ISULABANTU Phase 3: Closed-loop environmental management systems in informal settlements in Durban, South Africa

PHASE 3 REPORT

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Executive Summary

In South Africa (SA), around 65% of the population lives in urban centres, with 1 in every 5 households living in informal settlements (SERI, 2018). Due to rapid urbanisation and population growth, informal settlements have formed a major challenge of the urban landscape, exacerbating issues related to poverty, inadequate infrastructure, housing and poor living conditions. Reflections on past upgrading efforts in SA suggest that top-down policies have not been successful to date. By contrast, participatory techniques in the upgrading processes have been used to enhance community empowerment and a sense of local ownership. However, participation and collaboration can mean various things for informal housing and settlement upgrading, and often the involvement of local communities is limited to providing feedback in already agreed development decisions from local authorities and construction companies. Representative structures that are leadership and membership based have a key role in organised upgrading processes. Highly organised groups with successful continuation of membership ensure that upgrading is a means and not simply an end (Escobar, 1995).

The ISULabaNtu project lies under the umbrella of sustainable bottom-up urban regeneration. The overall research, including research and results presented in this report, adopts a postcolonial perspective to urban transformations and explores community-led approaches for informal settlements upgrading in the Durban metropolitan area (McEwan, 2009; Pieterse, 2010; Watson, 2013). As breaking the cycle of poverty in urban settings is not simply a question of service provision but rather that of multiple deprivations compounding on each other, broadening the framework for measuring poverty and inequality is necessary. Beyond inadequate and unstable income, other aspects of inequality include: poor quality and insecure housing, inadequate provision of infrastructure and basic services, high prices paid for necessities, limited safety net, and limited participation and power in political systems (Mitlin and Satterthwaite, 2013, p.89).

The main focus of this report has been the assessment of the current environmental management systems in three informal settlements around Durban and the exploration of the potential for closed-loop environmental systems for settlement upgrading. Acceptability for residents and potential linkages between sustainable environments with respect to appropriate sanitation technologies and improved livelihoods, job creation and food security have also been tested. Finally, by focusing on the residents' experiences and perceptions of the provision of infrastructure and their realities, questions around how environmental management systems can be designed to be user-centric and sustainable have been addressed.

The report consists of five sections:

Section 1 contains the introduction and the study background.

Section 2 presents the literature review, including themes around the policy context, policies and the regulatory environment, urban agriculture, solid waste management (SWM), recycling, electricity provision and community resilience.

Section 3 demonstrates the methods and methodology used in this research.

Section 4 presents findings from the qualitative data and

Section 5 presents findings from the quantitative data collected in the course of this research.

1. Introduction and study background

There has been research on the impact of environmental improvements in the context of informal settlements (Parikh et al., 2012; Parikh, 2007). However, the aspect of closed-loop environmental systems and associated management with business models delivery needs further inquiry for resource-constrained settings such as informal settlements, where ‘frugal innovation’ may be necessary. For example, in Namibia Stop 8, residents are connected to the municipality metered water supply, pre-paid electricity, and water-borne sewerage reticulation but there is a gap on understanding management systems required for the same. The challenge is also further enhanced by scarcity of environmental resources, population growth and increased demand and consumption of water. Water scarcity is increasingly becoming a challenge in South Africa (Donnenfeld et al, 2018).

Phase 3 therefore focusses on potential of closed-loop systems where wastewater generated can be reused for agriculture thereby addressing water scarcity challenges. Part of the process is evaluating community acceptance for such technical solutions to ensure buy-in. A combination of literature review and stakeholder interviews has been used to assess the nature and condition of existing infrastructure systems, presence of closed loop systems and feasibility. The nature of processes, partnership models and business models required to ensure the provision of resilient infrastructure through user-centric processes (Schillebeeckx et al. (2012)) will be explored through participatory tools.

The findings from Phase 3 could be applied for city systems especially in a context where water is a scarce resource and waste generation likely to increase with future population growth.

The three investigated sites were:

Namibia Stop 8

Located in the northern region of eThekwini on the outskirts of Durban, South Africa, Namibia Stop 8 was built in 2010-2014 by community contractors who delivered 2,500 dwellings providing homes for 10,000 people (SDI South African Alliance, 2012). Residents had been moved there from two settlements: Namibia and Stop 8. The housing provided was a mixture of government RDP which were 40sqm and FEDUP provided houses which were larger at 56sqm. Namibia Stop 8 has water supply, a sewage system, and access to electricity.

Havelock

Havelock is an informal settlement which is located 8km from Durban city centre, with an estimated 200 dwellings and approximately 400 people living in the settlement. The settlement sits on privately owned and municipality owned land. The settlement has various hazards such as: illegal electrical connections, dangerous electrical cables sprawled across paths, fire hazards and flooding. The municipality have installed ablution blocks and a detail enumeration has been conducted for the proposed re-blocking of the settlement.

Piesang River

Piesang River is a settlement located 25km north of Durban city centre. Incrementally upgraded with formal structures in the early 1990s a variety of building types were constructed, such as two-story flats, cottages, and single-story houses. Houses have access to water supply, sewage system and electricity.

1.1 Aim

The aim of WP3 is to respond to the following objectives:

- To assess current environmental management systems in low-income settlements and informal settlements
- To explore potential for closed-loop environmental systems, acceptability for residents and potential linkages between sustainable environments with respect to appropriate sanitation technologies and improved livelihoods, job creation and food security

- What processes and partnership models are required to promote user-centric and resilient infrastructure provision in informal settlements?
- How can environmental management systems be designed to be user-centric to ensure sustainability?
- What are the key challenges and opportunities associated with the provision of infrastructure and services such as SWM?

2. Literature review

This section provides a brief overview on the approaches for the provision of services for low-income housing along with the concept of co-production in service provision. The review looks at participatory community-upgrading in South Africa.

Politics of participation

There are two main ways in which the politics of participation are admitted in development planning, who participates and the level of participation (White, 1996, p.7). This can be split into four categories, the homogeneity or heterogeneity of participants, and the immediate or strategic level of participation. If participation is driven by technical solutions, it can often obscure the politics of participation (White, 1996). The de-politicisation of participation can lead to participation being only nominal.

The heterogeneous interests of participants are both diverse and dynamic. This means that participation should be regarded as a process, where the dynamics between stakeholders and participants changes over time, either increasing or decreasing. Having a policy or toolkit that reflects that is vital, both in ensuring the sustainability of the project as well as its transformative value. (White, 1996)

Participation can also come in between top-down and bottom-up approaches. This can construct power and interests. This construction can evolve into changing the interests and the relation between top-down and bottom up groups. White (1996) argues that for processes to be genuinely transformative, they must apply to the 'weaker' force as well as for the outside agency and on their relationship. In essence, participation aims to challenge the existing power structures between agents, and for genuine change to happen, participation should create dynamic, two-way change between those agents. The absence of conflict in participatory programmes should be regarded as suspicious (ibid, p.15).

Hickey and Mohan (2004) argue that the success of participatory approaches lies in grounding and engaging them with issues of politics and power. Furthermore, they can move beyond technical and technocratic fixes towards a more structural transformation. This is the end-goal of empowering participation (ibid).

2.1 Policy context

2.1.1 History of South African infrastructure provision

South Africa had their first free democratic elections in 1994 (Terreblanche, 2003) South Africa was previously ruled by the Apartheid government, an ideology that called for separate development of the different racial groups in South Africa (ibid). This racial segregation affected the development and modernisation of the nation not only socially, but through infrastructure provision as well. The Group Areas Act of 1950 and the Promotion of Bantu Self-Government (1959) demanded that different racial groups had to inhabit separate areas. A disproportionately small land area was reserved for black people, and even then, they could not own land. Their homes were placed in townships outside of towns and cities, where work was available, and they could only rent property from legal white owners (ibid). Infrastructure provision, such as roads, power connections, and waste management, was focused on white areas in towns and cities. This context provides the back-drop for present-day South Africa, where the relatively young government is trying to update and increase infrastructure services (ibid).

Post-Apartheid South Africa is dealing with updating and providing infrastructure to meet the demands of a growing population, that has increased by 15 million since 1994 (World Bank, 2018). In 2012 the government had set aside 3 trillion South African rand (ZAR) for upgrading projects around water, sanitation, waste management, roads, and other services around the country (Gale, 2012). It is argued that the issue of infrastructure upgrading, and provision does not lie in lack of funding, but in lack human capital. The public sector is lacking skilled engineers to address service delivery (Gale, 2012).

2.1.2 Durban

The city of Durban is administered by the eThekwini municipality, and has a population of 3.8 million (aThekwini Municipality, 2018). There is a clear spatial separation of residential areas and economic activities, meaning people do not generally live in the area where they work (Sutherland et al, 2013)

People in Durban maintain strong connections to the rural areas of South Africa, where they might have emigrated from. This means that often they regard their 'urban' home as transient. (ibid.) This affects the willingness to invest in their communities.

The decision-making body in the city is shaped by strong technical and spatial knowledge through officials (ibid). This means that the city has been able to provide relatively progressive service provision and to address 'pro-poor' goals (ibid.). On the other hand, there is a lack in public participation. Local and community politics have also come into play at the ground-level, where language is rendered technical, so there is little community resistance to development projects (ibid.). However, the eThekwini Water and Sanitation unit (EWS) shows a concentrated effort to include public participation in decision-making. (ibid.)

UKZN have developed a draft policy review taking into consideration existing policies on urban farming guidelines, sanitation systems and resource recovery, water and sanitation, agriculture, pollution, housing and electricity. The draft review presented in Appendix 1 also attempted to explore avenues for environmentally friendly solutions such as use of grey water for urban farming. A gap between policy and implementation was noted i.e. environmentally friendly policies are in place but there are challenges in relation to acceptance, implementation on ground and understanding of requisite management systems. Since of the objectives of this phase was to assess livelihood creation and food security, the policy review has focussed heavily on urban agriculture. The review showed that urban agriculture is not common in Durban, this has been highlighted by the lack of urban agriculture guidelines. Therefore, the eThekwini municipality has come up with initiatives to promote urban agriculture in both low income and high-income areas. Agricultural hubs have been established in low income areas to provide support for growers within the hubs while green roof gardens are more in the commercial and middle to high-income areas. The establishment of green roofs has shifted the attention of urban agriculture from low income and in most cases informal settlements to the inner-city environment with limited space.

The use of wastewater in agriculture is still at the research phase in South Africa. The government policy review shows that the water and sanitation national and local municipal policies encourage the use of greywater, however there is little evidence on the use of grey water in urban agriculture in eThekwini. There is need for collaboration of policies from different departments to consider sanitation technologies that allow for integrated closed loop environmental management systems.

A preliminary review of sanitation technologies currently used in informal settlements has been conducted (see Appendix 2) by UCL and UKZN. The review noted an increase in innovation in sanitation provision and faecal waste treatment in Durban, in an effort to identify solutions that are sustainable for all. New technology is pushing to reduce water consumption in latrines and overcome the cultural beliefs surrounding handling of human waste. From the technologies and ideas discussed in this literature review it is clear that such practices are only being implemented on a small scale; increasing their application to service more townships will take more time. New technologies such as Urine Diversion Toilets are tested and implemented in low-income settlements, but the inner city is still served by networked infrastructure which is seen to be superior. So, there are challenges around acceptance of such technologies. Community Ablution Blocks (CAB) are being constructed for informal settlements in an attempt to provide technologies which are simple and easy to access and are seen to be more acceptable than other decentralised solutions. The only challenge raised was around safety concerns for women and children using such facilities.

2.1.3 Role of community structures and leadership

Representative structures that are leadership and membership based have a key role in organised upgrading processes. Highly organised groups with successful continuation of membership ensure that upgrading is a means and not simply an end (Escobar, 1995). This relates to levels of community participation and the aim of immediate vs strategic goals. Furthermore, simply providing these structures is not enough if access to them is not ensure. If access to these representational structures is dominated by a few or the community elite, it can further alienate the most vulnerable within the community (Patel, 2015).

Reliance on external upgrading drivers, such as NGOs or researchers, does not ensure sustainability of participatory upgrading processes. In-situ upgrading relies on integration to power structures around the community. Transformative development goes a step further and requires a transformation in power structures (Hickey and Mohan, 2004). In the case of Havelock, the antagonistic relationship with neighbours in surrounding formal housing is a key barrier in the in-situ upgrading process (Ferrera Nunez et al., 2017 (Phase 2 Report)).

One of the most common criticisms of participation in development is the lack of tangible evidence of social change. Lack of tangible and explicit benefits may discourage community members from participation. (Escobar, 1995) The navigation between immediate and strategic gains is a delicate balance and can affect the level of participation (Hickey and Mohan, 2004b).

Breaking the cycle of poverty in urban settings is not simply a question of service provision. In order to understand how multiple deprivations compound on each other, broadening the framework for measuring poverty is necessary. Essentially, this means spreading measurements of poverty beyond income measures (Mitlin and Satterthwaite, 2013, p.89) Other aspects of inequality include: inadequate and unstable income, poor quality and insecure housing, inadequate provision of infrastructure and basic services, high prices paid for necessities, limited safety net, and limited participation and power in political systems (ibid).

Lack of security around tenure and title deeds is one major concern across informal settlements. The question of whether inhabitants in informal settlements are willing to invest in improving their living conditions if they face the threat of eviction is pertinent, especially in the case of Havelock. (Jabeen et al., 2010) This is particularly important to analyse, as the formal neighbours around Havelock are displeased. Furthermore, despite pro-poor policies aiming to supply free basic electricity to the indigent people in the municipality driven by the goal to prevent child deaths by electrocution and to reduce the risk of fires, safe and reliable power connections are yet to reach the settlement. In the meantime, this means that inhabitants are forced to pay more for illegal electricity connections.

Objective

Objective 1: Urban farming guidelines and urban agriculture existing in Durban

People /Partners

Mr Lawrence Maduramunthu, eThekwini's chief horticulturist, eThekwini Municipality, South Africa

Mr Teddy Gounden eThekwini Water & Sanitation (EWS), eThekwini Municipality, South Africa

Activities

Interviews (8th of August 2017)

Information from eThekwini's Strategic Executive Mr Teddy Gounden

Desired outcomes

Information on the existing situation regarding urban agriculture in Durban.

Information on whether there are guidelines on urban agriculture provided by eThekwini municipality

Objective	People/ Partners	Activities	Desired outcomes
Objective 2: Interventions for reuse of grey water for irrigation	Sharon Migeri	Desktop research - reviewing literature on the use of waste and wastewater in agriculture for crop production in South Africa.	Information on practical examples of wastewater/ grey water use for crop production in South Africa, and Durban as a case study
Objective 3: Review government policies linking agriculture and sanitation technologies that allow resource recovery	Deborah Trollip – Process Scientist Umgeni Water Prof Chris Buckley - UKZN Water Research Commission Mr Tendani Nditwani National Water Resource Planning Department of Water and Sanitation	Desktop research - reviewing policies and legislative mandates governing water and sanitation, agriculture, pollution, housing and electricity.	Information on policies and legislative mandates governing water and sanitation, agriculture, pollution, housing and electricity.

Table 1. Conceptual mapping framework looking at urban agriculture activities, guidelines regulations and the policy environment within the eThekwini Municipality.

2.2 Government policies and regulations for the provision of services

2.2.1 Housing

The Department of Human Settlement manages housing and on a national level. It works in collaboration with the provincial governments and municipalities, each of which has its own human settlements department. The Department carries out its legislative mandate according to the Housing Act (Act No. 107 of 1997). Section 2(1) (a) of the Act compels the government to give priority to the needs of the poor in respect of housing development. Section 2(1) of the Act provides for the general principles applicable to housing development. The Social Housing Act (Act No. 16 of 2008) aims to establish and promote a sustainable social housing environment, to define the functions of national, provincial and local governments in respect of social housing. There are entities that report to the Department of Human Settlement which operate as regulators or development finance institutions. These include Social Housing Regulatory Authority (SHRA) which is responsible for the disbursement of institutional investment and capital grants to social housing institutions. Rural Housing Loan Fund (RHLF) is authorised to empower low-income households in rural areas to access housing credit. Estate Agency Affairs Board (EAAB) regulate, maintain and promote the standard of conduct of estate agents, issue fidelity fund certificates to qualifying applicants, prescribe the standard of education and training of estate agents, investigate complaints lodged against estate agents and manage the Estate Agents Fidelity Fund.

In KwaZulu-Natal province the department of human settlement aims to administer the clearance of slums in the province and to rehabilitate existing houses for victims affected by political unrest and correct the previous dysfunctionalities of the Housing Resettlement Programme. The need for housing is influenced by rapid urbanisation, this has led to the need to intensify the provision of housing infrastructure and homes in integrated and habitable settlements. Housing plans and designs do not consider sanitation technologies that can allow for integrated closed loop environmental management systems.

Housing is discussed in more detail in ISULabaNtu Phase 1 Report and Phase 4 Report.

2.2.2 Water Supply

The Department of Water and Sanitation (DWS) manages water and sanitation on a national level. The Department is governed by the National Water Act (36 of 1998) which legislates the way in which the nation's water resources are to be protected, used, developed, conserved, managed, and controlled. Water and sanitation sectors in respective municipalities ensure the provision of services to communities in a sustainable manner. It is in terms of the National Water Act (NWA) that municipalities obtain the water that they use in providing services to their customers. In addition, the NWA also governs how a municipality may return effluent and other wastewater back to the Nation's water resources. This is in line with Section 155(7) of the Constitution of the Republic of South Africa which provides the national government, with the legislative and executive authority to see the effective performance by municipalities, including water, sanitation services and disposal systems.

In 2000, the government announced that it would implement a Free Basic Services (FBS) policy to cater for poor to households who could not afford to pay for them (Tissington, 2013). However, the Department of Water and Sanitation have limited resources to provide free services to individuals in their jurisdiction and the practice is often not sustainable. According to Statistics South Africa (Stats SA) in 2011, it is estimated that there were 3 million registered poor households identified by municipalities, of which only 1.7 million households (57.9%) received Free Basic Sanitation (Tissington, 2013).

Four water supply systems are approved by the DWS for the provision of access to potable water for domestic households:
a) A manually operated water dispenser;

b) An individual household yard supply which supplies 300 litres per day (a ground tank, where the flow is regulated through a metered flow limiter device);
c) A semi-pressure supply in which the household service is provided via a roof tank; and
d) A full pressure supply with or without a flow limiter.

Provision of water in informal communities is achieved through a water dispenser or standpipe within 200 metres of every household as prescribed by the Department of Water Affairs (DWA) as the basic level of potable water. The water dispenser or standpipe is located at the boundary of the settlement or along an established road for operational reasons.

All water supplied to a household shall be tested by the water service authority/provider, with the frequency of testing depending on the size of the community. The test results should comply with the South African National Standards (SANS) 241. These standards provide limits for domestic water which are categorised into health risks, aesthetic risks and operational risks as shown by Table 2 below.

Determinants	Risk	Limit
E.coli or Faecal coliforms count/100ml	health	Not detected
Free chlorine mg/L	health	≤ 0.2
Fluoride	health	≤ 1.5
Total organic carbon mg/L	health	≤ 10
Total dissolved solids	aesthetic	≤ 1 200
Total coliforms count/100ml	operational	< 10
Heterotrophic plate count count/1ml	operational	< 1 000

Table 2. Selected properties and limits required for domestic water.

Municipal water and sanitation sectors are also responsible for establishing guidelines which include tariffs to be paid by customers. The tariffs must be disclosed on the basis for determining its water or sanitation services for the current year and make estimates for the following three years. Although national and local municipal policies encourage the use of greywater, there is little evidence on the use of grey water in urban agriculture in eThekwini.

2.2.3 Sanitation

The approved 2016 National Sanitation Policy consists of 7 pillars and policy principles: 1) to ensure integrated planning of sanitation services; 2) to strengthen institutional arrangements for sanitation services; 3) to ensure participation in sanitation services; 4) to ensure capacity and resources for sanitation services delivery; 5) to ensure financial effectiveness and efficient sanitation services; 6) to ensure sustainable sanitation provision in the country; and 7) to strengthen regulation of sanitation services (DWS, 2016).

Under the Water and Sanitation Budget Vote 2015/16 three sanitation systems are approved for the provision of access to sanitation for domestic households according to the policies and practices of the eThekwini municipality water and sanitation unit (2013): a privately-owned Urine Diversion (UD) toilet, a connection to the municipal waterborne sewerage reticulation system and an on-site privately-owned sewage disposal. Waterborne sewage disposal may be provided by means of privately-owned septic tank and conservancy tank systems and privately-owned low volume sewage treatment plants. A person wishing to use the sewage disposal system must apply to the Municipality in the form required. Night soil pail, unimproved pit latrines and chemical toilets are not permitted unless motivated and approved by the Head: Water and Sanitation under exceptional circumstances. In informal settlements an ablution block connected to municipal waterborne reticulation (an ablution block consists of toilets, showers, and clothes washing facilities) is provided as a means of sanitation or a toilet block where no connection to waterborne reticulation is available (a toilet block consists of toilets and urinals only with no water supply provided to the toilet block). An ablution block in any informal settlement should be located within 200m of every household. Each toilet is provided with its own VIP pit which will be emptied as and when required by the municipality at no cost to the settlement inhabitants.

A large drawback of any new sanitation initiative introduced in Durban that endeavours to achieve sustainability and minimise natural resource consumption is that it will always be compared to sanitation provision in Durban's city centre. Residents in low-income neighbourhoods feel like second-class citizens with these new systems while other residents of Durban are able to use flush toilets; the disparity is evident in the overall quality of infrastructure and housing than just in sanitation between the two groups, but these new 'sustainable' programmes have made township residents feel as though they are saving resources for wealthier communities to use. The only system that addressed this issue were CABs, but obvious questions are raised about safety for women and children in using the system, indicating that the latrines are not accessible to all members of the community equally. Hence, for any sanitation technology to be wholly successful in Durban, action must be taken to introduce the same services across the entire area and not just the low-income neighbourhoods. With countries like South Africa being stressed for resources like clean water, it is important to encourage practices that are manageable in the long-term for all residents and bring resilience to whole communities- a realisation clearly stressed in the National Sanitation Policy 2016, particularly in the context of predicted increased urbanisation in South Africa which will continue to pose challenges to urban sanitation systems and water scarcity management, as well as wastewater management. Examples such as Cape Town's (now postponed) "Day Zero" demonstrate that water is a scarce resource and that there is an urgent need to design and implement water and sanitation technologies which will help conserve it.

Those issues have been considered in the *Reinvent the Toilet Challenge*, funded by the Bill & Melinda Gates Foundation, which has been taking place in Durban in partnership with the eThekwini Water and Sanitation unit and the University of KwaZulu-Natal. The challenge aims to establish and evaluate prototypes of dry on-site sanitation systems to characterise the physical and chemical properties of excreta streams, as well as decentralised low-water consuming sanitation systems. The challenge is one of the initiatives which offers opportunities to design innovative and appropriate solutions for the needs of fast-growing cities with inadequate existing sanitation and FSM systems[1].

2.2.4 Water provision and management

Recycling and conserving water in South Africa is recommended and desired. Low rainfall, high demand and economic drivers lead to very detailed water management policy across different provinces and municipalities.

The Free Basic Water Implementation Strategy was first introduced in 2000 (Department of Water Affairs and Forestry, 2002). It was a policy that an estimated of 3 million people would benefit from, but only around 1,7 million receive it (Migeri, 2018). Since South Africa has been suffering from severe drought since 2015, it is hard to ensure the sustainability of the program. This policy benefits those who live in informal settlements that have been provided ablution blocks (ibid).

Grey water is defined as "urban wastewater without any input from toilets and so generally includes sources from baths, showers, hand basins, washing machines, dishwashers and kitchen sinks" (Jefferson et al., 2004). Recycled water has a range of application in non-agricultural and agricultural spaces. The most common application of grey water reuse is toilet flushing, which can reduce the demand of water in dwellings by 30%, which is a common practice in South Africa (Karpiscak et al., 1990; Jefferson et el., 2004). Public perceptions around grey water and direct potable reuse can either make or break reuse schemes. An example of this is in

[1] Other innovative solutions which have been deployed, to various extents, in South Africa are presented in more detail in Appendix A.

Australia where direct potable reuse projects are not operating due to perceived public health risks in recycled effluent – sewage which is treated to a drinkable standard (Horne, 2015). The Minister of DWS Nomvula Mokonyane encouraged water reuse and recycling during the Water and Sanitation Budget Vote 2015/16. The budget vote highlighted possible innovative measures to ensure water conservation. These measures include advocating water wise landscaping, rain water harvesting and use of grey water. Greywater can be used for activities such as crop production, firefighting, flushing of toilets, industrial cooling and irrigation of parks.

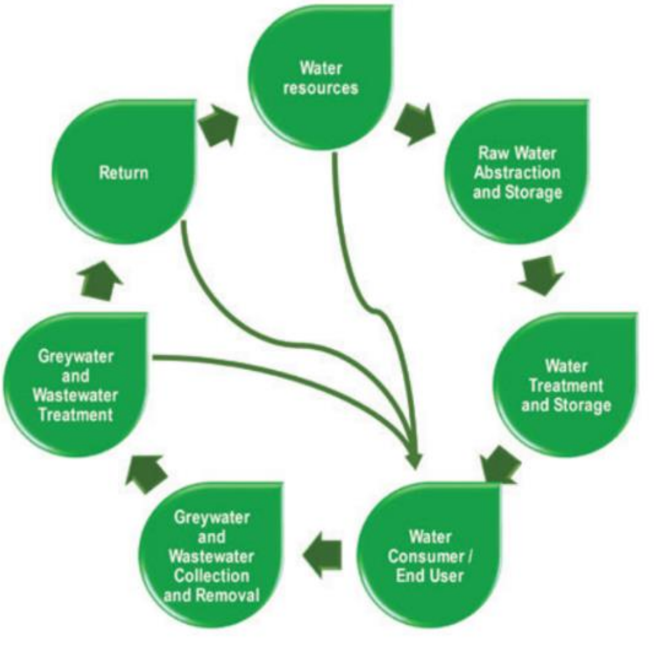

Figure 1. Water management cycle in South Africa (DWS, 2016: 4).

In the eThekwini-municipality, there is little guideline on safe use of grey water. Existing guidelines for wastewater use have focused mainly on the potential harmful effects of heavy metals and have not considered the potential benefits of using nutrient-rich effluent from low cost sanitation technologies for irrigation purposes. In this context wastewater refers to effluent generated from domestic waste treatment systems including grey water. According to the national sanitation policy (2016) current policies do not address the policy position on grey-water. There is no specific reference to grey-water in the National Water Act (NWA) No. 36 of 1998 (DWAS, 1998). The Department of Water Affairs in terms of Section 36 of the National Water Act (1998) requires that a person who irrigates with wastewater must submit to the responsible authority a completed registration form or any other information requested in writing by the responsible authority for the registration of the water use. The Department of Water Affairs and Forestry (DWAF) processes applications for any type of treated effluent re-use. However, wastewater intended for food production or sports facilities that promote probable direct contact with surfaces, the provincial Departments of Health (DOH) become involved (Steyn and Jagals, 2000).

Rodda et al., 2011 evaluated the impact of medium-term sub-surface irrigation of vegetable crops with domestic greywater on soil, plant growth and yield, and microbiological quality of crops. The study concluded that greywater irrigation increased plant growth and crop yield. However, it could lead to accumulation of sodium and metals in soil with time, and hence in plant crops. Greywater irrigation could increase microbial loads on plants, although of the microorganisms investigated, only *E. coli* and total coliforms showed significant increases.

The use of aquatic vegetation to absorb nutrients from treated waste water has been is another form of nutrient harvesting. This might constitute an effective means of removing nutrients from effluents and the harvested plants can then be used directly as fertiliser or added to compost. Currently the Pollution Research Group (PRG) of the University of KwaZulu Natal (UKZN) is conducting a study on the evaluation of duckweed and *Azolla* spp. for biomass production, removal of N and P from decentralised waste water treatment effluent and the potential fertiliser value of the biomass. Most of the work done on greywater for crop production is still in the research phase in South Africa.

2.2.5 Agriculture

The South African agriculture sector is governed by the Department of Agriculture, Forestry and Fisheries (DAFF) with each province having its own DAFF. It manages value chains from inputs, production, and value adding to retailing on a national level The DAFF carries out its legislative mandate according to following Acts listed in Table 3 below.

Act	Purpose
Agricultural Produce Agent Act, 1992 (Act No. 12 of 1992)	Provides for the establishment of an Agricultural Produce Agents Council and fidelity funds in respect of agricultural produce agents and for the control of certain activities of agricultural produce agents
Animal Improvement Act 1998 (Act No. 62 of 1998)	Provides for the breeding, identification and utilisation of genetically superior animals in order to improve the production and performance of animals
Fertilizers, Farm Feeds Stock Remedies Act, 1947 (Act No. 36 of 1947)	Provides for the appointment of a Registrar of Agricultural Remedies and Fertilisers Farm Feeds, Agricultural Remedies and Stock Remedies; the registration of fertilisers, farm feeds, agricultural remedies, stock remedies, sterilising plants and pest control operators; the regulation or prohibition of the importation, sale, acquisition, disposal or use of fertilisers, farm feeds, agricultural remedies and stock remedies and the designation of technical advisers and analysts
Marketing of Agricultural Products Act, 1996 (Act No. 47 of 1996)	Provides for the authorisation of the establishment and enforcement of regulatory measures to intervene in the marketing of agricultural products, including the introduction of levies on agricultural products and to establish a National Agricultural Marketing Council
Perishable Products Export Control Act, 1983 (Act No.8 of 1983)	Provides for the control of perishable products intended for export from the Republic of South Africa

Table 3. Legislative mandates governing Department of Agriculture, Forestry and Fisheries.

There are entities that report to the DAFF these include Agricultural Research Council conducts research with partners to generate knowledge, develop human capital and foster innovation in agriculture through development and transfer of technology and the dissemination and commercialisation of research results according to Agricultural Research Act, 1990 (Act No.86 of 1990). Perishable Products Export Control Board (PPECB) ensures the orderly export of all perishable products and to monitor the maintenance of a continuous cold chain for exports and monitor minimum quality standards. Pollution and rivers (Department of Environmental Affairs). The review shows no linkages between agricultural policies, water and sanitation in relation to resource recovery from waste and wastewater and agricultural reuse.

