water management, energy and construction that require a new way of working, new skills and new knowledge will not easily be adopted even if they are technically and economically feasible. Innovations are often isolated showpieces that hardly contribute to the overall transformation of the urban water system.[36] These innovations are hardly evaluated and improved. Neither does replication of demonstration projects take place on a large scale. Therefore, they remain isolated and fail to influence mainstream day to day urban water management practice. Brown and Keath have argued that sustainability practitioners and strategists should focus more on providing the capacities and tools for replication and improvement of demonstration projects rather than just the demonstration of technology itself.[37] For a successful transition from current cities to flood proof ecocities, it is essential to make innovations more competitive compared to mainstream practices. In Rotterdam, RDM Campus aims provides an environment for improving innovations to be able to compete with mainstream practice. At the same time students and practitioners gain new skills and knowledge that will enable them to work in this new market of sustainable technologies.[38]

Creating a commercial market

It is necessary to create a commercial market for innovations in order to realize flood proof ecocities. At this moment, there are hardly any incentives for developers and citizens to demand local water management and energy innovations. Such incentives could be created by awards, subsidies, increased competition among developers, and binding targets and regulations with regard to water management for instance on water robust buildings, source control, water quality, quality of the urban landscape, and integration with water management. For citizens, waterboard taxes should be made dependent on the surface of connected paved area to the sewer system to stimulate local water retention and water use on private property.

The task of designers

In a spatial development process with a more important role for citizens, the role of the designer will change from a determining role to a facilitating and inspiring role. Co-design with citizens becomes an important approach to develop solutions that are feasible from a societal point of view. The role of design is not to produce a blueprint for a future situation, but to inspire stakeholders to take the direction towards flood proof ecocities. Additionally, the role of design is to provide input for discussions and stakeholder involvement. The Rijnhavenpark, a project that is discussed in chapter 4 of this book, is a good example of this approach.

New roles for professionals and citizens

The capacity of urban professionals and citizens to perform different roles than the traditional roles, is an enabling factor for realizing flood proof ecocities. For example, using the urban water system for new functions implies that urban water managers and citizens will have to fulfil new tasks that are unfamiliar to them. An example of a new role is the waterboard as a developer of water plots for floating urbanisation. The water utility company may become a facilitator of local water supply. A possibility is that local water treatments are owned by residents and that the water utility develops a new business model based on supplying technology and service contracts.

Institutional mechanisms

Professionals should no longer be rewarded based on effective execution of their fragmented statutory tasks, short term targets and costs minimisation. Instead, they should be judged on their contribution to the total system performance and long term targets. This creates room for stakeholders to be involved in long term collaborative projects. To secure public interests, selection of urban development partnerships should be based on costs, quality and system impacts rather than costs only. This should be supported by a management culture that is leadership driven rather than responsibility driven. Such a culture requires that professionals will have to do what is considered beneficial instead of doing what is legally prescribed. These changes will increase the potential of sustainability innovations to breakthrough to day-to-day professional practice.

03. Adaptive urban development on the water: floating cities

"We are tied to the ocean. And when we go back to the sea, whether it is to sail or to watch - we are going back from whence we came." - **John F. Kennedy**

The previous chapter presented concepts and technologies for adaptive urban development of existing cities on the land. These technologies and concepts can be applied in city expansions or in urban renewal projects in existing cities. This chapter will elaborate on developing an entirely new model of a city by making use of floating urbanization. The chapter is structured around the same objectives of adaptive urban development that were discussed in the previous chapter.

- → Increase land availability rather than create land scarcity
- → Decrease flood risk rather than create flood risk
- → Produce energy, food, water and nutrients instead of only consuming resources and producing waste
- → Have positive impact on ecosystems and create habitat rather than degrade ecosystems

Similar as the previous chapter, at the end of this chapter the feasibility and knowledge gaps, and the realization process will be discussed.

3.1 Increase land availability

To understand the necessity of constructing floating cities for land availability, first the global impact of conventional land based urbanization needs to be understood. At present, there are about 3.5 billion city dwellers living on an estimated 2 million square kilometres of land. This is an average density of 1750 inhabitants/km^2. Notwithstanding the objective of urban densification that was discussed in the previous section, data shows that the urban density has actually been declining with the rising population over the past decades.[39] Until 2100, 5 billion city dwellers will be added to the global urban population. With rising living standards, people generally require more space. If still the estimation is made that this process will take place with the same density, another 2.85 million square kilometres of land are needed. This new urban areas equals 69 times the total area of the Netherlands, or more than half of the total land area of the European Union.

As cities grow, they generally use fertile cropland for this purpose because this is the area that is mostly located around cities. At this moment, there is a total area of 16 million square kilometres of croplands in the world.[40] Losing 2.85 million square kilometres of cropland to new urban areas means a reduction of 18% of fertile cropland. At the same time the demand for food will rise dramatically due to the growing cities, rising living standards and increasing popularity of biofuels. It is estimated that already by 2050 global food supply needs to increase with 70% to 100% compared to current levels to achieve global food security.[41] The remaining cropland should become 2 to 2.5 times as productive as current productivity to achieve this. To achieve this growth, an annual productivity growth of 2 to 2.4% over the next 38 years is needed. However, figure 3.1 shows that the productivity growth of agriculture, is already declining for decades. The required fresh water resources and fertilizers to support the needed doubling of agricultural productivity are also lacking. From the perspective of land availability and food security, it is therefore not feasible to accommodate 5.0 billion additional city dwellers in new urban areas on the land.

