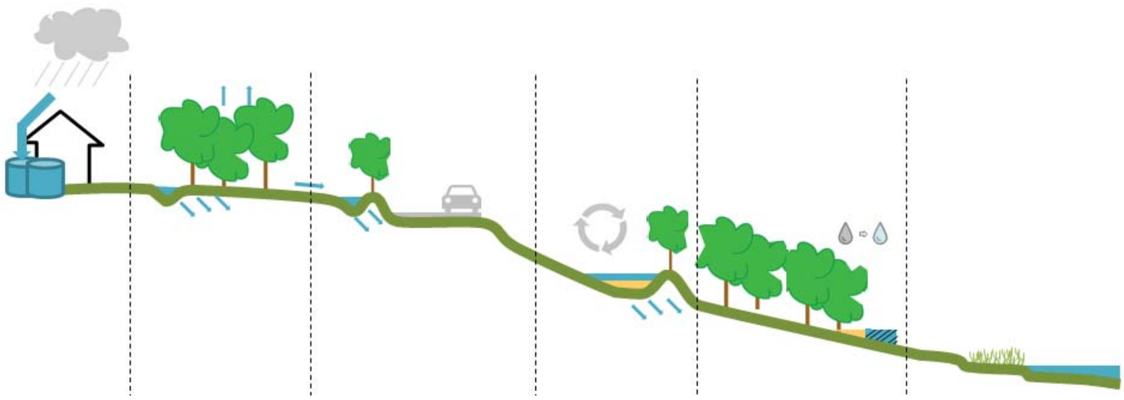
Draft landscape-based stormwater management strategies for the Jemo and Mbezi River catchments

Water Resilient Green Cities in Africa



Report 2
Work Package 2

Prepared by
Ole Fryd, Antje Backhaus and Lise Herslund (lead authors)

in collaboration with
Dagnachew Adugna, Alazar Assefa, Marina Bergen Jensen, Given Justin, Patience Mguni, Simon Mpyanga, Abraham Workneh and Kumelachew Yeshitela (contributing authors).

Chapter 1 Introduction

Water is the source of life. Water is a necessity for plants to grow, for animals to thrive and for humans to survive. The abundance of water causes flooding and erosion. The absence of water leads to water stress, withering of plants and wildfires. This research aims to combat floods and water stress in cities by embracing water as a necessity for life. Specifically, the study explores the potential of using vegetated urban green spaces as a system of 'sponges' that can collect, retain and balance out water resources in the city across different seasons of the year.

Adaptation to climate change with more intense rainfalls and longer periods of drought has made resilience an important policy issue for cities (Evans, 2011; Bulkeley et al., 2014). This is more so in urban Africa, where increased floods and water shortages are also seen simultaneously as consequences of existing patterns urban development on one hand and obstacles of new city development on the other (McDonald et al., 2014). Addis Ababa and Dar es Salaam are examples of this.

In both cities there is a potential for improved water resilience in terms of flood protection and water supply augmentation if sufficient detention volumes are provided in the urban landscape by linking urban water systems to green infrastructure (GI) (Backhaus et al., 2015, Fryd et al., 2012). However, green areas are diminishing fast in both cities and vegetated surfaces are increasingly being sealed by rapidly growing built-up areas (Lindley et al., 2015; Yeshitela et al., 2015; Mng'ong'o, 2004). The challenge is how to establish a strong GI for increased water resilience in cities where the urbanization process is poorly managed and the institutional capacity for securing green spaces is weak (Jha et al., 2011; Herslund et al., 2015).

In both Dar es Salaam and Addis Ababa there is a discrepancy between formal land use as outlined in the master plans and the actual diversity and layering of uses taking place on the ground (Jørgensen et al., 2014). The continued encroachment of green spaces is not only a result of limited enforcement but also because the plans cannot keep up with the pace of urbanization – they are outdated before they are approved. Most plans are based on a rationalist, top-down approach and therefore also lack practical guidelines and actual projects on how to incorporate water resilience and strengthen GI in urban farmland and residential areas (Herslund et al., forthcoming).

To overcome such problems authors in climate change adaptation, GI and water resilience fields highlight the need for viewing urban governance from an ecological perspective and taking up a more 'experimental approach' instead and beginning to value (Evans, 2011; Backhaus and Fryd, 2012). Such an adaptive approach to urban governance ideally acknowledges the 'unpredictable and unplannable' nature of cities (Evans, 2011). As such, emphasis within urban governance shifts from total control of the urbanization process towards seeking out 'room for innovation' and adaptive learning (Ahern et al., 2014) as a way to enhance innovation and meaningful implementation.

Robust planning for GI partly depends on the awareness and the valuation of the ecosystem services provided by GI, by both city offices and the local communities (Schäffler & Swilling, 2013). To enable this robust planning, Castán Broto and Bulkeley (2013) suggest 'experiments' as a planning and governance tool to reach actors and institutions outside the formalized system and Herslund et al. (2015) propose local projects on adaptation in vulnerable areas to strengthen relations between the official city and local communities as well as building up networks between different official sectors and NGOs. As such, a key issue in planning for resilience to floods and indeed for a more enhanced GI in developing cities like Addis Ababa and Dar es Salaam is the meaningful participation of local communities and co-management of green spaces and flood risk (Sultana & Thompson, 2013) thus supporting a more bottom-up approach to planning and governance.

The purpose of this project 'Water Resilient Green Cities in Africa' is to experiment with water resilience in the urban green spaces of Dar es Salaam and Addis Ababa by seeking out opportunities for the implementation of Landscape-Based Stormwater Management (LSM). Together with stakeholders and university partners, the project seeks to develop relevant catchment plans and 1:1 demonstrations on how water shortage and flooding problems may be addressed using the GI-based approach of LSM in the two cities.

This report provides a mid-way review of maps and knowledge generated in the two case catchments of Jemo in Addis Ababa and Mbezi in Dar es Salaam and initial drafts for catchment plans and strategies that can serve as a knowledge base and a framework for activities to be implemented during the remaining years of the project. In Chapter Two of this report, the respective catchments are delineated and their physical characteristics described, with future development trends and flood prone areas highlighted. Urban agriculture and rainwater harvesting as are some of the best practices that are found to be taking place within the catchments which could be researched more, and possibly upscaled.

Chapter Three gives an introduction to a participatory method used for local experimentation and plan making within the WGA project; 'the design charrette' and the results from it being tried out in a local condominium housing area in the Jemo catchment in Addis Ababa. The design charrette is a multiple-day; intensive collaborative planning and design workshop held on-site that provides a forum for the inclusion of all affected stakeholders in the making of a vision and plan for the development of an area (Kegler 2008). Although the 'design charrette' is an approach developed and widely used the Global north, the WGA project team pioneers its use in Addis Ababa, adapting it to the local context with informative results.

Finally, Chapter Four puts forward the resultant draft catchment management strategies for the Jemo and Mbezi catchments based on the synthesis of the information found in Chapters Two and Three. The two strategies highlight the possible interventions in the catchments based on LSM which could be pursued to enhance the water resilience of Addis Ababa and Dar es Salaam. For the Jemo catchment in Addis Ababa, a layered retrofit strategy is recommended based on the 'greening' of the different land-uses currently, and likely to be, in the catchment. For the Mbezi catchment in Dar es Salaam, a more multi-scalar 'urban densification and treatment train' approach is recommended, privileging the implementation of different LSM elements at different scales i.e. at building level, land parcel level, settlement level, river valley and tributary levels within the catchment.

Chapter 2 Physical analysis of the two case catchments

The purpose of this chapter is to provide a mid-way review of the maps and ideas identified and developed for Addis Ababa and Dar es Salaam during the first two years of Water Resilient Green Cities in Africa (WGA) and share this knowledge across the teams from Addis Ababa, Dar es Salaam and Copenhagen. Emphasis is on knowledge related to the two case catchments along Jemo River in Addis Ababa and Mbezi River in Dar es Salaam. This chapter aims to summarise the existing knowledge deriving from maps and preceding catchment analyses and establish a synthesis of physical key characteristics in the two river catchments that can serve as a knowledge base and a framework for developing activities to be implemented during the remaining two years of the project.

2.1. Methodology

This study comprises a review of maps produced during the first two years of the project, ground truthing through transect walks along the two river catchments in September-November 2015, and through discussions with project researchers in Addis Ababa and Dar es Salaam.

The review comprises maps of Addis Ababa and Dar es Salaam produced and/or presented by WGA project members (i.e. PhD students, city researchers and directors) between 1 September 2013 and 1 October 2015, maps identified through targeted internet searches (using search words such as "Dar es Salaam" and "power lines"), and additional relevant maps that have been made available to the researchers in Addis Ababa and Dar es Salaam, but which have not been shared with the broader WGA group. All 1614 files in the WGA project folder on the University of Copenhagen's server were reviewed along with the 582 files that have been uploaded to the shared WGA project folder in the Dropbox. Files included e.g. Word documents, PowerPoint presentations, PDF files of reports, theses and research papers, image files, and georeferenced datasets for ArcGIS. Among the documents were maps presented in previous project reports (Backhaus et al., 2015; Kombe et al., 2015; Yeshitela et al, 2015) and at project conferences, workshops or seminars.

All available maps were compiled in Illustrator CS6, a graphic design software. Each map was given a separate layer, a descriptive name along with a source indication and saved to the Illustrator file. When necessary, the maps were rescaled, rotated and stretched so that they could be overlaid, superimposed and compared despite differences in file formats, coordinate systems, projections or the like. A single Illustrator file compiling all maps was developed for each of the two cities. A total of 49 layers were included in the file for Addis Ababa. 87 layers were compiled in the file for Dar es Salaam.