2.2.6 Urban agriculture

2.2.6.1 Definitions

Urban agriculture may include activities in urban settlements where people use land and other resources such as water and available germplasm (crops and animals) to produce food and food products for their own consumption and/or for sale to residents/consumers living in close proximity. Urban agriculture may have a role to play in addressing urban food insecurity problems. Mouget, (2000) defines urban agriculture "as the sustainable use and utilization of natural resources and other inputs by people for plant and/or animal production purposes, either for own consumption or for marketing produce in close proximity to and/or in urban settings". Richter et al., 1995 argues that it is not the location that defines urban agriculture but the fact that it is embedded in and interacting with the urban eco-system. It is apparent that the term urban agriculture could have several meanings. For example, the idea of sustainability according Mouget (2000) may not apply in urban settlements where growing of crops and keeping of animals is not planned.

The Urban Development and Resilience Unit of the World Bank conducted case studies on urban agriculture in four cities, Bangalore (India), Accra (Ghana), Nairobi (Kenya) and Lima (Peru). In this context, urban agriculture was defined as an industry located within or on the fringe of a town, city, or metropolis that grows and raises, processes and distributes a diversity of agricultural products from both plants and animals, using inputs found in and around that urban area. Table 4 below shows results from the case studies, highlighting main water source used for agriculture and main types of agriculture in the urban areas. The impacts of urban agriculture in these four cities included provision of employment and income to farmers and contribution towards food and nutritional security.

	ACCRA	**BANGALORE**	**LIMA**	**NAIROBI**
Main water source for agriculture	Rain water Wastewater (urban)	Rain water - Bore wells	River water (peri-urban) - Municipal drinking water - Wastewater	Rain water wastewater
Food staples	Maize Rice Roots/ Tuber Millet/Sorghum	Rice Sorghum	Maize Rice Tubers	Maize Roots Tubers
Main types of low-income urban and peri-urban agriculture in the city	Container gardening Homestead gardening Open space commercial horticulture Subsistence and commercial livestock Fisheries	Container gardening Homestead gardening Commercial horticulture and cereals Commercial livestock	Container gardening Homestead agriculture Community gardens Institutions (e.g., colleges, meal centres) Commercial horticulture Livestock and fish farming	Container gardening Homestead gardening Commercial horticulture and cereals Commercial livestock

Main crops grown/ animal species reared by low income household	Vegetables, Maize ,Cassava Poultry, Sheep and goats Fish	Rice ,Sorghum Maize Vegetables Fruits - Poultry - Sheep and goats - Cattle and buffalo	Vegetables - Fruits - Aromatic plants - Forage - Ornamental plants	Vegetables Maize Poultry Sheep and goats plants

Table 4. Case studies, highlighting main water source used for agriculture and main types of agriculture in the urban areas in Accra, Bangalore, Lima and Nairobi.

2.2.6.2 Urban agriculture in eThekwini municipality

Activities relating to urban agriculture in major cities such as eThekwini, Durban have not been well-documented. This section aims to look at urban farming guidelines and farming initiatives existing in Durban, interventions for reuse of grey water for irrigation and review government policies for water, toilets, housing, electricity, fire, solid waste, agriculture and pollution.

The effects of climate change will affect the urban poor disproportionately more and increase their vulnerability compared to other urban dwellers (Jabeen et al., 2010). Within this group, it is especially women that will bear the brunt of the consequences (UN-Habitat, 2015). Within the South African context, this could mean increased periods of drought, flooding, and disruptions in food security and service provision (Jabeen et al., 2010).

The benefits of urban agriculture (UA) are numerous. It can help cities to adapt to climate change, improve food security, and help transition urban areas into a green, circular economy (UN-Habitat, 2012). On a micro-level, it can help keep informal settlements cool, especially where corrugated iron is used as building material, and increase air quality (Jabeen et al., 2010). Furthermore, UA helps diversify local economy and sources of income, making communities more resilient to external threats, such as flooding or unemployment (Mougeot, 2000).

UN Habitat states that UA can help mitigate the effects of climate change, when appropriately managed and planned. (UN Habitat, 2014) Pilot projects to integrate urban and peri-urban agriculture within urban development strategies were implemented in three cities in Burkina Faso, Nepal, and Sri Lanka. (ibid.) It was found that UA can help sequester carbon dioxide (CO_2) emissions as well has help reduce food expenditure. Approaching UA from a sustainability perspective brings into focus many of the Sustainable Development Goals (SDG).

There is contest on the definition of UA and what it entails. The separation between rural agriculture and urban and peri-urban agriculture is blurred. Mougeot (2000) asserts six different dimensions that are associated with urban agriculture; Economic activities, location, areas, scale, products, and destination. Defining urban or peri-urban areas should be reviewed regularly, as the definitions/categorisation of city limits, population density or other urban elements is in constant change. This process is an opportunity to increase co-operation within communities and involve them in a participatory process towards urban agriculture. This aspect of urban development is a potential asset to help diversify urban management strategies and build more resilient communities. (ibid)

Most urban farmers are men and women with low-incomes who grow produce mainly for self-consumption. This happens on small plots which are self-claimed, and often lack any support of protection (Mougeot, 2000). However, women are more likely to be invested in saving-schemes and building individual household resilience against disasters and un-expected expenses (Jabeen et al., 2010). Increasing UA possibilities within communities helps diversify household incomes and increase the agency of women. According to the review of Migeri (2018), the impacts of urban agriculture in South African cities included employment opportunities and income to farmers, as well as additional food and nutritional security.

There is evidence of support and interest in urban agriculture on the part of the eThekwini-municipality, but there is little to no guidelines on the matter. The eThekwini municipality drought management fact sheet has a single advice on watering gardens at night to reduce evaporation rate of water (eThekwini Municipality, 2016). Multiple programmes have existed to promote urban agriculture such as the eThekwini Agro-Ecology programme, that liaises with field staff in communities (Migeri, 2018).

2.2.6.3 Urban farming guidelines

There are no guidelines for general urban agriculture in eThekwini municipality, however there are specific guidelines for designing green roof gardens. The content of this guideline is intended for information purposes only and does not constitute legal advice. The guideline for designing green roof gardens highlights structural considerations, safety considerations, roof shape, planting medium and plant selection. The main objective of the guideline is to protect the existing roof of the building, a number of layers of different material are used before planting (Figure 2).

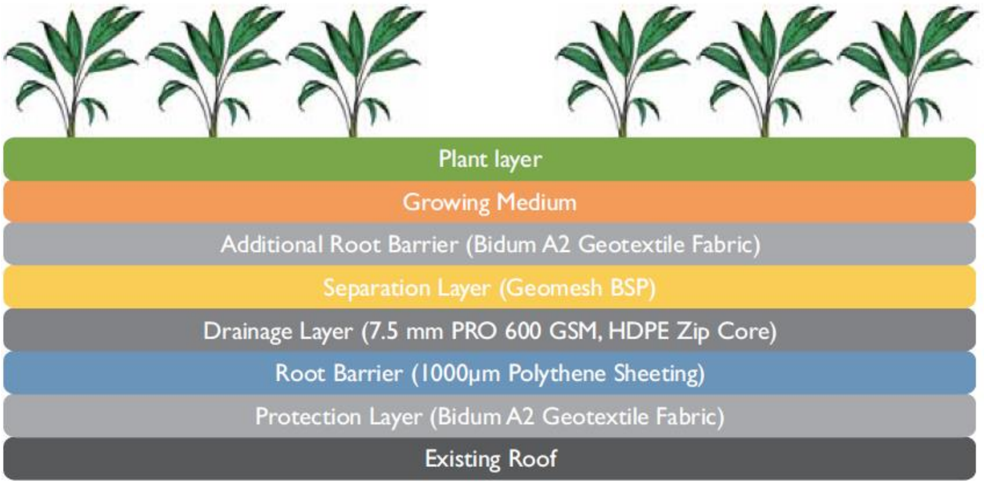

Figure 2. Schematic diagram showing layers of different materials installed to protect the existing roof of the building.

Such roof gardens, however, are challenging and costly to implement, and are not the most suitable solution for low-income, informal settlements where the ability to invest in a proper roof top garden remains too low. Individual urban food gardens in backyards have a much higher potential to be feasible in such environments, however, currently there are no specific guidelines for individual urban farming activities.

2.2.6.4 Pollution

The Department of Environmental Affairs (DEA) is responsible for controlling coastal area, rivers and pollution by providing citizens with an environment that is not harmful to their health or wellbeing and protecting the environment for the benefit of present and future generations. Pollution in this context refers to air pollution, water pollution and land pollution. Water pollution refers to direct or indirect introduction of substances or energy into the marine environment by humans, resulting in harm to living resources, hazards to human health, hindrances to marine activities including fishing and impairment of the quality of sea water (Glossary of Environment Statistics, 1997). Air pollution is contamination of the indoor or outdoor environment by any chemical, physical or biological agent that modifies the natural characteristics of the atmosphere. Pollutants of major public health concern include particulate matter, carbon monoxide, ozone, nitrogen dioxide and sulphur dioxide (World Health Organisation, 2012). Land pollution is the deposition of solid or liquid waste materials on land or underground in a manner that can contaminate the soil and groundwater and threaten public health

The DEA is divided into different branches which manage different aspects of the environment these include, oceans and coastal branch which promotes management and strategic leadership on oceans and coastal conservation in South Africa, climate change and air quality management branch which aims to improve air and atmospheric quality, lead and support, inform, monitor and report efficient and effective international, national and significant provincial and local responses to climate change and the chemical and waste management branch which manages and ensures chemicals and waste management policies and legislation are implemented and enforced in compliance with chemicals and waste management authorizations, directives and agreements.

The DEA is governed by a number of legislative mandates. However, the following mandates are directly linked to coastal, rivers and pollution. The National Environmental Management: Waste Act, 2008 (Act No. 59 of 2008), reforms the law regulating waste management in order to protect health and the environment by providing reasonable measures for the prevention of pollution; provides for national norms and standards for regulating the management of waste by all spheres of government; and provides for the licensing and control of waste management activities. The National Environment Laws Amendment Act, 2009 (Act No. 14 of 2009), which amends the National Environmental Management: Air Quality Act, 2004, so as to provide for a processing fee to review a licence, and to include directors or senior managers in a juristic person for the criteria for a fit and proper person. The National Environmental Management: Integrated Coastal Management Act, 2008 (Act No. 24 of 2008), which establishes a system of integrated coastal and estuarine management in the country; ensures that development and the use of natural resources within the coastal zone is socially and economically justifiable and ecologically sustainable; determines the responsibilities of organs of state in relation to coastal areas; controls dumping at sea and pollution in the coastal zone; and gives effect to South Africa's international obligations in relation to coastal matters.

2.2.7 Solid waste management

According to the eThekwini Municipality Integrated Waste Management Plan (2016), the Department of Water and Sanitation (DSW) provides households weekly waste collection. The report specifies that in formal residential areas this collection is done by DSW-owned vehicles, but in low income/high density settlements (i.e. informal settlement areas), the collection is done by private contractors hired by the DSW. These private contractors are known as Community Based Contractors (CBCs). The utilisation of CBCs is outlined as useful, as they are familiar with their collection area, and the collection method creates employment within low-income communities. However, there is little evidence of quality control with this method. For domestic waste, the DWS provides different colour bags for waste storage. Currently garden refuse and other organic material goes into landfill in Durban (eThekwini Municipality, 2016, p.46).

The eThekwini municipality classifies hazardous waste as any waste which poses a danger or is likely to pose a risk to the human health or the environment, due to its chemical reactivity or toxic, explosive, corrosive or other characteristics (eThekwini Municipality, 2016, p.57).

A review of waste management plan conducted in 2016 indicates that there is a small gradual decrease in amount of waste that is landfilled. Landfilling of waste is identified as the least favourable option in the waste management hierarchy (eThekwini Municipality, 2016, p.56).

2.2.8 Recycling activities

Recycling is identified as a key component for waste minimisation within DWS (eThekwini Municipality, 2016, p.83). The levels of recycling activities have a large range. Within informal communities, recycling is usually done on an individual level as a way of income. The DWS has an 'orange bag' initiative, which is to encourage households to utilise recyclables such as cardboard, plastics and paper. This kerbside collection happens on the same day was domestic waste collection.

Individual recycling happens at buyback centres, where recyclables are weighed, and an enumeration is paid per kilogram. There are seven buyback centres, which are located across the municipality (eThekwini Municipality, 2016, pp.83-87). The municipality estimates that 12.1% of households do not get regularly serviced (eThekwini Municipality, 2016, p.113). These households burn, dump, or bury their waste.

2.2.9 Electricity

The Department of Energy is responsible for the provision of electricity in South Africa. The Electricity Regulation Act, 2006 (Act No. 4 of 2006), establishes a National Regulatory Framework for the electricity supply industry and makes the National Electricity Regulator of South Africa (NERSA) the custodian of the National Electricity Regulatory Framework. The Act provides, for licences and registration as the manner in which generation, transmission, distribution, trading and the import and export of electricity are regulated. The Minister of Energy, in terms of Section 34(1), is empowered to make determinations for the establishment of Independent Power Producers (IPP) for the purpose of greater competition in the Electricity Generation Sector, so as to increase the supply of electricity. Eskom is a public utility supplying electricity to approximately 95% of the South African population. Electrical tariffs are established by IPPs and approved by NERSA. In 2018 NERSA approved a 6.84% average price increase which was implemented on 1 July 2018 for municipalities. These policies do not have an impact on resource recovery from waste and waste water for agricultural use.

eThekwini municipality has also embraced the Government's Free Basic Electricity programme, first introduced in 2003, which provides first 65kWh free and the balance of up to 150kWh at a reduced tariff to indigent customers (at 98.52(c/kWh) after the rate increase) (Masekameni et al, 2018).

According to a Durban government representative, due to the nature of informal settlements, being compact and irregular in construction, the municipality are required to ensure the electrical infrastructure has a higher standard of safety. Otherwise, the electrical design is no different to a design applied to any other township development. One of the biggest stumbling blocks, as pointed out by the same representative, is the accessibility both in terms of landowners' approval and the residents' participation. Once these issues are resolved, the sites are serviced as soon as possible in co-ordinance with the standard code of practice (private email communication, January 2019). Table 5 below demonstrates backlogs in basic infrastructure delivery in the municipality, including electricity.

Basic Service	Existing Backlog (consumer units) as at 31 March 2017	Delivery ranges per annum	Timeframe to address based on current funding levels *
Water	53188	2000-4000	13-26 years
Sanitation	147806	8000-10000	15-18 years
Electricity	237456	8000-13000	18-30 years
Refuse removal	0	1500-2000	0 years
Roads	1080.02 Km	10-15	72-108 years

Table 5. Existing backlogs in infrastructure delivery in eThekwini Municipality (2017) (eThekwini Municipality, 2017: 90).

There is no legal electricity provision in Havelock, however the community members have drawn illegal connections from neighbouring formal housing or street lights. Other major source of energy is paraffin, which is used for cooking and heating (ISN and CORC, 2012). There is access to grid electricity in Namibia Stop 8 and Piesang River.

2.2.10 Community resilience

Escobar (1995) argues that neoliberalism leads to state responsibilities being reduced, where citizenship is redefined by the market. Simply increasing agency and assets in informal communities does not alleviate the inequalities related to political and social participation. In fact, it further alienates these communities from the structures around them.

Jabeen et al., (2010) argue that lessons can be learnt and drafted into policy around how urban poor and informal settlers cope with vulnerability due to changing climate as well as extreme weather events. Understanding how to respond to hazards can help sustainable and applicable policy in local governments, that people can understand and apply. Moreover, much of the developing world is dealing with deficits around infrastructure provision, poor quality construction and lack of maintenance of existing infrastructure (Jabeen, Johnson, and Allen, 2010). Adaption to stresses and external hazards should be built into wider development perspective (ibid.).

This review has provided some insight into participatory development, and how upgrading practices should move beyond instrumental solutions. On the other hand, simply relying on community self-organisation and initiative does not provide sustainable change if it is not supplemented with technical expertise and inclusion to political structures. Therefore, this study combines these frameworks, and looks at participatory slum-upgrading and community resilience with a socio-technical framework.

3. Methods and methodology

Mixed methods have been used to collect data for Phase 3 with both qualitative and quantitative data collected to allow for data triangulation and to gain a good understanding of the complex socio-political structures and relationships, and daily realities in the settlements. Convenience sampling was applied for focus groups participants (according to availability) and in-household interviews where households were approached and asked for their participation according to availability until at least 50 households were reached, in each of the three settlements.

Data was collected in three phases. The first phase in May 2017 comprised of collection of qualitative data using tools including transect walks, community mapping, focus group discussions and seasonal calendars. The fieldwork for Phases 3 and 4 was combined to enable the project teams in the UK and Durban to work jointly. The Phase leaders initially provided training to the community researchers from the three selected case studies (Piesang River, Namibia Stop 8 and Havelock) on the tools and above-mentioned instruments used. Thereafter, the UK team, together with SA project member's Dr Claudia Loggia, Prof Chris Buckley and Dr Alfred Odindo visited the three case studies.

The next phase of data collection focused on quantitative data which was collected through in-household surveys in the three townships led by community researchers in two rounds: in February 2018 and then in June 2018. The purpose was to build on the observations that came from the transect walks and focus group discussions. This part of field work was intended to serve three major purposes:

1. Gauge the community perceptions of the infrastructure provision (including water, sanitation, electricity access) and the realities on the ground in each of the three settlements;
2. Investigate waste management and recycling within communities:
    a. Are habitants satisfied with waste management?
    b. What kind of support does the municipality offer?
3. Understand the interest in urban farming:
    a. Are habitants interested?
    b. Is there any previous knowledge on farming?
    c. How much time and resources, (both monetary and non-monetary), are they willing to invest?

Finally, stakeholder interviews were conducted by Dr Priti Parikh in June 2018.

3.1 Qualitative methods

3.1.1 Team Transect Walk

The project team walked around the three settlements of Piesang River, Namibia Stop 8 and Havelock marking key environmental features of interest such as rivers, lakes, communal facilities via notes and photographs. Key community members participated in the walk alongside the team from UoW, UCL, UKZN and CR. The team identified and discussed the nature and condition of existing infrastructure, including water, sanitation, waste disposal and treatment, flood/rain water, solid waste management, roads.

Figure 3. Transect walk in Namibia Stop 8.

3.1.2 Focus Group Discussions

The FGDs with community members (8-10 women in each of the three townships) covered issues such as gaps in existing services: water, sanitation, electricity and solid waste management, and priorities and needs for improvement environmental management and perspectives on various forms of infrastructure interventions.

Figure 4. FGD in Piesang River.

3.1.3 Priority mapping

Respondents (8-10 women in each of the three communities) were asked to rank high and low priority for water, sanitation, roads, electricity, sanitation, wastewater treatment, flood management, solid waste management, land tenure, house, education, health clinic, jobs. Every person in the group was provided a table to fill out (see Table 6 below).

Services	Ranking/Priority to pay
Water	
Sanitation (Toilets)	
Energy/Electricity	
Reducing Flooding	
Housing	
Improved roads	
Solid waste management (Garbage collection and disposal)	
Sanitation waste treatment and disposal	
Education/schools/nurseries	
Health clinic	

Table 6. Priority ranking template which FGDs participants were asked to fill out.

3.1.4 Seasonal calendar

Seasonal calendar was developed by community members (8-10 women in each of the three townships) from by jointly filling out the below template (Table 7). The goal was to indicate the shocks and stresses within the community by examining the peak times of flooding, high and low-income periods, water shortage, health problems, school holidays, school fee payment and busy market months, as well as peak months of energy consumption.

Month	Flooding	High Income	Low Income	Water shortage	Health problem	School Holiday	Pay School fees	Market Busy	Energy Use
January									
February									
March									
April									
May									
June									
July									
August									
September									
October									
November									
December									

Table 7. Seasonal calendar template.

3.1.5 Stakeholder interviews

9 interviews have been conducted with key stakeholders working on issues concerning informal settlements in Durban and more broadly in South Africa. The below table lists out the 9 participants.

Interview Code	**Name**	**Role/Title**	**Organisation**
I-A	Gary Cullen	Project Manager of Green Corridor	eThekwini Municipality
I-B	Geoff Tooley	Manager for Catchment Management	eThekwini Municipality Coastal, Stormwater and Catchment Management (CSCM)
I-C	Teddy Gounden	Strategic Executive Water and Sanitation	eThekwini Municipality
I-D	Cathy Sutherland	Senior Lecturer	School of Built Environment and Development Studies, UKZN

I-E	Nick Alcock	N/D	Khanyisa Projects and Aqualima Trust
I-F	Dan Naidoo	Senior Manager: Strategic Support	Umgeni Water
I-G	Vishnu Mabeer	Senior Planning Officer	eThekwini Water and Sanitation
I-H	Vanessa Watson	Professor	School of Architecture, Planning and Geomatics, University of Cape Town
I-I	Helge Mehrtens	Project Coordinator	Durban City Council for Bridge City KwaMashu Open Space Project

Table 8. Stakeholder interviews.

3.1.6 Data analysis

Qualitative data in the form of transcripts (FGDs and stakeholder interviews), observations (transect walks and community mapping), seasonal calendars and priority ranking tables has been analysed through content and discourse analysis using NVivo software which allows for coding qualitative data sources, assigning them into different emerging themes and visualising results.

3.2 Quantitative methods

3.2.1 In-household surveys

In-household surveys have been conducted by trained community researchers in all three settlements. A total of 152 surveys have been completed with the intended 50 reached or exceeded in all three settlements (Figure 5). Houses were selected through random sampling techniques.

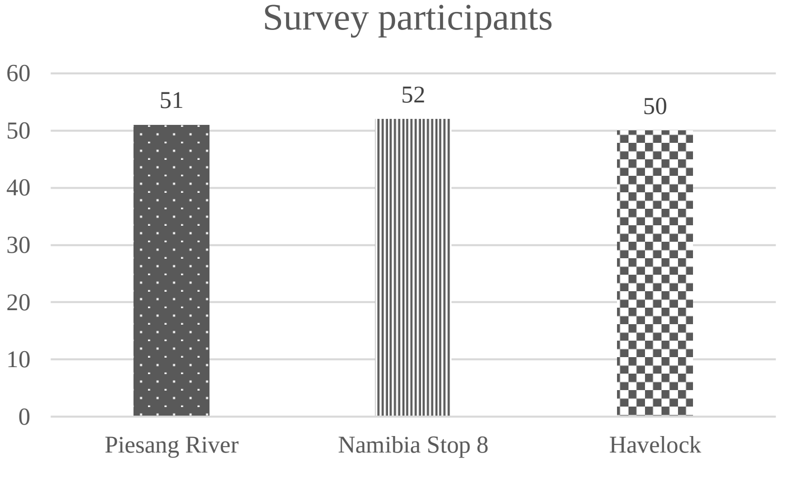

Figure 5. In-household survey participants in each of the three settlements.

In addition to exploring the demographic profile of the participants (gender, age, occupation, income, HH size), survey questions covered the following areas: solid waste management, recycling activities, farming, water and grey water use, flooding, access to sanitation and access to electricity. A survey template can be seen in Appendix 2.

3.2.2 Data analysis

Quantitative data was analysed using SPSS statistical software. Quantitative and qualitative data was triangulated to validate the results.

4. Qualitative findings

Transect walks in Piesang River and Namibia revealed a strong interest in vegetable farming through both farming on individual plots and communal plots managed by the Parks Authority. Water scarcity was noted to be a challenge. There were water meters installed in both communities. The transect walk in Havelock started from top side of Havelock where there are 6 (3 male and 3 female) ablution blocks built by the eThekwini municipality in April 2016. The Transect Walk highlighted solid waste management, flooding and water quality management challenges near the stream on-site. Phase 3 leads noted potential environmental and health risks due to poor waste disposal practices.

FGDs: For Phase 3 both communities (Piesang River and Namibia Stop 8) raised interesting points about the extent and reliability of water supply, need for clarity on issues such as access routes and billing for water and energy services. Residents discussed the value they placed on activities such as vegetable farming both at individual and communal scale. In Havelock residents highlighted other environmental and social risks such as fire hazards due to cooking and electricity cables, lack of safety near ablution blocks and flood risks.

4.1 Settlement characteristics

4.1.1 Piesang River

Piesang River (PR) is a well-established settlement with pucca houses. The upgrading process started in 1980s and carried on in 1990s. The transect walk started from the community hall which is the FEDUP's and SDI's office. There are a few houses with kutcha extensions spread throughout the settlement as well as a few double-storey houses. Councillor rooms, *Habitat for Humanity* houses, FEDUP housing, and double-storey FEDUP flats (which are less popular as it is dark inside, and they have no adjacent plots) are also present in the settlement. Overall, Piesang River consists of relatively big, nice houses with large plot areas and in some cases also guttering, fencing around the property, as well as security doors installed. Praise towards the building training provided by SASDI-alliance during FEDUP housing building process was mentioned and appreciated by the study participants.

There are bitumen roads with storm water flowing through the middle as the mid road section has a dip to collect rain water. Footpaths are partly grass and partly bitumen. A road sloping to one side with a dip on the side to facilitate flow of rain water has also been observed.

There is one communal garden and some fruit trees spread around. The soil appears fertile enabling a variety of trees and vegetables to be cultivated.

Tuck shops are common, and the settlement also has a post office, an old age home, a pension office, a supermarket and a taxi rank.

Community appears to be highly organised which might be due to the presence of the FEDUP office on site and FGDs respondents perceived themselves to be either connected or well-connected within the community. Some livestock (chickens) were seen around the settlement.

Figure 6. Piesang River settlement with a relatively favourable landscape.

4.1.2 Namibia Stop 8

Namibia Stop 8 is a community-led housing project supported by FEDUP through housing and finance. The Federation houses through a community-led project are larger (circa 50sqm) as compared to the also present municipal RDP ones which are circa 40sqm. In addition to the size, difference in roof tiles and external plaster in RDP and Federation houses is also noticeable. Some houses have solar geysers on the roof which were installed by the municipality before COP17. Dish TV is relatively common. Interior of housing has been modified and decorated to suit individuals' life styles and tastes. Walls have been painted or otherwise decorated. Many houses have been observed to possess multiple electrical appliances, such as a TV, fridge, radio, and speakers. Some of the rear households do not have official access to the main road and rely on the goodwill of the houses in front of them. Several houses near the main road have started fencing their boundaries which leads to challenges in accessing the main road. This poses risk for fire, emergencies and flood evacuation. Families in affected houses have complained about this and were waiting for a response, at the time of data collection. Land title deeds were also being resolved.

During the construction of houses agreements were set up with hardware shops and uTshani Fund provided finance to bridge the gap, as well as help in making estimates for costing. Community predominantly invest through sweat equity and group savings scheme (the 'Urban Poor Fund'). Community self-organisation was critical in the building of FEDUP houses with the construction being supervised by a Community Construction Management Team and group savings playing an important role in the financing of self-building of houses (See Phase 4 report for further information). Some members expressed interest in improving the roof gutter to collect rain water for vegetable gardens or learning about other localised, low-cost and low-tech techniques for irrigation. During the transect walk Prof Buckley and Dr. Odindo demonstrated the feasibility of using 2 litre plastic bottles for irrigation.

The settlement is situated near building material shops and services which is convenient for any construction or upgrading work. There are speed bumps put in place throughout the settlement to ensure safety of children and, according to Community Researchers, they ae effective. The main road is higher than the houses leading to overflow of water to the houses in the rainy season. Some roads are paved but there are few formal walkways between houses.

Figure 7. Namibia Stop 8 settlement.

4.1.3 Havelock

Havelock is an informal settlement on a hilly site. Housing in the settlement consists of shacks only, with illegal electricity connections from the nearby formal housing. One ablution block is situated across the stream which floods frequently and has a makeshift bridge going over it to cross from one side to the other. There is a laundry and drying area near the second ablution block which is also close to the stream. Despite weekly waste collection rubbish is dumped into stream with dirty nappies posing risk of spreading disease. A pile of solid waste was also seen above a sewer line.

Hardly any vegetation can be seen other than bushes near the ablution block. One bush used to be a vegetable garden, but now is highly dangerous due to amount of electrical wiring going through it. Similarly, access routes and paths within the settlement are narrow, steep, slippery and with electric cables (of various quality) posing a hazard. Scrap tyres are used to improve pathways especially during rainy season.

Figure 8. The challenging terrain in Havelock.

Havelock revealed some signals of community participatory initiatives. In fact, in 2012, the settlement conducted an in-depth enumeration of the shacks. After extensive mobilization, the leadership from Havelock was invited to meeting in Mayville where they heard about the saving scheme and advice and solutions on how *ISN* (Informal Settlements Network) methods can offer assistance to communities. This strengthened the relationship between the community and ISN. Workshops were hosted to train community-based enumerators in understanding the questionnaire, and thereafter, capturing the data on CORC provided computers. The initiation of the enumeration exercise saw the establishment of four teams: a data collection, a numbering team, a measuring team and a mapping team. The data was captured and returned to the community where the dataset was verified. Moreover, the dataset was spatially referenced via Geographical Information System (GIS). The results were presented to the eThekwini metro. Currently, the metro (and also the National Treasury) seems to be very interested in re-blocking this settlement (ISULabaNtu Report Phase 1, 2017).

4.2 Priority mapping

In Piesang River all the respondents identified water supply as a top priority followed by energy access (electricity), education for children, including schools and nurseries, and housing and sanitation. As all houses have flush toilets, the availability of water is critical to be able to properly use them and avoid clogging, hence the high importance placed on water in the priority ranking exercise. Additionally, given the rather high value placed on urban farming which is water intensive, it further elevated the water supply as having the highest priority for residents. Energy access, and more specifically electricity connection, was listed as second most important due to the high connection charges and high electricity bills that residents receive, as well as frequent power cuts. Therefore, reliability and high costs of electrical connection and power consumption are seen as an important issue. Education (schools and nurseries, and school fees) are of high importance for families with children. Sanitation access, which was number 4 on the list for Piesang River residents, links to the issue of water supply and to the use and maintenance of toilets, which are overall highly appreciated, however, without a reliable water supply challenging to use and keep clean.

Piesang River	
SERVICES	RANKING/PRIORITY TO PAY
Water	1
Energy/Electricity	2
Education/Schools/Nurseries	3

Sanitation (Toilets)	4
Housing	4
Health Clinic	6
Employment/Jobs	7
Sanitation Waste Treatment and Disposal	8
Improved Roads	9
Solid Waste Management (Garbage collection and disposal)	10
Reducing Flooding	11

Table 9. Priority ranking in Piesang River according to respondents declared priorities.