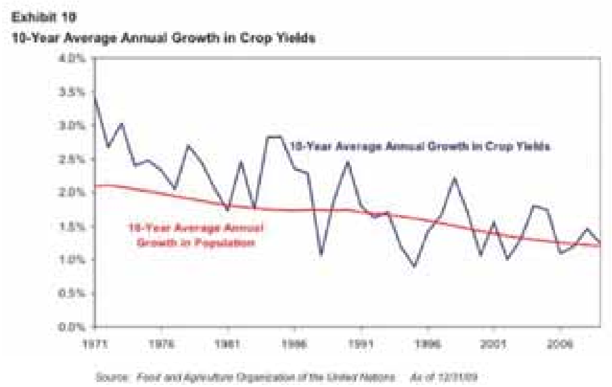

Figure 3.1:
Productivity growth in agriculture has already been declining for some decades

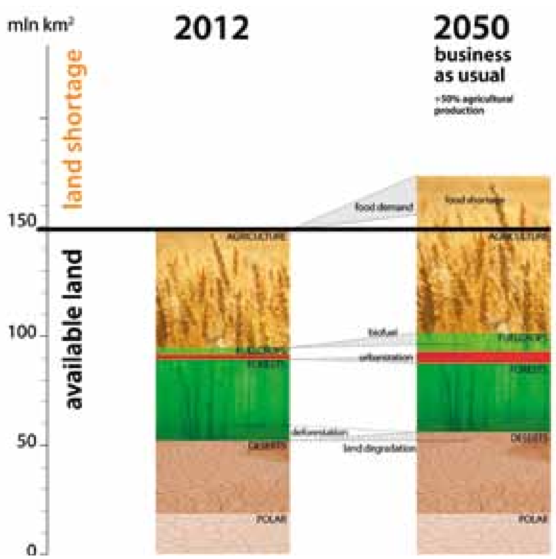

Figure 3.2:
Global land availability, in 2050, the world lacks an estimated 22 million square kilometres, or more than two times China. If the required CO_2 compensation is taken into account, the shortage is even much larger (DeltaSync, 2012)

A more feasible strategy that is proposed in this book, is to urbanize on the sea. About 70% of the earth surface is sea. This area is not yet optimally used. Only 0.8% of the global sea surface is needed to accommodate 5.0 billion people in floating cities at the same average urban density as current land based cities. This density can be easily achieved because the average density of urban areas is quite low. Urbanization on the sea would keep the fertile croplands around current cities in existence. These croplands are urgently needed to produce the required food in the next century.

3.2 Decrease flood risk

Besides addressing the problem of land scarcity, floating cities are also an interesting solution for reducing flood risk. No damage to the construction will occur because floating buildings will adapt to the rising water level. In addition, floating cities may serve as emergency shelter for urban areas nearby during major flood disasters that are more frequently taking place. Because floating cities can be relocated, they are also flexible and reversible, which is a benefit to deal with uncertain future developments such as climate change. As described in the first chapter, the increase in flood risk is mainly due to urbanization, socio economic changes and more extreme weather events. Income rise and population rise will lead to an increase in yearly flood damage to about 30 billion US$ in 2100. Floating urbanization is an alternative strategy that does not increase flood risk. Therefore, on a global scale the economic benefits of floating urbanization are in the order of magnitude of multiple billion dollars every year by preventing a rise in yearly flood damage.

3.3 Produce resources

Next to reducing flood risk, floating cities can play a key role in increasing global food supply and global energy production by productively using waste products of land based cities. Cities on land produce CO_2, heat and nutrients as waste products. These waste products could be used by floating cities to produce food and biofuels. Around floating cities, floating algae farms and seaweed farms could be constructed that protect the floating city against waves. They will absorb the CO_2 and nutrients waste of the land based delta cities and at the same time produce biofuels and food resources for the floating city and land based cities.

Algae biomass production is still in its early years. Biofuel production from microalgae with lipid contents of around 40% gives a biodiesel yields of 40 to 50 tons per ha per year[42] and by far exceed the most promising yields from land crops.[43] Growing algae to produce biofuel can be 10 to 20 times more productive compared to corn or sugarcane.