The maps presented multiple source of information. By overlaying and superimposing information across layers and themes (for example, by changing transparency options across several layers in Illustrator CS6), the accuracy of data was scrutinised and the mapping of e.g. catchment delineation, location of tributaries, land use and building density was subject to reflection, reasoning and appropriation by Ole Fryd, who was core responsible for the review. Draft versions of the Illustrator files were made available to all project researchers through the Dropbox with a view to enhance transparency and discussion at the stage of data analysis.

Three meetings were conducted with the team members in the two cities either through conventional meetings or virtually via Skype. Core team members in Addis Ababa included Abraham Workneh , Alazar Assefa, Dagnachew Adugna and Dr Kumelachew Yeshitela. Core team members in Dar es Salaam included Given Justin and Simon Mpyanga. At the first meeting the collated baseline information was presented to the core researchers from each city. The content was discussed and additional maps that seemed to be lacking were requested and sourced among local partners. The first meeting also included an initial brainstorming of ideas for the catchment strategy. An elaborated and consolidated compilation of maps was presented at the second meeting. Further, suggested key elements for the catchment strategy were presented and discussed. The third meeting served to consolidate ideas and reach an initial level of consensus about contents to be included in the draft catchment strategy. See Chapter 4 for details about the catchment strategies.

Transect walks were conducted along the full length of the two river catchments. The transect walk along Mbezi River was conducted by Ole Fryd on 14 September 2015 (downstream from the Indian Ocean to Goba Kibululu, 13 km), 15 September 2015 (midstream from Goba Kibululu to Mbezi Luis at Morogoro Road, 12 km) and 19 September 2015 (upstream from Mbezi Luis at Morogoro Road to the source of the river by La Pentecoste Church in Kibamba, 11 km). The transect walk along Jemo River was conducted by Abraham Workneh, Alazar Assefa, Dr Kumelachew Yeshitela and Ole Fryd on 22 October 2015 (upstream from Alem Bank to the source of Jemo River in the Oromiya region and back, 10 km), by Dr Kumelachew Yeshitela and Ole Fryd on 23 October 2015 (midstream from Alem Bank to Ayer Tena, 7 km) and by Ole Fryd on 28 November 2015 (downstream from Ayer Tena to Nefassilk Lafto, 9 km). Photos were taken at even intervals of 5 minutes along all transect walks. The walks were monitored on Google Maps via iPhone (3G connection) and traced manually by drawing the walk in Google Earth upon return from the field. The transect walks were included as a separate layer in the Illustrator file for each city.

2.2. Findings

Findings regarding the catchment delineation, the physical characteristics at present, the development trends and the potential synergies are outlined below. Findings from the Jemo River catchment in Addis Ababa are presented first, followed by a similar presentation of findings from the Mbezi River catchment in Dar es Salaam.

Catchment delineation

The Jemo River catchment follows a 15 km stretch of the main river course and covers approximately 16 km^2. See Figure 1a. The catchment extends from the rural Oromiya region in the Northwest (approximate coordinates 9^{o}00’28” N; 38^{o}38’25” E) to the Southeast through the areas of Alem Bank, Ayer Tena, Repi Hill, the Jemo condominium site to the merging of Jemo River with the Harbu River by Nefassilk Lafto (approximate coordinates 8^{o}57’20” N; 38^{o}43’35” E). The highest point is located about 2900 meters above sea level. The lowest point is 2222 meters above sea level.

The Mbezi River catchment follows a 28 km stretch of the main river course and covers approximately 52 km^2. See Figure 1b. The catchment extends from the semi-rural Kibamba district to the Southwest (approximate coordinates 6^{o}48’50” N; 39^{o}05’00” E) to the East through the areas of

Mbezi Luis, Goba and Kawe to the river's discharge into the Indian Ocean (approximate coordinates 6°43'30" N; 39°14'05" E). The highest point is located about 230 meters above sea level. The lowest point is at sea level by the discharge point into the Ocean.

Figure 1. Delineation of the Jemo River catchment in Addis Ababa (top) and the Mbezi River catchment in Dar es Salaam (bottom). Sources for the Jemo catchment: DEM terrain analyses conducted by the Addis Ababa team, four different waterway maps, two topographical maps and three different orthographic photos. Sources for the Mbezi River catchment: Three DEM terrain analysis conducted independently by the Dar team, Given and Thomas Bergstrøm (KU), catchment delineations by COWI (2013), two topographical maps and one orthophoto. Illustrations by Ole Fryd. Orthophotos © Google Earth.

Physical characteristics

Jemo River catchment is characterised by high and steep hills in the rural upstream part of the catchment (covering approximately 22% of the total catchment area), Repi Hill as a geographical landmark located mid-stream in the catchment and the flatter historical wetland areas south of Repi Hill. See Figure 2a. The upper soil layers are dominated by clay soil throughout the urbanised area. Clay loam is predominant on Repi Hill and the soil layer on the steep hills upstream is categorised as thin or absent. The main river course is located centrally in the catchment generally creating a Vshaped terrain profile. The river cuts through the central part of the catchment as a deep gorge at Alem Bank and Repi Hill. The building density is relatively high with an estimated average runoff coefficient of approximately 0.50 in the urban part of the catchment (according to estimate by Dagnachew Adugna). The predominant land use type is residential which takes up 46% of the catchment area (estimate by Dagnachew Adugna based on land use map), while the remaining major land uses are categorised as rural land in the Oromiya region (23%), multifunctional forest (13%), road network (5%) and river buffer (5%). Generally, newer residential developments are located to the North of Jemo River, whereas older residential developments are located to the South of the river. The river and its major tributaries provide the core blue and green corridors in the catchment. Green patches are generally sparse, dispersed and under pressure by urban land use change. Wetlands have been encroached upon to provide land for residential development. A large quarry site and the major landfill site in Addis Ababa are located in the catchment immediately next to major waterways.

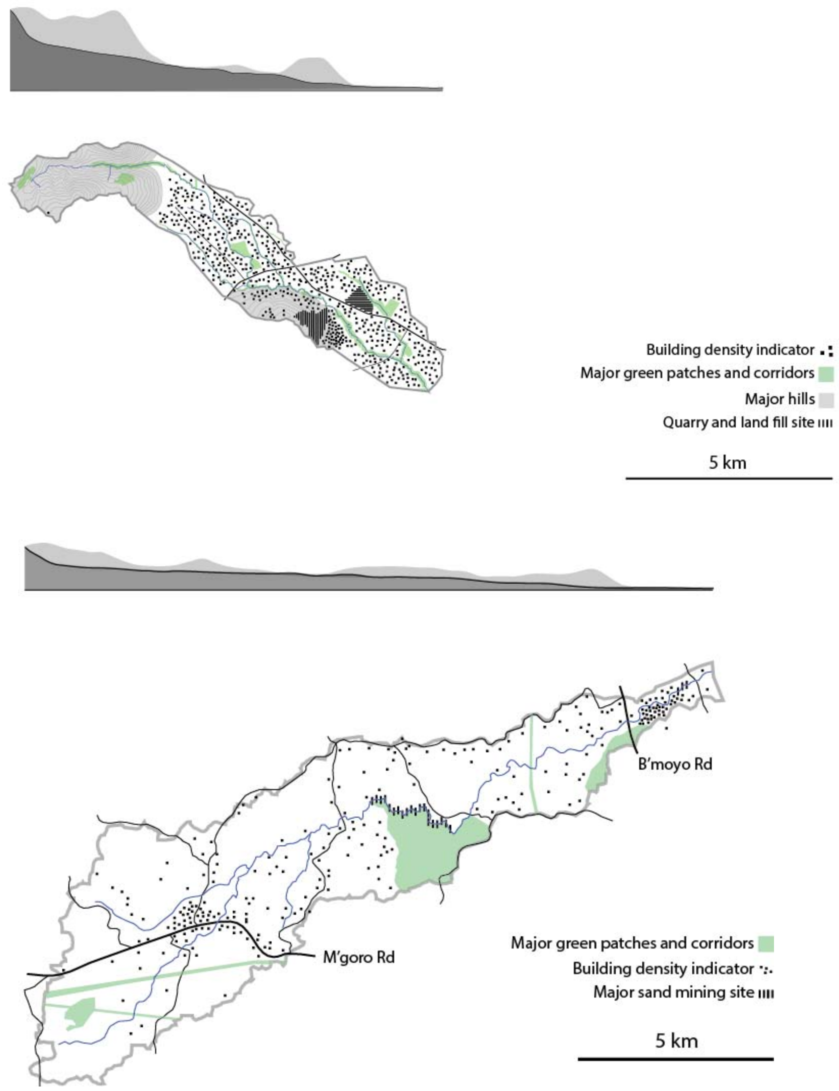


Figure 2. Key characteristics of the Jemo River catchment (left) and the Mbezi River catchment (right) with conceptual longitunal sketch drawings along the main river course (top, not to scale, dark grey line reflects the main section, light grey indicates hills in the background) and plan drawings (bottom). Maps are extracted from data in the multi-layered Illustrator files for the two catchments and include land use maps, road maps, topographical maps and aerial photos among other maps. Note that the building density indicators are indicative only. Illustrations by Ole Fryd.