In Namibia Stop 8 water, sanitation and SWM have been identified as the top three priorities. Houses have flush toilets which require a lot of water to flush yet the water supply can be erratic. At times of low or no supply, the community order a tanker from the municipality. Additionally, when the water supply stops, bath water is used for flushing. Sanitation again links to the water supply on which toilets rely and which, when erratic, makes it challenging to maintain clean toilets and even use them. SWC takes place once a week in the settlement, however, despite residents being overall satisfied with the service, some felt that it was insufficient and there would be waste accumulated in plastic bags outside the house or on the street. Education was also ranked as third most important issue, similarly as in Piesang River, mainly for families with children.

Namibia Stop 8	
SERVICES	RANKING/PRIORITY TO PAY
Water	1
Sanitation (Toilets)	2
Solid Waste Management (Garbage collection and disposal)	3
Education/Schools/Nurseries	3
Sanitation Waste Treatment and Disposal	5
Energy/Electricity	6
Health Clinic	7
Reducing Flooding	8
Employment/Jobs	9
Housing	10
Improved Roads	10

Table 10. Priority ranking in Namibia Stop 8 according to respondents declared priorities.

In Havelock, water, housing and energy have been identified as the top three high priority issues with water ranked number 1 and housing ranked number 2 reflecting the inferior housing stock and living conditions in the settlement which consists predominantly of shacks. Water supply and toilets in the house were highly desirable. Electricity connections in the settlement are illegal and unreliable and pose a hazard as electrical wiring is found all over foot paths and on the road, which has caused fires and electrocutions before. Additionally, erratic supply means that electrical appliances get damaged during power surges.

Havelock	
SERVICES	RANKING/PRIORITY TO PAY
Water	1
Housing	2
Energy/Electricity	3
Employment/Jobs	4
Sanitation (Toilets)	5

Education/Schools/Nurseries	6
Sanitation Waste Treatment and Disposal	7
Reducing Flooding	8
Solid Waste Management (Garbage collection and disposal)	9
Health Clinic	10
Improved Roads	11

Table 11. Priority ranking in Havelock according to respondents declared priorities.

4.3 Seasonal calendar

Residents developed a seasonal calendar highlighting variation in incomes and climatic patterns during the year. This was used to assess impact on environmental systems and infrastructure provision. It was interesting to note that with three sites in the same city the seasonal characteristics and challenges around water resources was noted to be different in Namibia Stop 8 as compared to Havelock and Piesang River.

a) Piesang River

Months of flooding: December and January.

Months of high and low income: High income in December due to yearly bonuses and April.

Months of water shortage: July due to no rains.

Months of health problems: August during transition from winter to summer.

School holiday period: June, December.

School fee payment period: When starting school there is a registration fee that has to be paid and then the rest is paid in January.

Busy times for markets: In December due to holidays, festivals and visitors.

High electricity consumption times (why?): June and July use of heaters in winter.

Month	Flooding	High Income	Low Income	Water shortage	Health problem	School Holiday	Pay School fees	Market Busy	Energy Use
January	**X**		**X**				**X**		
February									
March									
April		**X**							
May									
June						**X**			**X**
July				**X**					**X**
August					**X**				
September									
October									
November									
December	**X**	**X**				**X**		**X**	

Table 12. Completed seasonal calendar in Piesang River.

b) Namibia Stop 8

Months of flooding: October.

Months of high and low income: High income in April due to pension disbursements and low income in January due to school fees. Months of high expenses are usually December (festivals/shopping) and January.

Months of water shortage: July due to lack of rains.

Months of health problems: May flu problem.

School holiday period: April to June which means more food is needed.

School fee payment period: Generally, January though some respondents pay in monthly instalments. School fees for government schooling are approx. 500R and private 2000R. Most of the respondents had children in government schools. In addition, they also pay for transport to ensure safety (150R).

Busy times for markets: In December due to holidays, festivals and visitors. Residents go to Inanda Mall to purchase household goods. It is near the police station.

High electricity consumption times (why?): December due to visitors and holidays as they use fridge more to store meat. Also, children are at home and play radio. Christmas time is also the time of increased electricity use.

Month	Flooding	High Income	Low Income	Water shortage	Health problem	School Holiday	Pay School fees	Market Busy	Energy Use
January			**X**	**X**			**X**		
February									
March									
April		**X**				**X**			
May					**X**	**X**			
June						**X**			
July									
August									
September									
October	**X**								
November									
December			**X**					**X**	**X**

Table 13. Completed seasonal calendar in Namibia Stop 8.

c) Havelock

Months of flooding: December and January

Months of high and low income: High income in December due to bonus and taking out savings from banks to buy presents for family. Low income in January as they do a lot of shopping in December.

Months of water shortage: June and July due to no rains.

Months of health problems: May often comes with the flu problem. January time is recovery from the eating and drinking post-Christmas.

School holiday period: March, June, September, December.

School fee payment period: Some pay in January and others on a monthly basis. Government school fees are 950R/child/annum and private school is 2800R/child/annum.

Busy times for markets: In December due to holidays, festivals and visitors.

High electricity consumption times (why?): June and July use of heaters in winter and December due to visitors and holidays as they use fridge and radio more.

Month	Flooding	High Income	Low Income	Water shortage	Health problem	School Holiday	Pay School fees	Market Busy	Energy Use
January	**X**		**X**				**X**		
February									
March						**X**			
April									
May					**X**				
June				**X**		**X**			**X**
July				**X**					**X**
August									
September						**X**			
October									
November									
December	**X**	**X**				**X**		**X**	**X**

Table 14. Completed seasonal calendar in Havelock.

4.4 Solid waste management

In all three settlements, there is solid waste collection from the municipality that takes place once a week, usually on Wednesday (in Havelock and Namibia Stop 8) or Tuesday and Wednesday in Piesang River, depending on which part of the settlement the residents are in. Bags are distributed to households to collect waste in. Collection of solid waste is outsourced to private contractors by the municipal corporation. There is no charge for residents for SWM.

Despite weekly collection, solid waste has proven to be a problem in the settlements. In Namibia Stop 8, solid waste is dumped into storm drains and during heavy rains, when water goes below the pavement through openings in the main road, accumulated waste results in drain blockages which has prompted a monthly cleaning to make sure the storm drain inlets are not blocked. Likewise, streets have to be kept clean to ensure that solid waste does not block the storm drains. Another issue is garbage (such as household items, e.g. unwanted furniture) being dumped in the stream. Solid waste dumped in the river is a problem also experienced in Piesang River, with an additional noticeable contamination from sewerage. Both have made residents stop using water from the river for farming in the settlement, which is further discussed in the following section.

Havelock is the settlement where SWM is the most problematic and poses the most risks and challenges. With organic waste being dumped near the ablution blocks by the stream when bins are full, rats have become a problem, posing a significant health risk. Solid waste is also disposed of in the stream, with nappies and other items which pose risk of contamination being frequently dumped there. Residents living in nearby houses have to clean up the stream themselves. Additionally, the settlement has been experiencing problems with recycling of bottles with private recyclers not always coming to pick them up which results in piles of glass bottles being accumulated near the stream.

Recycling is mostly done by ragpickers who earn a living from segregating solid waste (bottles, plastic, cardboards, cans etc.), collecting it either from designated places where community members dispose of those recyclables, or picking it up from around the settlements, and selling it to private dealers. Presence of such informal recycling activity has been reported in all three settlements, with very few (if any) respondents reporting doing recycling themselves in their houses or on their property grounds.

4.4.1 Challenges

SWM is currently recognised as an important challenge by the municipality. As contended by one of the interviewed stakeholders, the city is currently working in silos with no integration of services which, along with appropriate O&M, is seen as critical to achieve efficiencies (I-C, I-D). One example mentioned was that

SWM, i.e. collection of solid waste, is outsourced to private contractors. If SWM was combined with cleaning of toilets that would be more efficient and cost-effective for the municipality. A social franchising model operating at a not-for-loss basis where a management firm would take up maintenance of services has been proposed and presented to the council and will be piloted in the Northern part of the city where the councillors are likely to support it with less overall resistance to such initiatives. If the project is successful, there would be an opportunity to scale it up to other areas.

SWM in itself is challenging and meeting the level of demand for solid waste collection can be challenging. The consequences of not meeting that demand, as well as malpractices of waste disposal, can result in environmental threats in the settlements, with waste getting into drainage systems and streams or rivers, posing hazard of water contamination, increasing water stresses and flooding due to blockages, as well as attracting pests.

4.4.2 Opportunities

If the social franchise project succeeds, it might have the potential to address issues of SWM in the three settlements. Another initiative is the stream clean-up project near the bridge at Quarry Road in which one of the interviewed stakeholders has been involved (I-D). The project has been a success and has seen community members clean up an area which had a lot of solid waste in a very short period of time.

Of notable importance is a similar project, though on a much bigger scale, called ‘Sihlanzimvelo Stream Cleaning Project’ in the Umlazi area with 3 assessors monitoring and supporting 22 co-operatives maintaining a total of 110km of streams and the Ink area with 4 assessors monitoring and supporting 37 co-operatives maintaining a total of 185km of streams. With 59 co-operative contracts with the eThekwini Municipality active, the project has employed 472 workers, many of them youth, and has focused on the following activities (Extracts from C40 CFF application):

- Removal of alien plants
- Reduced response time for sewer leak detection and repair
- Removal of solid waste from the river systems
- Improved water quality
- Reduction in crime
- Improved quality of life in these communities
- Reduction in the blockage of culvert crossings and the associated damage
- Stabilised riverine zones through indigenous vegetation planting
- Increase resilience against climate change impacts
- Improving communities’ ability to engage with formal municipal processes
- Capacity building in communities to better understand the value of natural infrastructure and the need to maintain it.

Though not without challenges, the Shilanzimvelo Stream Cleaning Project has set an example of one viable solution to addressing the SWM challenge across various settlements in eThekwini. More on the project can be found in Appendix 3 which contains the thesis written by Haaniah Hamid as part of her UCL MSc in Engineering for International Development (led by Dr Priti Parikh) entitled *A socioecological study of solid waste management and drainage challenges in Havelock informal settlement, South Africa*. This study presents an analysis of SWM challenges in the Havelock settlement and offers valuable insights into the potential of existing solutions which could address the issues at stake, as well as a critical perspective on their downsides and shortcomings, while offering recommendations for ways in which SWM and drainage could successfully be tackled in the settlement. The reader is encouraged to read the appended thesis as it adds an important study component to Phase 3 of ISULabaNtu.

Another successful project of similar nature has been the pilot project for eThekwini Municipality - the Palmiet Rehabilitation Project which was developed through stakeholders’ engagements which resulted in an action plan. The Community of Innovation (CoI), forming a working group of key actors in the project, was established to oversee the implementation of the action plan. The project has seen several positive outcomes, among them- improved waste management. The waste would attract rats and was believed to be the root cause for the high number of snakes in the area. Through close collaboration with the community, aimed at curbing the littering and the pollution of the Palmiet River, a recycling pilot project was implemented in September 2016. The pilot did not only address the waste issue but also addressed poverty alleviation and job creation. In addition to the recycling project, the Durban Solid Waste commenced with waste collection by handing out black refuse bags to the Quarry Road Informal settlement communities. This initiative was implemented at the beginning of February 2017 and has since been well received by the community members (eThekwini Municipality, 2017).

4.5 Farming and water use

Results from the gathered qualitative data for each of the three settlements are demonstrated in the table below. A brief background of the history of farming (if any) and current agricultural activities is provided, followed by currently cultivated crops, existing skills and need for additional training, water use and key challenges as expressed by the participants.

HAVELOCK	PIESANG RIVER	NAMIBIA STOP 8
Little to no current farming activities; a co-operative in the past but no longer active; high interest in farming (for own use instead of buying produce, and for selling).	Individual and co-operative farming active in the settlement; municipal corporation provided land, HHs allocated plots; no committee managing the co-op; 2 large farms: one managed by co-op, the other one by individuals; high interest in farming.	Backyards used to grow vegetables among approx. half of participants; high interest in farming.
Interest in farming: Yes	Interest in farming: Yes	Interest in farming: Yes
Current crops: some individual fruit trees.	Current crops: different vegetables and fruit trees.	Current crops: different vegetables.
Skills & training: some residents have farming certificates; interest in learning more about farming.	Skills & training: very good knowledge of vegetable growing; no expressed need for more training.	Skills & training: good knowledge of vegetable growing; interest in learning more about farming.
Water use: unable to use water from stream due to contamination; water from ablution blocks.	Water use: tank water used (often empty); river water (poor quality).	Water use: tank water used; grey water occasionally used to water plants + grey water reuse project underway; nearby stream (low water level).
Challenges: lack of land/space; potentially available land close to sewer line; quality of the soil; sufficient water supplies.	Challenges: pollution of the river front which used to be used for vegetable growing; poor water quality from the river & sufficient water supplies.	Challenges: fencing for gardens and area used for farming near the stream to protect crops; sufficient water supplies.

Table 15. Urban agriculture activities, conditions and challenges in each of the three settlements.

Figure 9. Most commonly occurring words in discussions on urban agriculture.

4.5.1 Challenges

Despite the overall high interest in fruit and vegetable farming within each of the three settlements, and some pre-existing skills and agricultural activities, there remains a number of challenges the residents are faced with to either continue or commence farming. Space, i.e. availability of land, poor quality of available water supplies and sufficiency of the required water supplies, as well as soil quality and availability of farming tools, which have been indicated as desirable when asked about what kind of help residents would like to receive to be able to farm, all demand attention if urban agriculture is going to develop or expand in each of the sites. Further challenges are discussed in the following section where examples of urban agriculture projects with various levels of success are presented, based on stakeholder interviews on the subject.

Even though the eThekwini municipality has previously had initiatives to promote urban farming in low-income areas for resilience and self-reliance, there has been lack of developed guidelines and plans for execution, which has translated into a limited capacity of the informal settlement dwellers to successfully carry out urban farming projects locally, including within their own homes.

4.5.2 Opportunities

The Infrastructure Management and Socio-Economic Development Department has an Agro-Ecology programme which was established in May 2009 with the aim to promote sustainable approaches to the way in which agriculture is planned and implemented in urban and peri urban areas. However, there are no guidelines.

The eThekwini area has been divided into 5 agricultural zones to facilitate the equal distribution of resources, taking into account catchments, road access and logistics. Hubs have been established in each zone to support growers with training and inputs, these hubs include Newlands, Umbumbulu, Inchanga, Mariannhill and Northdene. Training includes ‘bio intensive’ food production where the soil in main crop production beds are built through a method of double digging and adding organic composts; compost making and organic pest control. The training also offers programmes for water conservation, composting and productive use of land.

According to Mr Lawrence Maduramunthu, eThekwini's chief horticulturist, many jobs are being created through this initiative, approximately 38 people are employed at the hubs, but the real impact is in communities. The field staff currently support approximately 241 gardens representing 1 896 growers.

The roof top gardens is an initiative by the eThekwini Architectural department. The initiative involves planting of vegetables and herbs on top of building roofs. The green roof pilot project (GRPP) is part of the eThekwini Municipality's Municipal Climate Protection Programme (MCPP) which was initiated in 2004 by eThekwini Municipality's Environmental Planning and Climate Protection Department (EPCPD). The overall aim of the programme is to make Durban more resilient to existing and future climate challenges. Priority Zone offices in Durban is a good example of green roofs in South Africa. The roof of this one storey building has been transformed into a garden that contains a variety of indigenous plants, vegetables and herbs. The garden was developed to serve as an example to other companies that it is possible to have a garden in the inner-city environment with limited space. Benefits of the rooftop gardens include bringing biodiversity back to the city and vegetation reduces the indoor ambient air temperature of the building. However, as mentioned earlier in this report, such rooftop gardens do not suit low-income housing contexts and have been challenging to implement there predominantly due to high cost.

There are also examples of successful initiatives promoting and supporting urban agriculture in informal settlements and low-income housing. For instance, Aqualima Trust have implemented 28 biogas digestors in a rural informal community Ndwedwe (I-E). Funding was provided by the national government. The biogas is generated by using biomass from livestock. The HHs for participation in the project were selected on the basis of involvement in agricultural activity and presence of livestock which are kept in kraals (enclosures) overnight so that the dung can be readily collected. Local builders built the bio-gas digestors. Some of the HHs also got involved in food gardens. Land ownership was noted to be a key challenge in tribal areas as the tribal leaders (chiefs) control access to the land. Water access, required to slurry the dung, was noted as another challenge to operate the biogas plant. Attempts were made to collect greywater to be diverted to the biodigesters to address the water challenge, however, this was not enough so then additional water supply and piping proved to be a challenge. Also, the high upfront costs of ZAR 30 000 to 40 000 made it unaffordable for scale up.

In other low-income settlements, Aqualima have implemented rain water harvesting systems and gravity feed low-tech irrigation systems. The challenge has been the low resource base and lack of skills for maintenance to ensure that the systems work. Ongoing support is therefore required from NGOs to maintain the systems. For example, de-clogging of irrigation systems and repairs would need external support which is a challenge for sustainability of such schemes. To ensure sustainability of such schemes, support of municipal teams would be required for O & M.

'Success of most urban farming schemes is highly dependent on local leadership'

as asserted by Nick Alcock (I-E). Leadership within the settlements has been seen to play a critical role not only in farming initiatives but also in construction and other self-upgrading activities which heavily rely on the presence of local leaders and their community mobilisation ability. In some urban farming schemes, the leader would contract work to labour and run the farm as a small business. In some instances, a large plot of land would then he subdivided and managed through co-operatives. The challenge often is how to share resources and the arising income. Additionally, sometimes there is a high turnover and lack of consistency of individuals who engage in farming, putting at risk the continuity and sustainability of the farming initiatives.

KwaMashu township also has a successful story where Aqualima have helped to install gravity flow pipes and install sprinklers for vegetable farming. The households now sell the crops; however, the income is less than that earned in a full-time job. Yet given the high unemployment rate of up to 30% for youth, this offers at least an intermediary solution but also proves that urban farming is not financially viable for all. Another initiative in KwaMashu is the Newlands Mashu Agricultural Hub which forms part of the Agricultural Management Unit (AMU) in the Parks Department of eThekwini Municipality. It serves as a bio-intensive vegetable growing hub and promotes commercially sustainable economic opportunities through agriculture by providing training and testing resource recovery, including wastewater (eThekwini Water and Sanitation & Pollution Research Group, 2015).

In terms of grey water reuse in informal settlements in rural areas in Durban, Aqualima installed a variety of systems including door-frame and vertical farming solutions in which grey water was used. This was undertaken, for example, in Joanna Road with an NGO Africahead. It was a low-tech yet functional solution where mesh was used for the vertical gardens. Grey water would be poured into a pipe and then soil used for filtration. The system was built out of plastic pipes. The second site was in rural areas where traps were put in locations used for washing dishes in households. Perforated pipes were then installed to allow filtration and then irrigation. The system worked well but the key challenge was the question of who would unclog/flush the pipes to remove silt/soil to allow for continuous filtration.

A small-scale farming solution for Namibia Stop 8 for an individual HH vegetable supply and designed with the use of recyclable materials, so that they are readily available in the settlement and do not incur additional costs on the HHs, has been proposed by a UCL MSC Engineering for International Development student Xuexin Li and can be found in Appendix 4. The research concludes that a small-scale farming device with controlled drip irrigation approach demonstrates the viability of vegetable farming for household consumption, and also a good practice in preparation of a collective scale farming within the community.

To sum up, promoting urban farming in low-income communities could promote livelihood creation and feed residents in highly dense urban settings. However, there is need to develop a community-centred approach if such initiatives are expected to be sustainable. Cropping patterns, tilling techniques and dryland farming techniques, which can reduce water use to avoid theft or over consumption of scarce water resources, need to be considered. The potential for reuse of grey water, and the acceptability of such uses, needs to be explored as grey water is disposed in open plots and streams. There is a tension between promoting activities which increase water scarcity in townships whilst they are also considered water scarce sites. While water issues lie at the centre of implementing sustainable urban farming activities in informal settlements, land and the lack of space also requires a careful consideration, as despite the high interest in getting involved in farming, space can be another key constraint. Provision of training on urban farming will also play a critical role, giving settlement inhabitants the know-how of best practices and most feasible crops given the local conditions (such as soil, precipitation etc.).

4.6 Flooding

Flooding in the three settlements occur predominantly in the summer months (Nov-Jan), as has been indicated by focus groups participants in the season calendars which they filled out (see section 4.3). Excessive rains pose flooding risk in Havelock, Piesang River and Namibia Stop 8, however, due to the inferior housing in Havelock (shacks as opposed to properly constructed houses) and the inferior infrastructure within the settlement (drainage, pathways etc.), the risk and the consequences of flooding are the most significant there.

Houses across the whole settlement frequently get flooded during the rainy season, with the houses near the stream being the most affected. 86% of survey respondents said they get affected. Used tyres and other scrap materials are used on the roads and pathways to improve accessibility during rains and to avoid stepping on the electricity cables which pose a serious threat of electrocution and fires. Additionally, settlement residents also wear plastic boots or slippers to further ensure safety from the unsecured cables. The stream cleaning efforts are also related to flooding in Havelock and have been made in order to improve the flow of water during flooding (rubbish disposed in the stream can cause blockages and clogging points along the stream, increasing the risk of flooding). What is more, at times of particularly heavy rains the water goes over the makeshift bridge, posing a serious challenge for access (i.e. getting into the settlement). The stream catchment area also suffers from the presence of cables which poses further risk. Flooding damages are typically severe with furniture getting wet (which the residents describe as ‘rotten’), clothing also getting destroyed, mud covering the floors and making it difficult to clean up, effectively making the living conditions perilous. In worst cases, houses collapse, and possessions get washed away. HHs members experience additional challenges caused by flooding, namely the inability to walk to the public toilets (since there are no toilets in the compounds) as the stream overflows, covering the bridge and making it impossible to cross it. Affected houses spend anything between R80-R3000 (£4-£160), however, often they do not have any expenditure associated with the fixing of damages as they either do it themselves, get help from the community or from the municipality. Those who are able to pay get help from contracted workers and source material from the local hardware store, find scrap materials around the settlement or nearby areas.

In Namibia Stop 8, the main road is higher than the houses level and during rainy season the water overflows, posing risk of flooding the houses, particularly in the vicinity of the road. However, FGD participants did not perceive this to be a serious challenge. Some of the houses near the main road have started fencing their boundaries (to protect their land and prevent others from encroaching on it) which leads to obstruction of access to the main road, in turn posing risk for fire, emergencies and flood evacuations. Not all households in NS8 get affected by flooding during heavy rains (52% of respondents said they experience flooding in or outside their house). For those who do, water usually gets in the house, mainly through the door (which is not always good enough to keep it away) or through the roof which can sometimes be improperly constructed causing leakages. Water also accumulates around the house, in the yards. Makeshift solutions to prevent the above are most common: digging trenches, putting towels under the door, plugging holes with various materials. The damage is usually fixed by the HH members and little to no money is spent. For those who do put money towards the damages, it ranges between R100-R1500 (median R400 (£21)).

Even though Piesang River appears to face the least challenges as regards flooding, nearly 70% of survey HHs reported being affected by it during the rainy season. The settlement experienced a major flood in 1987 but flooding has reduced after the construction of the bridge. However, the houses near the river still get severely affected by rains as the soil is expandable clay which shrinks and expands thereby undermining foundations and walls of houses. The area is seen as wetlands and sometimes houses collapse during rains. Some residents complain about leaks in asbestos roofs, others dig trenches to alleviate impact. Those able to pay for damage repair spend anything between R20 to get help with trench digging to R15000 (£80) (median R1000 (£53)), which was the most serious expense for one of the HH where the roof had to be replaced. Occasionally, electrical goods also get affected and damaged (e.g. fridges), which can result in losses.

4.6.1 Challenges

Flooding poses serious challenges for all three settlements and often affects other informal settlements which suffer from poor and inadequate infrastructure, unable to cope with the amount of water received during heavy rains and with residents incapable of putting solutions in place which would alleviate the risk of getting impacted. Floods not only cause physical damages to the houses and household goods (such as furniture or appliances) but it also poses health and safety threats in settlements such as Havelock where electrical cables cover the ground and the risk of electrocution at times of heavy rains is considerably increased, with accidents frequently occurring, occasionally resulting in deaths.

The additional challenges associated with rivers and streams which are poorly maintained and overflow during heavy rains, boosting water levels in the surrounding areas and further exacerbating the damages. Even if residents get moved to other, safer areas (such as community halls) during floods, they tend to go back to the same housing and settlements once floods end (I-H) which subjects them to the same problems and threats in the future.

4.6.2 Opportunities

The eThekwini municipality are working on early warning systems and hazard mapping for all river systems with informal settlements seen as top priority areas. They have a disaster management team which evacuates settlements during flood events. On one occasion, during a disaster in Piesang River, they evacuated the community and took them to a new location which was already full. They now use informal channels of transmission to engage with local community members. For example, currently when high risk is perceived they contact individuals like Cathy Sutherland who have strong links and have built trust with local communities to tell them about the risk. The communities then start responding and have been seen to adapt to circumstances. This works better than a top-down flood evacuation strategy as residents can develop adaptation strategies which work for them, ranging from taking children to high spots, keeping valuables safe and dry, and other informal measures.

4.7 Water access and sanitation

Water and sanitation access are provided in all three settlements, however, Havelock is the one where HHs do not have toilets in their houses and where water has to be fetched from the ablution blocks, as opposed to the other two where HHs have access to both in their houses.

In Havelock, there is 24-hour water supply to the ablution blocks. Families typically take 20L containers and collect water from the ablution blocks through 2-5 trips/day. Both men and women are involved in collecting water though women are the ones making sure there is always enough water in the house. Water is heated in kettles or on paraffin stoves. The water supply is regular and generally reliable, and FGD respondents felt that they had enough water to satisfy their in-HH needs. However, some women expressed their desire to have hot water baths in their houses rather than having to use the municipal showers, indicating aspirations higher than what the current level of service provision is. Water access is free with no queues, as reported by FGD participants.

Regarding sanitation, residents use the ablution blocks which are open between 5am and 10pm. If residents want to use the blocks during the night they need to find the caretaker to open the locks. There is currently more than one caretaker in the settlement. The ablution blocks were built by the Municipal Corporation in April 2016 to replace red toilet containers with the blue toilets. They are in blue containers with a public tap in the middle with circa 12 taps. The female toilets contain 4 WC cubicles and 2 shower cubicles, along with a wash basin with two taps.

Generally, no problems with the units have been reported by FGD participants, however, no cleaning products and no toilet paper were noticed during the transect walk and the streetlight behind the toilet has been disconnected by the Municipal Corporation as it was illegal, leaving no lighting near the ablution block. If there is blockage, the operator calls someone from the Municipality and they come to fix it.

Residents are willing to pay for toilets in their houses which they would prefer mostly for convenience, particularly so they do not have to leave the houses at night and worry about having to use the toilets before they get closed.

Namibia Stop 8 presents a different context, with water and sanitation access present in every HH. Water supply is a combination of municipal water supply and the surplus from the municipal tanker. Municipal water supply is usually 4am to 8/9pm but this is not reliable. After applying for a water connection, HHs now have meters to measure consumption (since end of 2016). Meter readings are taken every month. There is an allowance of 300L/day/HH of free water i.e. 9000L/month/HH. If the houses consume more, they are charged on a tariff which makes high levels of consumption expensive (the more above the free limit is used, the more expensive it gets). Water bills are approx. R1000/month, depending on consumption.

Water tanker from municipality is ordered when the network water supply is erratic. Taker water is free of charge. This poses a significant problem as the houses have flush toilets which need a lot of water for flushing. When the water supply stops, residents use bath water for flushing. The reliability of water supply in the settlement has been unanimously indicated as one of the main challenges.

Some houses have solar geysers for water heating which were installed by the Municipality before COP17.

All houses have toilets as they are connected to the sewer lines. The biggest challenge related to them is the above-mentioned unreliable water supply which means that sometimes HH members cannot properly use the toilets as there is no water to flush them. Water from washing or bathing is then reused for this purpose.

Piesang River's situation is yet again comparable to that of Namibia Stop 8, rather than Havelock's. All houses have access to metered water connections and toilets. After the housing upgrading in 1985 everyone now has water in their houses. Some houses have 24-hour water supply and for some it is available between 4am to 8pm. If there is a leakage or a water pipe burst, residents call the Municipality (who fix the issue) for a water tanker. At the time FGDs were conducted, participants reported that most of the HHs were not getting water bills as they were waiting for title deeds.

There are flush toilets in all the houses. For those who do not have water supply at night, HH members fill up a few buckets at 5pm to flush the toilet during night time. If there is a toilet blockage, residents get a local plumber to fix who charges circa R50-150R (£3-£8) (less for pensioners).

4.7.1 Challenges and opportunities

In RDP housing and for UD toilets pits are still the dominant solution. Pits constructed by the city are lined. Initially, the plan was for the city was to build the toilets and for HHs to maintain them. However, this does not work in practice and now the EWS also manage desludging through private contractors. Desludging is mostly manual with barrows due to narrow access points. The cost is circa R600/pit for small pits and R900-1000/pit for the larger ones which need to be emptied every five years. The city has LaDePa (Latrine Dehydration and Pasteurization) plant to covert faecal sludge to pellets with a capacity to treat waste from 25000 pits. The first plant is not working but 4 machines have recently been ordered (with the delivery set for August 2018). At the time of the interview with Teddy Gounden (June 2018), the demand for emptying stood at 36000 pits.

In relation to WASH projects, Aqualima work on Urine Diversion (UD) toilets and black soldier fly larvae for treating faecal sludge from urine diversion toilets. The key challenges with new sanitation technologies, as pointed out by Nick Alcock (I-E) is that they require change in management regimes which makes implementation complex.

There are concerns over what happens when dry UD toilets are converted to pour-flush ones and how and where the waste is treated, if at all. DEWATS has been proposed as a potential treatment solution but it requires land, which might pose a challenge. eThekwini Housing will be testing this out in Banana City with UKZN and EWS.

O&M remains one of the most critical challenges for WASH initiatives across the municipality, as is further discussed in section 4.9.

4.8 Access to electricity

As contended by Teddy Gounden (I-E), the electricity department have made good progress in installing OH cables and electrifying informal settlements. This also includes streetlighting which increases safety at nights and reduces illegal tapping of electricity, as well as health and safety risk to children posed by cables on the ground. However, despite those efforts, not all settlements enjoy proper access to electricity.

Overall, there is access in all three settlements. However, each one faces different challenges.