Food production, in particular aquaculture can be realized in floating cities. There are multiple concepts and technologies available for water based food production. The concept of aquaponics, for instance, can be applied for this purpose. Aquaponics is a combination of hydroponics and aquaculture. Hydroponics is a method to grow plants in a liquid solution consisting of water and the required nutrients for a particular plant.[44] Aquaponics combines plant growing with fish farming in a self contained eco system. Plants and bacteria use the nutrients that fish create and purify the water. Both freshwater fish and marine fish can be produced in floating tanks. This is much more efficient than cattle farming on land to fulfil the world's rising protein demand. Aquaculture can be more space efficient as producing meat on the land, the production of biofuel can be 10 to 20 times as efficient per unit area as biofuel production on the land. Therefore placing these activities on the ocean makes space available on the land for instance to create nature again out of croplands. Another huge benefit is that less fresh water resources are needed for this type of production. Figure 3.3 shows that if it is possible to make the combined development of cities, food production and biofuel on the sea 50 times more efficient than average land productivity by closing the loop and the application of best practices, only 0.15% of the oceans is needed and a third of the current agricultural area on land can be taken out of production.

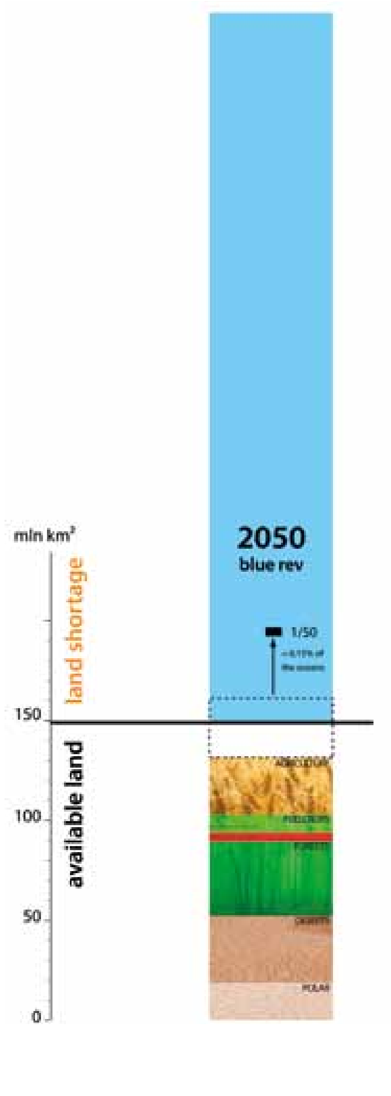

Figure 3.3:
Blue revolution: locating a part of the urban areas on the ocean and replacing inefficient food production on land by efficient sea based production (DeltaSync, 2012)

Floating cities are the missing link to close the linear resource flows that characterize the current delta cities. Because the proposed method of aquaculture can be based on salt water and uses waste nutrients from delta cities instead of artificial fertilizers, it is one of the few possibilities to increase the global food and biofuel production without increasing the extraction of fresh water resources and rock phosphate. This concept of a floating city based on cyclic resource flows is called the cyclicity (DeltaSync, 2012). Figures 3.4 - 3.6 illustrate the concept. In the cyclicity blue energy[45] can be produced by making use of the osmotic pressure between fresh water and salt water. Also the concept to use water for heating and cooling of buildings by applying heat pumps that was described in the previous chapter, can be applied in the floating city. In floating cities that are near the deep ocean, Ocean Thermal Energy Conversion (OTEC) can be applied as an additional energy source.[46]

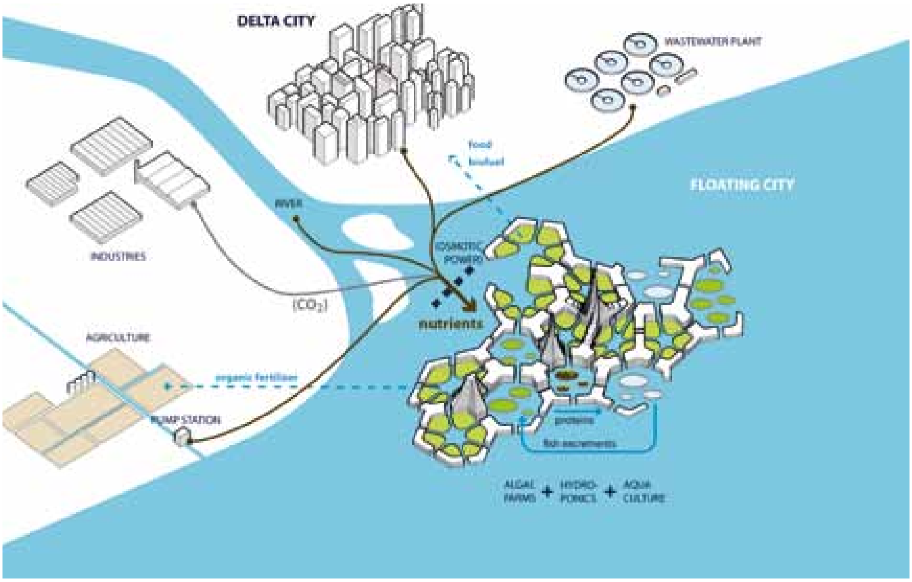

Figure 3.4

Scheme of the Cyclicity. Waste from delta areas is used for production of food and energy creating a symbiotic relation between the land based city and the floating city (DeltaSync, 2012).

Figure 3.5:
Impression of the Cyclicity. (DeltaSync, 2012).