The Mbezi River catchment is characterised by undulating hills that take up more that 90% of the catchment (from Kibamba to western Kawe), steep hillsides immediately West of New Bagamoyo Road, and a flat and low-lying coastal area in eastern Kawe between New Bagamoyo Road and the Indian Ocean. See Figure 2b. The predominant soil type is clay-bound sand and gravel. The coastal area to the East of New Bagamoyo Road has sandy soil. The main river course is located centrally in the catchment generally creating a U-shaped terrain profile. The catchment is characterised by relatively low-dense dispersed residential development with free-standing houses in an open landscape. Higher building densities occur along main roads and around the sub-centres of Mbezi Luis and Kimera. The low-lying downstream part of the catchment comprises high-dense informal housing, some of which have been legalised. Major roads are predominantly located on high grounds along the ridge of hills. The location of roads intersects with the boundary of the catchment to the North and to some extent also to the South and West. A military forest reserve located mid-stream in Kimera forms the largest green patch in the catchment. Three power transmission lines, the river and the major tributaries provide the major coherent blue and green corridors that are free from development. Sand mining (that is, the removal of sediments directly from the river bed mostly for the purpose of cement brick production) is an issue in the catchment, in particular in the eastern part of Goba and to a lesser extent in Kawe. Soil erosion is a critical issue along the river, in particular around Mbezi Luis and Kawe. Local valleys along tributaries are small scale fractals of the catchment as a whole with less developed open land in the upper part of the basin and higher building densities and more intensive erosion in the lower part of the basin close to the main river.

Flood prone areas

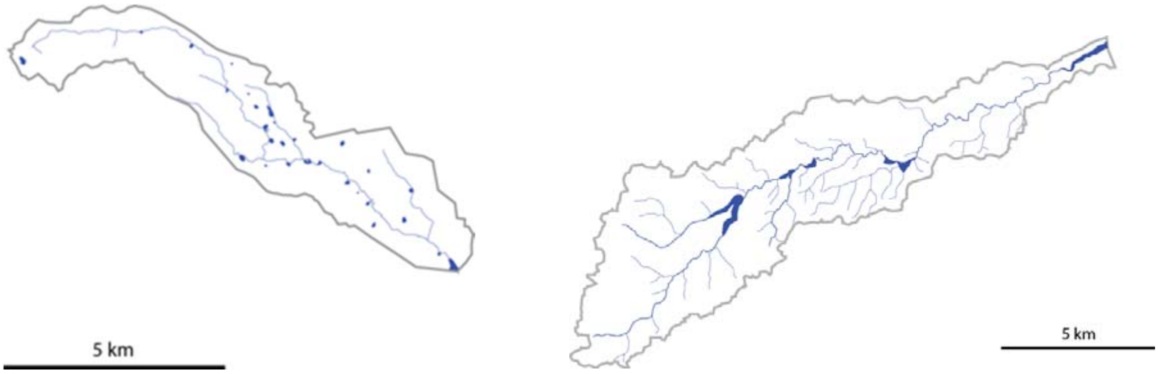


Figure 3. Map of the Jemo River catchment (left) and Mbezi River catchment (right) with the main course of the river, location of tributaries and areas prone to pluvial flooding. The map for the Jemo River catchment is based on eight river maps, four terrain maps, two aerial photos, one wetness map and two blue spot maps developed by the Addis Ababa team. The map for Dar es Salaam is based on 18 river maps, eight terrain maps, three aerial photos, one wetness map, observations in the field and local narratives about flooding around bridges. Illustrations by Ole Fryd.

In both the Jemo River catchment and the Mbezi River catchment the risk of flooding is highest along the banks of the main river, where larger tributaries merge with the main river or where river flows are restricted by road bridges or other physical obstacles. See Figure 3. In the Jemo catchment, the specific locations for river swelling and flooding are around Ayer Tena and by the wetland area in the southern tip of the catchment. In the Mbezi catchment, the highest flood risk is in the river valley near Luis and Kibululu, and close to the river mouth in Kawe.

Development trends

Figure 4 depicts the future development trend for the two catchments. In the Jemo River catchment, a new ring road is planned to pass through the northern part of the catchment. The construction of the ring road will lead to demolition of some of the older residential areas in the North. Ongoing urbanisation puts pressure on the existing green spaces with potential further encroachment on river buffer zones and currently undeveloped land including low-lying wetlands. Some development is expected to expand uphill on Repi Hill and possibly also in the hills upstream in Oromiya. Massive development on the steep hill sides of Oromiya is not expected, as areas to the east and south-east of Addis Ababa are flatter and hence easier, cheaper and safer to develop compared with the hills to the west and north of Addis Ababa. The Oromiya Region is a different jurisdiction to the City of Addis Ababa which might impede the magnitude and pace of development outside the city boundary. The city administration attempts to maintain and promote buffer zones along urban waterways. This provides an opportunity for coherent blue and green corridors in the city, should the city administration and the decision makers succeed in implementing and enforcing this policy. Condominium housing estates are continuously planned and constructed throughout the city. Ongoing experiments emerging from this study can potentially lead to important pilots that can be implemented, monitored, assessed, standardised and scaled up. One such example is the collaboration and solutions developed though the design charrette in the Jemo Condominium site (see Chapter 3).

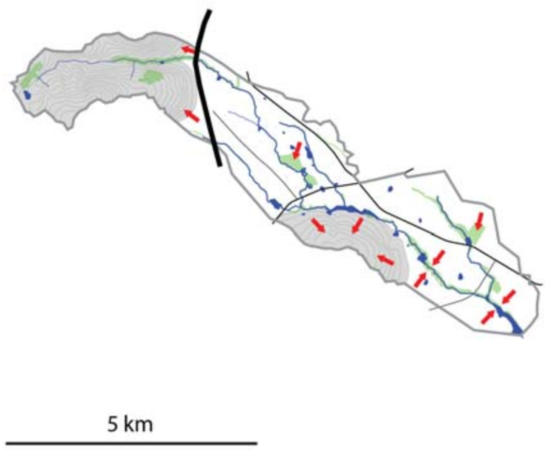
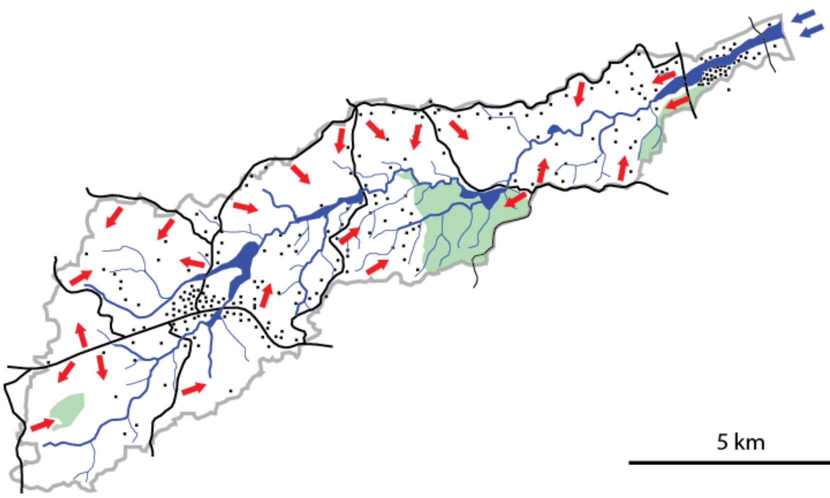


Figure 4. Maps of the current development trends in the two catchments. In the Jemo River catchment (left), a new ring road (bold black stroke) is planned to pass through the catchment. The red arrows indicate the direction of the development pressure. In the Mbezi River catchment (right) roads are being upgraded. The development pressure is indicated by the red arrows. Further, global sea level rise might exaggerate the flood risk issue in the coastal zone which is indicated by the blue arrows. Illustrations by Ole Fryd.



In the Mbezi River catchment, roads are being widened and paved to provide an upgraded and finer grained road network. This is expected to lead to increased development. Most development is expected to occur in proximity to the main roads on the hilltops, and then gradually development will expand downhill towards the valleys. Highest growth rates are occurring and expected in the less developed Northern and Western parts of the catchment around Goba and Mbezi Luis and increasingly also in Kibamba. The development puts pressure on the remaining open green spaces and will further increase peak flows in the waterways, which will aggravate the flood risk and the scale of erosion downstream in the catchment. The widening of tributaries due to increased and more intensive peak flows resulting from urbanisation and land clearance has already been observed in the catchment. Many houses located on the river banks have collapsed and been “washed away” because of soil erosion, river widening and/or flood incidents. This issue is most critical in the downstream Kawe area, but occurs throughout the catchment. House owners are currently protecting their properties by different erosion control measures such as planting bamboo along the river banks, stacking sand bags, car tires and rock gabions around their land parcel, or constructing solid retaining walls in reinforced concrete as a means to protect their house. These interventions might help protecting the individual plot but will also exaggerate the impact of erosion and flooding elsewhere in the river system. This leads to a misalignment between individual and collective benefits and costs. Sand mining is expected to remain as a business activity in the catchment. Locally, sand mining is considered to be a social and economic issue rather than an environmental challenge (according to Given Justin’s talks with local stakeholders). To stop sand mining other employment opportunities should be available and there should be a shared commitment in the community and at the different levels of government to terminate sand mining activities. Alternatively sustainable sand mining practices should be adopted. Technical solutions for more sustainable sediment trapping and removal are available and can be pursued (See e.g. Environment Agency, 2010).

Best practices

A series of local good practices observed in the catchment serve as a source of inspiration for potential future research, application and upscaling.