In Havelock, houses predominantly rely on illegal connections for which they do not pay, other than for the (informal) connection fee to the person who provides it, which can be costly (R250-R800). Additionally, if there are issues with the power lines or any damages, the residents are also responsible for paying for those, which they tend to do as a group (collect money and purchase necessary parts together). Such incidents happen frequently during the rainy season. As mentioned in section 4.1.3, electrical cables can be found spread on the ground around the settlement, which has caused electrocutions and deaths before, and poses a serious risk not only for the residents (many of whom are concerned about the safety of their children) but also risk of fires. This is precisely what the electrification efforts undertaken by the municipality have tried to eliminate.

Electricity is used to power fridges, TVs, kettles, irons, microwaves, stoves, cell phones, lights, radios, hair dryers, toasters, fans, mosquito killers, etc. Very few houses use electric heaters. The electricity supply is unreliable with power cuts sometimes lasting as long as three days. Fluctuation in voltage causes damage to appliances and residents then need to get them repaired which usually costs around R20. When asked about getting a legal connection to the grid network, FGD participants expressed willingness to pay for prepaid cards but not for metered connections as they are worried about high bills.

In Namibia Stop 8, every FGD participant had prepaid electricity cards which need to be topped up. The cards start from 10R (and as high as 400R). Some FGD participants felt that the disadvantage is that there is no government subsidy. The group also felt that if they added small amounts 20-30R to their card regularly, they would get government subsidy. 100R on the card would be equivalent to 67 units, 50R – 36 units (kWh). There is approx. 50W/month free after which HHs are charged on a tiered tariff system. On average, HHs spend R270/month (median R225), with the price ranging R10-R1000, among survey respondents, all of whom had access. Residents generally understand the importance of electricity and the need to pay for it, but they feel it is too expensive and would like to see some level of help from the municipality to make it more affordable. Another challenge is the damages to the cables (e.g. when someone cuts the cables), which means fridges have to be switched off and food goes to waste. Additionally, for cooking people have to then buy paraffin which poses a high risk of fire and should ideally be avoided.

Electricity services are used to power fridges, TVs[2], kettles, irons, microwaves, stoves, cell phones, lights, radios, washing machines in some houses, and fans (not all houses). Very few houses use electric heaters. Some houses with solar geysers on the roof were seen during the transect walk.

Piesang River is similar to Namibia Stop 8 in that majority of HHs have legal, metered electrical connections and use prepaid cards, which was facilitated after the federation helped with enumeration. Initial connection fees are approx. R350 for each house. Average monthly cost is 100-300R, as reported by FGD participants, and approx. R300 (median R300), ranging between R30-R800 among survey respondents. Electricity is used for stoves, heaters, hair dryers, fridges, lights, irons, kettles, TVs, and cooking. Quite a few houses also have geysers for hot water. FGD participants felt that electricity is critical for them and they would not be able to love without it, therefore they are willing to pay for it, seeing as there is currently no other option.

The settlement also has streetlights which helps keeping it safer at night.

4.9 Key challenges

4.9.1 Transit or permanent?

Typically, informal settlements are seen as a transit where the emphasis is on providing interim services and residents would be planned to be moved to RDP housing and townships. The challenge is to meet the high demand for services despite such notions being prevalent. Umgeni Water would like to step out of the comfort zone and look at new initiatives for service provision. At the moment, they provide services to the

[2] Dish costs 300R initially and then 700R/month depending on which TV channels are used.

periphery of informal settlements. They are interested in exploring the potential of networked infrastructure in informal settlements but are concerned about steep slopes and high density.

The transit nature of the communities poses another challenge. Whilst it was expected that the communities would be in transit camps/informal settlements for a short duration due to housing backlog, some of the communities end up there for as long as 6-20 years. EWS do provide interim services for informal settlements but the population is large and the facilities few. Sometimes facilities are installed and there is a surge in population, meaning that the provided services no longer suffice (I-C).

4.9.2 O&M, WASH, tribalism and decentralised vs centralised services

The key challenge for the city is keeping with the O&M costs and resourcing for WASH services (I-C). The key question is how to provide services and then maintain them in a sustainable manner. This would require employing more people and setting up teams to manage services in informal settlements. Currently, EWS have 6000 staff members, a number which has doubled in the last few years. Finding resources to operate and maintain services in informal settlements is a key challenge facing the city. The economic case does not stack up as most of the informal settlements fall under the free basic services schemes with limited or no revenue generation potential.

Some houses in rural parts have septic tanks for treatment. In addition to rural to urban migration there is also a trend of urban to peri-urban(rural) migration (circa 150000 people) where people go back and live in nice houses and some still claim benefits. The tribal land ownership is contentious at the moment as the services provided to HHs on that land cannot be charged for. Some HHs tap into services and live on nice properties on tribal land. There are discussions about changing it, but this would require an amendment to the constitution and is a sensitive issue. A lot of those houses use a lot of water which has detrimental impact on water pressures. They also install septic tanks which are not managed well. Sometimes if the pits are not lined for toilets they discharge into streams.

The IDP (Integrated Development Planning) and spatial planning document does not cover the charging of services and this is a big gap and barrier for scaling up services.

With urine diversion toilets, for example, the challenge that the city faces is that when they are built there are still gaps due to population growth. If the city contracts them in bulk for a settlement it is cheaper (circa R5500 (£300)) but if they have to go in and fill gaps for the new houses it becomes expensive (circa R 14000 (£770) (I-C).

Additionally, there has been discussions on the trade-offs for centralised and decentralised services. In Besters (Camp) community, a highly dense community 4km away from airport, the households have pit toilets. The politicians requested for sewers, but the road access was non-existent and with high densities EWS built toilets. Phoenix township similarly has pit latrines. The question of extending centralised services and the sewers network remains a contentious one.

4.9.3 Safety

One of the largest issues in Havelock is the lack of safety, referring to both illegal electric wiring and fire safety. The shacks are built densely and from fire hazardous materials. Illegal wiring has caused casualties and present a large monthly cost as municipality cuts connections up to twice a month. Unpassable paths and contaminated areas, particularly around the stream, can cause accidents, as can the unpassable bridge during heavy rains.

Safety is also compromised in times of flooding, in all three settlements. The challenges of undertaking evacuations in times of heavy rains or other disasters are significant and can be life-threatening.

4.9.4 IDP Housing and the spatial divide

In the recent years standalone housing/settlements (IDP housing and townships) have been shrinking with an increase in back yard shacks in Cape Town. Cheap land was the key driver for locating IDP housing out of the city which resulted in a spatial divide. So, the divide actually worsened as low- income groups were provided housing outside the city periphery at a large scale. Some of the housing schemes did not have social infrastructure such as schools and health clinics. This reflects a failure of the housing policy. There is a need for integrated city planning approaches with promotion of mixed housing schemes. In the initial 10 years the housing policy did deliver on a large number of houses, but the houses were terrible and poorly located.

The 3-storey housing scheme near the airport was an attempt to build housing in good location with a high-density development. However, this was too expensive for the intended occupants and was captured by land lords (gangs).

Recently in Cape Town there has been a shift to backyard shacks which are perceived to be safer. In particular, it is seen to be better for women on their own. However, this might be specific to Cape Town. The number of houses being delivered through the housing policy has reduced. There is a strong interest in social housing co-developed by NGO’s and government, examples of which include SDI and Cape Town Municipality partnership.

As summed up by Nick Alcock (I-E), some of the key barriers to infrastructure provision are:

KEY BARRIERS TO INFRASTRUCTURE PROVISION		
POLITICAL	SOCIAL	PHYSICAL
• With proportional representation from various sub-groups of voters, informal settlements would end up with a ward having 2 to 3 different councillors often in different political groupings with conflicting messages. The townships typically have one councillor as it is more homogenous.	• The rapid increase in population: especially noted after service provision resulting in increased densities. • Trust building: it takes a few months to build trust before implementation in communities which can significantly delay interventions.	• Include steep slopes, heavy rains and proximity to rivers/streams.

Table 16. Key barriers to infrastructure provision (I-E).

5. Quantitative findings

A total of 103 respondents (each representing one household (HH)) took part in the in-HH survey. The breakdown across the three settlements and genders is demonstrated in Figure 10 below.

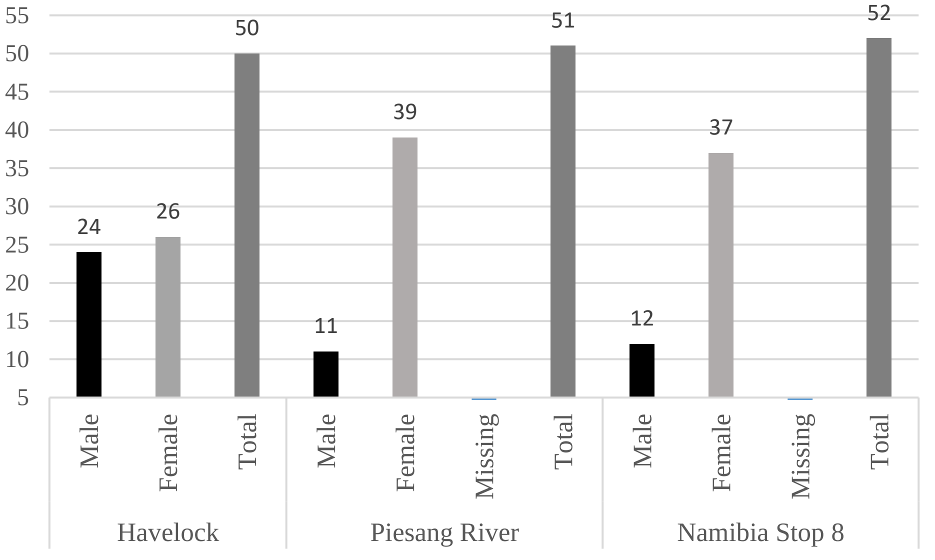

Figure 10. In-HH survey participants split by gender in Havelock, Piesang River and Namibia Stop 8.

Considerably more women than men participated in the survey in Piesang River and Namibia Stop 8 than in Havelock where the male vs female split was more balanced.

Demographic characteristics of each of the settlements are presented in section 5.1, followed by survey findings covering solid waste management, farming and water use, flooding, sanitation and access to electricity. The section concludes with a summary of key identified challenges and opportunities.

5.1 Demographic settlement characteristics

5.1.1 Havelock

The average age of respondents in Havelock was 33 years (median= 31 years) (Figure 11).

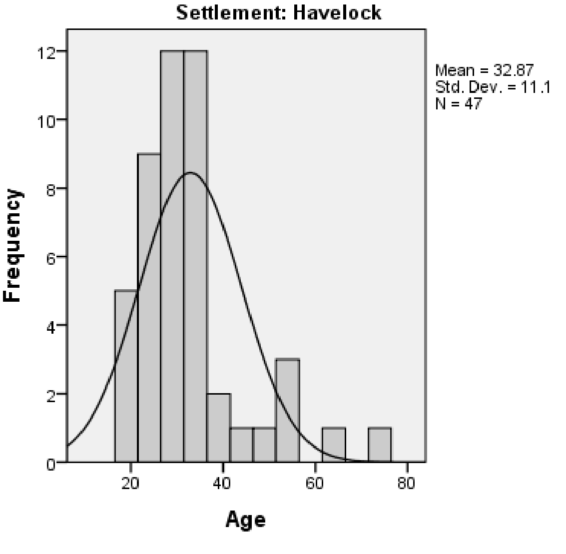

Figure 11. Age distribution of survey participants in Havelock.

76% had secondary education, while primary and higher education saw 8% of participants. Another 8% never attended school or did not complete any level of education.

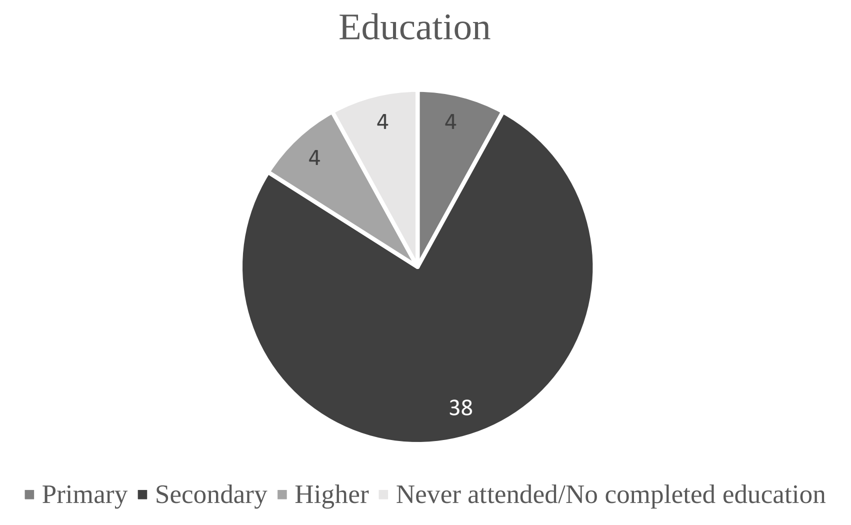

Figure 12. Number of survey participants with primary, secondary and higher education, as well as those who never attended school, Havelock.

There were, on average, 2 adults per HH in Havelock (median=2), and 0.5 children (median=0). 24% of respondents were renting their houses as opposed to 76% who owned them.

40% of respondents were employed. The occupation status of other respondents can be seen in Figure 13 below.

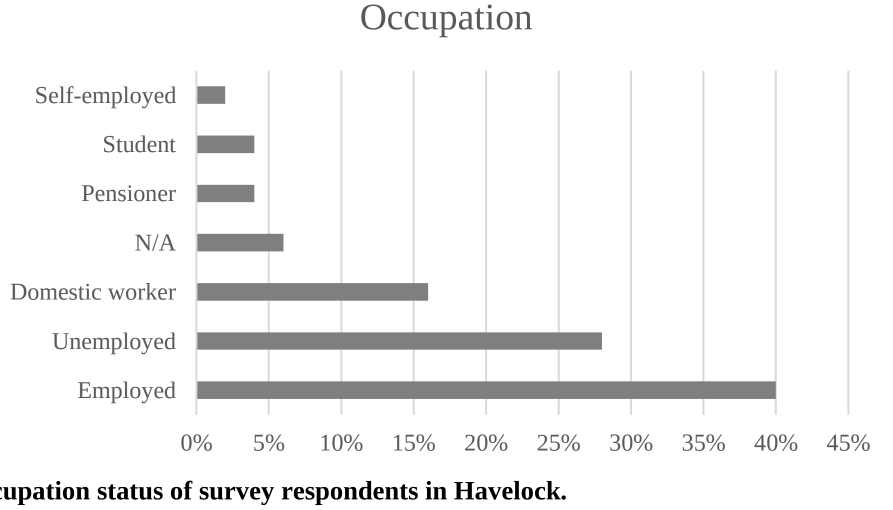

Figure 13. Occupation status of survey respondents in Havelock.

Income questions were asked using a range of brackets into which respondents identified themselves falling into. The results are shown in Figure 14.

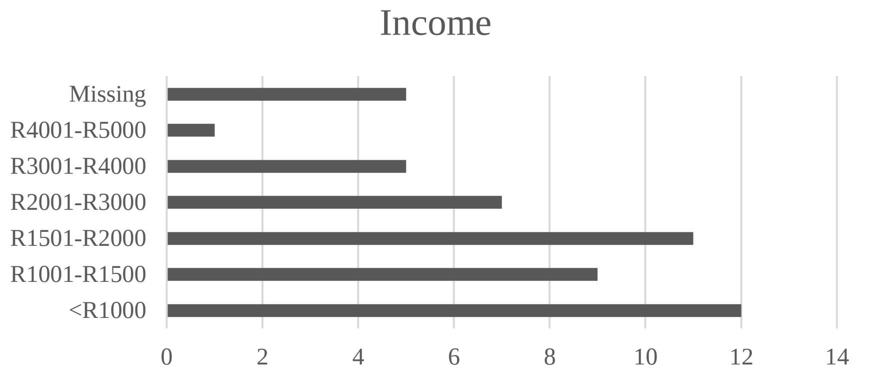

Figure 14. Number of survey respondents in Havelock falling into different income brackets.

5 respondents did not declare their range of income and only 1 respondent fell into the R4001-5000 bracket. No respondents declared income higher than R5000.month.

Over 50% of respondents felt very connected to their community, with an overall positive feeling about feeling connected.

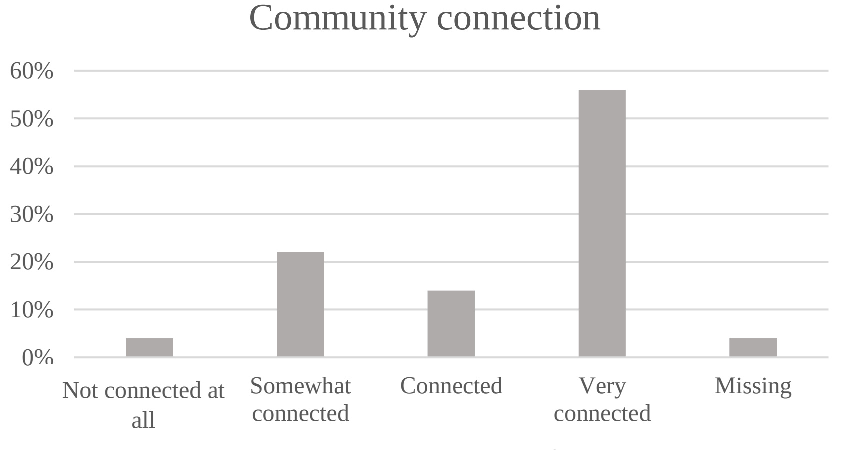

Figure 15. Responses to the question on how connected respondents felt to their community, Havelock.

5.1.2 Namibia Stop 8

The average age of respondents in Havelock was 47.8 years (median= 44.5 years) (Figure 16).

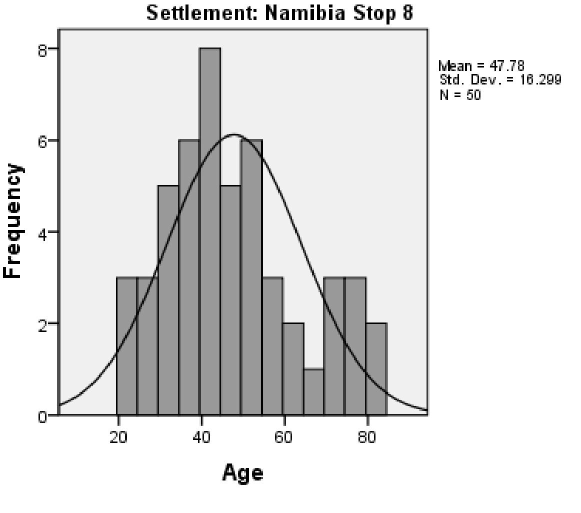

Figure 16. Age distribution of survey participants in Namibia Stop 8.

71.2% had secondary education, 19.2% primary education and 5.8% had a higher education. Another 3.8% never attended school or did not complete any level of education.

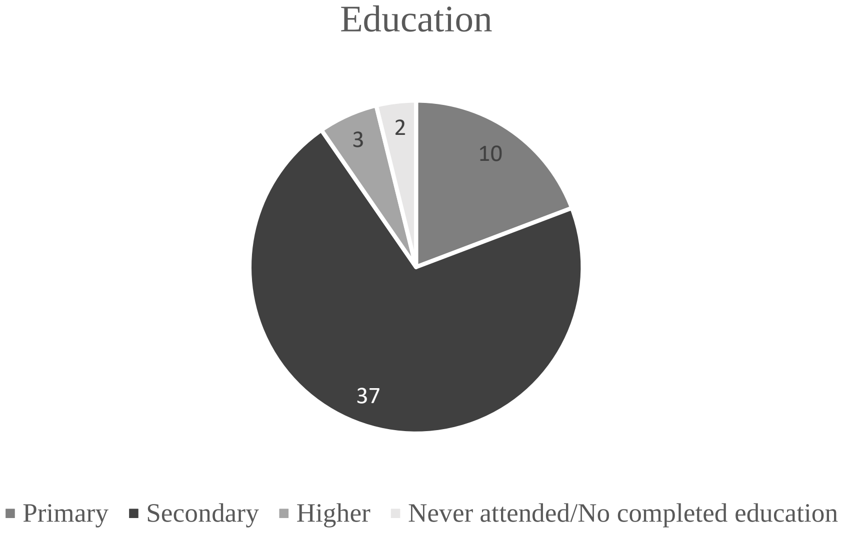

Figure 17. Number of survey participants with primary, secondary and higher education, as well as those who never attended school, Namibia Stop 8.

There were, on average, 3.3 adults per HH in Namibia Stop 8 (median=3), and 1.95 children (median=1). 15.4% of respondents were renting their houses as opposed to 82.7% who owned them.

Nearly 40% of respondents were unemployed and just under 30% were employed. 15% were pensioners and just over 5% declared being self-employed. The full breakdown of occupational statuses can be seen in Figure 18 below.

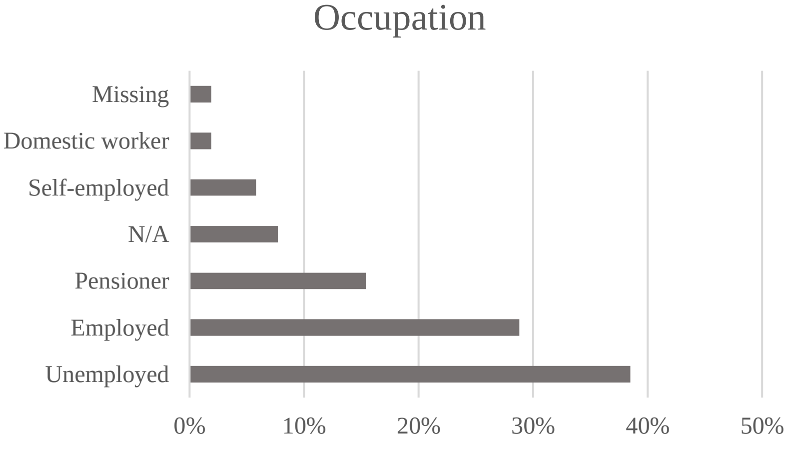

Figure 18. Occupation status of survey respondents in Namibia Stop 8.

The highest proportion of respondents fell into the R1501-2000/month income bracket. 9 respondents did not declare their incomes. There were 6 respondents who said they fell into the <R1000/month income bracket. Overall, the range of incomes was greater than in Havelock.

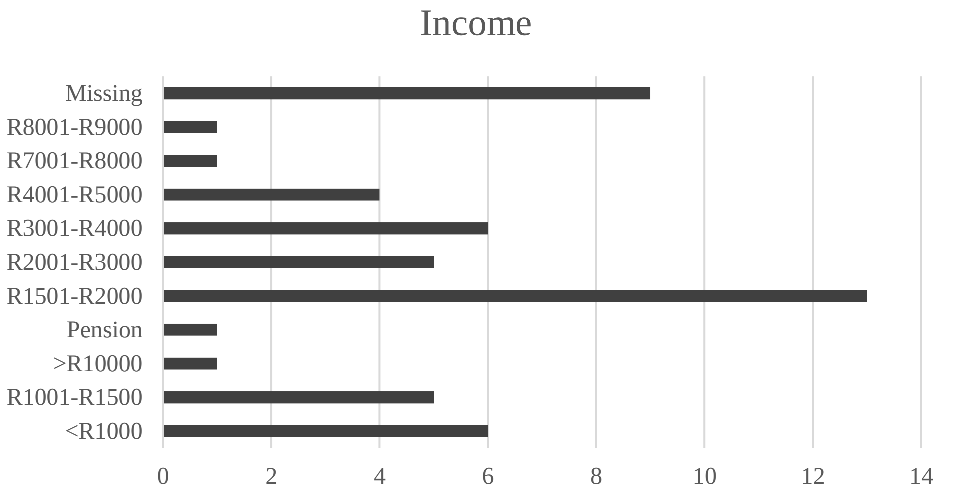

Figure 19. Number of survey respondents in Namibia Stop 8 falling into different income brackets.

Over 40% of respondents felt very connected to their community, with both connected and somewhat connected declared by 25% of respondents. 5% did not feel connected at all. The feeling of connectedness was not as strong as in Havelock.

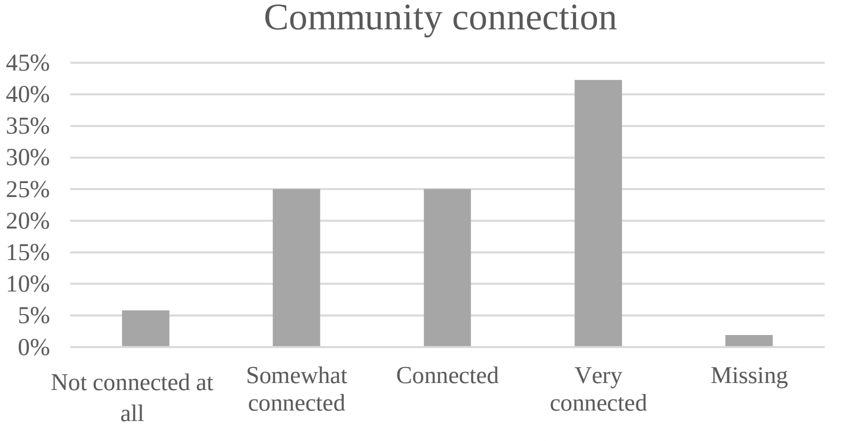

Figure 20. Responses to the question on how connected respondents felt to their community, Namibia Stop 8.

5.1.3 Piesang River

The average age of respondents in Piesang River was 55.8 years (median= 58.5 years) (Figure 21), the highest out of all three settlements.

Figure 21. Age distribution of survey participants in Piesang River.

47.1% had secondary education, 41.2% primary education. No respondent declared having higher education and 7.8% never attended school or did not complete any level of education

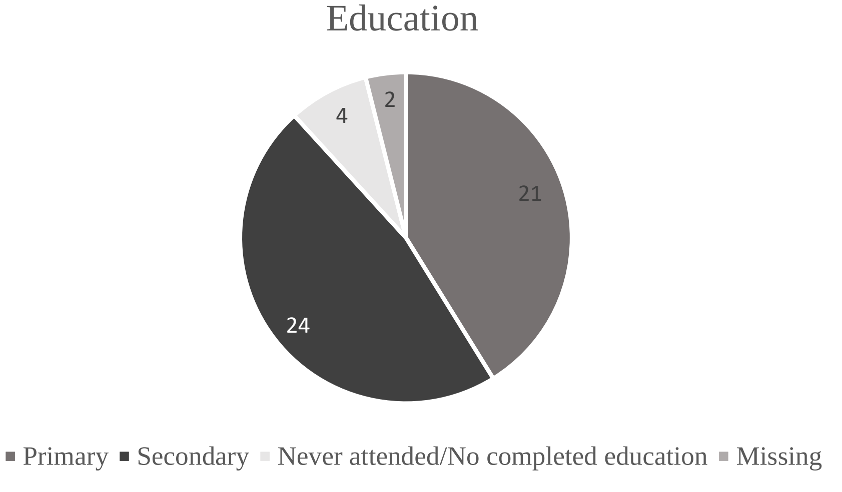

Figure 22. Number of survey participants with primary, secondary and higher education, as well as those who never attended school, Piesang River.

There were, on average, 4 adults per HH in Piesang River (median=3)- the highest out of all three settlements, and 1.77 children (median=1). 3.9% of respondents were renting their houses as opposed to 96.1% who owned them. The ownership rate among Piesang River HHs was the highest out of the three settlements.

Just over 25% of respondents were employed vs 27% who were unemployed. 33% were pensioners, which was the highest proportion among the three settlements and is also reflected in the average age of survey participants. A full breakdown of occupations among respondents in Piesang River can be seen in Figure 23 below.

Figure 23. Occupation status of survey respondents in Piesang River.

The highest number of respondents (17) fell into the R1501-2000/month income bracket. 6 respondents did not declare their incomes. The average monthly was on the lower end of the range (counted up to R10000) which was associated with the relatively high number of pensioners in the settlement.

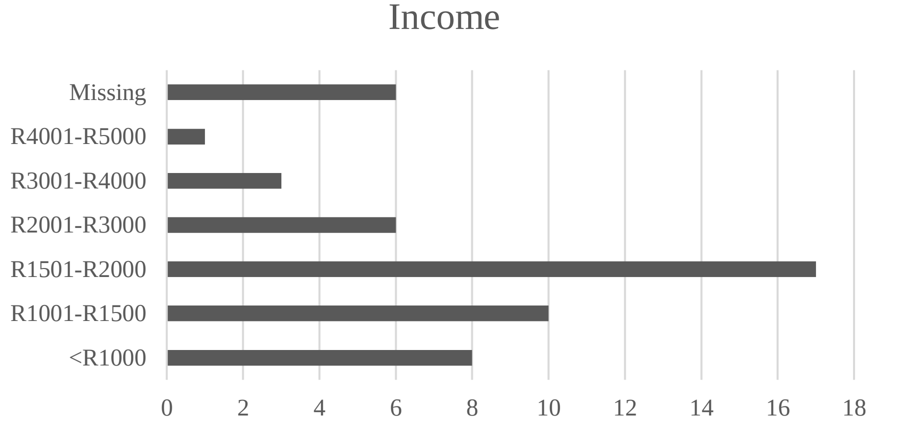

Figure 24. Number of survey respondents in Piesang River falling into different income brackets.

Nearly 60% of respondents felt very connected to their community, 23.5% felt connected and 14% felt somewhat connected. No respondents declared not feeling connected at all. The overall feeling of connectedness to the community was high.

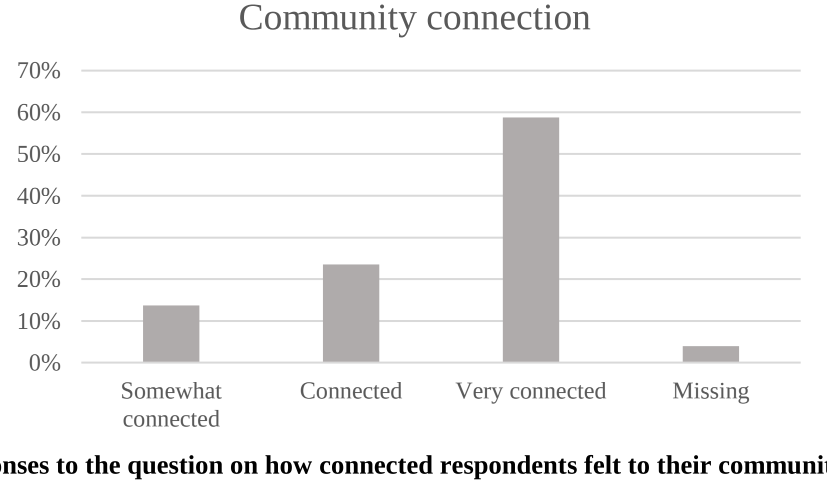

Figure 25. Responses to the question on how connected respondents felt to their community, Piesang River.