3.4 A positive impact on ecosystems

By extracting nutrients and CO_2 from the surroundings, floating cities already have positive impact on the ecosystems in delta areas. Extracting CO_2 will also be a measure against the increasing acidity of the sea water, which is a major threat to coral reefs worldwide.[47] Also an excess of nutrients in delta areas has a negative impact on marine ecosystems, an impact which is reduced by the cyclicity concept. In a cylicity, the productivity per square meter of the aquaponics system is much higher than the conventional practice of catching (and depleting) stocks of wild fish. The change from catching wild fish towards aquaculture can be compared with the transition from hunter gatherer societies to agriculture on the land. This transition increased the food availability to a great extent. Consequently, a part of the population was no longer needed for food production and could spend time on the development of technical innovations, science, culture, religion and political organization. The first civilizations and cities were the result of this development. It took place on the land within the last 11,000 years after being hunter gathers for about 7 million years since the ancestors of modern human beings diverged from the ancestors of the current great apes.[48]

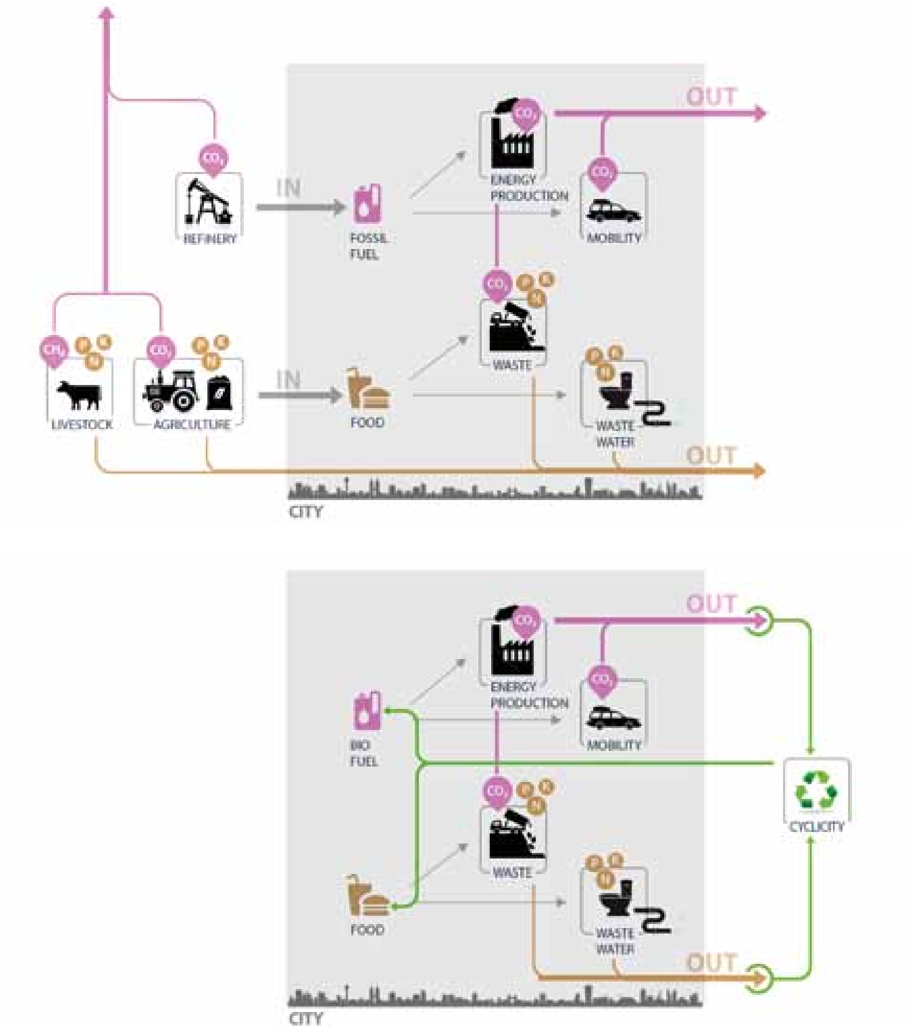

Figure 3.6:
Current cities have a linear metabolism (top), the cyclicity concept (bottom) creates a closed loop of nutrients between the land city and the floating city

On the sea, the biggest part of our planet, humanity is still in the hunter gather phase and should also make the transition to food production in an organized, planned and structured way. This change is called the Blue Revolution in this book. Because the food productivity will rise dramatically compared to the current hunter gatherer practices, only a very small part of the ocean will be needed for food production. In the remaining part of the ocean marine nature reserves should be created to protect fish and other species. This strategy will give marine ecosystems a long term perspective to survival, a perspective that is currently lacking with the global collapse of fish stocks due to overexploitation and the continuing destruction of coral reefs.