Best practices observed in the Jemo River catchment include urban agriculture along river banks where water is available and seasonal flooding is tolerated. Plots of urban agriculture are partly managed by local farmers who have established their plots over a longer period of time or increasingly also by government driven allocation of farming plots to unemployed inhabitants The lack of experience by some users has been observed to lead to mismanagement of land along river banks. Water supply from mains is either infrequent or not available to the households. Consequently, many mid-range developments have water tanks installed to collect water when water is available from the mains and store it for future use in the household when needed. Lower-income communities generally rely on the supply of water from communal taps, which is carried to the households in Jerry cans. This shows the effort and logistics that goes into water management in these neighbourhoods. On sloping residential streets the flow of stormwater runoff is sometimes diverted to the street edge by simple ‘road bumps’ located perpendicular to the main flow direction. The condominium sites have semi-autonomous committees that are responsible for a range of social, economic and environmental activities at the condominium site, yet their ability to steer the condominium management is different in each section. This potentially eases the option of selforganisation at the community level. The city administration of Addis Ababa seems to acknowledge the value of street trees, open green spaces and green corridors in the planning and design of the city. The local administrations at ward and sub-ward level provide plants to local communities e.g. for the greening of the open spaces such as condominium backyards and along street. The commitment to landscape based solutions is also reflected in Ethiopia's Climate Resilient Green Economy strategy (FDR of Ethiopia, 2011).

Best practices in the Mbezi River catchment include urban agriculture along river banks where water is available and seasonal flooding is tolerated. Two land owners in the catchment (i.e. Mr. Kabelwa and Mr. Mapunda) have implemented rather sophisticated examples of landscape based stormwater management. The precedents include a self-sufficient water collection and management system at the household level; terraced orchards with ditches intercepting and infiltrating water to increasing soil moisture and improve growth conditions for the fruit trees; ponds located upstream in local valleys that collect surface water runoff, reduce or eliminate peak flows, retain water for irrigation, laundry and other purposes through the dry season, increase soil moisture and greenness in downstream plots and provide a recreational destination point in an otherwise homogeneous and generic residential neighbourhood. Water supply is either infrequent or absent, which makes residents rely on storage tanks that are filled with water from the roof, from water trucks or from water mains depending on the options and budget available to the household. Goba Secondary School, located just outside of the Mbezi River catchment, provides another precedent for stormwater harvesting and soil stabilisation control through the planting of elephant grass. See Figure 5.

Figure 5. Images of local best practices observed in and around the Mbezi River Catchment. Left: Mr. Kabelwa's pond located in a local valley where water is collected for use in an orchard. Right: Rainwater harvesting system at the Goba Secondary School. Photos by Given Justin.

Most coping strategies in the Mbezi River catchment seem to operate at the household level. However, the provision of infrastructure is frequently organised in clusters of five to twenty households. The so-called '10 Cells' form an informal entity responsible for the financing, construction and maintenance of local roads and energy supply. Specifically, this relates to the tenure arrangement and the management of shared private roads connecting the settlement to the public road infrastructure or connecting the cluster of households to the public energy grid. The 10 Cells might be a suitable scale to discuss green infrastructure development and specifically stormwater management beyond the household level as it directly relates to issues like physical infrastructure, accessibility, landscaping and property value.

2.3 Summary and recommendations

The Jemo River catchment is already densely built up though some urban transformation activities are expected to occur in the near future. The recommended approach to improved water resilience is to develop schemes for the different types of land uses, where roads, buildings and green areas are retrofitted according to the density, topography and water quality conditions. Further, landscape based water management is expected to help achieving green infrastructure development goals outlined in the urban master plan through better integration of blue and green infrastructures.

The Mbezi River catchment is generally urbanising ‘green field development’ with highest development rates in proximity to major transport arteries. Water resilience strategies can be developed and applied across spatial scales. Landscape based stormwater management practices for the new hill-top settlements would be beneficial, having the valley topography delineating the scale. It is anticipated that smaller scale pilots can be implemented and tested at site, neighbourhood and sub-catchment level and then be scaled up for wider application across the catchment and city levels. It needs to be stressed that pilot projects are recommended for both the Jemo River catchment and the Mbezi River catchment.

Chapter 3 Charrette - a method for bottom-up GI planning

Bottom -up planning approaches seem a relevant contribution to the existing top-down master planning in Addis Ababa and Dar es Salaam. Both cities have very different planning cultures with different efficiencies. However, the local empowerment of inhabitants to improve their own living conditions is relevant in both cities. As large classic grey water infrastructures are non-existing or managed inadequately, local green infrastructures seem to have a high potential as supplements to improve local live quality, solve some of the existing environmental problems and/or steer future potentially environmentally harmful developments.

In order to develop site-adapted designs of green infrastructure that are suitable for the existing conditions and manageable by the local communities, our research project uses the "design charrette" method, a participatory planning instrument. The design charrette is a multiple-day collaborative planning and design workshop held on site that is inclusive of all affected stakeholders. Developed and mostly used in the countries of the global north (Kegler, 2008), we are breaking new ground in trying to adapt this planning method to our local conditions in the study catchments in Addis Ababa and Dar es Salaam.

3.1. The Design Charrette Method

The Design Charrette is a planning workshop, happening at the site of the planned intervention and with a high transparency of all planning steps to the public. Usually, a charrette consists of three main phases (see figure 6) . The first one is the pre-charrette phase, used for the collection of information and material about the site. A one day pre- charrette with the public, e.g. in order to collect information about the local inhabitants problems and wishes, can be part of this preparation phase. The main charrette is a three to seven days lasting planning exercise at the site, containing informal and formal planning processes. Different planning methods, such as community walks, group discussions, document analysis and interviews, are combined and conducted with different stakeholders, such as the local inhabitants, political and administrative stakeholders, locals clubs and groups, schools etc. The charrette activities are generally always open to interested public that "drops by". However, the days are structured with "open house" events where the general public is actively invited to participate in debates, smaller group events where e.g. a women’s club is invited to come for discussion, or meetings with one or two important stakeholder e.g. from the local administration to discuss specific ideas and concepts. During the main charrette days, ideas and concepts are discussed, tested via models and in expert discussions and then presented for evaluation. Through this process, the final plan/concept/idea is emerging; based on a large consensus and tested by the experts. Spatial design experts such as urban planners and designers play a key role throughout the process. They do not merely keep record of the citizens’ wishes and intends, they moreover provide creative suggestions, professional corrections and they are also patient debaters and neutral listeners. There will be something like a step-by-step narrowing gap, mutual learning and joint exploring of “new grounds” (Kegler, 2008). Jointly with the whole community, problems and concerns are raised and discussed, visions are developed and tested and continuously feed into a new plan or design for the site (see figure 6). Such an endevour needs to be meticulously planned and prepared, but at the same time, all professional participants need to engage with the process and upcoming ideas without prejudice.

Figure 6. Illustration showing the different steps in the charrette process (source: http://creativityiseverywhere.net/?p=760)

A strong core team that facilitates the charrette process, can manage to welcome new guests and inform about the state of the process constantly, while at the same time other team members are transforming new ideas into spatial concepts and designs, test these concepts against expert knowledge and communicate to the public, media and administrative stakeholders. A core team should contain people of different competences such as:

1. Coordinator/ "Jazz conductor"
2. Moderator (not biased, not shy, independent, charismatic)
3. "Diplomat" contact to stakeholders
4. Charrette secretary (logistics, documentation, pictures, budget)
5. Innovative thinker /Engineer (expert knowledge on specific topics such as water quantification, erosion control, hydrology, local vegetation)
6. Innovative thinker, Architect (innovation skills, generalist with ability to synthesise multiple ideas and inputs)
7. Graphic designer/ Illustrator cartoonist

The main charrette days end with the presentation of the final plan to the public. Immediately followed by the third phase of the Charrette. Now the plan is refined and possibly detailed plans are worked out. The results are passed on to important stakeholders and on a post charrette day, plan implementation with a detailed step-by step working program for all stakeholders is agreed upon. Further information on the charrette method can be found here: http://www.charrettecenter.net

3.2. Example Jemo charrette

As the first participatory planning event of the WGA project, a design charrette at the Jemo condominium in Addis Ababa was conducted from the 26th to the 28th of June 2015. One block within the Jemo condominium site, consisting of 11 apartment houses and two community houses, was chosen for the charrette process. This site represents the typical development in Addis Ababa, where informal housing areas step by step are being replaced by condominium housing. Large land areas are developed into condominium sites, increasing the impervious ground cover of the city and thus contributing to flooding and erosion problems in the respective watersheds. At the same time, many condominium areas are served by insufficient water supply infrastructure and often have difficult social structures. The people living in the condominium apartments come from all areas of the city and from different social backgrounds. Thus there is no grown neighbourhood community and many inhabitants are not used to a live as flat owners. On the other hand, large green areas between the condominium houses provide space and potential for community use and green infrastructure development.

Specifically at the chosen site in the Jemo condominium different problems where identified during the charrette process:

- Insufficient water supply by public mains (long interruptions and too little water pressure to lift the water above the first floors)
- Flooding of public areas and partly ground floors during the rainy season
- Lack of safe space for the children to play
- Lack of sitting spaces for inhabitants and elderly in the open spaces
- Fast aging building structures due to inadequate maintenance and lack of finances
- Disagreement on individual land-use for gardening and farming on public areas

As the main stakeholders, all inhabitants, representatives from the development committee, representatives from the local administration (sub-ward/ ward level) as well as representatives from the city's planning and construction office were invited to take part in the three days charrette program.

The program consisted of different activities (see figure 7) such as a session for the listing of problems and issues at the site, a joint walk through the project site, the documentation of organisational issues, focus group discussions, an inspirational lecture, a children's arts competition and group discussions with models of the site. Over the course of the three day charrette a joint plan for the re-development of the site was developed and agreed upon (see figure 8).

Figure 7: Pictures from the charrette. Top left: alternative design solutions for the community space are drawn up for discussion. Top right: Walk through the site in order to identify problems. Bottom left: Group discussion with the model. Bottom right: Discussion in the womens' group. Photos: Antje Backhaus.