5.2 Solid waste management

Solid waste collection was reported to be present in all three settlements on a once a week basis. Despite the majority of respondents in all three settlements expressing satisfaction with the service, between 15-21% of respondents were not satisfied with solid waste collection in their respective settlements. Figure 26 demonstrates responses to the question on whether or not the respondent was satisfied with SWC or not. The major reasons for dissatisfaction were the frequency of waste collection which was considered too low given the amount of waste generated each week, which means that waste has to be stored in and around the house before it is picked up by the collection trucks.

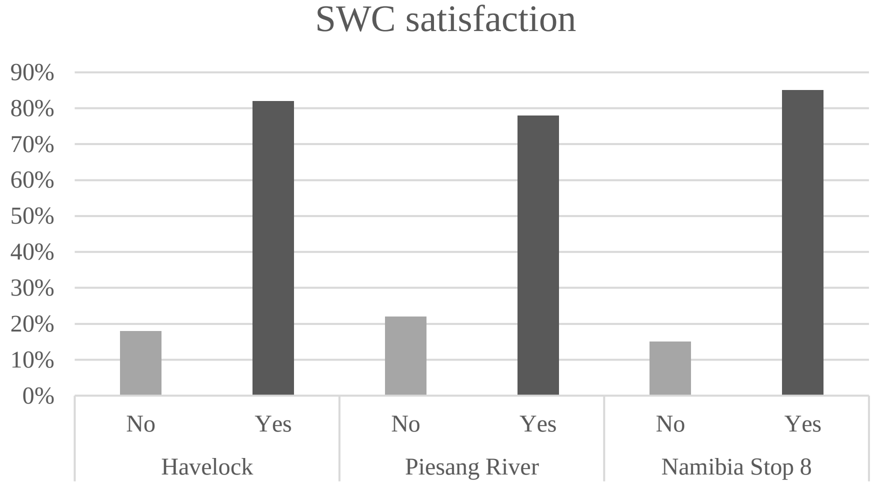

Figure 26. Satisfaction with SWC (yes/no) in Havelock, Piesang River and Namibia Stop 8.

Street outside the house and plastic bags outside the house were reported as the most common ways of disposing of uncollected waste.

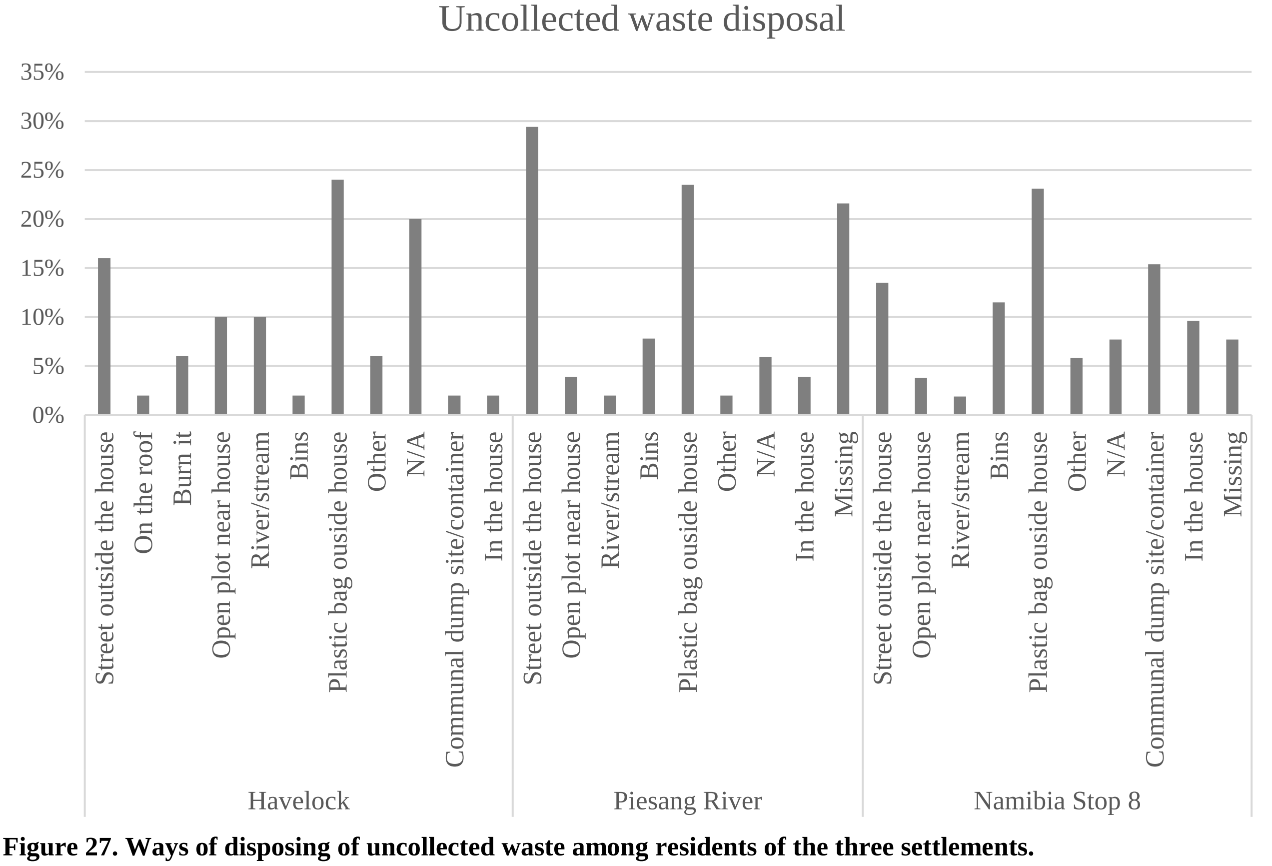

Figure 27. Ways of disposing of uncollected waste among residents of the three settlements.

Waste segregation is not common, with Namibia Stop 8 having the highest number of respondents who said waste was segregated at 35% as compared to 20% in Havelock and 6% in Piesang River (Figure 28). Houses and communal plots were the most common places where waste would be segregated across the three communities in the instances where segregation was done at all.

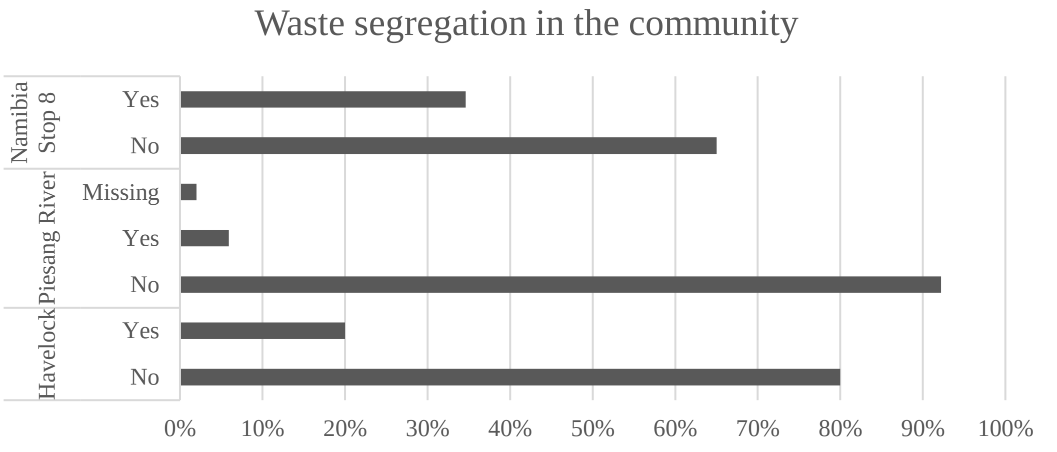

Figure 28. Incidence of waste segregation in Namibia Stop 8, Piesang River and Havelock.

Similarly as waste segregation, recycling was not reported as common in the three settlements. Again, Namibia Stop 8 had the highest percentage of HHs who reported recycling activities. The breakdown can be seen in Figure 29 below. No recycling help from the municipality was reported by any survey respondents.

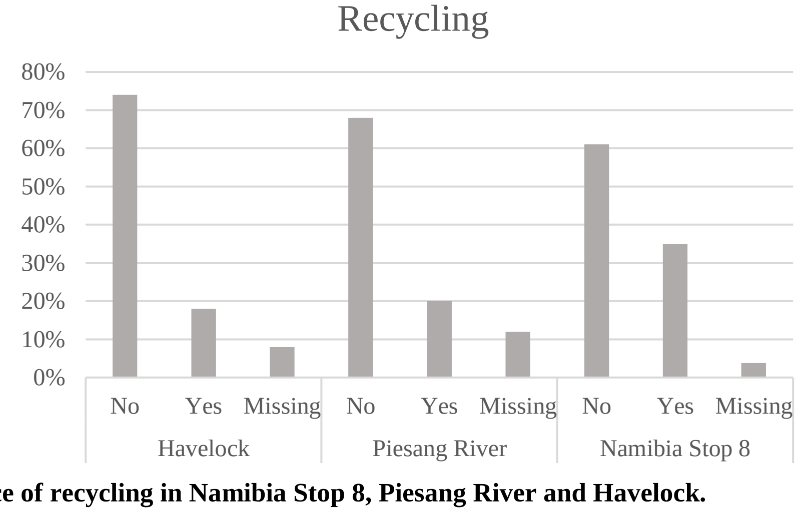

Figure 29. Incidence of recycling in Namibia Stop 8, Piesang River and Havelock.

5.3 Farming and water use

Vegetable farming on one's own plot has not been reported as common, particularly in Havelock where only 14% of respondents (7 HHs) said they were growing vegetables. Piesang River and Namibia Stop 8 had 35% and 33% of respondents declare some vegetable farming activity, respectively. Overall, only a small proportion of HHs were involved in farming at the time of data collection. However, interest in vegetable farming was much higher, with 41% of respondents in Havelock, 44% of respondents in Piesang River and 49% of those in Namibia Stop 8 expressing interest in it and a considerable proportion of respondents declaring previous knowledge of farming: 78% in Havelock, 67% in Piesang River and 61% in Namibia Stop 8.

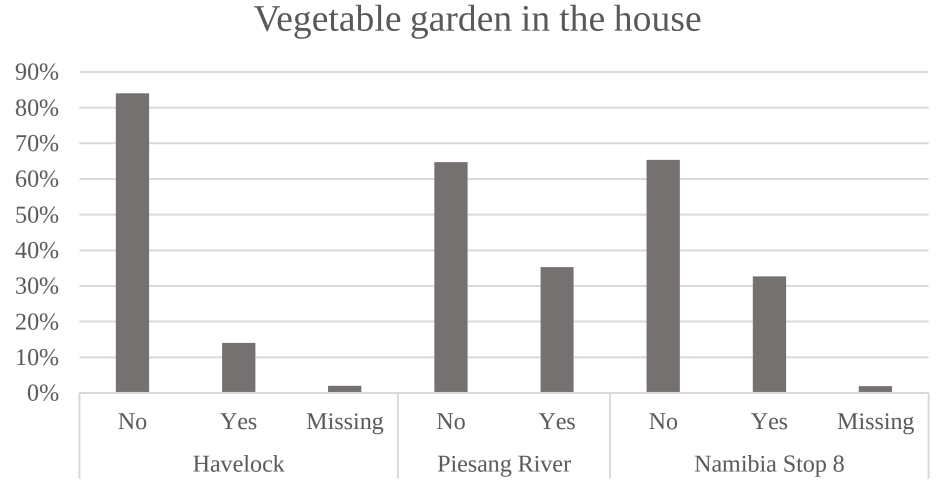

Figure 30. Percentage of HHs with and without vegetable gardens in the three settlements.

Water is seen as a challenge across the three settlements and it was important to understand where the HHs would draw water from if they were to start a vegetable garden or other farming activity. Nearly 40% of Havelock respondents said the municipality tanker would be a source of water for agriculture, whereas in the other two settlements house tap was the most common choice, with 65% respondents in Piesang River and 46% of those in Namibia Stop 8 indicating it, confirming a more reliable water supply than in Havelock. Reuse water was indicated as a potential source in Namibia Stop 8 more often than in Piesang River and Havelock, with 28% of respondents seeing it as an option.

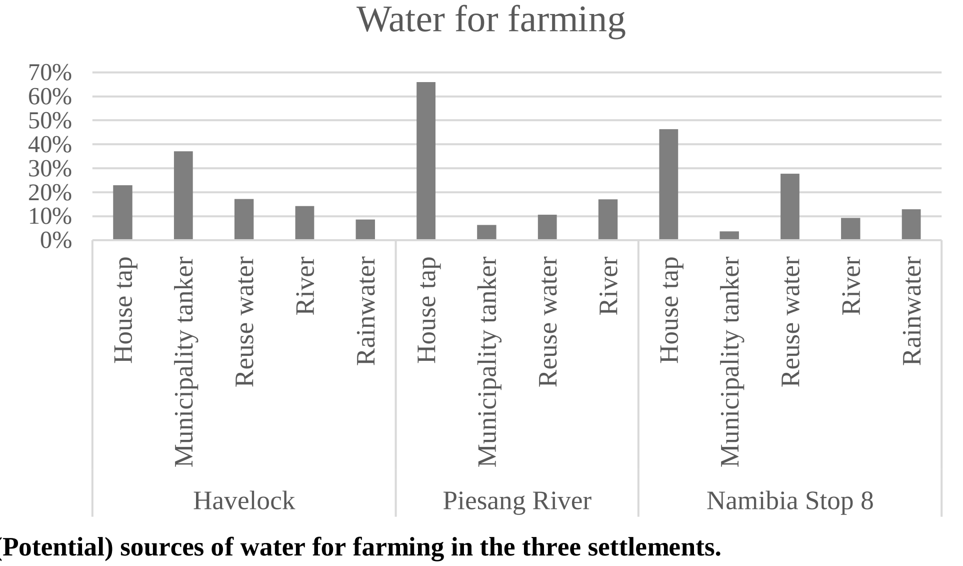

Figure 31. (Potential) sources of water for farming in the three settlements.

The availability of water in house taps is reflected in the above figure, as well as in the fact that 96% of Havelock respondents said they fetch water outside of the house, whereas only 8% of Piesang River respondents and 4% of Namibia Stop 8 respondents said they do. In Havelock, water is fetched from the municipal tap once or twice a day and usually everyone in the HH is responsible for fetching it, depending on who is at home and available.

Disposal of used water varies across the settlements. In Havelock, the stream is the most common way of disposing of it, in Piesang River it is the drain that is used to that end and in Namibia Stop 8 the range of practices is wider, with the plot outside of the house, a vegetable garden and toilet/showers being the most common ways, as reported by respondents.

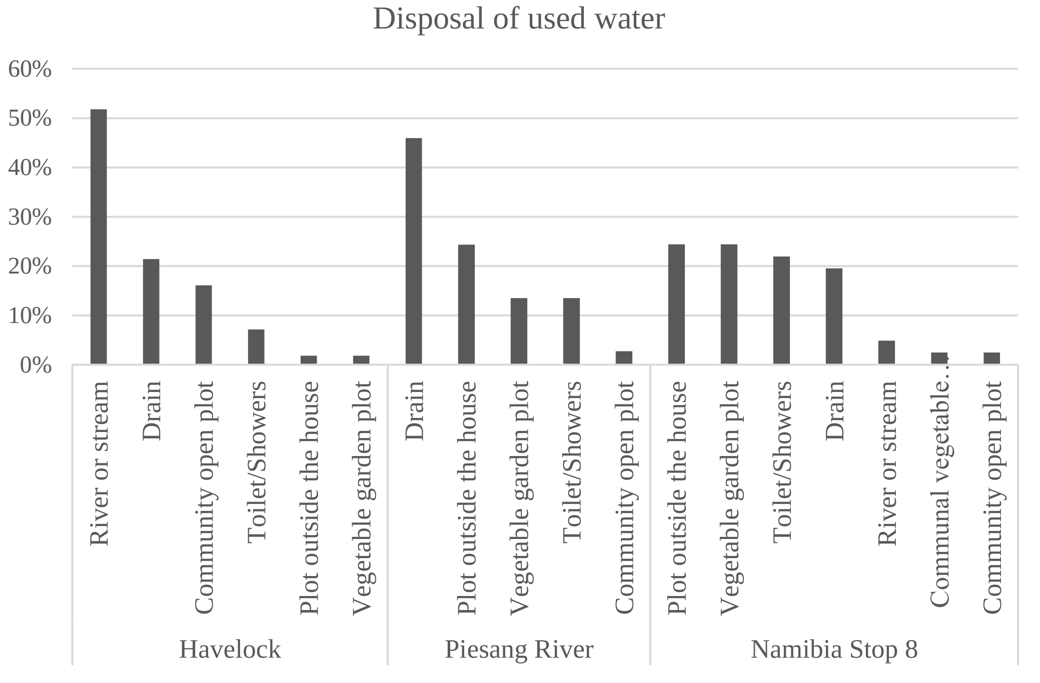

Figure 32. Disposal of used water in the three settlements.

Despite some previous knowledge of farming among respondents in all three settlements, majority of respondents in each one of them said they would be interested in attending farming workshops if they were made available to them. In Havelock, as many as 94% of respondents expressed interest. Attending them once a week or even a few times a week were the preferred frequencies for the respondents and was dictated by their schedules.

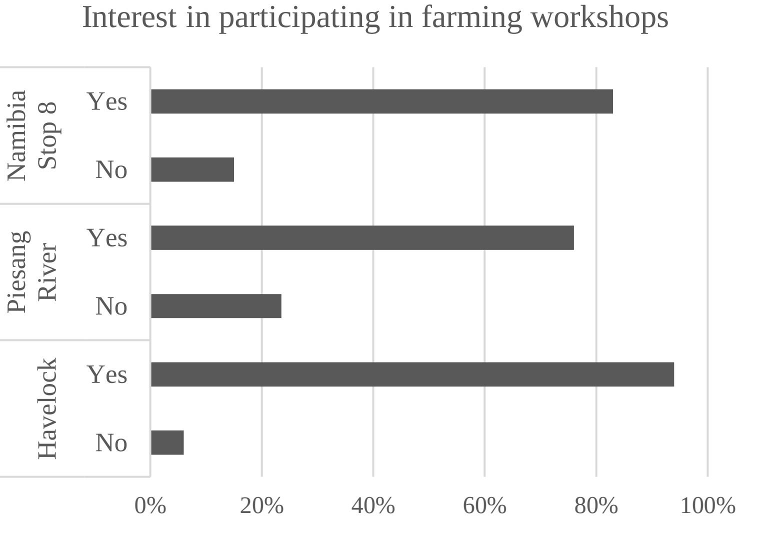

Figure 33. Interest in participating in farming workshops among respondents in Havelock, Piesang River and Namibia Stop 8.

For those employed and with regular working hours it would be fewer hours per week than for those without regular occupations and more free time during the day. Elderly respondents were less likely to be interested in farming themselves.

In Havelock, the most desirable support for agriculture were seeds, manure and training; in Piesang River: seeds, manure and free water; whereas in Namibia Stop 8 seeds, free water and training, as shown in Figure 33 below.

Figure 34. Most useful support for agriculture as indicated by survey respondents.

As pests can be a problem in informal settlements and can have an impact on the viability of agricultural activities, respondents were asked whether pests were an issue in their respective settlements and houses. Overall, pests were reported to be a problem in 60% of HHs in Havelock, 82% of HHs in Piesang River and 85% of HHs in Namibia Stop 8, suggesting a relatively important challenge, also for urban farming activities.

5.4 Sanitation

Access to sanitation differs particularly between Havelock and the other two settlements. In Havelock, only 8% of HHs reported having a private flush toilet in the house, as opposed to 92% in Piesang River and 100% in Namibia Stop 8. 100% of respondents in Havelock said they use public toilets but only 18% of those in Piesang River and 25% of those in Namibia Stop 8 said they do, mostly when away from home and in need of using a toilet (e.g. while in town and with no other option but to use a public toilet). Therefore, given the sanitation access differences, sanitation challenges also vary, as is shown in Figure 35.

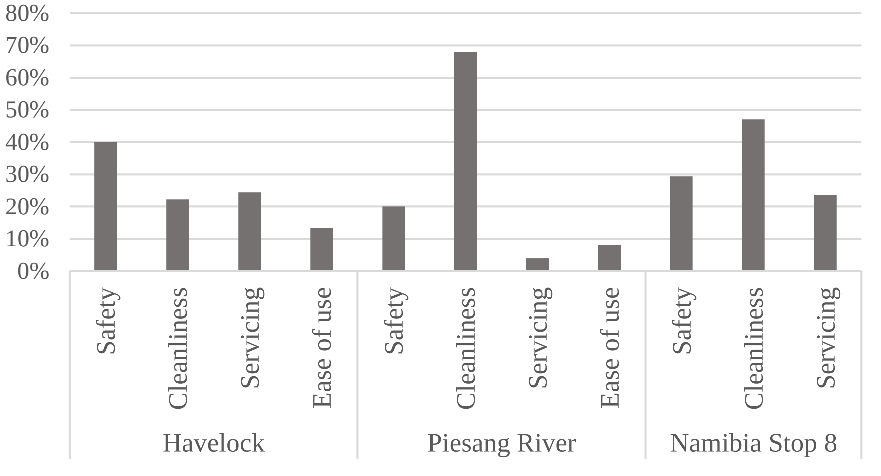

Figure 35. Sanitation challenges as perceived by respondents in the three settlements.

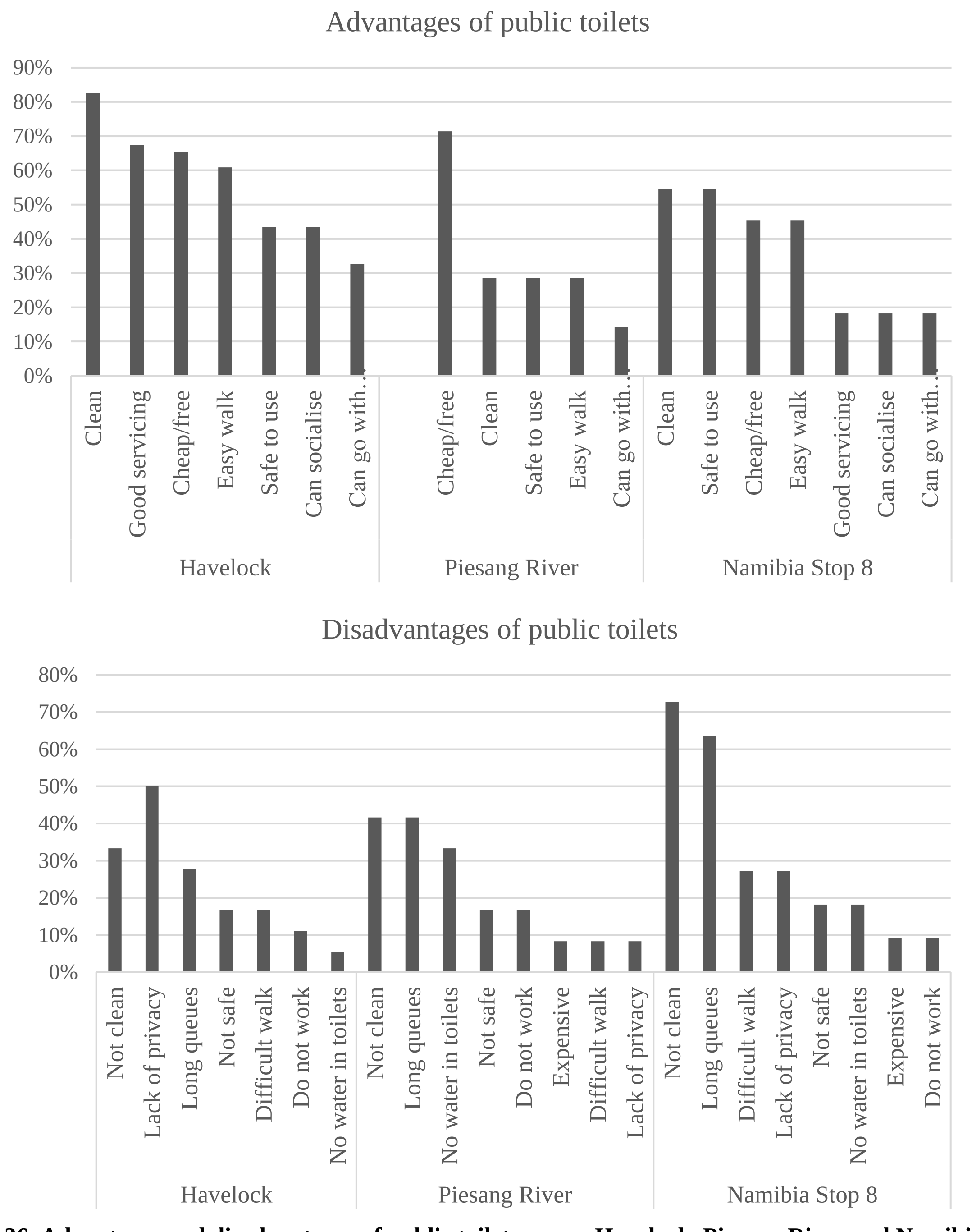

Figure 36. Advantages and disadvantages of public toilets across Havelock, Piesang River and Namibia Stop 8.

The perceived advantages and disadvantages of public toilets among respondent s from all three settlements are demonstrated above. In Havelock, where reliance on public toilets is the most prevalent, public toilets' most important advantages are cleanliness, good servicing and them being cheap/free to use. The lack of privacy is seen as the biggest disadvantage, with long queues and lack of cleanliness for some being the next most frequently mentioned disadvantages. In Piesang River, the fact they are cheap or free to use is seen as the key advantage of public toilets, with the lack cleanliness and long queues being mentioned as disadvantages for just over 40% of respondents, respectively. No water in toilets was also seen as a challenge, which could refer both to public toilets and private toilets in respondents' houses. Cleanliness and the safety of use of public toilets were the two main advantages of public toilets for respondents in Namibia Stop 8, as well as affordability and ease of walking to them. However, at the same time over 70% of respondents said that the lack of cleanliness was a challenge, as were long queues.

5.5 Flooding

Flooding in the house has been reported to occur in 86% of HHs in Havelock, 69% of HHs in Piesang River and 52% of HHs in Namibia Stop 8, which reflects the quality of housing in each of the settlements. Flooding affects HHs in different ways which vary across the settlements yet with some cross-cutting issues which prove challenging regardless of the settlement, as demonstrated in the below Figure.

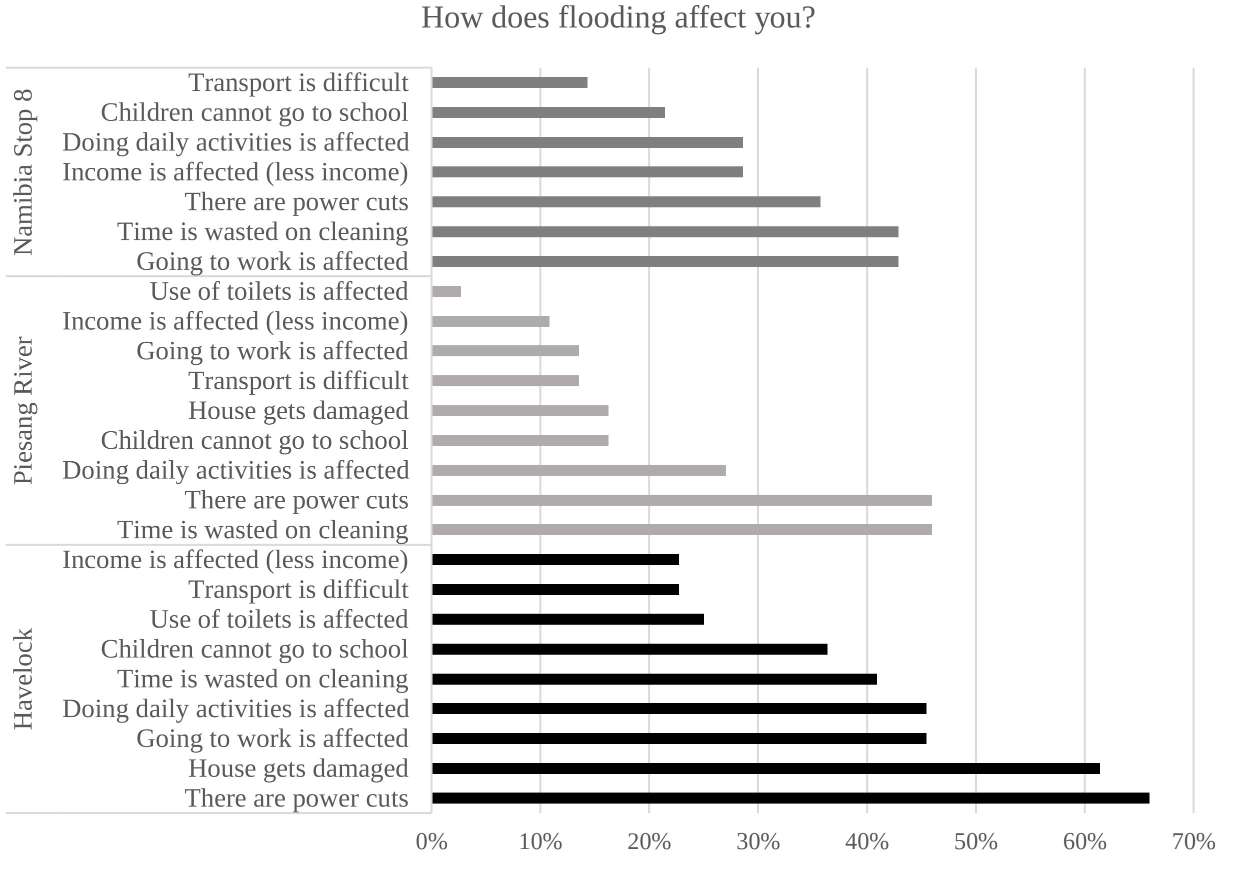

Figure 37. Ways in which HHs get affected during flooding.

Power cuts, damages in the house and time wasted on cleaning after the flooding, as well as other daily activities and going to work/school being affected were the biggest problems caused by flooding.

5.6 Access to electricity

74% of respondents in Havelock, 96% in Piesang River and 100% in Namibia Stop 8 reported having electricity in the house. All connections in Havelock were illegal whereas those in Piesang River and Namibia Stop 8 were all legal grid network connections. The illegal electric connections in Havelock are made dangerous in the rainy season which has been indicated as the major problem with electricity for residents in Havelock. In Piesang River and Namibia Stop 8 power cuts have been reported to cause the most challenges along with high bills and high connections costs.