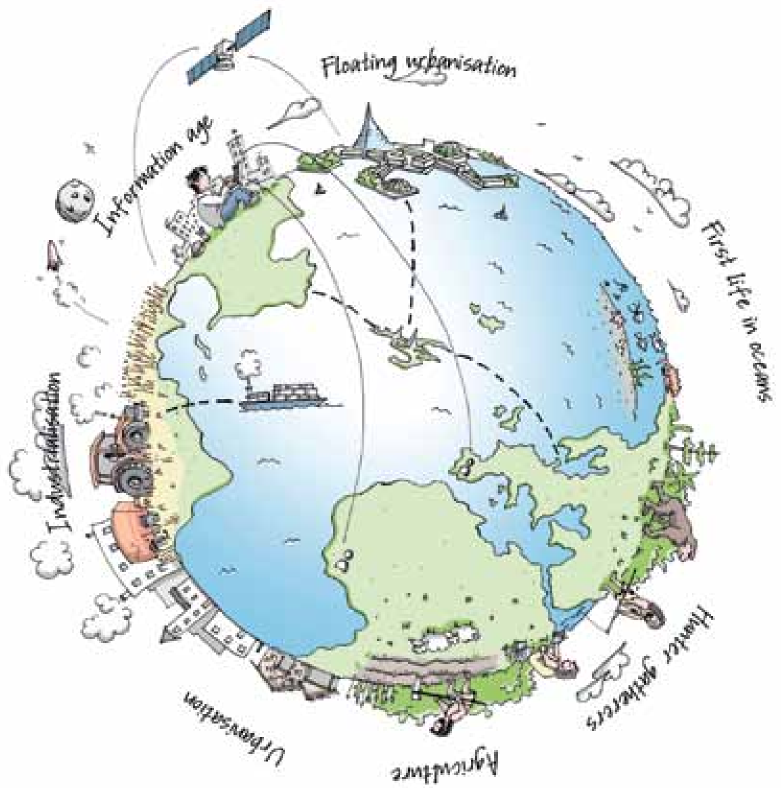

Figure 3.7:
Back where we started from: floating urbanization as a logical next step in human development (DeltaSync, 2012)

Floating cities can also provide habitat for multiple species. Most of the marine life is concentrated in a relatively small fraction of the sea with shallow areas, around land-water interfaces and near structures such as coral reefs. The construction of floating cities will make the length of the land-water interface substantially longer and proportionally increase the ecological potential of the coastline. Around floating cities wetlands and artificial reefs should be created to protect the floating city from waves and at the same time create valuable habitat for a wide range of species. Artificial reefs can be made from recycled materials or waste products such as glass or metal. Around floating cities in deep water, artificial reefs and wetlands could be constructed as connected floating or suspending objects. The result would be that the amount of shallow water would increase and the potential habitat for wildlife would expand.

3.5 Feasibility and knowledge gaps

Is it possible to create floating cities on the sea? Could it really be the solution to some of humanities most urgent problems such as land scarcity, urbanization and finite resources? In this chapter the feasibility and knowledge gaps to achieve floating urbanization will be discussed.

Technical feasibility and gaps

Many floating projects that have been realized demonstrate that is technically possible to build on the water. Offshore projects such as oil platforms but also large cruise ships have such a scale that they can almost be considered floating cities. Other elements such as floating infrastructures, shallow water and deep water mooring systems, artificial reefs, floating wetlands are already available on the market. This is also the case for decentralized production technologies of drinking water, energy and other utilities. The main technical knowledge gap for the development of floating cities is therefore not the development of new technologies but more the integration of a huge amount of different existing technologies and the up scaling and improvement of these technologies. This is the essential challenge for the coming years. One of the key components of the urban expansion strategy on the water is the use of waste nutrients and CO_2 to produce algae, fish and crops. The technologies to achieve this are already on the market and rapidly developing. In particular the further improvement and the integration of these technologies in floating cities is a gap that needs to be addressed in the coming years.

Design feasibility and gaps

The idea to create floating cities is not new and over the years many designs and plans have been proposed for floating cities on the sea or inland water. In 1895, Jules Verne already described a constructed floating island in his novel l'Ile a Hélice. More recently, a huge amount of innovative designs for floating buildings already have been made. Most of them could be easily implemented in floating cities. What is lacking, however, is an urban design philosophy that is specifically developed for floating cities. Many designs for floating cities are still clearly derived from land based cities and focused on the building scale. Others have a futuristic character similar to space ships. Integrated knowledge about urban densities, building typologies and a broader vision and imagination on how it would actually be to live in a floating city is still lacking. There is therefore a need to develop urban design instruments that are specifically accustomed to floating cities. This includes solutions for public space, separation between public space and private space, mobility and transportation, densities, land use and above all, more detailed knowledge and understanding about the possible way of life in floating cities.

Figure 3.8:
Jules Verne, l'Ile a Hélice (1895), in this book the already a constructed floating island was described

Environmental feasibility and gaps
Floating cities will be surrounded by wetlands and artificial reefs and create habitat for many species. Floating cities will also absorb CO_2 and nutrients and solve part of the environmental problems of delta areas on land. One field of knowledge that still needs to be developed is the impact of floating cities on water quality and ecology. Creating small platforms creates shading and hiding places for fish. However, covering water surfaces that are too large could deprive the water from sunlight and will have negative impacts on plants and fish. This problem could be addressed by leaving parts of the surface in a floating city open. The knowledge how much water should be left open and what the maximal size of floating platforms could be without negative impacts on the water quality and ecology is an area of research that will be investigated in the coming years.