Figure 8: Map showing the proposed re-design of the condominium site. Developed during the design charrette. Map drawn by Alazar Assefa, two students and Antje Backhaus

The final maps shows the following re-organisation of the condominium site: The main street that crosses the area is closed off in the middle in order to give room for a joint community space only used by pedestrians for gatherings and children's play. For security reason, this middle area should be fenced off. Consequently the parking along the street is re-organized into two parking areas on the former street space. The large open green space in the west behind the buildings is re-organized into eleven plots for urban farming, so that each condominium house can individually organize urban farming and gardening activities. The yards between the houses are re-organized to give room for sitting places, flood control measures and stormwater harvesting tanks to be used for water supply.

Reflections of the first charrette

The experiences from our first charrette prove the instrument to be valuable for our purpose of facilitating a process where a plan for integrated LSM retrofits and green space development at the selected condominium site in Addis Ababa is co-developed and jointly agreed upon by a diverse group of residents, professionals and government stakeholders. This approach represents a kind of partnership between the local communities of the condominiums and the city administration. The drafted plan is currently (December 2015) being developed into more detail and supported by key stakeholders in the city administration. Hopefully the further process will bring the ideas of the plan into life.

As this was the first design charrette conducted by our research team and the first charrette in Addis Ababa, many difficulties occurred on the way. Problems with the task division in the core team, difficulties to invite and motivate the local participants as well as the invited stakeholders from the different administrative levels can be named as the most severe. However, flexible adjustments of the program and a strong commitment by the moderator led to a successful plan development.

The teething troubles will hopefully be reduced in the charrettes to come. The experiences from the first charrette give hope for the charrette process to help increasing the inhabitants feeling of ownership and responsibility for their own living environments and empower them to develop own small scale improvements that suite the local conditions. From the catchment point of view, similar measures as the ones planned for in the Jemo charrette, widely transformed to the other condominium blocks could substantially help to improve problems of flooding and water scarcity in the local area. The Jemo charrette results hereby serve as a source of inspiration to the cities planning office, which seeks to include ideas of water harvesting and flooding control into future housing schemes.

Chapter 4 Developing LSM strategies for the two case catchments

The thematic and theoretical backdrop introduced in Chapter 1, the review of maps and the physical analyses provided in Chapter 2 and the methodological reflections in Chapter 3 on charrettes as a means to facilitate integrated planning solutions formed the basis for the development of draft LSM strategies for the Jemo and Mbezi River catchments which were presented in a previous version of the WP2 Report 2 (see Fryd et al., 2016). The draft strategies comprised several sub-strategies which were discussed and presented at the WGA project conference in Dar es Salaam in January 2016. Feedback received during the project conference were collected and used to revise the initial strategies. Further, the second reports in the two other work packages of the WGA project (i.e. WP1 and WP2) were reviewed in early February to inform the catchment strategies and their sub-strategies.

Ole Fryd was key responsible for drafting the two initial catchment strategies during October-December 2015, but the task was a team effort. Core team members working on this task (i.e. Abraham Workneh, Alazar Assefa, Dagnachew Adugna and Dr Kumelachew Yeshitela in Addis Ababa, Given Justin and Simon Mpyanga in Dar es Salaam, Antje Backhaus, Lise Herslund and Marina Bergen Jensen in Copenhagen) provided invaluable contributions to the development of ideas, the discussion and appropriation of options, and the prioritisation of strategies and sub-strategies presented in this chapter. For details on the methodology see Section 2.1 of this report.

The strategies below are largely based on concepts developed during the preceding two years of the project. Many ideas have emerged in an organic process through observations and discussions with peers in the WGA teams, but the project has also facilitated a series of semi-structured activities to stimulate innovation. Notable contributions to the development concepts include the first impressions and early brainstorming of ideas presented by the team from Copenhagen University after their first visits to the Jemo and Mbezi River catchments. Other ideas were developed and elaborated in a workshop setting involving all WGA researchers during the first project conference in Dar es Salaam in January 2014. These early ideas include green belts along contour lines as a backbone for stormwater detention (idea led by Antje Backhaus and Marina Bergen Jensen), parks along rivers and wetlands parks (ideas led by Abraham Workneh and Dr Liberatus Mrema), road swale-trench system with for deep infiltration and water storage incorporated into the road construction (ideas led by Marina Bergen Jensen), identification of point source contamination and treatment in bioretention swales (ideas led by Marina Bergen Jensen), and rain tanks, infiltration trenches and multifunctional dry basins at the condominium sties (ideas led by Ole Fryd and Antje Backhaus). A second milestone in the development of concept was a PhD workshop held on the 3rd of Octoer 2014. Nine ideas were developed and critiqued during a semi-structured process involving all six PhD students and all members of the team from the University of Copenhagen. Five of the ideas were related to LSM 'technologies', whereas the remaining four ideas emphasised processes of knowledge development and implementation. The proposed technologies included multifunctional design and use of green spaces, road swale-dyke systems accommodating urban agriculture and solid waste management, the utliisation of cheap local materials including waste materials for the constrution of LSM measures such as rain tanks, the design of water storage ponds, and smart technologies like a phone app to warn about water incidents and provide guidance on the construction of LSM measures. The process oriented ideas included the combination of bottom-up and top-down planning initatives,collaboration with 'champions' on the development of city visions, engagement with existing users of urban green space to support their livelihood activities, and the utilisation of design charrettes to facilitate this multi-level and collaborative process.

4.1. Draft strategy for the Jemo River catchment

Chapter 2 summarised the Jemo River catchment to be densely built up at present and recommended a retrofit strategy where each LSM solution is designed to fit the local condition in terms of building density, topography and water quality. Further, the implementation of LSM measures is expected to help achieving green infrastructure development targets set out in the master plan for Addis Ababa. Infiltration is generally problematic in the catchment due to low soil permeability. To facilitate infiltration under this condition, one option is to work with deep gravel-filled trenches that cut across existing soil fractures and create better contact between water and soil.

A layered retrofit strategy is suggested for the Jemo River catchment. See Figure 9.

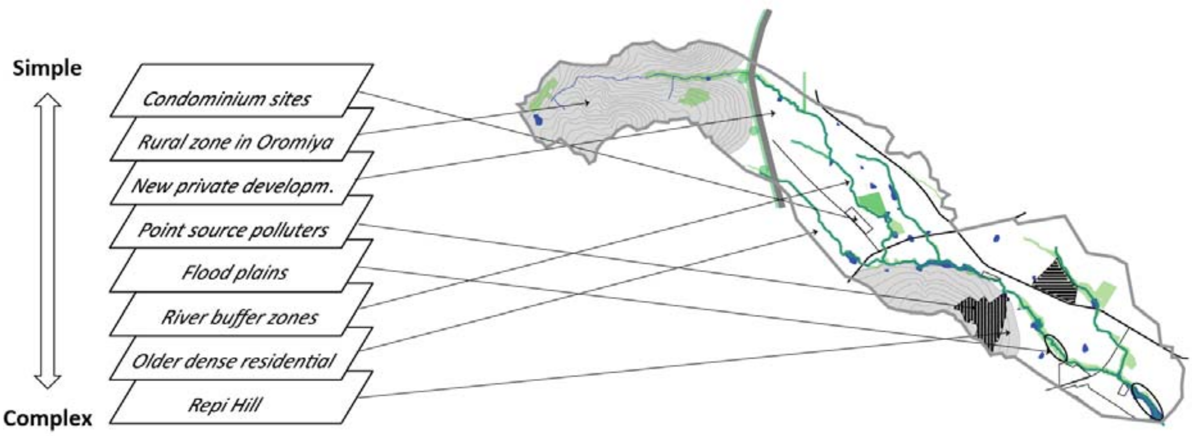


Figure 9. Layered retrofit approach for the Jemo River catchment. A set of sub-strategies are proposed for the catchment. Illustration by Ole Fryd.

The catchment strategy comprises eight sub-strategies. Some of the sub-strategies are expected to be relatively simple to implement due to a low level of technical and social complexity. Using the condominium sites as an example of a relatively simple sub-strategy, technical complexity is low due to the availability of land for LSM interventions and because the likely LSM measures have already been widely implemented internationally. Social complexity is low because of the relatively few stakeholders to consult to facilitate action on the ground and assumed relative cheapness of interventions in the condominium sites. Repi Hill is an example of a sub-strategy with a high level of technical and social complexity because of land scarcity, development pressure, steep slopes, multiple stakeholders with conflicting interests and the need for innovative LSM solutions that have not yet been developed or implemented elsewhere. The eight sub-strategies are outlined below.

Condominium sites. The implementation of LSM measures at the condominium sites is expected to be a relatively simple task. Following the design charrette process and the plan resulting from the charrette described in Chapter 3 the condominium sites provide options for on-site stormwater management that utilises the local open green spaces. LSM measures suggested during the charrette include visible and invisible solutions on the soil surface and below ground. Further, the charrette helped to facilitate a partnership between the city administration, the condominium committee and the broader group of residents which might pave the way for implementation. See Section 3.2 for details on the initial design charrette. A post-charrette consensus plan has been developed and has been presented to the City Administration of Addis Ababa. It is hoped that a full scale LSM pilot project can be implemented at the Jemo Condominium site in the near future. This is pending approval and support from the City government. Since the charrette in June 2015, PhD students Alazar Assefa and Dagnachew Adugna have further developed two different LSM plans for the case site. The proposals form part of their individual PhD studies. Alazar Assefa's proposal generally adopts 'green' landscape-based solutions on the ground surface whereas Dagnachew Adugna's proposal emphasises invisible underground water retention measures. From a research perspective the two contrasting approaches provide relevant design alternatives that can be compared and assessed for their strengths and weaknesses. Should funding be available for the full or partial implementation of the two proposals, they could be monitored over a longer period of time in terms of e.g. technical performance and user satisfaction which could lead to relevant research findings. This is expected to be beyond the scope of the funded WGA project and the individual PhD studies, but provides an interesting opportunity, should the necessary resources be made available to the project term.