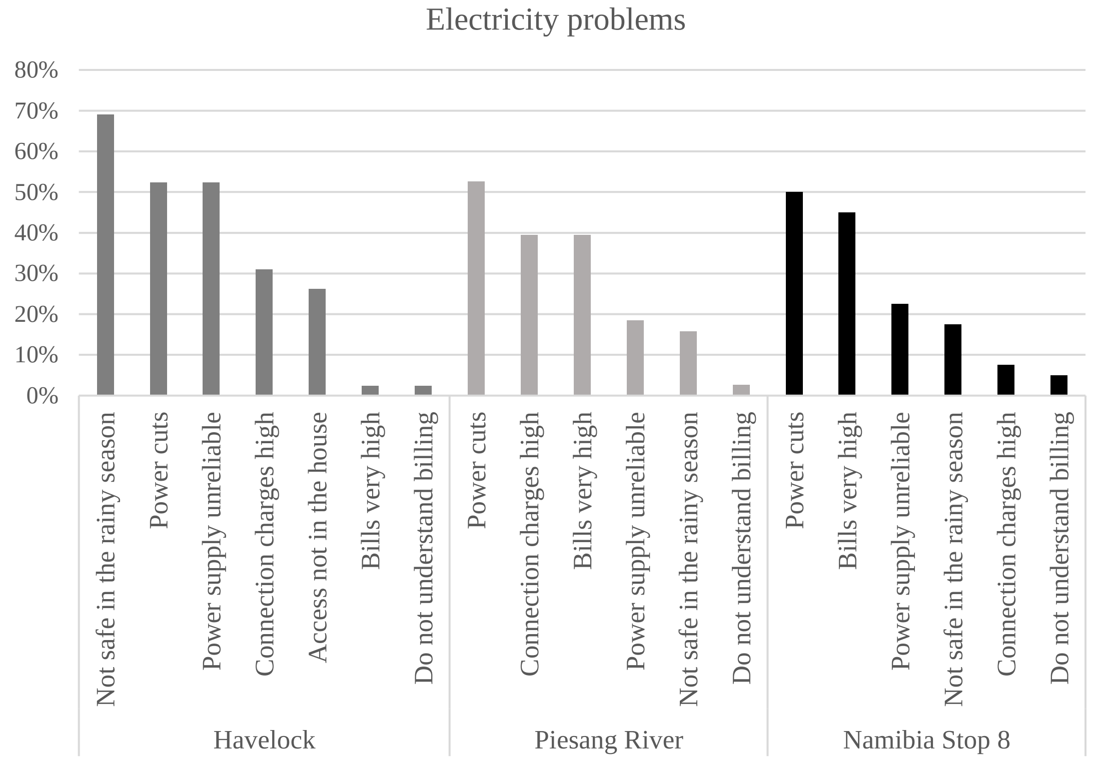

Figure 38. Problems with electricity connections in the three settlements.

Mobile phones, TVs, lamps and radios were the most commonly owned appliances across all three settlements.

Appliance/Settlement	Havelock	Piesang River	Namibia Stop 8
Mobile phone	86.0%	95.9%	94.0%
TV	72.0%	89.8%	96.0%
Lamps	62.0%	73.5%	88.0%
Radio	52.0%	77.6%	84.0%
Fridge	16.0%	18.4%	26.0%
Fan	14.0%	4.1%	2.0%
Stove	14.0%	30.6%	24.0%
Heater	10.0%	34.7%	30.0%
Kettle	6.0%	12.2%	6.0%
Iron	4.0%	16.3%	14.0%
Microwave	0%	8.2%	12.0%

Table 17. Ownership of electrical appliances in the three settlements.

Electricity bills were not applicable in Havelock as the connections were illegal and as such there were no monthly bills. However, payments for other costs associated with the electrical connections were the responsibility of the respondents who participated in the survey. In Piesang River, respondents were also predominantly the ones in charge of bills and in Namibia Stop 8 there was a split between the respondent, the house owner and everyone in the HH as the ones in charge of making payments for electricity.

5.7 Key challenges

There is a number of challenges faced by residents in each of the settlements. The precarious housing conditions in Havelock mean that electricity is not safe to use during the rainy season and flooding due to the risk of electrocution and there are power cuts during flooding and heavy rains. Houses get damaged and time is wasted on cleaning while other daily activities, including work, get affected. That challenge is present in all three settlements in instances where flooding occurs in the house. High electricity prices resulting in high energy bills were seen as a challenge for respondents in Piesang River and Namibia Stop 8 where the connections are billed.

Access to sanitation is overall good, whether private or public. However, cleanliness of sanitation facilities, whether in the house or at public toilets, is seen as the biggest problem.

There is a high willingness to get involved in farming activities (vegetable and fruit farming), however, the resources and the support to enable it are scarce and respondents reported the need for seeds, manure, free water and more training in order to be able to start farming. In Havelock, access to water would be enabled from the municipality tanks and the stream (although not without challenges due to the poor condition of the stream), whereas in the other two settlements water from the house taps would be used. Yet that poses a challenge at times when there are water shortages and the available supply does not cover the HH needs. Used water from HH activities was not seen as one of the top choices for the use in farming.

Solid waste disposal is ensured by the municipality, however, there is no sorting or recycling other than that done by individuals who do it to make profit off of it. In some instances where more waste is generated than can be managed in the HH, waste is disposed on the streets outside the houses or on the roofs. Even though waste collection takes place every week, some HHs complained that it is not sufficient. Yet overall satisfaction with SWC was reported as high.

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Appendix 1: Sanitation practices in low-income and informal settlements

Informal settlements predominantly developed on the 'buffer strips' left behind by Apartheid, with inadequate forms of housing and an absence of adequate service provisions due to a lack of legislative control by the former White Administration of the City. Historically, such settlements emerging on the City boundaries would be destroyed by authorities, but today they are found across the City on both private and state land (Makhatini et al, 2002, 2 in Marx et al. 1996).

The racial segregation left by Apartheid in Durban has caused the City to be economically dysfunctional and ensured different racial groups had differing standards of municipal services. This relationship between race and poverty left informal settlements with limited service provision. Most have informal pit latrines constructed by residents themselves and were not serviced or funded by the municipality. There are some settlements that receive sanitation services from the municipality in the form of chemical toilets, but these were only introduced to neighbourhoods if a particular health hazard or technical challenge had been identified (DPU Durban). By and large, service provision and housing quality outside of the City Centre previously occupied by colonial authorities remains fragmented and underserviced; this includes sanitation services and collection, disposal and treatment of human waste. The result is poor communities being structurally trapped in areas of low service provision (Marx 2002 in Marx et al. 1996). New technology is currently being developed and implemented across the municipality to encourage sustainable faecal sludge management practises with the community, but also remind locals of old practices of waste treatment used in Durban before the gradual rise in population.

1. Latrine Systems in Durban

1.1. Urine Diversion Toilets Project (2003-2010)

In December 2000, boundaries of the eThekwini municipality were expanded to include new, predominantly rural areas which had little or no water and sanitation infrastructure. Before this expansion, the municipality was providing VIP latrines and 200 litre water tanks to rural communities, and the new expansion caused a backlog of services; the high cost of emptying VIPs and the inaccessibility of many rural settlements forced municipal authorities to rethink their service provision methods (Roma et al. 2011).

Development and implementation of Urine Diversion Dehydration Toilets (UDDTs) began in eThekwini in 2002, regarded as the most cost-effective technology to address the sanitation backlog in both rural and peri-urban areas. The driving force behind the initiative was an effort to prevent further outbreaks of waterborne diseases among the population and lowering the maintenance costs of sanitation systems; the cholera outbreak in August of 2002 caused 45000 to be urgently emptied simultaneously and the stress put on the municipality resources meant resource management had to be reviewed for the future. The project is unique in its integration of household water facilities (yard tanks) and sanitation services (UDDTs) with household hygiene education and operation and maintenance, all offered as a single package (ibid).

Beginning in 2003, the project provided households with a UDDT and 200 litre yard water tank. By 2011, records showed that 75000 were verified and ongoing mapping of UDDTS by EWS using GIS was taking place; the number was expected to increase to possibly 90000. The project was regularly reassessed and implementation teams conducted follow-up visits and providing services for new migrants in the area. Estimates of on-going construction lay at around 10% per year (Roma et al. 2011).

UDDTs are waterless toilet systems where urine and faeces are separated at the source. The design is replicated from the the Swedish concept (Narsiah 2011). Urine is piped into a urine soak-away pit which is constructed below ground. A wall mounted waterless urinal for male use also diverted urine to the soakaway pit. Even though the urine is not being used as fertiliser, the urine diversion is useful because it allows faeces to dry and hence avoid odour, flies and faecal sludge production. Users were encouraged to add dry sand or ash after each defecation event in order to cover the fresh faeces, facilitate drying and act as an odour and fly control measure.

Double vault UDDTs have 2 vaults: when one is full, its contents are allowed to dry out and slowly decompose as most of the pathogens die off, while the second vault is in use. Thus, handling of dry faeces is relatively safe provided that basic precautions such as gloves and and hand washing are taken.

Once a vault is filled, it is manually emptied by a household member who is trained by the municipality or a local private cleaning contractor, if the household prefers to pay for cleaning. Residents are told to bury the contents. A vault typically takes 6 – 12 months to fill depending on household size and toilet use patterns (Roma et al. 2011).

The project does not include a method for nutrient recovery, but research is being conducted in the use of faecal waste from UDDTS. VUNA is an example of a collaboration project between EWS and UKZN and Eawag in investigating nutrient recovery from urine. It is discussed in further detail below.

Observing the UDDT from a physical context, the volume of waste material handled in a UDDT is less than a VIP latrine, where urine, faeces, cleaning material and possibly greywater are all mixed and collected in a pit. Manual emptying of VIPS is considered dangerous due to health hazards. Whereas UDDTs allow safe onsite disposal of human excreta without a need for municipal intervention. The waste is decomposed before it is exposed to the outside environment, reducing the risk of environmental damage. This is in contrast to VIPs which potentially expose the faecal sludge to the soil and perhaps also into groundwater. Due to the low population density and no groundwater use for drinking purposes in the new rural areas, the urine soakaway pit in the UDDT system posed no pollution risk to groundwater (ibid).

1.1.1. Response to the UDDTS

UDDT toilets have faced mixed review by residents, civil servants, academics and municipal officials (Lorimer 2011). Firstly, residents expressed that the toilets are expensive to implement and are marketed in such a way that householders have no option but to agree to their installation. The municipality would pay to cover the 6000 Rand for the UDDT toilet, but the household would have to pay the 20000 Rand for the accompanying septic tank. A full flush system would cost 100 000 Rand to install. These low-income communities thus have to manage 20 000 Rand for a UD toilet system or would have no toilet, and a UDDT system would be better than having no proper toilet in their homes. Communities desire full flush toilets but these are simply unaffordable and unsustainable, as 30% of household water is flushed down the toilet (Narsiah 2011). South Africa is a water-stressed country and cannot afford to flush this resource down the sewer when the demand for drinking water is increasing (Veith 2010).

There is also a huge responsibility on residents to maintain the toilets, to prevent odour by pouring sand or ash over faecal matter after each use, and emptying chambers once they are full and the faeces has dried. Householders must also bury the dry waste. This all falls on top of the need to remove taboos surrounding the handling of faecal matter amongst South Africans. Furthermore, there have been serious issues where a road separates residents using waterborne sewerage and flush toilets and other residents with UDDT toilets. The division of services is creating an urban bias for municipal services, as residents on the region's outskirts are being asked to conserve water for those living in the City Centre, who use flush toilets and have higher water use habits in general.

1.1.2. Dry Toilets and Buying Liquid Waste

In order to encourage locals to use urine diversion toilets, the municipality is looking to buy liquid waste from households in order to produce fertiliser. The idea is to install 20 litre jerry cans to capture the urine, and a municipal worker will be employed to collect the cans once a week. Households could be paid around 30 Rands (approximately $4), which is not a small amount considering that 43% of the population in South Africa lives on less than $2 a day. Since residents are responsible for emptying their own pits, there is no sufficient control measure to check if disposal is taking place adequately. This collection method allows control over urine collection and includes a financial incentive so that residents want to use the toilets. Dry toilets have faced some criticism because of cultural ideas and taboos surrounding human waste amongst locals, and this idea of urine collection will have to overcome community hesitation and encourage use of facilities as well (Veith 2010).

Dry toilets have been successful in rural areas because faecal waste can be used locally, but in denser neighbourhoods, the collection and transportation of waste faces some dissatisfaction.

1.2. Community Ablution Blocks (CABs)

Another provision introduced by EWS in low-income neighbourhoods of eThekwini are CABs: these communal water and sanitation facilities included flush toilets, hand wash and laundry basins in areas around Durban which had connections to the main sewer system. This is a more economically feasible option than setting up connection to individual homes, and also provides communities with flush toilets like residents in the city centre (Roma et al. 2011). This reduces feeling of inferiority amongst the peri-urban community.

It should be noted that no references are made regarding treatment of urine or faeces – connection to the main sewer system means reuse for agriculture is not being taken into account and the system does not improve sustainability. There is also limited information about the accessibility of these facilities for different members of the community; from a gender perspective, it is important to consider safety for women and children and who predominantly uses the blocks.

2. Emptying Latrine Systems

2.1. Manual Pit Emptying in eThekwini

eThekwini Water Services (EWS) provides a service to empty every pit toilet in the municipality every 5 years free of charge, in an effort to control overflowing and contamination, particularly in dense urban environments. This initiative is based on the assumption that the number of pit latrines will diminish rapidly as sanitation services are upgraded. This included the new urine diversion toilets. However, as of 2006 and until new toilets were put in place, EWS would be responsible for emptying at least 20 000 pits a year. This was a huge economic and resource challenge for Durban. EWS provided a municipal desludging service where possible in areas accessible to suction tankers at a subsidised fee of USD 13 per emptying (the real cost ranged between USD 73 and 246). But many areas urgently in need of service were in low income settlements not accessible to suction tankers due to issues such as bad roads, high population densities and steep slopes. No small scale service providers have emerged to provide an alternative to these areas, primarily because they cannot compete with the subsidised prices offered by the municipality, and the high capital cost of operating conventional suction tankers (Gounden et al. 2010).

In 2003, the municipal water and sanitation utility, eThekwini Municipality Water and Waste (EMWW) carried out a pilot programme to test different approaches to pit emptying which could be scaled up to service all communities and settlements, until pit latrines were replaced. The municipality finally decided on implementing manual pit emptying throughout the region. This was large due to access issues: a relatively high proportion of pit sites are hilly, densely settled areas that cannot be accessed by vacuum tankers. This manual approach carries the least risk of mechanical failure and offers employment opportunities and small business development. This was known as the eThekwini Pit Latrine Evacuation Programme (ePLEP) (ibid).

2.1.1. eThekwini Pit Latrine Evacuation Programme (EPLEP)

The programme involved recruiting local businesses, contractors and labourers from within communities, and providing them with on-site training. A project liaison committee would be established to manage interactions with the community, select locals for the job, liaise with individual households and notify them of the pit emptying schedule.

For health and safety provision, workers would wear appropriate protective clothing, remove waste with shovels and hay rakes and transfer it to 100 litre drums. These would be trollied to shuttle trucks and dumped into a collecting skip, where the sludge be diluted, screened and cleared of debris. The debris would be retained in the skip before being taken into a dump site while the diluted sludge will be drained away through the nearest sewer manhole.

ePLEP was closely aligned with the national Extended Public Works Programme, an initiative designed to create short term jobs and improve long-term employment prospects of participants through providing life skills and job training (Gounden et al. 2010).

One overarching criticism of the programme is that residents and pit emptiers will interact in broad day light, and it is likely that locals will resent the smell of waste skips in the neighbourhood. However, it is appreciated that risks to public health are reduced, with safety of workers ensured by protective clothing - particularly as these workers are local residents themselves, recruited from within the community.

There is currently limited information about the success of this manual emptying programme, so it is hard to assess receptive the community has been with the recruitment process and waste disposal and collection.

2.2. Manually Operated Pumps

For pit latrines which collect urine and faeces in one combined pit, it is possible to use manually operated pumps to empty the faecal sludge because of their watery consistency (Eawag & Spuhler 2012). The Gulper and the Manual Pit Emptying Technology (MAPET) are two examples of systems which are relatively new to the eThekwini municipality, but show potential for larger scale pit emptying in the future.

2.2.1. The Gulper

The Gulper is essentially a hand pump similar to those used for water extraction with a pipe that is lowered into the pit while the operator stands at ground level. As they push and pull the pump handle, the sludge is pumped through the pipe and discharged through a spout. The sludge is collected in barrels or carts to be disposed or treated elsewhere. The tool can be made locally from PVC casing and metal (ibid).

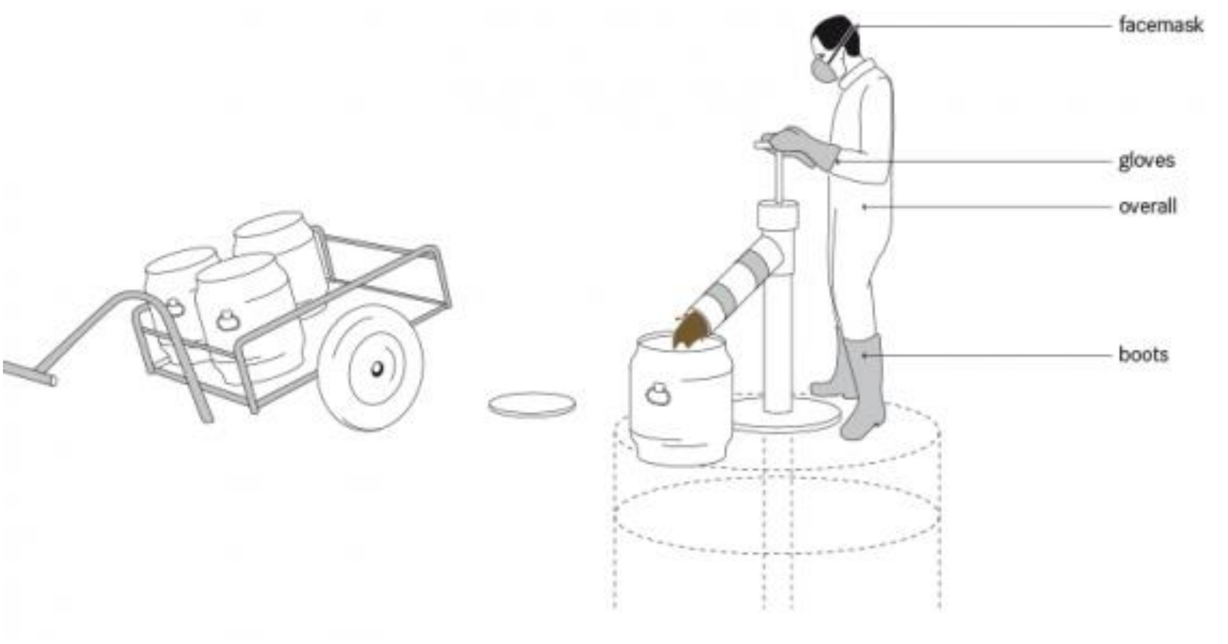

Figure 1. Diagram showing the Gulper system in use and the protective clothing required in its operation (Source: Eawag & Spuhler 2012)

2.2.2. MAPET

The MAPET system is similar to the Gulper, but contains a manual pump connected to a vacuum tank mounted on a separate push cart. A hose is connected to the tank and is lowered into latrine pits. As the hand pump is turned, air is sucked out of the tank while sludge is pushed in to the tank. The system is able to extract sludge up to 3m pit depth, depending on the consistency of the sludge itself (ibid).

Figure 2. The MAPET in use in Congo (Source: Eawag & Spuhler 2012)

Both of the systems are regarded as simple to operate by locals, and only basic safety training in pit emptying is required. This takes the responsibility of emptying pits off the households and avoid collision with cultural issues surrounding human waste. The most important factor to consider is the viscosity of the sludge so that it can effectively be pumped out of the pit and does not clog the pipes. The main difference between the Gulper and MAPET is the number of operators; while the Gulper only needs one, the MAPET requires three, increasing the systems costs for the municipality and households. Aside from any free of charge emptying that the municipality offers, residents are responsible for paying for pit emptying, which can prove costly for low-income neighbourhoods in the area.

3. Treatment of Faecal Sludge

3.1. Night Soil and Historic Practices of Faecal Sludge Management

Looking back to Durban in the 19th Century, the general population was in charge of their own household waste's disposal and practised efficient faecal sludge management. Human waste was collected from homes several times a week with carts going from street to street, and treated into night soil (Harrison & Wilson 2012) The city managed collection, manufacturing and selling of night soil for agricultural purposes on its own till 1867, when the rise in Durban's urban population led to the city's transition to a water sewage system. The change was brought on due to a fear of spread of diseases in areas with a growing urban density (Kearney 2012 in (Benoit 2013). Despite having this history and familiarity with sludge management practices, the use of human waste for fertiliser is relatively unknown and hardly practised in present day Durban. For the few that are aware of treatment technology, they generally associate practises with the use of faeces, whereas most of the valuable nutrients are found in urine. The population is not keen on the idea of using urine, on their crops, and there is a big fear that the urine will burn plants and damage soil and vegetables. Many locals have refused to use or consume crops fertilised by urine, leaving human waste to we conveniently flushed away and forgotten instead of being sustainably used (Harrison & Wilson 2012).

3.2. VUNA

In 2010, EWS partnered with the Swiss Federal Institute of Aquatic Science and Technology (EAWAG) to develop VUNA, a new sanitation system which would allow nutrients to be recovered from urine and enable sanitation promotion in the municipality. The project has been funded by the Bill and Melinda Gates Foundation (Roma et al. 2011). EAWAG has experience of successful research on nutrient recovery from urine in low-income contexts, and this project had three main objectives; to promote the use of toilets in the community by treating urine as a valuable product, produce a fertiliser, and reduce pollution to protect the local environment. The word VUNA means 'harvest' in the isiZulu language and also is an acronym for 'Valorisation of Urine Nutrients in Africa.' The project brought together several research institutes to create a novel nutrient recovery system, with the Pollution Research Group (PRG) at the University of KwaZulu-Natal (UKZN) providing scientific resources and leading field studies in Durban. The Swiss Federal Institute of Technology in Zurich (ETHZ) and Lausanne (EPFL) were involved in studies to promote urine collection and investigating the pathogens occurring in urine during treatment (EAWAG). Much of the research focused on the treatment processes for recovering urine and the final quality of the products (ibid). Research looked into different treatment processes to recover nutrients from the urine, including struvite precipitation – which is used to recover phosphorous - complete nutrient recovery, and electrolysis. Great emphasis was put on devising an efficient treatment process that would remove harmful substances so that high-quality fertiliser can be produced.

The first stage for treatment is collection and transportation of urine, which makes community acceptance of urine diverting toilets crucial, as well as establishing an economically and efficient method of urine collection. Two schemes were tested for collection: The Institutionalised Scheme required municipal workers to collect urine in jerry cans from household toilets, while the Incentivised Scheme allowed toilet users to be compensated with financial incentives when they dropped of their jerry cans themselves at designated collection points (ibid).

The first pilot plant was installed in Eawag's main building in Zurich, where urine was collected and tested from urine-diverting toilets and waterless urinals. Approximately 100 litres of urine were collected on each working day to be used in production of fertiliser. Using this study, four pilot plants were set up in eThekwini, including one at a field-test site in Newlands-Mashu and one at eThekwini's Water and Sanitation (EWS) Customer Care Centre in Durban (EAWAG). Further expansion was decided in 2015, which would give rise to several challenges; collection logistics and management on a larger scale would impact system costs and urine treatment plants would require process control so that high quality is fertiliser is consistently produced. Furthermore, it is also important for the local community to accept the system's practices as it grows (ibid).

3.3. LaDePa

In partnership with Particle Separation Solutions Ltd (PSS) the Ethekwini municipality developed the Latrine Dehydration and Pasteurisation (LaDePa) machine which can convert sludge from VIP latrines into a low grade fertiliser. The main advantages of the system are its low capital cost and the use of basic mechanical and electrical technology. It is also simple to operate and can be containerised for mobility. Such features make it a system compatible for use where VIPs are commonly found in large urban environments (Harrison & Wilson 2012). A diagram of the system is shown below.

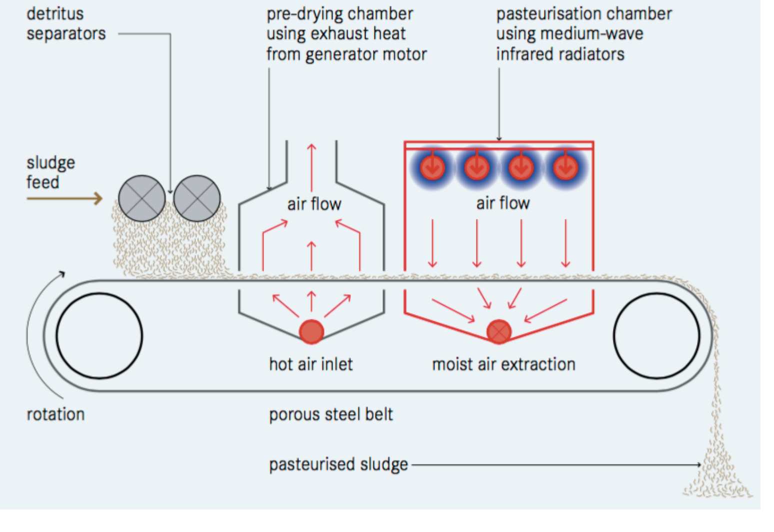

Figure 3. Schematic diagram of the various stages in the LaDePa system (Source: Tilley et al. 2014)

Sludge is separated from garbage - such as plastic bags -that may have fallen into pits - by a screw compactor that extrudes the sludge through 6mm holes onto a porous continuous steel belt. The sludge is formed into pellets of thickness varying between 25 and 40mm. At the same time, the waste is ejected separately so that it can be disposed of. The extruded sludge is partially dried and then pasteurised using infrared radiation, and extractor fans help air flow to fully dry the pellets. These final pellets are then completely pathogen free and suitable for use on edible crops (Tilley et al. 2014). It is found that the energy consumed by the plant per person equivalent is roughly half that consumed on a conventional sludge plant (Harrison & Wilson 2012).

Following trials of the LaDePa system in Durban, evidence is found that one plant is able to treat approximately 2000 tonnes of sludge from VIP latrines a year from across the area, in conjunction with the pit emptying programme being carried out by the municipality. The fertiliser pellets have a registered trademark and can be sold as a low nutrient fertiliser once it has been licensed (Tilley et al. 2014).

As with any new technology, use of the LaDePa machine must overcome certain challenges. Firstly, the link between VIP emptying requires a level of honesty from the VIP emptying subcontractor, who are paid by the eThekwini municipality on the volume of sludge removed rather than the number of VIPs emptied. It is relatively easy for the subcontractor to add water, detritus or sand to the sludge mixture and dilute it, reducing the efficiency output of the plant and the percentage of nutrients in each pellet of fertiliser (Harrison & Wilson 2012). Furthermore, the design of VIPs is also found to be a limiting factor; large vaults have been built to reduce the frequency of emptying required as sludge disposal, collection and treatment methods did not exist in the past. Now that machines like the LaDePa are being developed, deep vaults make emptying extremely difficult, and there is consideration being taken for future pit designs to take ease of access into account (ibid).

3.4. Struvite Production

Struvite production is another treatment technique that can be used in faecal sludge management because urine contains most of the excessive nutrients leaving the body. Nitrogen and phosphorous are both found in urine and are two elements essential for plants growth. It is possible to take advantage of these nutrients by directly applying urine to plants and crops, or process it to solid fertiliser called struvite (NHMgPO4-6H2O). Struvite is produces by adding a source of Magnesium – such as Magnesium Chloride or Wood Ash – to urine, so that it binds with the Nitrogen and Phosphorous and precipitates out in a white crystalline form. The crystals must then be lifted out of the solution, dried and processed into usable form (Tilley et al. 2014). They are already currently produced in Durban using 1000 litres per day, collected from household urine-diverting dry toilets. Struvite is an effective way to produce a compact product that can be easily stored, transported and used when and where it is needed, when there is no use or desire for urine-derived nutrients. The process is simple and requires only a mixing chamber and has proven to work in different countries and contexts. A major disadvantage, however, is that struvite production produces an equivalent amount of effluent with a high pH and ammonium concentration that requires further treatment. Other important elements such as Potassium, still remain in this solution. Hence, although it is effective, it should not be implemented without a subsequent effluent treatment method (ibid).

4. Conclusion

There has been an increase in innovation in sanitation provision and faecal waste treatment in Durban, in an effort to identify solutions that are sustainable for all the population. New technology is pushing to reduce water consumption in latrines and overcome the cultural beliefs surrounding handling of human waste. From the technologies and ideas discussed in this literature review it is clear that such practices are only being implemented on a small scale; increasing their application to service more townships will take more time.

Interventions made by the eThekwini municipality at EWS in low-income neighbourhoods, although attempting to combine services with training and education for locals, do not always address service dissatisfaction; for example, residents felt that expensive urine diversion toilet systems were being forced on them, and no alternative sanitation option was being offered. For successful use of any new designs, such issues must be addressed by the municipality. Additionally, there is limited information about the success of initiatives since they have been introduced and how large service coverage is today. This limits one’s assessment of programmes and makes it difficult to determine which has been the most or least successful amongst locals.