Economic feasibility and gaps
Floating cities need to have a thriving economy and enough jobs for its inhabitants. In a globalized economy that is connected through modern information technology, the location of companies is becoming more and more independent from the location of the market. Many companies already produce and sell products all over the world. They could also find an excellent location in a floating city. Floating cities could be created near international shipping routes, giving companies connectivity advantages over land based companies. The extensive aquaculture around floating cities would also generate jobs and create opportunities for high tech companies to develop and implement new technologies. If floating cities are located outside the territorial waters, they could benefit from tax benefits and attract many companies and entrepreneurs. An example of such a plan is BlueSeed, a silicon valley floating technology incubator that is planned 12 nautical miles from San Francisco to attract entrepreneurs from all over the world without the need to apply for work visa.

Floating cities will not be connected to mainland electricity and water networks. Mainly decentralized technologies for water and energy production will be used. Floating cities are a great testing and developing ground for these technologies but at the same time, they would also be a growing market for them. This will increase the attractiveness for companies to invest in research and development of these technologies. Lower costs and a higher quality will be the result. Also jobs will be created. Ultimately, decentralized sustainable technologies will be better able to compete with the land based outdated infrastructures that are dependent on fossil fuel input and were invented during the industrial revolution. Floating cities therefore also provide the means for land based cities to become more sustainable by developing a new model of city and generating more efficient and competitive clean technologies.

Other economic benefits of floating urbanization are the prevention of flood damage compared to urbanization on land and saving scarce agricultural land from being converted into urban space. The conversion of land would ultimately be paid by the global human population in the form of rising food prices. This is already happening today. The location acquisition costs to build a city will also be much lower on the sea than on the land while construction costs will be higher.

Although the general economic feasibility looks promising, the current economic models for real estate development are probably not suitable for floating city development. Cities could sell pieces of water in a similar way as they sell plots of land to real estate developers. However, usually cities are not the owners of the sea. New economic models need to be studied and developed to support floating city development. As an alternative to sea acquisition, floating cities could also rent a coastal location from a certain country. The rent could be paid by delivering ecological services such as CO_2 capturing, biofuel production and waste processing from cities on land. Such a non-monetary symbiotic economic model could prove to be of great value as a possible alternative to the current growth dependent global financial system that is not properly functioning and unsustainable in the long term.

Figure 3.9:

Blueseed: a plan for a floating hi tech startup incubator 12 miles from the coast of San Francisco, USA

Governance feasibility and gaps

How could a floating city be governed? Over the last decades there has been a shift from top down hierarchical steering (government) towards more network driven decentralized forms of policy making with multiple actors (governance). Floating cities offer an opportunity to take this development a step further by using the opportunities that decentralized technologies offer. In the floating city, decentralized concepts for water supply, energy production and other utilities are applied. Citizens and groups of citizens have the opportunity to manage their own utilities and produce electricity and water instead of only being a passive consumer of large utility companies that are still dependent on fossil fuels. This will increase the influence of citizens in society and strengthen their independence compared to their fellow citizens in land-based cities. Citizens are better capable than ever before to assume such a role. The level of education and access to technical information has never been as high as it is today.

While ordinary governance structures from cities on the land with municipal councils, aldermen, a mayor and elections could equally be applied in floating cities, it is important to notice that the current democratic models that are based on elections and representations partly stem from the past logistic impossibility to collect all citizens in one room and allow everyone to speak and vote on a certain issue. With modern information technology this has become possible. Therefore, in a floating city, citizens could have much more direct influence on the city governance and directly vote and discuss certain city issues online. Human behaviour in floating cities is also a field of research that should be studied. Another knowledge field that should be investigated is how floating cities could be part of nation states, or alternatively floating cities on the ocean could constitute their own state and become members of international organizations such as the United Nations.

3.6 Research agenda

In this chapter, knowledge gaps have been identified for floating urbanization that need to be addressed in the coming years. Similar to the research projects on adaptive urban development on land, also project for adaptive urban development on water have been identified. Table 3.1 provides an overview of these projects and the knowledge gaps they address.

3.7 Realization process: Rotterdam and other delta cities

How can we get from the current situation towards a future with cities on the sea and a population of billions of people living on the oceans? The answer to this question forms a connection between this chapter and the previous chapter. Cities on the land were not developed in one day. They started as small villages that developed into cities, a process that sometimes took centuries. Similarly, the first floating districts and small cities will not be created on the ocean. It is more likely that they will be created in the current delta cities as part of the land based adaptive urban development strategy. From that position the scale of floating developments can increase until the step to the sea and ocean can be made. At the same time, considering the challenges of land scarcity in the 21st century and the rapid process of urbanization, water based development should take place faster than it is currently occurring.