Rural zone in Oromiya. The land furthest upstream in the Jemo River catchment is currently agricultural farmland with smaller forest patches. Some of cropland is on very steep slopes and soil erosion is an issue. Because of the steep hill slopes in this part of the catchment, urban land use change is expected to be minimal. Stormwater runoff volumes and flow rates are expected to remain largely the same as today, with the possibility of reducing peak flows by implementing better stormwater management practices in the future. In the regional development plan drafted by Dr Kumelachew Yeshitela and colleagues the land was allocated for an afforestation program. It is found reasonable to maintain the afforestation program as part of the catchment strategy. It is proposed to promote multifunctional forestry in this part of the catchment to support agroforestry, biodiversty promotion, soil stabilisation and recreational activities. Afforestation is particularly important in areas with very steep slopes that are subject to erosion. In combination with the afforestation program, the currently unsustainable cropping practices on hill slopes could be improved by adopting swale-dyke systems, which are currently being developed as part of Alazar Assefa's PhD project. See Figure 10.

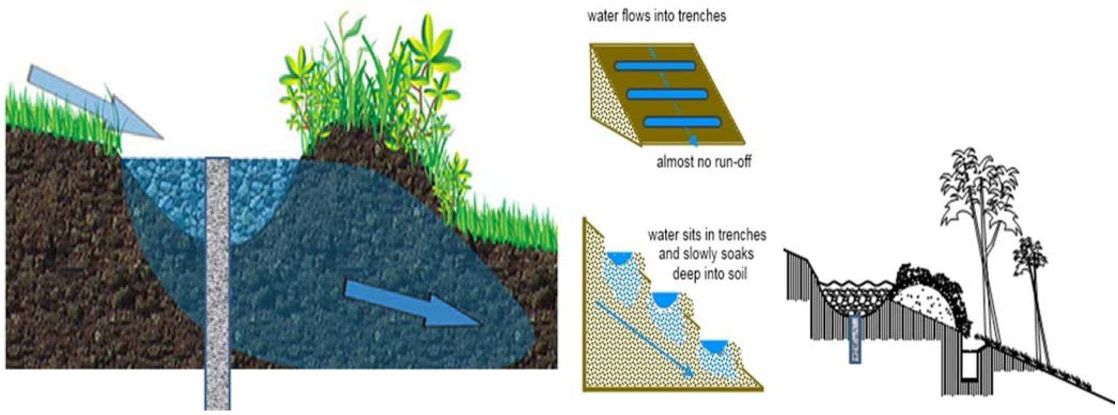


Figure 10. The Stormwater Interceptor Swale and Dyke (SISD) is one of several innovations being researched by Alazar Assefa as part of his PhD study. The concept was initially conceived by Marina Bergen Jensen and has been developed in collaboration with Alazar Assefa. The SISD might be one of the options for a terraced cropping system in the rural area in the Oromiya region or as interceptors on Repi Hill. Illustrations by Alazar and Marina Bergen Jensen.

New private residential development. Though most of the catchment is already densely built up, new private residential developments are still emerging, most notably around Alem Bank and in the southern part of Jemo. On site stormwater management practises can be promoted in these developments to mitigate negative impacts such as flooding and erosion downstream in the river system. Possible interventions include e.g. rainwater harvesting, use of harvested water for garden irrigation, rain gardens for temporary retention and infiltration of stormwater runoff at the land parcel level, and infiltration trenches for the percolation of water into the soil. The proposed LSM measures have been widely used internationally and are expected to be a fairly easy to implement in the Jemo River catchment in terms of technology. The challenge relates to awareness building, knowledge dissemination, training of consultants, contractors and property owners, and the development of policies to support the adoption of LSM measures in new developments.   What is needed as a start is an initiative to inform and support independent land holders who are in the process of developing a new property within the catchment. The measures and tools that could stimulate the process include e.g. the development of technical guidelines on selected LSM measures (such as rain tanks, rain gardens and infiltration trenches) and an economic cost-benefit calculator helps to estimate the payback time and return on investment. Some of these tools are available internationally, or example in the United Kingdom and in Australia, but will need to be adapted to fit the local context in Addis Ababa.

New ring road. The urban master plan suggests a new outer ring road along the eastern boundary of Addis Ababa's metropolitan area by the foot of the hills in the northern part of the catchment. The implementation of the ring road will partly be on currently undeveloped land, but will also lead to the demolition of existing residential areas. The development of the new ring road can serve as a model for integrated grey, green and blue infrastructure planning. The road can serve as an interceptor of excess stormwater runoff from upstream areas and thereby mitigate downstream flooding. As an interceptor and distributor of excess water, the ring road can double as a linkage between currently unconnected blue and green corridors – specifically the major northern and southern tributaries of Jemo River – which will densify the urban blue and green network, facilitate fauna passage and support meta-populations of amphibians and other species. Further, the management of road runoff is identified to be increasingly important internationally (see e.g. Hvitved-Jakobsen et al, 2010) and LSM measures are commonly applied for pollution control. The WGA project director Marina Bergen Jensen is one of the leading researchers on this topic internationally and this knowledge could be utilised to develop good practices for highway design and stormwater management in Ethiopia. Moreover, the potential design of the new ring road as a combined grey, green and blue corridor provides new design opportunities for the integration of pedestrian walkways, bicycle lanes and light rail systems along the road. This will reduced the risk of future urban transport lock-ins because of mono-modal car dependency, and is expected to provide better and more sustainable cities in the long run.

Point source polluters. The rivers in Addis Ababa can generally be categorised as open sewers with very poor water quality. As part of Dagnachew Adunga's PhD project, point sources of pollution in the catchment have been mapped out, samples of river water have been collected at various sites along the Jemo River, and the samples has been tested to study variations in the water quality across the dry and rainy season. The quality of river water seems to be strongly influenced by some key point sources of pollution. To mitigate the impacts of pollution, improved onsite water management and treatment options are recommended. Policies for this are already in place in Addis Ababa, but strong enforcement of these policies seems to be lacking. A wide range of onsite wastewater treatment systems are available on the market. Some options are relatively energy intensive. Others options have relatively large land requirement if seen in isolation from other land use activities and potential synergies. Importantly, the selected treatment option should be targeted the particular contaminant profile of the site. For details about wastewater management, see Laugesen et al. (2010). Point sources of pollution that should be targeted in the first place include the quarry site, the landfill site and the concrete pipe manufacturer between the quarry and the landfill. The key target is expected to be coarse sediment control and landfill leachate treatment. Point source pollution control is fairly easy from a technical point of view, but can be challenged by potentially conflicting social, economic and political interests.

Flood plains. To maintain a sound green infrastructure in the city and to meet some of the goals outlined in the urban master plan for Addis Ababa, the remaining flood plains and wetlands need to be protected from encroachment. It is anticipated that a more intensive programming and use of the flood plains can increase their resistance to encroachment. As part of the LSM catchment strategy, it is proposed to develop these areas into multifunctional flood plains that support urban agriculture, remnant wetlands, ecological connectivity and provide recreational desire paths and short cuts between neighbourhoods. Terrain modifications including the active levelling and grading of the terrain to accommodate different functions is expected to be a key feature. One example could be cropping systems on elevated dikes (reversed swales). The development of multifunctional flood plains is not easy. Some precedents are available locally and internationally, but more research is needed to address the technical, social and economic barriers. Liku Workalemahu's PhD project on this topic is critically important to understand the complexity of the task and to come up with integrated solutions that meet multiple criteria.

River buffer zones. The local government has decided to implement a general 50 meter buffer zone along waterways in Addis Ababa. The urban master plan reflects this initiative though the width of the buffer zone varies across the Jemo River catchment. Generally the width of the buffer zone increases with the width of the river and hence the buffer zone is widest in the downstream areas and narrower along the upstream tributaries. In practice, the implementation of the buffer zone is expected to be difficult as many places covered by dense residential settlements and as the river course provides a deep gorge in the urban landscape. Broadly speaking, the city turns its back on the waterways and there is little interaction between the river, the riverside and the urban context. Still, the river buffer zone is expected to be a critically important strategy to succeed with integrated blue and green infrastructure planning in Addis Ababa. For the buffer zone to be successful – to gain genuine support at the political level and among the general public (some of which are going to be relocated if the green buffer is implemented as planned) – the buffer zone needs to provide multiple benefits to the city as a whole It needs much brainstorming and through research to qualify the discussion on river buffers, but as a start the buffer zone is expected to serve as an ecological corridor and a flood zone, it needs to provide land for water retention and wastewater treatment (possibly linked to the point source polluters listed above), it should offer recreational space and hiking opportunities, and it should facilitate riverfront cafés and restaurants and maybe river baths some years down the track. Alazar Assefa's work on SISD can possibly be adapted to the context of river buffers. Dagnachew Adugna's research can provide design criteria for water treatment. Further there is a potential link to Justin Given's PhD research on in-line water treatment options, specifically the amended dual-porosity filter for the treatment of river water. PhD candidate Kalkidan Asnake, EiABC, focuses on river buffer zones in Addis Ababa in her research and there is a good opportunity for synergy between her research and research conducted by members of the WGA team.