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Appendix 2: Quantitative in-household survey questionnaire

PRE-QUESTIONNAIRE

1. Name of household head?

____

2. If you are not the household head your name?

____

3. What is your age and gender?

____

4. What education have you completed?
   a. Primary
   b. Secondary
   c. Tertiary
   d. Other (what education?)

5. How many adults and children (below age of 16) live in the household including you?

____

6. What is your occupation?

____

7. Do you work in any other job? If so, what?

____

8. Is your house rental or owned?

____

9. What is your average monthly income?

<R1000	
R1001 – R1500	
R1501 – R2000	
R2001 – R3000	
R3001 – R4000	
R4001 – R5000	
R5001 – R6000	
R6001 – R7000	
R7001 – R8000	
R8001 – R9000	
R9001 – R10000	
R10000 +	

10. Do you have any other assets, such as tv/car/motorbike/fridge/computer?

11. How well connected do you feel within the community?
    a. Not connected at all
    b. Somewhat connected
    c. Connected
    d. Very connected

SOLID WASTE MANAGEMENT

12. Is solid waste being collected?
    a. Yes
    b. No

13. How frequently is solid water/garbage collected?

    a. Daily
    b. Once a week
    c. Once every two weeks
    d. Never
    e. Other _____________

14. Are you satisfied with the service?
    a. Yes
    b. No

15. If not satisfied why? (List reasons)

16. Where does the waste go if it is not collected?

    a. Street outside house
    b. open plot near house,
    c. river/stream

d. Bins
e. Plastic bag outside house
f. other_______________

17. Is the waste segregated within your community?

a. Yes
b. No

18. If above is yes, where?

a. House
b. Communal plot
c. Other_________

19. Do you recycle?
a. Yes
b. No

20. If above is yes, list what items you recycle?

____

21. Do you get help from the municipality for recyling for the following:
a. Recycling plot
b. Training
c. Financial support
d. Collection of recycling
e. Other________________________

FLOODING

22. Does it flood outside your house?
a. Yes
b. No

23. List which months it floods outside your house

____

24. How are you affected by the flooding?
    a. Transport elsewhere is difficult
    b. Going to work is affected
    c. Less income
    d. Time wasted on cleaning
    e. Doing daily activities
    f. Using toilets
    g. Children cannot go to schools
    h. Power cut
    i. Damage to house
    j. Other ________________________________

25. How much money is spent on average during/after flooding to repair housing as a result of damage due to rains?

____ Rand

26. How much working time is lost due to floods?

_________________________Mins/day

FARMING

27. Do you have a vegetable garden in your plot outside your house?
    a. Yes
    b. No

28. Are you interested in vegetable farming?
    a. Yes
    b. No

29. If above is yes, list the names of vegetables/plants that you would grow
    ____

30. Where would you get the water from for watering the vegetables/plants
    a. Your house tap
    b. Tanker from municipality
    c. Reuse water from washing clothes/bath/cooking
    d. Other_______________

31. Do you have any previous knowledge of farming or the seasonality of plants?

    a. Yes
    b. No

32. How much time would you invest in a vegetable plot?

    ___________________________________mins/day

33. How much would you be willing to invest in watering a vegetable plot?

    _____________________________Rands

34. Would you be willing to participate in community-led farming workshops if they were available for you?

    a. Yes
    b. No

35. How often would you attend such workshops?
    a. Once a week
    b. Once a month
    c. Other __________________________

36. What type of support do you expect from the municipality for vegetable farming?

    a. Free water
    b. Seeds
    c. Manure
    d. Training
    e. Cash award
    f. Other __________________

37. Are rats or other pests a problem for you?

a. Yes
b. No

WATER USE

38. Do you get water through taps in your house?
    a. Yes
    b. No

39. If above is No answer the following:
    a. Do you have to fetch water from elsewhere? (Yes/No)
    b. How far away? (Distance in __-____meters)
    c. How often do you fetch water daily? (Once, twice, other______)
    d. Who is responsible for fetching the water? (Women, man, girl child, boy child)

40. Where do you throw your used water?
    a. In plot outside house
    b. Vegetable garden in yard
    c. Communal vegetable garden plot
    d. Community open plot
    e. River/stream
    f. Other __________________

SANITATION

41. Do you have a private toilet which you use
    a. Yes
    b. No

42. If above is yes is it a flush toilet
    a. Yes
    b. No
43. If your house has a private flush toilet list the advantages

____

44. If your house has a private flush toilet list the disadvantages

____

45. Do you use public toilets
    a. Yes
    b. No

46. If you use public toilets what are the advantages?

    a. Clean
    b. Good servicing
    c. Safe to use
    d. Cheap/Free
    e. Chance to meet people socially
    f. Easy walk to toilets
    g. Can go with family and friends
    h. Other _________________________

47. If you use public toilets what are the disadvantages?

    a. Not clean
    b. Not safe to use
    c. Expensive
    d. Difficult to walk to the toilets
    e. Flooded in rains
    f. Does not work
    g. Lack of privacy
    h. Long queue
    i. No water in toilets
    j. Other: _____________________

48. What are the challenges you face around sanitation?
    a. Safety
    b. Cleanliness
    c. Are they serviced?
    d. Ease of use

ELECTRICITY

49. Do you have access to electricity in your house?

    a. Yes
    b. No

50. How much do you pay per month?

    ___________________________________ Rands

51. Are there any problems with electricity?
    a. Access not in house
    b. Connection charges high
    c. Bill is very high
    d. Do not understand billing system
    e. Power cuts
    f. Power supply not reliable with surges damaging appliances
    g. Not safe in rainy season
    h. Other ________________

52. What electric devices do you have?
    a. Radio
    b. Television
    c. Mobile Phone
    d. Lamps
    e. Heater
    f. Other ________________

53. Who is responsible for paying bills in the household?

____

Appendix 3: A socioecological study of solid waste management and drainage challenges in Havelock informal settlement, South Africa

This appendix is a synthesis of MSc project completed by Haaniah Hamid as part of the MSC Engineering for International Development at the Civil, Environmental and Geomatic Engineering Department, University College London, under the supervision of Dr Priti Parikh.

Aims

The aim of this work was to use a socioecological lens for development to understand the underlying causes and status quo of, and potential solutions for SWM and drainage issues. It explored the levels at which these occur, the people and groups involved; their interactions with waste and with each other.

Objectives

- Characterise the underlying causes of, and corresponding solutions to SWM and drainage challenges according to Bronfenbrenner's socioecological framework.
- Assess secondary data from the Havelock case study according to the framework.

Literature review

Multi-scalar framework

Solid waste and drainage management, or the lack of it thereby, are not issues that can be attributed to a singular cause. Factors such as individual behaviours, neighbourhood norms, municipal resources, and national strategy all come into play. The socio-environmental condition of a locality is a reflection of a system in which physical and conceptual components interact; for instance, the physical 'stuff' of plastic, or kitchen waste, and the conceptual spheres of socioeconomic status (Marshall & Farabakhsh, 2013). To assess potential SWM and drainage solutions is to assess the state, and potential state of the urban socio-environment, and this as stated by Bjerkli (2015) is a result of multiple networks and processes 'operating at different geographical scales'.

It is thus crucial to consider SWM and drainage as part of a complex adaptive system whereby cause – effect relationships between social and ecological states vary according to the particular spatial and time contexts. Figure 2 illustrates the multiple scales that make up a complex adaptive system; whether considering the myriad causes of SWM and drainage challenges, or the stages of management such as generation, collection, and disposal, it is clear there are multiple scales at work. A reductionist approach to managing the socio-environmental conditions in which SWM and drainage issues arise compartmentalizes each of these scales without recognising that these disaggregate levels are ‘partly a function of broader scale processes’ (Chowdhury *et al.*, 2011). It is essential therefore to regard ‘neighbourhood and larger scale dynamics in a multi-scalar approach’ (ibid).

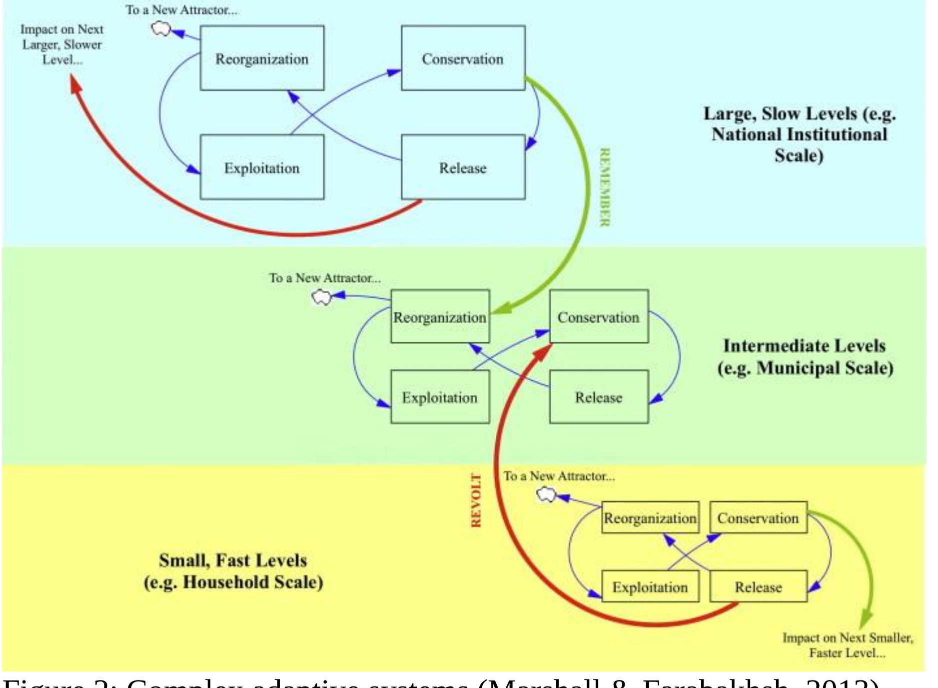

Figure 2: Complex adaptive systems (Marshall & Farabakhsh, 2013)

The relevance of a multi scale approach to environmental management is emphasised by Deng (1998) in the ‘ecological harmony’ section of a chapter proposing a new framework for sustainable development in Africa. It is asserted that environmental policy should arise from a mutual communication process between the micro, meso, and macro scales. Acknowledging that community scale institutions are the primary access point for natural resources, Deng suggests that the household should constitute the unit of analysis at the microscale. However, this creates a ‘no mans’ land’ consisting of the public spaces where drainage and SWM issues most often arise. Though often considered the responsibility of the meso-scale authorities such as local government, these areas often suffer from social irresponsibility whereby there is a lack of authority to enforce responsible behavioural norms on the micro-scale participants in an environment. The effects of this are witnessed in the prevalence of illegal dumping sites for instance. The micro and meso scale are therefore clearly crucial to the state of environmental management on the ground. This is not reflected in the macro scale by the consideration or involvement of lower level stakeholders. Furthermore, the intellectual and materials resources available at the macro scale, Deng argues, are not passed down adequately, thus missing capacity building opportunities.

Deng's analysis highlights the importance of considering the multiple scales and stresses the importance of mutual communication between levels. It is therefore imperative to not only organise cases by scales, but also to analyse the extent of reciprocal involvement and communication.

To this end, Bronfenbrenner's (1979) ecological framework for human development will be used to organise and analyse case studies and the position of the solutions within the wider urban socio-environment. Originally developed within the field of child psychology, the framework categorises the interactions between individuals and their multi-scale environments. The levels of environmental influence are shown in Figure 3.

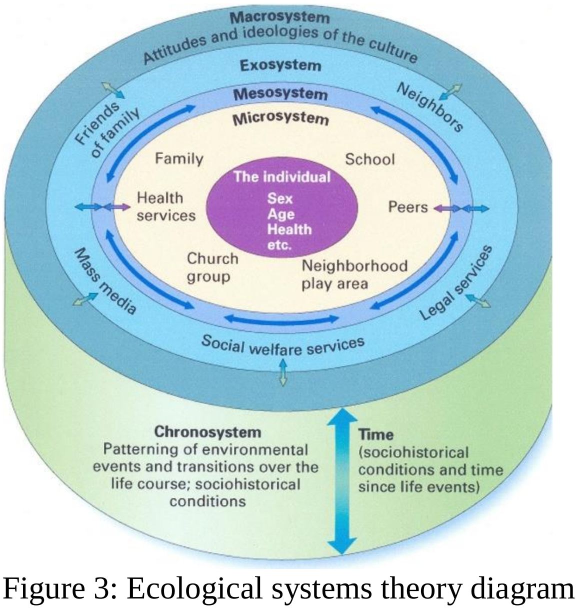

Figure 3: Ecological systems theory diagram (Hansen, 2014)

The underlying behavioural aspect of solid waste management is well established (Davies *et al*., 2005; Desa *et al*., 2011; Timlett & Williams, 2008), this supports the use of Bronfenbrenner's framework by acknowledging that ultimately SWM is a product of behaviours, which in turn are a product of the multi scale environments presented. Furthermore, there is precedence in applying an ecological framework to environmental management, within which SWM and drainage are encompassed: Mwiinga (2014) describes the reciprocal relationship between behaviour and environment with the example of environmental education affecting the use of strategically placed waste bins on one hand, and the demand for the very provision of bins on the other. In another example, an ecological analysis of corporate social responsibility programmes shows that legislation at the macrosystem level blocks lower level beliefs and attitudes towards food waste from materialising into action. This occurs when regulations do not allow for companies to redistribute leftover food to the homeless, despite the companies stating that they would prefer to do so (Musgrave & Woodward, 2016). Finally, Boon *et al*. (2012) used Bronfenbrenner's theory to measure resilience to environmental hazards including flooding, asserting that 'an ecological understanding of human development and resilience requires an examination of the influence of community, subculture and culture on basic psychological and interpersonal processes throughout the lifespan'.

ORGANISING AND ANALYSING CASE STUDIES:

The socio ecological framework was used to organise case studies and the significant factors identified within them to be arranged in order of proximity to smallest scale (Boon *et al*., 2012). In this case, proximity will be determined in relation to physical waste products and the source of flooding or drainage issues (i.e. a stream). By extension, the microsystem 'individual' is the one who first interacts with the waste or flooding source. For SWM, this is the disposer in whose possession a physical product transitions into the state of refuse.

Microsystem

Microsystem level solutions primarily concern those who dispose of waste in times and spaces outside of the designated provision; those who experience household level flooding; and at the intersection of waste and drainage, those whose waste disposal habits contribute to flooding by blocking up drainage routes. The choices made by individuals in their approaches to solid waste and drainage management can be broadly categorised into participation and innovation.

Participation

Participation occurs when an individual chooses to take part in recommended positive practices. At the individual level, SWM efforts encompass minimisation, by which the initial volume of waste is reduced; recycling or the separation of waste products for recycling; and simply a curbing of illegal dumping habits. Since schemes which propagate these are all voluntary, participation is the factor that determines success (Swilling, 2010).

The Think Twice educational campaign was aimed at introducing waste separation to preselected localities in Cape Town. Success would be based on the uptake of waste separation behaviours by households who were each provided with bags for recyclables as well as monthly pamphlets and posters. Whilst the year-long campaign was deemed successful in middle and high-income areas, with increases in the recovery of recyclables up to 45% in some areas, the scheme was judged a failure in lower socioeconomic areas (Nkala, 2012). The disparity on the impact of the campaign on SWM behaviours arose from factors including poor communication, inferior marketing strategies, and the perception of recyclables as a valuable product (ibid). The failure highlights the discrepancies of services between higher and lower income areas as the campaign was carried out by local contractors. This also shows that whilst a programme may be considered universal in the exosystem, in this case the Cape Town Local authorities, enacting policies through mesosystem and microsystem organisations leads to wider ranging quality standards at each level. This is evident in the fact of contractors serving high income areas producing better marketing and educational materials than those operating in low socioeconomic settings. Furthermore, this case study highlights the impact of socioeconomic scale on the perception of waste materials as low income residents felt that contractors should pay for the collection of the separated materials as a commodity with value. Informal waste collectors in these areas also took advantage of the separated materials, thus representing a mesosystem player that interacts with only with certain economic levels of microsystem. A final point of consideration is the make-up of waste in high and low-income households; the former has a far higher percentage of recyclable packaging in their waste whilst the latter's waste is primarily organic (Bowden, 2006). This may account for willingness to participate in the separation scheme as it is more targeted towards the contents of waste generated by higher income individuals.

Participation in schemes relies upon the assumption that knowledge, usually concerning the environment, motivates behaviour change. This can be observed in a lack of understanding of causal links between poor SWM and the resulting public health effects. This is the case amongst residents in urban slums in Uganda who expressed concern over disease vector populations like mosquitos, but not over the presence of waste that was propagating this issue (Mukama *et al.,* 2016). Environmental concern, which in turn arises from environmental education, has indeed been correlated with participation in good SWM behaviours. 'Education' can take many forms as demonstrated by Cape Town's Waste Wise initiative is an example of an educational programme targeting behaviour change. A number of schemes were incorporated into the model, from placing environmental awareness into the high school curriculum (Ferrara *et al.*, 2008) to flash mobs praising good disposal practices (City of Cape Town, 2013). Granzin and Olsen (1991) found that having more environmental knowledge has a significant influence on taking part in recycling. Iyer and Kashyap (2007) found that the effects of information programmes on the uptake of recycling behaviours was longer lasting than incentive programmes, albeit the latter had a bigger effect initially.

Behaviour is also affected by factors arising within the microsystem itself, social norms for example strongly influence littering (Kalgren *et al*., 2000). Shultz in turn found that the development of the social conscience which produces these can also be attributed to purposeful information and messaging; this was the case in the 1950s with the 'Keep America Beautiful' campaign to shift the culture of public littering (Hepburn, 2017). As a Canadian NGO worker in Nairobi's slums reflected

- a concern for environmental conservation may not be the innate reason why littering and illegal dumping is less prevalent amongst residents of developed 'clean' countries; rather littering is seen as unsociable - a moral and criminal issue (Douglas, 2015).

In a study of participation rates in recycling schemes, providing feedback data on performance was found to be more effective than information in activating recycling as a social norm (Schultz, 1999). Thus, behavioural change within a microsystem can often be traced back to efforts propagated at high levels, but equally depend upon the level of uptake within the microsystem itself.

A final illustration of these interactions comes from an Environmental Education scheme in the South African township, Mkhondo. Here, school aged learners underwent an extracurricular environment programme in the hopes of tackling littering behaviours. The effects of the education however proved to be minimal as the social norm of disseminating refuse, and the already littered environment overrode the participation of learners in better disposal behaviours (Msezane & Mudau, 2014).

Innovation

Innovation is classified as an adaptation strategy, that in informal urban environments, arises as in response to socio-ecological stresses. Innovation is distinct from participation as actions are autonomous; individually led and arising within the microsystem (Thorn *et al*, 2015).

Microsystem innovation strategies are found particularly in response to inadequate drainage and the risk of flooding where individuals have been found to upgrade personal property to protect against flooding. In the Cape Flats informal area, vulnerability reduction measures that residents have taken to protect dwellings from flooding have been identified as using pallets or stilts to raise housing and mitigate seepage through the floor; and concrete flooring upon which the housing structure is placed (Bouchard *et al*., 2007). Similarly, in the informal settlement Keko Machungwa in Tanzania, where flooding has been exacerbated by the construction of warehouses across streams, microsystem incepted coping strategies focus on reducing structural vulnerabilities by raising doorsteps, using sandbags, and constructing foot bridges from tree logs. Access to the latter is limited however as the elderly and children are not able to use them – this demonstrates how the benefit of microsystem upgrading innovations often does not extend to other levels in the multiscale system (Sakijege *et al*., 2012).

'Necessity breeds invention. And that necessity might just be what makes slum dwellers well equipped to take on a crowded, resource-strapped future.' – indicative of the relative importance placed on solid waste vs. drainage management (Higgins, 2013).

Mesosystem

The mesosystem in the socioecological framework arises from interactions between microsystems. This manifests in the form of local groups such school and religious local communities, and community led cooperatives.

Cooperatives and Community Based Organisations

Cooperatives have been trialled as a community led platform for dealing with infrastructural and service challenges. The South African government has propagated the creation of cooperatives as an enterprise development and job creation mechanism. A Greenfund evaluation of waste sector cooperatives in South Africa found that 7.8% of cooperatives sampled in the field were focused on labour intensive city cleansing activities such as litter picking and street cleaning. This was regarded as surprisingly low given the scope to absorb non-skilled labour as well as extend service provision. Barriers identified included a lack of transport infrastructure, knowledge of funding opportunities, and training on governance and operation (Godfrey *et al.*, 2015). Additionally, some of the particular physical characteristics of waste from informal areas can exacerbate transportation issues; the 'wet' nature of kitchen waste increases density, sand and ash are often included which is abrasive to vehicles (Karani & Jewasikiewitz, 2006).

On the other hand, successes were characterised by recognition of work, strong leadership, and growth opportunities. Better integration of cooperatives with local authorities and initial support were deemed key to realising the potential of cooperatives and combatting the high mortality rate amongst registered organisations in the sector (Godfrey *et al.*, 2015). This review highlights the role of the exosystem in facilitating and supporting mesosystem structures.

An example of an exosystem institution driving change that is enacted successfully by the mesosystem is found in Polokwane City in the Limpopo Province of South Africa. The 'Polokwane Declaration of Zero waste (2000)' was developed along with revised sanitary and refuse by laws to deal with SWM. Under the scheme, the city contracts 4 litter picking cooperatives in addition to the weekly refuse services. This provision involves 47 workers and a four-ton truck for disposal of waste gathered by litter picking. The systems in place in Polokwane are deemed successful with 'no refuse bag left by the roadside to litter the city' (Ogola *et al.*, 2011).

Mesosystem structures are of particular importance when considering the communal areas in a settlement that suffer from solid waste dumping and flooding. Action at the individual, household level of the microsystem is not adequate for managing these spaces. Committees formed to deal with flooding in several Cape Flats townships have experienced varying levels of success and failure. In the township Kosovo for example, a local government initiative in 2010 saw a local group formed and employed to clean drains and the area to moderate flooding risk. Internal tensions between community leaders and groups in Kosovo disrupted the work due to accusations of nepotism in the formation of the group. These tensions have also hindered the implementation of other ideas such as fining waste dumping in drains. On the other hand, informal mesosystem arrangements in Kosovo have worked successfully – this is seen in neighbours and friends banding together to fill paths and dig drainage trenches (Drivdal, 2015). It can thus be concluded that the interference of exosystem structures/ the involvement of money can affect the outcomes of mesosystem scale group activities.

In Durban itself, the eThekwini Municipality sponsored Sihlanzimvelo stream cleaning project supports 59 cooperatives that manage approximately 300km of streams. Between the cooperatives 472 people are employed in stream maintenance that aims to reduce flooding incidences in vulnerable communities. The cooperatives are involved in removing alien vegetation, clearing solid waste, erosion control, and planting gardens in the catchment areas. Figure 4 shows the impact of some of the work carried out. This is an example of exosystem institutions facilitating change and collaboration at a community level; indeed, one of the intended outputs in the funding application was the enabling of communities to engage with formal municipal processes (Tooley, 2018). Although the cooperative – municipality relationship in this case is positive, the scheme has not been without tensions. This has happened in areas where the cooperatives at work are not local; it has been stressed that working in the physical environment in which the microsystem individuals reside is important for both interpersonal relations and self-regulation of the community's practices.

Figure 4: streams before cleaning being used as dump sites (top); streams being maintained by the project (bottom) (Tooley, 2018)

Figure 5 illustrates the multiscale intervention strategy outlined by NGO Practical Action to develop Community Based Organisations (CBOs) to carry out refuse collection services in Zimbabwean urban settlements. Success of the CBOs was established by reductions in both dumped waste and the incidence of diarrhoea and malaria. Pivotal to this success was capacity building of locals and negotiations with the local authorities – these were facilitated by Practical Action (Mubaiwa, 2008). In this case, one of the factors to which success can be attributed is the presence of an external organisation bridging between the mesosystem and authority exosystem, a relationship which has proved to be contentious as in the earlier scenarios.

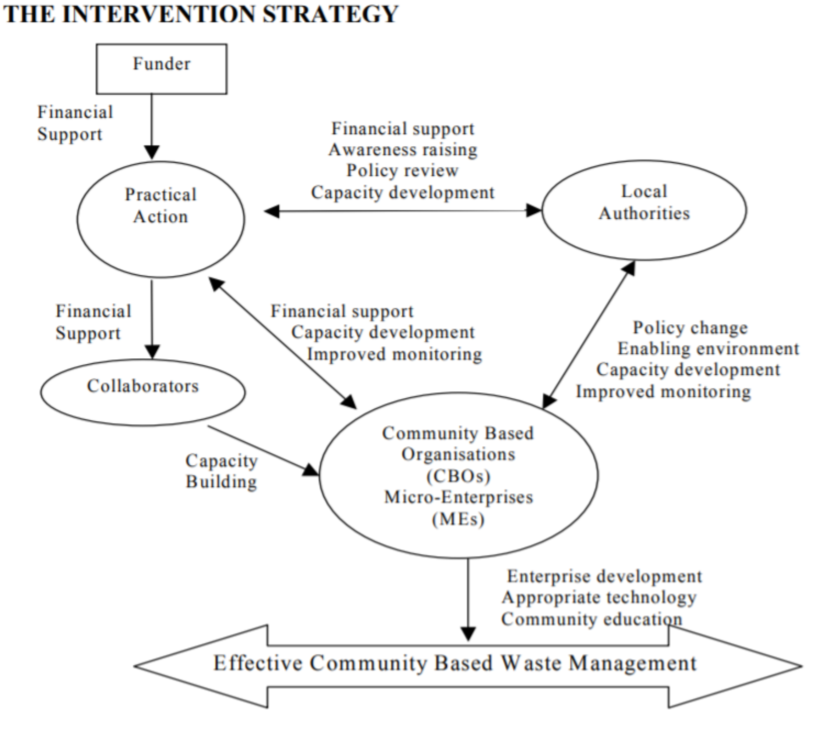

Figure 5: Refuse collection CBO Intervention strategy, practical action (Mubaiwa, 2008)

Communal refuse bins and skips

A final example of a mesosystem level SWM practice is the use of communal bins or skips, instead of, or supplementary to kerbside collection. Community organisation around such structures mirrors the earlier example of neighbours collectively digging trenches or housing flood affected belongings. Such interactions in the mesosystem, it could be hypothesised, are more dependent on decisions made by individuals at the microsystem level. Lwandle Township in the Western Cape employs both kerbside and communal collection, with the latter generally operating from public skips or bins. Very low levels of cleanliness have been found to correlate with a lack of legal recognition for housing in the area; inadequate bin capacity; and a municipal collection frequency of once every one or two weeks. By contrast, high levels of cleanliness were found in both kerbside and communal collection areas that shared the features of adequate bin capacity and a high collection frequency of 5 times per week. Waste accumulation most frequently occurred around communal skips where resident dispose of waste around the area and not within the skip itself. The build-up of leachates and stagnant water occurs as waste is not separated; the resulting condition of the area means that workers are reluctant to clean the vicinity of the receptacles (Puling, 2004). This demonstrates that treatment of an area by decision makers at the exosystem scale may influence the development of differing collective behaviours within communities.

Examples of community involvement centring around communal skips are found in Cape Town's informal settlements and townships. Here, under the Masicoce program, women are hired under yearlong contracts to collect and transport waste from households in informal areas to communal skips. A lack of integration with municipal collection services at times has however led to overflowing of these receptacles and thus additional work in cleaning the surrounding area. Other Cape Town areas where service is limited to communal skips have seen the rise in voluntary women groups that carry out litter collection and street sweeping. Their incentives for doing so include improving health and hygiene, the safety of their children, and the potential for employment (Miraftab, 2004).

Exosystem

In this paper, the exosystem refers to authoritative bodies that do not interact directly with the microsystem yet exert a level of decision making and control over the environment and policy landscapes that ultimately affects the individual. As has been established by the case studies discussed thus far, exosystem scale organisations such as municipal authorities and state governments have an extent of influence over both microsystem and mesosystem level initiatives. This is achieved through policies and legislation that can serve to both enable (Ogola *et al.*, 2011;

Mubaiwa, 2008) and impede (Drivdal, 2015; Puling, 2004) good SWM and drainage practices and progress.

There are internal subscales within the exosystem. In South Africa, these have differential and overlapping responsibilities with regards to the chain of policy, resources, and financing that culminates in local infrastructure and services – in this case waste management. These discrepancies are 'hampering the government's commitment to achieving the rights stated in the Constitution and related legislation' (Madubula & Makinta, 2012). Table 1 sets out functions involved in waste management and the agencies to which these are assigned, demonstrating the cause of confusion.

Component	Broad Function	Activity	Current Assignment				Issue
			Nat	Prov	Local	Pvt	
Policy Making Regulation	Standard Setting	Norms & Standards	X	X			What is to be provided
		Access Targets	X		X		
	Planning	Plans for service expansion		X	X	X	Adequate facilities and
		Plans for service improvement		X	X		
Service Provision	Asset Creation	Social Capital			X		Adequate facilities and
		Physical Capital			X	X	
	Financing	Tariffs			X		Financial Sustainability
		Subsidies to Consumers			X		
		Grants to Service Providers	X				
	Operation	Consumer selection			X		Effective and Sustainable Services
		Recurrent expenditures					
		General Area cleansing			X	X	
		Waste minimisation			X	X	
		Waste Collection			X	X	
		Waste Transport			X	X	
		Wast disposal			X	X	
		Maintence			X	X	
		Staffing			X		
Policy Making Regulation	M & E	Economic	X	X	X		Quality of Service deliver
		Financial	X	X	X		
		Operational	X	X	X		
		Monitoring and Evaluation	X	X	X		

Table 1: Functional roles and responsibilities for solid waste management in South Africa (ibid)

Economic Instruments

A tool exclusive to the exosystem, and for which there is a legal mandate in South Africa is economic or financial instruments (EIs). These may take the form of fines, incentives, or taxes which all aim to shift behaviour with responsive financial drivers. Whilst these are theoretically available to authorities, many municipalities cite proper implementation of the existing Waste Act as a necessary precursor to developing more sophisticated SWM incentives (Nahman & Godfrey, 2010). Other antecedent conditions cited for the implementation of EIs are education, governmental capacity building, better recycling infrastructure and improved existing services. As has been shown, improvements in collection frequency and receptacle capacity can vastly improve SWM conditions (puling, 2004). Many such infrastructural issues have been found to be barriers to good

SWM in informal settlements. In Kenya for instance, poor road infrastructure, vehicle quality and prompt collection were cited, as well as access to collection points being affected in the rainy season when routes become compromised (Henry *et al*. 2006). Godfrey and Nahman (2007) suggest that there are two main barriers for economic instruments in South Africa. First is the trade-off between levying environmental taxes and raising revenue; a successful tax would deplete itself through the minimisation of waste and pollution. In practice, such taxes are often viewed by cash strapped authorities as revenue generators, easing pressure on tax payers to actually modify waste practices. Second is a lack of institutional capacity as effective billing systems, monitoring, and auditing are required for the deployment of EIs. Furthermore, implementing such systems in informal areas with limited access to electronic billing and formal property registration presents additional complexity.

Service privatization

One approach taken by local authorities is to privatize, and thus decentralize, waste management. There are many of instances of this occurring – in Durban Community Based Contractors are used for primary collection from low income, high density areas. A case study of Clermont Township evaluates the effectiveness of the private company eThembeni community service Solid Waste Management who are responsible for collection, and in areas with proper roads, street cleaning. When residents miss the weekly 6am collection time, waste ends up being dispersed throughout the week. The private collectors feel that this makes their work appear ineffective, though the onus of this issue should be on the residents. In addition, the collectors also report being subjected to verbal abuse and a low social standing (Ngeleka, 2010). This may be a result of services being devolved, whilst jurisprudence of the area remains with the local government in theory but is not acted upon to tackle the issues of illegal dumping and workers' rights that have arisen.