Table 3.1
Adaptive urban development on water research projects that will be executed in the coming years to address knowledge gaps that were discussed in this chapter

Project	Knowledge gaps
Floating structures and utilities	Integrating technologies and up scaling from house to neighbourhood and city level. Integrating floating aquaculture innovations in floating structures.
Urban design of floating cities	Urban design instruments specifically accustomed to floating cities, including public space, separation, identities, mobility and possible ways of living in floating cities
Realizing floating urbanization	Development of new economic models, new methods of collaboration between research, government, companies and SME's, starting pilot projects
Impacts on water quality and ecology	Data and understanding about water quality and ecological impacts, establishing design guidelines based on this understanding.
Rotterdam as entrepreneurial water en adaptation showcase	Role of showcases in the development and transition process of water cities

Rotterdam

The city of Rotterdam has included plans for floating districts as part of the municipal climate adaptation and urban planning policy. Port activities move from the centre of the city to the west where new ports are being developed to allow for larger ships to dock. The old port areas and sites will lose their old function, leaving a vast area directly near the city centre open for redevelopment. This area of 1600 ha is called the Stadshavens area, and is located outside the dikes. It will be one of the main locations for the future urban expansion of the city instead of the old strategy of expanding outwards (suburbanization). Floating urban development presents the opportunity to create new urban space in the vast area of the old ports that will become available. Moreover, it makes for a flexible and climate proof solution that can cope with uncertain future scenarios. Following the realization of the Floating Pavilion, Rotterdam intends to build 6000 sustainable floating homes over the next 20 to 40 years.[50] Figure 3.11 shows in which ports have been designated by the municipal policy for floating urbanization on the short term or long term. Compared to alternatives such as land reclamation, floating structures have a lower impact on the local environment. Land reclamation can have serious environmental consequences, such as reduction in biodiversity, erosion and pollution.

Figure 3.10:
The floating pavilion in Rotterdam, the first step towards floating districts
(Photo: R. De Wit, Source: DeltaSync)

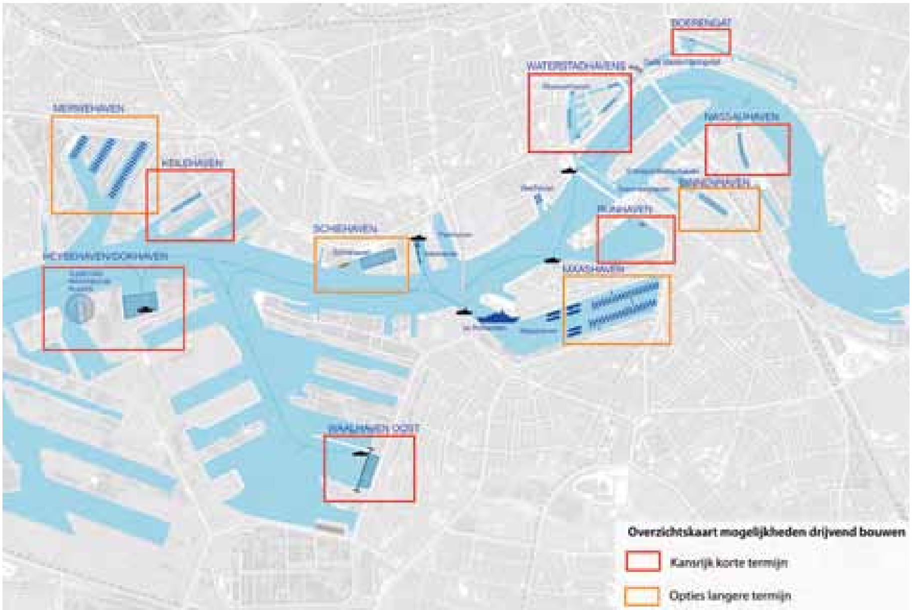

Figure 3.11:
Ports in the city of Rotterdam where the municipality facilitates floating buildings on short term (red) and longer term (orange) (Municipality of Rotterdam, 2011).

With RDM AquaDock, a testing, development and demonstration centre is available in the port of Rotterdam for floating urbanization. AquaDock is located in the Dokhaven and facilitates the collaboration between education institutes, start up companies, research institutes and the government. The partners involved in developing the AquaDock project are City of Rotterdam, Port of Rotterdam Authority and Rotterdam University. At AquaDock new technologies for floating urbanization can be tested, improved and scaled up to make the step towards floating districts and eventually, floating cities. The integration with education and entrepreneurship ensures that a new generation of floating urbanization experts and companies is delivered that is needed to develop floating cities in practice.

Figure 3.12:
Vision of AquaDock, a testing and demonstration centre for floating urbanization in Rotterdam (RDM Campus, 2011)

The example of the Rijnhaven, one of the ports that are designated for floating urban functions shows how a phased development process could look like. Floating urbanization has started with the realization of the Floating Pavilion, a floating exhibition and conference centre that is currently used by the National Water Centre as the main showcase of the Dutch water expertise. The Rijnhavenpark, a concept for floating public space combined with a wide range of urban functions was developed during the past years. The concept includes functions such as: green space, hotel, restaurant, flexible office space, theatre and stage, and many other functions. The Rijnhaven project is a first step to develop a portfolio of different urban functions on the water that are all needed to develop a comprehensive floating city that is more than a collection of buildings. Instead it would also include public space, public functions and infrastructure. One of the key characteristics of the concept is the flexibility, it is possible to add or expand certain functions following changing societal requirements and boundary conditions.