Older dense residential areas. Existing older residential areas are characterised by a high building density, streets with cobblestone paving, and smaller gardens or courtyards. Some LSM measures can possibly be implemented at the land parcel level and the recommendations for new private developments listed above can be adjusted or replicated. However, due to the building density and land constraints in the older residential areas, most water management is expected to occur on and along local residential streets. This issue is addressed by Alazar Assefa in his PhD research. He suggests the implementation of combined road bumps and infiltration tree-pits. See Figure 11. The road bumps redirects the surface runoff from the often steep sloped streets to the infiltration pits which are located along the street edges as curb extensions. The infiltration pits can be vegetated and linked to street tree plantings. A range of design configurations exist internationally. The pits are equipped with deep gravel trenches to facilitate water percolation into the soil. It is a challenging research task that is expected to require much work due to much technical uncertainty, but the outcome would be a major contribution to the discussion on LSM.

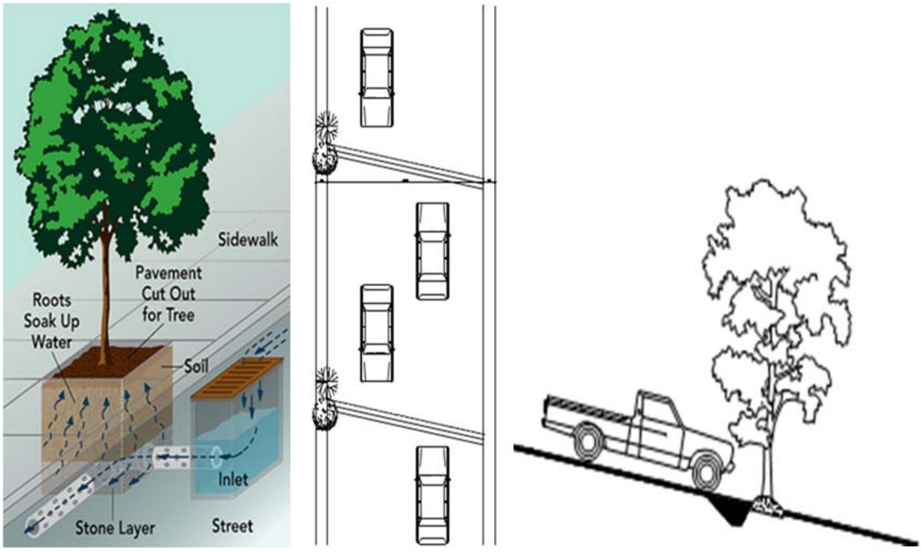


Figure 11. Concept for road bumpers and tree-pits for stormwater interception and inflitration along streets. The concept was initially conceived by Marina Bergen Jensen and has been developed in collaboration with Alazar Assefa. Illustrations by Alazar Assefa.

Repi Hill. Repi Hill represents a mini-transect of a watershed with the associated challenges and conflicts. The currently forested hilltop is challenged by urban land use change, the hill side and foothill are dominated by dense formal and informal settlements and the low-lying flood plain is gradually being filled up and covered with new buildings. Repi Hill is a particularly complex site because of the hill slope, the building density, the formal and informal activities, as well as a range of social and political issues. A design charrette is proposed for Repi Hill following the slogan: 'If you can make it here you can make it anywhere.' The LSM plan for Repi Hill is expected to include a combination of options listed above, such as the multifunctional afforestation program to mitigate soil erosion or reclaim the quarry site, on-site water management at residential plots, street bumpers and infiltration tree-pits along cobblestone covered streets, swale-dyke systems along contour lines to intercept water, as well as multifunctional flood plains and attractive river buffer zones. The charrette at Repi Hill will complement the first charrette at the Jemo Condominium site (described in Chapter 3) by a larger level of technical and social complexity. Further, it will help challenging, developing, appropriating and/or consolidating the draft ideas listed in this report.

4.2. Draft strategy for the Mbezi River catchment

Green field development along major transport arteries - from hill-tops towards the valleys - was identified to be a characteristic development trend in the Mbezi River catchment. Landscape based stormwater management practices for hill-top settlements were recommended.

The key concept for the Mbezi River catchment is a stormwater treatment train that spans across spatial scales from the building level to the river catchment level while targeting new green field developments in a densifying suburban landscape. See Figure 12.

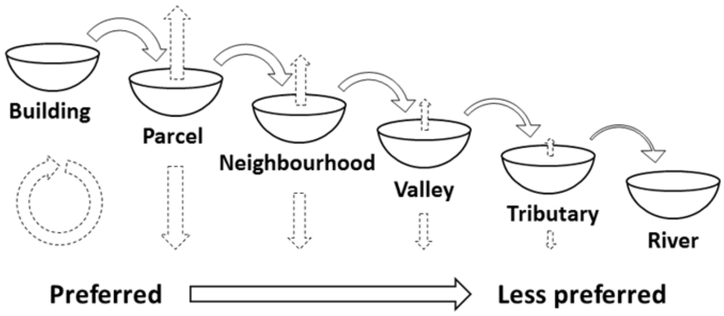


Figure 12. Conceptual diagram of the stormwater treatment train approach suggested for the Mbezi River catchment. Water should generally be managed as far upstream as possible. Illustration by Ole Fryd.

Importantly, any upstream LSM intervention will generally have positive impact on downstream communities in terms of flood mitigation, erosion control, soil moisture and inter-seasonal water availability. Water retained upstream will not contribute to an accumulated problem downstream. The reverse relationship does not exist to the same degree as downstream interventions do not have any direct synergy effects on upstream communities. Hence, as a general principle, water should be managed as close to the source and as far upstream as possible. Land parcel level stormwater harvesting, use and infiltration are optimal solutions in many cases. Yet, on-site interventions need to be balanced with options at the neighbourhood and tributary level according to what is practically feasible in the specific location.

The Mbezi River catchment strategy comprises six sub-strategies. Each sub-strategy reflects a particular spatial scale. It should be noted that boundaries between different scales can be fluid. The sub-strategies in the Mbezi River catchment have a much stronger hierarchy compared with the sub-strategies presented for the Jemo River catchment (see Section 4.1). Building and parcel level interventions are preferred over neighbourhood and valley interventions which again are preferred over tributary and river level interventions. The six sub-strategies are briefly presented below and summarised in Figure 13.

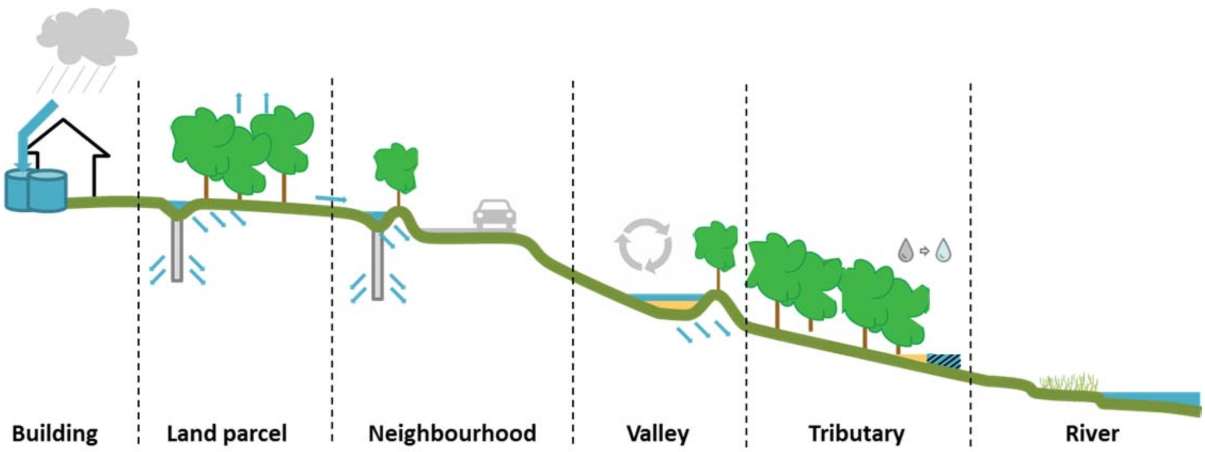


Figure 13. Longitunal section of the suggested treatment train approach for the Mbezi River catchment. Illustration by Ole Fryd.

Building level. Building level LSM measures include rainwater harvesting and storage in rain tanks located on the ground or in underground reservoirs. The rain tanks be prefabricated or built *in-situ*. The harvested water is suitable for non-potable uses such as washing, cleaning, garden irrigation and toilet flushing.

Land parcel level. Stormwater can be managed in the private garden by allowing water to infiltrate through the lawn or planting beds, or by choosing permeable pavings. Water can also be directed to underground soak-aways that allow water to percolate into the soil. Local depressions in the garden can provide temporary or permanent basins with fluctuating water levels. The collected water can be used for irrigation. Generally, these options will help increasing soil moisture in the garden.

Neighbourhood level. In Dar es Salaam clusters of houses are organised into '10 Cells' that manage local roads, electricity supply and other utilities and amenities. The 10 Cells level can possibly be activated for stormwater management, for example in the integrated design of roads and stormwater interceptors and infiltration pits (see Figure 12) or the construction and management of community level water reservoirs.

Valley level. Local valleys receive stormwater runoff from the surrounding areas. Existing precedents in the Mbezi River catchment provide promising examples of LSM interventions that utilise the topography of local valleys (see Figure 5 above). Examples include water reservoirs that double as fish ponds, sediment traps and recreational destinations.

Tributary level. Because of gravity, water naturally accumulates in the tributaries. The tributaries are generally greener and more lush than the surroundings, but also subject to erosion and widening of the water course. The implementation of barriers perpendicular to the water flow in the tributaries may provide options for water retention, sedimentation and in-stream treatment of river water.

River level. Urban agriculture occurs along the banks of the river, utilises the immediate access to water and appears resilient to seasonal floods. Low-lying flood plains allow water to fluctuate and the surrounding land buffer can be design to accommodate different functions in response to the varying water levels. For details about potential design options see Khatib (2014). In-stream barriers can possibly support the development of sustainable sand mining practices.

The sub-strategies are supported by in-depth studies carried out by the six PhD students involved in the WGA project. Simon Mpyanga's PhD research provides valuable insights into the potential of LSM in landscape design from the garden level to the tributary level. Given Justin's PhD research on in-stream water treatment is directly linked to the tributary level mentioned above. Dagnachew Adugna's PhD study on water quality can inform Given Justin's study on priority pollutants and required treatment performance levels. Alazar Assefa's PhD research on swale-dyke systems and infiltration pits can inform the development of LSM interventions at the land parcel and neighbourhood level. In return, the precedents found in the Mbezi River catchment can inform the work on ponds and basins that form part of Alazar Assefa's research.

A design charrette is recommended to be implemented along a specific tributary in the Mbezi River catchment. The design charrette should aim at capturing the multi-level approach suggested above. That is, to stimulate discussions and innovations that span from building and parcel level interventions, through 10 Cells and valley level solutions to possible options at the tributary and river level. The tributary level is expected to be a feasible scale for the design charrette as this scale addresses the social and technical complexity of the task while increasing the likelihood that a specific plan can be co-developed by stakeholders within the timeframe of a charrette and thus serve as a baseline and model for future interventions.

Next steps

The contents of this report will be presented and discussed at the annual project conference of the WGA project to be held in Dar es Salaam on 18-22 January 2016. The team will discuss the feasibility of options and the way forward from here. As such, the report, and Chapter 4 in particular, will serve as a framework and 'check-list' for the time in Dar allocated for work on the catchment strategy.

The draft catchment strategies presented here are expected to be refined during 2016 in response to more detailed work in the case sites and through the more detailed and in-depth PhD studies within the project. Sub-strategies, therein technical innovations such as the SISD and social innovations like the planned future design charrettes, will be developed, applied and evaluated in response to inputs from the broader research team provided during the annual conference.

Final catchment strategies are expected to be presented to key stakeholders and disseminated to a broader audience in the two cities towards the end of the WGA project in 2017.

Readers of this report are encouraged to provide their feedback, suggested changes and recommendations to the authors of this report. Please direct your comments to Dr. Ole Fryd at ole.fryd@unimelb.edu.au.

For feedback please contact ole.fryd@unimelb.edu.au

References

Backhaus, A., Adugna, D., Mhina, G.J., Fryd, O. and L. Herslund (2015). Water Resilient Green cities in Africa. Report 1, Workpackage 2. http://ign.ku.dk/english/research/landscape-architecture-planning/landscape-technology/water-green-africa/

Backhaus, A. and Fryd, O. (2012). Analyzing the first loop design process for large-scale sustainable urban drainage system retrofits in Copenhagen, Denmark. *Environment and Planning B: Planning and Design* (39), 820 – 837. doi - 10.1068/b37088

Castán Broto, V. and Bulkeley, H. (2013). A survey of Urban Climate Change experiments in 100 cities. *Global Environmental Change* 23, 92-102. Doi -10.1016/j.gloenvcha.2012.07.005

Environment Agency (2010). Good practice management of in-channel sediments. Department for Environment, Food and Rural Affairs (DEFRA), United Kingdom. Sourced on 04 January 2016 from http://evidence.environment-agency.gov.uk/FCERM/en/SC060065/MeasuresList/M1/M1T1.aspx

Evans, J.P. (2011). Resilience, ecology and adaptation in the experimental city. Transactions of the British Institute of Geographers, 36, 223-237.'

Fryd, O., Backhaus, A., Adugna, D., Assefa, A., Jensen, M.B., Justin, J., Mguni, P., Mpyanga, S., Workneh, A., Yeshitela, K. and Herslund, L. (2016). Draft landscape-based stormwater management strategies for the Jemo and Mbezi River catchments. Report 2, Work package 2. http://ign.ku.dk/english/research/landscape-architecture-planning/landscape-technology/water-green-africa/

Fryd, O., Dam, T. and Jensen, M.B. (2012). A planning framework for sustainable urban drainage systems. *Water Policy* 14 (5), 865-886. doi - 10.2166/wp.2012.025

Jha, A.K., Bloch, R. and Lamond, J. (2011). Cities and Flooding: A Guide to Integrated Urban Flood Risk Management for the 21st Century. The World Bank, Washington

Jørgensen, G., Herslund, L., Lund, D.H., Workneh, A., Kombe, W. and Gueye, S. (2014). Climate Change Adaptation in Urban Planning in African Cities: The CLUVA Project. In: *Resilience and Sustainability in Relation to Natural Disasters: A Challenge for Future Cities*. Eds: Gasparini, P, Manfredi, G, Asprone, D. pp 25-37. SpringerBriefs in Earth Sciences, Springer International Publishing. doi - 10.1007/978-3-319-04316-6_3

Khatib, L.A. (2014). Options for Landscape based Stormwater Management & Green Infrastructure in Urban Areas within developing Countries: A case study of an informal settlement in Dar es Salaam, Tanzania. Master Thesis, University of Copenhagen. http://ign.ku.dk/english/research/landscape-architecture-planning/landscape-technology/water-green-africa/

Lindley, S., Gill, S.E., Cavan, G., Yeshitela, K., Nebebe, A., Woldegerima, T., Kibassa, D., Shemdoe, R., Renner, R., Buchta, K., Abo El-Wafa, H., Printz, A., Sall, F., Coly, A., Ndour, M., Feumba, R., Zogning, M., Tonyé, E., Ouédraogo, Y., Samari, S. and B. Sankara (2015). *Green Infrastructure for Climate Adaptation in African Cities*. Pauleit S et al. (eds) (2015) Urban Vulnerability and Climate Change in Africa. A Multidisciplinary Approach. Future City 4, Springer International Publishing Switzerland. http://link.springer.com/chapter/10.1007%2F978-3-319-03982-4_4

Herslund, L., Lund, D.H., Jørgensen, G., Mguni, P., Kombe, W. and Yeshitela, K. (2015). Towards Climate Change Resilient Cities in Africa - Initiating Adaptation in Dar es Salaam and Addis Ababa. Pauleit S et al. (eds) (2015) *Urban Vulnerability and Climate Change in Africa*. A Multidisciplinary Approach. Future City 4, Springer International Publishing Switzerland. http://link.springer.com/chapter/10.1007%2F978-3-319-03982-4_10

Herslund L, Backhaus A, Fryd O, Jørgensen J, Jensen MB, Limbumba TM, Liu L, Mguni P, Mkupasi M, Workalemahu L and Yeshitela K. (forthcoming) Conditions and opportunities for green infrastructure – aiming for green, water-resilient cities in Addis Ababa and Dar es Salaam. Landscape and Urban Planning

Hvitved-Jacobsen, T., Vollertsen, J. and Nielsen, A.H. (2010). Urban and Highway Stormwater Pollution: Concepts and Engineering. CRC Press.

Kombe, W., Limbumba, T.M., Mkupasi, M.J., Abebe, K. and Workalemahu, L. (2015). City Level Institutional Comparisons of Landscape Based Stormwater Management in Dar es Salaam and Addis Ababa Cities. Report 1, Work package 3. http://ign.ku.dk/english/research/landscape-architecture-planning/landscape-technology/water-green-africa/

Laugesen, C.H., Fryd, O., Koottatep, T. and Brix, H. (2010). *Sustainable Wastewater Management in Developing Countries: New Paradigms and Case Studies from the Field*. Reston, VA: ASCE Press.

McDonald, R.I., Weber, K., Padowski, J., Flörke, M., Schneider, C., Green, P.A., Gleeson, T., Eckman, S., Lehner, B., Balk, D., Boucher, T., Grill, G. and Montgomery, M. (2014). Water on an urban planet: Urbanization and the reach of urban water infrastructure. *Global Environmental Change* 27, 96–105. doi -10.1016/j.gloenvcha.2014.04.022

Mng'ong'o, O. (2004). A browning process. The case of Dar es Salaam City. KTH, Skolan för arkitektur och samhällsbyggnad. ISBN:91-7323-086-3

Sultana, P. and Thompson, P. (2013). Participatory floodplain management: Lessons from Bangladesh. In Mark Scott , Iain White , Christian Kuhlicke , Annett Steinführer , Parvin Sultana ,

Thompson , P., Minnery ,J., O'Neill, E., Cooper, J., Adamson, M. and Russell, E. (2013) Living with flood risk/The more we know, the more we know we don't know: Reflections on a decade of planning, flood risk management and false precision/Searching for resilience or building social capacities for flood risks?/Participatory floodplain management: Lessons from Bangladesh/Planning and retrofitting for floods: Insights from Australia / Neighbourhood design considerations in flood risk management/Flood risk management – Challenges to the effective implementation of a paradigm shift, *Planning Theory & Practice*, 14 (1), 103-140, DOI: 10.1080/14649357.2012.761904

Yeshitela, K., Assefa, A., Mpyanga, S. and Mrema, L (2015). Green structure analysis for Water Resilient Green Cities in Africa. Report 1, Work package 1. http://ign.ku.dk/english/research/landscape-architecture-planning/landscape-technology/water-green-africa/