Figure 3.13:
Rijnhavenpark in Rotterdam, one of the many possible configurations of this flexible floating urban growth model (Stichting Rijnhavenpark/DeltaSync, 2011)

Figure 3.14:
One of the many possible public functions in the Rijnhavenpark (Stichting Rijnhavenpark/DeltaSync, 2011)

Other delta cities
Next to Rotterdam, other developed port cities such as the port of London, New York/ New Jersey and New Orleans face similar challenges with regard to the revitalization of old port areas. Some of these ports, such as the city of New York have already

expressed interest in the floating urbanization strategy. It is therefore likely that the old port areas will be the first location of floating districts. In San Francisco, the Seasteading Institute is working on the development of floating cities for a new generation of pioneers to test their ideas on government. In Japan, the Shimizu corporation has developed a concept for self supporting floating islands with high rise skyscrapers. The islands could together form a nation of a million inhabitants. Delta cities that are rapidly expanding in vulnerable flood plains such as Jakarta, Manila and Ho Chi Minh City could also benefit from floating cities as a strategy to preserve agricultural land, provide affordable housing and reduce flood risk. A good opportunity for cooperation and exchanging knowledge on floating urbanization is Connecting Delta Cities (CDC). The goal of Connecting Delta Cities is to develop a network of delta cities that are active in the field of climate change related spatial development, water management, and adaptation, in order to exchange knowledge on climate adaptation and share best practices that can support cities in developing their adaptation strategies.

Figure 3.15:
Floating city design with skyscrapers, Japan (Shimizu Corporation)

3.8 A people's perspective

Do people want to live on the water? Even if creating floating cities might make sense from a city's perspective, it still would not work if people would not want to live there. It seems that people are quite interested to live on the water. Historically, there are various examples of floating houses including Lake Titicaca in Peru, a floating village in China and the traditional houseboats in Amsterdam. More recently a market survey by USP marketing consultancy indicated that in the Netherlands 30% of the people considers living in a floating house a 'serious option'.[51]

Even in the current housing crisis in the Netherlands, the floating housing market has declined less than the market for ordinary houses. Living on the water offers also many possibilities for water recreation and offers a sense of freedom to the inhabitants. More importantly, floating urbanization also creates the opportunity for citizens to be actively involved in the water supply, energy production and food production of their city. This will increase their independency. In land based cities, citizens face great difficulty to contribute to sustainable development. It is obligatory to connect to fossil fuel networks and people have to go to the supermarket to buy food. Current cities are built in such a way that for a significant part of the population there is no other option than to use the car to go to work. Even if people want to behave in a sustainable way, our current parasitic cities do not provide the enabling context to do this. In a floating city, people can be much more involved in energy production and water supply. They can use water based electrical boats to go to their work. They do not have to feel guilty that they live in a parasitic city. On the contrary, the floating city has positive impact on the land based city and the ecosystems.

Also living on the water offers many possibilities for a flexible living style. The location and the house can be sold separately. In a floating city, it is possible for citizens to move with their house to a new city or new location within the same city, for instance if they have found a new job. Alternatively, it is possible to stay at the same location, sell their house and buy a larger house for the same location, for instance if their family expands. Floating urbanization therefore offers a much more dynamic lifestyle that is probably attractive to many citizens.

Figure 3.16:
In floating cities people can move with their house to another location. Utilities can be integrated in infrastructure (DeltaSync/SEV, 2008)

04. Conclusion

"If at first an idea isn't absurd, there's no hope for it."

– Albert Einstein

It is expected that until 2100 a total of 5 billion people will move to cities. Per day this means a 150,000 people start to live in a city. In the same period, resources such as fossil fuels, fresh water resources, phosphates and fertile topsoil are running out. This unprecedented urbanization process will convert a large part of the fertile croplands in urban areas. At the same time the food demand from this shrinking productive area will double due to population increase and rising living standards. Most of the urbanization will take place in vulnerable delta areas. Global flood damage will increase from a current 20 billion US$ per year to 50 billion US$ a year on average in 2100. To create a perspective to deal with this huge challenge in the 21st century, two things are needed. First, the current parasite cities need to transform from parasitic and vulnerable cities into productive and resilient cities. Transforming the existing cities, however, will not be enough to deal with the challenges the world is facing. The second component of the strategy therefore means that a part of the cities and food production should be located on the sea to create more space. Floating cities should be surrounded with floating food production to use the waste nutrients and CO_2 from land based cities. The crops, fish and biofuels that are produced will be partly supplied back to the land based cities and consequently close the nutrient and carbon cycles at a city level all over the world. This adaptive urban development will create a symbiosis between cities on land and water in the 21st century.

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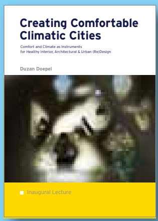

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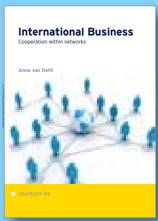

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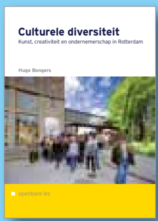

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