Using the modes of privatization present in Cape Town for waste management services, a concerning hypothesis is presented by Miraftab (2004); namely that the neoliberal agenda that underpins privatization propagates vestiges of apartheid and the casualization of labour. The argument follows that privatization distances the governmental authority from labour; this has facilitated major cuts to service costs as private companies such as TEDCOR pay two thirds of what municipal workers would earn. It has also aided a reliance on short term contracts and voluntary groups in some areas – such as the previously mentioned Masicoce scheme. These models, it is argued, are exploitative and lack security. Further to this, the savings that the authorities make via private services are not reflected in the spatial distribution of public spending, in effect 'disadvantaged neighbourhoods, through their residents' underpaid and unpaid labour and/or lower level of services, subsidize the better services to the affluent suburbs' (ibid). This emphasises the significance of centring spatial and distributive justice principles (Rawls, 1971) within decentralization approaches to environmental management.

Roads infrastructural upgrading

Infrastructure upgrading is a measure that local authorities have the prerogative over. In the case of SWM and drainage challenges, roads in particular can have a significant effect. Infamously poor road conditions, especially in slums in Nigeria have been closely linked to indiscriminate refuse disposal. A combination of steep slopes, unpaved roads, thin coverings that wash away, narrow widths, and a lack of drainage make vehicle access and even receptacle storage impossible in many areas (Onu *et al*., 2014). Much of this is attributed to inadequate urban and transport planning that has led to disconnected networks.

UN Habitat (2012) proposes a 'street led approach' to upgrading informal areas. This extrapolates from the physical uses of a road to the symbolic role of streets in social connectivity. The use of streets as a driver of upgrading is mirrored by the slum networking approach which views roads as drainage conduits, and the blueprint for other service networking, like water and sanitation (Parikh *et al*., 2002). The UN Habitat approach rationalises that formalising streets enables the inclusion of informal residential areas onto the maps and registries which are used for service provision, such as SWM collections. The Kampung Improvement Program (KIP), Neighbourhood Upgrading and Shelter Sector Project (NUSSP) in Indonesia are used to illustrate these ideas. Here, street upgrading has led to better service provision, community willingness to carry out maintenance, and local capacity building. Parkinson *et al*. (2007) recommend that roads should be kept as low as possible so as not to redirect flooding onto households, it should also be insured that the lowest lying sections have sufficient drains fitted with grills to avoid solid waste blockage.

Integrated services

One of the challenges facing decision makers attempting to plan participatorily is the low priority given to SWM by informal settlement residents. A waste management scheme in Karachi, Pakistan's Shah Rasool colony recognised this and so ran a Hepatitis B vaccination campaign and supported flood control efforts to gain the community's confidence in then dealing with its SWM issues (Zurbrügg & Ahmed, 1999). Similarly, Teddy Gounden (2018) of eThekwini Municipality Strategic Executive Water and Sanitation envisions the integration of services combatting this: combining solid waste collection with toilet cleaning for instance. An attempt akin to this was tested in Ivory Coast where waste collectors unsuccessfully offered toilet and bathroom cleaning services in a bid to increase willingness to pay (Anschütz, 1996). Successful service integration has occurred however: in Gedaref, Sudan where payment is collected as part of the sugar price; and Surabaya, Indonesia where SWM fees are part of an occasional lump sum for general social welfare efforts (ibid). This demonstrates the one size fits all approach to integrating services is not likely to work for authorities; consultation of willingness and priorities is key in identifying viable collaborations between services.

METHODOLOGY FOR EVALUATION

Bronfenbrenner's framework has been indispensable for unpicking the complex stakeholders, relationships, and socioecological factors that comprise SWM and drainage issues. Further to this however, is the appraisal of the strategic routes identified at each level of the multiscale framework. This requires evaluative indicators against which to measure and contrast results (Bamberger, 2012). An evaluation of conceptual frameworks for assessing urban environmental quality and wellbeing by van Kamp *et al*. (2003) established that the abstracted nature of human ecology approaches (which Bronfenbrenner falls under) necessitates the use of a set of indicators for a level of testing to occur. Indicators may arise from within the research, or from independent sources (Bamberger, 2012). The latter approach is chosen here with Schubeler *et al*.'s (1996) MSWM framework being the primary source.

The MSWM framework was developed as a World Bank working paper under the UNDP/UNCHS (Habitat)/World Bank/SDC collaborative programme on Municipal Solid Waste. The framework lays out principles for guiding the development of SWM strategies. Specific strategic objectives are set out under the identified factors of the political, institutional, social, financial, economic, and technical that the framework considers crucial for attaining efficacy and sustainability in waste management. Evaluation of solutions identified at multiscale levels will therefore be carried out against the extent to which the solutions perform against these outlined objectives, and with regards to the context of Havelock. Helpfully, the framework separates the 'actors' involved in waste management in a way that facilitates the superimposition of Bronfenbrenner's socioecological scales. The resulting matrix is shown in Figure 8.

Whilst the framework was clearly developed with a waste management perspective, it is justifiably applicable to the drainage management and flooding issues also covered in this work. Firstly, as is discussed in Schubeler's (1996) working paper, solid waste management is generally not prioritised above issues such as health, drainage, and water supply in service poor communities. This is reflected in the satisfaction levels reported in Havelock with many residents feeling that the SWM present was adequate. In such areas, flooding has been an instigator for dealing with SWM (Visvanathan & Tränkler, 2003). Addressing flooding is therefore a way of indirectly addressing SWM as pressure to deal with this increases as other services are put in order. Secondly, the ecological distribution of waste cannot be uncoupled from the spatial environment, of which drainage systems or the lack of, are a part (Baabereyir *et al*., 2012). This is encountered in Havelock where flood reduction measures include stream clearing. When flooding is the result of monsoon rains and poor housing materials, the waste or reuse source of much of these materials is highlighted as another intersection of SWM and drainage.

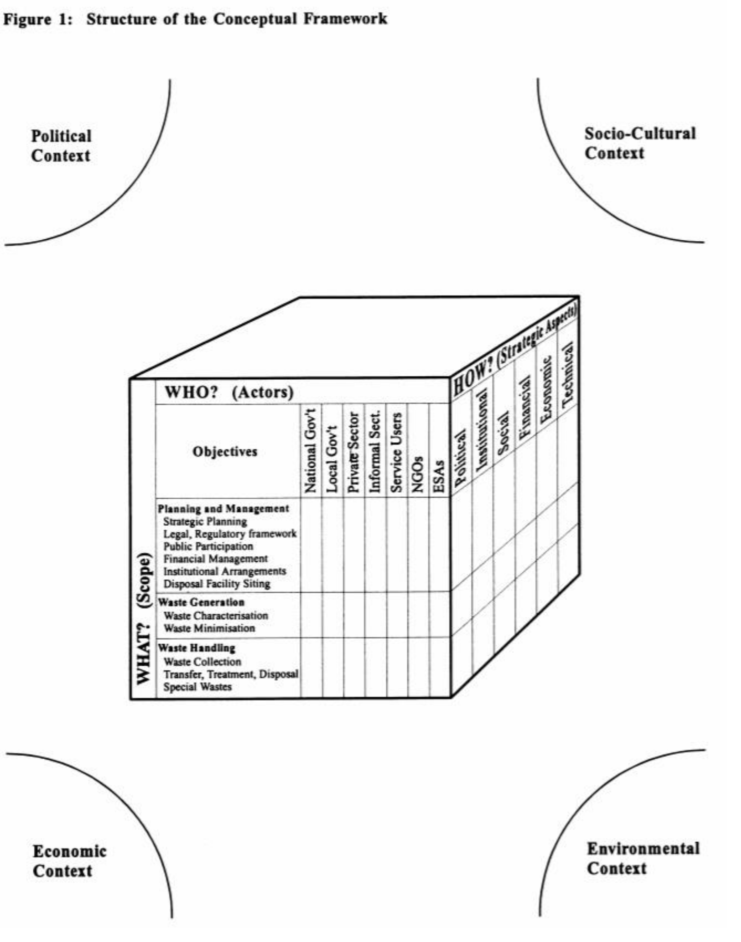

Figure 8: structure of the conceptual framework (Schubeler *et al*., 1996)

A summary of the MSWM framework objectives are presented in Table 2. The following is an analysis of the environmental management approaches identified in the literature review; evaluated against the MSWM framework objectives as well as the practicality of implementation in the context of Havelock.

<table>
<tr><td colspan="6">Goal</td></tr>
<tr><td colspan="2">To promote the health and well-being of the entire urban population</td><td colspan="2">To protect the quality and sustainability of the urban environment</td><td>To promote the efficiency and productivity of the urban economy</td><td>To generate employment and income</td></tr>
<tr><td colspan="6">Overall aim
To establish sustainable MSWM systems which meet the needs of all citizens, including the poor</td></tr>
<tr><td colspan="6">Strategic Objectives</td></tr>
<tr><td>Political</td><td>Institutional</td><td>Social</td><td>Financial</td><td>Economic</td><td>Technical</td></tr>
<tr><td>Determine MSWM goals and priorities

Define clear roles and jurisdiction for MSWM

Establish an effective legal and regulatory framework</td><td>Devolve responsibility and authority for MSWM to local governments

Establish effective municipal institutions for MSWM

Introduce appropriate management methods, procedures and service targets

Build municipal</td><td>Orient MSWM to the real needs of people, including the poor, women & children

Encourage proper waste handling patterns by the population

Raise people’s awareness of MSWM problems and</td><td>Establish practical and transparent cost accounting and budgeting systems

Mobilise adequate capital investment resources

Raise sufficient revenues for recurring expenses ensure adequate</td><td>Promote economic productivity & development through adequate MSWM service

Environmentally sound waste collection, recovery and disposal

Ensure long-term economic effectiveness of MSWM systems

Promote waste minimisation</td><td>Achieve low lifecycle cost of waste management facilities and equipment

Technology that facilitates user and private sector collaboration

Ensure that technical systems effectively limit environmental pollution</td></tr>
</table>

	capacity for MSWM Increase efficiency and through private sector involvement Extend lower cost MSWM service through community participation	priorities Mobilise community participation in local waste management Protect health and socio-economic security of waste workers	O&M Improve the efficiency and reduce costs of MSWM service	and material efficiency Generate employment and incomes in waste management	
Strategic Issues					
Relative priority of collection services in relation to safe waste disposal Priority attributed to waste minimisation reduction and recovery	Optimal distribution of functions and responsibilities? Devolution of MSWM responsibility in spite of limited local government capacity Involving local governments in	Adaptation of waste management services to the needs of poor households and women Effectiveness of awareness building or direct community involvement	Failing incentive of local institutions to use available cost accounting methods Use of collected revenues for the intended MSWM purposes	Trade-off between low-cost waste service and environmental protection Control of industrial and hazardous waste in spite of small, scattered sources Trade-off	Coherence of technical systems in spite of differing requirements and decision makers Estimation of lifecycle costs of technical alternatives Appropriate

Meeting the service needs of irregular and illegal settlements Mix of instruments for waste management: regulations, incentives and/or motivations Contribution of ESAs to MSWM policy formulation	system planning and development Responsiveness of waste management to real needs and demands Raising the professional standing of waste managers	Equity of MSWM service access to the poor Collaboration with and support of informal waste workers	Incorporating incentives for cost reduction and efficiency	between efficiency of waste service and employment creation	standards for sanitary landfill design and operations

Table 2: Overview of the Conceptual Framework for MSWM (Schubeler *et al.*, 1996)

Results - Havelock Case Study

The ‘results’ referred to in this section are an explanation, and organisation of the data collected via use of the mixed methods tools covered by the fieldwork. This culminates in a comprehensive picture of the SWM and drainage status, from the perspective of each level of the socioecological framework.

CONTEXT:

The baseline SWM provision in Havelock consists of ‘kerbside collection’, in line with the municipality’s stated service provision commitment (eThekwini Municipality, 2016). In practice however, this does not mean that collection by municipal services is door to door; rather the transect walk revealed that refuse bags are collected from the kerbside of the main road that runs on the periphery of the settlement – ‘roads’ within the settlement are informal pathways that are inaccessible to collection vehicles. The municipality’s general policy with regards to informal settlements is to delegate service to community-based contractors (CBCs) (ibid).

It is apparent from both the transect walk, focus group, household questionnaires, that the stream at the ‘bottom’ of the settlement is a key source of flooding during the rainy season. A settlement profile video produced by SDI Alliance (2012) illustrates this, as well as recording the experience of a resident whose housing materials are insufficient to protect again flooding when it rains, this experience is corroborated by the focus group who discussed the annual rebuilding of housing post floods. Furthermore, the transect walk did not reveal any purpose-built drainage channels - instead internal pathways are described as slippery. The focus group elaborated that rains impact accessibility within the settlement, especially for women.

SECONDARY DATA RESULTS:

Microsystem:

The method used for data collection at the individual, microsystem level was the household questionnaire. Responses to this paint a picture of residents’ personal experiences of, and interaction with infrastructure and services. 18 respondents were recorded in the survey. Whilst this sample size is sufficient to build a case study, the figures drawn from quantitative questions are not statistically significant, so generalizations are not made from these (Onwuegbuzie & Collins, 2007).

The experience of the households sampled with existing services was mostly positive with 27.8% of the respondents reporting dissatisfaction. The reasons given for dissatisfaction were that the area is still dirty, rubbish is thrown in the stream, the plastic bags provided by the authorities are not adequate as they get filled too quickly - they are either not big enough or there are too few - and there are insects that have been attributed to the solid waste. Mosquitos, roaches, rats, and cats were highlighted as particularly problematic pests.

Flooding is experienced by the clear majority of respondents: 88.9%. Most of the flooding was attributed to heavy rain in the summer months. One respondent lives close to the stream and stated that the swelling of this was the cause for flooding as the water reaches the house. It could be extrapolated that the presence of solid waste in the steam exacerbates the problem of it overflowing. When the stream is swollen, it presents a mobility issue as 4 of the respondents reported being unable to cross the stream, thus blocking them from going to work and using the ablution blocks.

Microsystem behaviours in Havelock are characterised by the ways in which individuals enact SWM. The levels of the waste hierarchy adopted by the municipality and shown in Figure 7 categorise the SWM decisions made by individuals in the settlement.

Figure 7: Waste management hierarchy, (eThekwini Municipality, 2016)

The lowest level of waste management is disposal. This pertains to the extraneous ways that uncollected waste is dealt with; the survey related that 6 households leave this outside their houses; 2 affirm that they deposit it in the stream; and the remaining 10 households use a mixture of burning, or leave the refuse in the road, on roofs, or near the ablution blocks. From these responses, it is clear that disposal behaviour varies between microsystems and results in uncollected waste being spread throughout Havelock.

Further up the waste hierarchy is recycling; one of the enabling steps to this is separation which 11 respondents stated did not occur in the community. However, 5 of the replies did point towards the occurrence of waste separation, with one person specifying that it was the separation of bottles. It is of note that the wording of this question (17) was in terms of community – a mesosystem structure. It is therefore not clear whether the responses to this were in a personal capacity or referenced a general existence of the separation practices. Question 18 elaborates on this by showing that some households separate waste in the home, varyingly cardboard, organic waste and bottles. For others, separation consists of people who ‘scavenge’ for bottles and cans from their garbage bags. Of those surveyed, 6 state that they do recycle, despite the lack of a formal municipality recycling programme. The main items cited as recyclable were tin cans, plastic and glass bottles, with 2 explicitly stating that they then sold these. Assuming that the sale occurs within Havelock, individuals using this SWM measure are actually engaging further up the waste hierarchy with ‘reuse’.

The final point of interaction between the microsystem and infrastructure is in the flood-proofing or repair of flood damaged housing. A resident who said they did not experience flooding attributed this to the superior building quality of their shack; it was specified in a few cases that flooding and leaks come from both the floor and roof. The focus group explained that rebuilding occurs after the rainy season, with households sourcing materials from the hardware store, scrap, or second-hand shops. An interesting intersection with the reuse concept occurs here in that reused materials are preferred due to the lack of, or lower cost. The rebuilding process also points towards the formation of initial, informal mesosystem structures as neighbours help each other out with construction.

Mesosystem:

The data suggests that there are some communal SWM and flood proofing efforts around which groups form and organise. As has been mentioned, informally this can be seen in the leveraging of neighbours for construction work – helping to abate hiring costs.

Communal efforts are especially important for addressing issues that occur in public spaces. One such initiative described is the use of tyres and other scrap materials on pathways during the rainy season for improved accessibility. The focus group also mentioned collective efforts during this time to clean up the stream, aiding its flow. This is likely a temporary measure as the transect walk described organic solid waste disposed at the stream site, as did some of the questionnaire respondents. Also, at the site of the stream is a collection of glass bottles, indicating an extent of cooperative collecting amongst residents. Both the transect walk and focus group addressed the bottle collection; intended for collection by a private recycling company, the company did not come for collection and the settlement could not source adequate transportation to move the materials to the recycling facility. This highlights that willingness to cooperate within the mesosystem must be supported by the necessary physical resources for successful completion.

One of the questionnaire respondents explained some of the SWM logistics in Havelock; refuse bags are given by the municipality to the local owner of a tuck shop who then distributes these door to door. This is an example of a mesosystem interaction which also underlines that there is an intermediary step between the residents and the exosystem municipality that is responsible for serving them. The same respondent also mentioned that certain community members have taught others about waste separation. Thus, it can be concluded that some of the mesosystem interactions existing within Havelock deal with the issues arising from SWM and drainage challenges.

Exosystem:

For the individuals resident in Havelock, the exosystem is the wider socioecological ecosystem in which they exist. As has been established, sub-contracting to locals for refuse bag distribution and collection means that most residents do not come into direct contact with the municipal officials or services. They are however affected and influenced by these bodies indirectly as the functionality of individuals within an environment is connected to the development of its urban and environmental planning context (Slocombe, 1993).

One of the key, recurring themes in the stakeholder interviews was the perspective of exosystem bodies of informal settlements as 'interim'. Dan Naidoo, senior manager at Umengi Water, and Vishnu Mabeer, eThekwini water and sanitation senior planning officer, explained that informal settlements are typically seen as transit areas where the ultimate end goal is relocation to townships or housing developments. This view was propagated by catchment manager Geoff Tooley whose department's priority for flood risk management is the list of relocation sites, as opposed to the installation of flood management infrastructure such as open channel in settlements. Tooley also mentioned that flood managements for informal settlements would most likely fall under the 'interim services programme' as an element of a road redesign initiative for fire fighter access. This is a direct acknowledgement of the 'interim' categorisation afforded to the settlements. This categorisation stems from the assumption that that unformal settlements were a temporary measure arising from a housing provision backlog. In practice this has not been the case, as stated by Teddy Goudon of the municipality's strategic executive for water and sanitation, who cited this underlying assumption as one of the barriers to infrastructure implementation. SDI's Havelock profile (SDI, 2012) traces the settlement's origins to 1990; plainly contradicting the idea of its impermanence which underscores the policy that governs its service provision. Dr Cathy Sutherland of the University of KwaZulu-Natal believes that a shift is underway in the terminology – from 'interim' to 'incremental'. This was echoed by Naidoo and Mabeer who cited incremental growth as an infrastructure provision challenge, particularly in cases where population increases because of service installation, a phenomenon also noted by Nick Alcock of Khanyisa Projects and Aqualima Trust.

A lack of available funding, particularly for operation and maintenance costs was a critical concern across the exosystem representative stakeholder interviews. Sutherland, Gounden and Alcock all raised this point in particular; one of Alcock's Aqualima Trust projects involves the declogging of irrigation systems – a function comparable to the clearing of streams – that currently relies on the support of an NGO to achieve this. Without municipal or NGI support, Alcock questioned the sustainability of the scheme for informal settlements.

Representing a municipality view was Gounden, he highlighted that the city is unlikely to set up more WASH related facilities in informal settlements, due majorly to the need for operation and maintenance funding, Due to the Government provision of free basic municipal services for poor households, most informal settlement dwellers fall under free basic services. This means that there is no revenue available for the municipality or other organisations working in these spaces, making the business case hard to justify. Naidoo and Mabeer also touch in the free basic services programme, asserting that this has raised the expectation for all service provisions to be free. This contrasts the requirement for funding to support ongoing maintenance of networking that Umengi could potentially carry out. At the exosystem level there is therefore a dichotomy perceived between the availability of funds, and the expectation of free services. This contrast may not be as apparent to mesosystem and microsystem structures who do not interact with the budgeting and decision making at hand.

Ultimately, pervasive to exosystem concerns, initiatives, and characterisations is the role of politics. This is central to the perspective of politics as a socioecological factor that shapes urban environments (Njeru, 2006). Alcock in his interview prioritised politics as the main barrier to infrastructure implementation. He elaborated that the particular system of proportional representation in place means that informal settlements like Havelock are represented by 2 or 3 councillors who may well have opposing messages. This is a situation specific to informal settlements as townships for example are likely to have more cohesive representation due to the relative homogeneity of views. Havelock has experience of conflict with the wider locality in which it is embedded (Thomas, 2013); it is hence not unreasonable to suppose that this divergence may also be represented in voting.

Evaluation

Microsystem: participation in behaviour change

Participation pertains to the adoption of recommended SWM best practices which are towards the top of the waste hierarchy: separation, reuse, recycling and minimisation.

Though political resources may be called upon to disseminate educational materials intended to prompt behaviour change, this approach does not necessarily designate clear roles and jurisdictions as the ultimate onus is placed on microsystem individuals. This is therefore the maximum limit for devolution – one of the institutional aims. There is also scope for institutions to involve private sector actors as was the case in the Think Twice campaign; this can raise the professional standing of waste managers as they additionally become educators. There is evidence of educational activities occurring informally in Havelock; a questionnaire respondent discussed a community member advising on waste separation. This suggests that there is a precedent, and potential audience in Havelock that institutions could fortify by formalising. It is also the case that participation at the highest level of the waste hierarchy – minimisation – could reduce service costs by lowering the necessary capacity. Recycling activities may have the opposite effect in terms of services but are more widely valuable by diverting part of the waste stream and redirecting materials back into the economy. Whilst attempting to address the root cause of SWM issues, this approach does not hold institutions responsible for cases where service provision may be inadequate, and existing scenarios which still need to be dealt with such as illegal dump sites and flooding.

Undeniably, participation signals positive social change, and the Havelock context means that informal and low-income residents are naturally beneficiary. Success is indicative of awareness raising, and informal workers can also benefit from the opportunities raised by waste separation. This latter benefit has been exercised already to an extent in Havelock with individuals reselling scavenged materials – this is the main way in which the approach could potentially meet financial and economic objectives. They did however explain that a lack of storage space impedes this. In and of itself, the participation route does not incorporate financial incentives or accounting methods. The technical requirements of participation have financial and institutional implications as resources would be needed to support the uptake of positive behaviours such as recycling. Provision of coloured bags for example is carried out elsewhere in the municipality so it is not unfeasible for extension of the service to the existing area, however the costs associated need to be borne either by the residents or municipality. Without revenue generation potential, the latter is unlikely.

Microsystem: innovation

By their nature, innovative approaches taken by individuals are independent of political institutions and their service provision levels. Rather, activities carried out – like the use of tyres on roads in Havelock – arise in response to needs such as reducing the danger of slippery pathways. Whilst responsiveness is a social objective, informal collaborations also raise the potential for conflict whilst not actually affecting service provision. Additionally, there is no revenue stream for O&M, and residents are required to put their own capital up to pay for materials. In Havelock's case there is a potential for secondary economic benefits in certain cases as some residents reported stream flooding prevents them from going to work; innovative approaches to building a stream crossing would therefore increase mobility and re-establish the earning potential of these people. The technology leveraged in innovation led approaches facilitates collaboration between individuals. The technology can also mitigate costs elsewhere; for example, the use of sandbags for flood prevention can alleviate the need for rebuilding and replacement materials post monsoon season. One of the main limitations of innovative approaches is the organic development of such measures; it is difficult to conceive a situation in which institutions formally instigate such activities. One option may be to increase awareness on the cost-benefit transaction of generically flood proofing for instance.

Mesosystem: cooperatives

The establishment of cooperatives for community led environmental management meets many of the MSWM political and institutional objectives. By devolving service responsibilities to community-based groups, clear jurisdiction over particular areas is established; roles are generally outlined; and informal communities are empowered to respond to their own needs. Collaboration between the municipality and cooperatives is symbolically visible in the Sihlanzimvelo stream cleaning project where cooperative employees wear eThekwini municipality uniform; this also formalises their professional standing. If the potential for internal tensions are avoided through proper planning and consultation, cooperatives can be socially beneficial by capacity building locals and increasing environmental awareness and responsibility through practical work. This also translates into economic activity for those employed by the cooperative, bypassing some of the trade-offs described in the economic objectives.

The financial capital that is required to start a successful, well supported cooperative is not insignificant. The Sihlanzimvelo project for example has a budget of 45 million rand, approximately £2.6 million. This works out as a cost of around 61,475 rand (£3546) per job opportunity created by the project. In Havelock's favour, this budget is held in its own municipality suggesting that there is potential scope for financial support. This project also highlighted the importance of training and capacity building as a prerequisite of establishing cooperatives, and the associated accounting systems that are put in place, particularly because jobs are targeted towards unskilled labour. For O&M costs to be sustained, cooperatives must be revenue generating, invoking willingness to pay amongst the local community. One of the advantages of a cooperative in this instance is that workers live within the ecosystem that they are working on, helping projects to become somewhat self-regulating.

The technology requirements of cooperatives vary considerably depending on the nature of the work being carried out. The availability of resources such as transport can be pivotal as is seen in Havelock's inability to shift recyclable bottles that have been collected. The initial capital accumulation must therefore be able to support such resources which would otherwise become a limiting factor. This may provide a platform for innovative public-private collaborations such as the hire of municipal vehicles, but also introduces liability that must be factored into costs.

Mesosystem: communal bins/ skips

Contrary to the MSWM political aims, the introduction of a communal bin prioritizes safe disposal over collection. It does however meet the specific needs of an informal settlement like Havelock because of the lack of accessible kerbsides in the area that prevents door to door collection; it is thus a more permanent alternative for disposal between collection times during which waste accumulates and is disposed of haphazardly. Legally, a communal bin mandates a proper framework for, and jurisdiction over illegal dumping as well as a definition of responsibility over cleaning and collection services. This may be an additional strain at an institutional level and may also disadvantage informal waste workers by impeding their sifting for recyclables.

Theoretically, a communal bin should better SWM awareness, practices and health within communities. In practice however, the social impacts of communal disposal can also be negative due to the build-up of waste and leachates in the surrounding area which concentrates unsanitary conditions in a frequently visited area. It is also important that leachates do not contaminate the stream in Havelock, which could be challenging due to the steep topography of the area. This may play into the economic objectives by providing employment in the form of cleaning and maintenance of the area, and by redirecting waste away from the rest of the environment.

Depending on the placement and use of a communal bin, there may not be significant changes to collection services required, with a small potential for less frequent collection. In this case, the main cost is the capital needed for the bin or skip itself, and then for O&M. Being a non-revenue generating initiative, this could be justified to the municipality via savings to service costs which are kept at a minimum for informal settlements anyway. Otherwise, local buy-in would be required initially.

By ultimately aiming to limit pollution, and providing an interface for both internal mesosystem, and public-private interactions, a communal bin or skip fulfils some technology objectives. It also requires that sanitary design and planning conditions be satisfied, helping to introduce a level of regulation to informal settlement SWM systems.

Exosystem: Economic instruments

Though led at an exosystem level, economic instruments ultimately place the onus of success on behaviour change by prioritising minimisation and recycling over collection services; in line with the MSWM framework's political objectives. Furthermore, the use of instruments in and of itself is viewed positively and financial incentives have proven to be drivers of change in informal settlements where necessity and the potential extractable value from waste proves more contentious than in higher income areas. In this, the municipal institutions are seen to be responsive to the fundamental demand of a low-income area; namely finances. On the other hand, disseminating EIs can add another layer of responsibility to institutions, except for the 'polluter pays' principle which is based on devolving responsibility.

Socially, EIs promote better SWM practices and draw attention to awareness of these with the carrot/stick of money. The free basic services scheme in place may however serve to exacerbate illegal dumping, especially if EIs are in the form of fines or taxes as residents are expectant of waste services being dissociated from payment. Practically, and in light of the financial objectives, such EIs are the most practical route as they are revenue generating, unlike incentives which would require financial capital that could be justified against hypothetical savings. The uptake of EI driven behaviours should ultimately result in lower costing and more efficient services; the long-term objective of financial considerations.

The main economic benefits of EIs focus around minimisation, and hence better environmentally sound practices. There is not significant scope for the promotion of economic activity – informal recyclables collectors may take advantage of EI driven waste separation for example – but this is not an objective of EI systems. Additionally, the long-term sustainability of relying on an economic solution to SWM is questionable as good practices should ideally move into the territory of societal norms for lasting and independent impact. Being an economic solution, exosystem institutions are not called upon in this instance for physical technology. The billing system inevitably put in place may serve to facilitate collaboration between the municipality and service users. This may be seen in an encouragement to use mobile phones as a payment platform for example.

Exosystem: Integrated service provision

Integrating SWM with other key services is a solid political attempt to meet service needs whilst motivating communities into action. The amalgamating of activities or payment systems mandates a need for legal frameworks, particularly with regards to land rights. This is especially important in delineating services and payments that are household based.

For institutions, integration may not devolve service responsibilities, but rather aggregate them. This arguably streamlines the remits of municipal departments given proper attention to initial set up. This approach also marks potential for institutional capacity building through the collaboration of previously unrelated services or schemes.

By placing more emphasised services at the forefront, integration is a way of adapting to the personal priorities of informal settlement residents. Despite this, success still hinges on the willingness of residents to pay or in the case where services are free, to engage with the new system.

The main motivation for service integration is improved efficiency; this is positive from a financial standpoint and can also present a potential revenue stream if SWM is embedded within a good or service that residents are more willing to pay for. Economically, streamlining may negatively impact the number of jobs involved with environmental services. By focussing on pressing issues like water and sanitation, service integration feeds into wider local environmental protection.

The technology implications of integrating services are unclear and very much dependant on the route of integration taken. In some instances, IT literacy would be requisite and could provide both a capacity building and public-private interface opportunity.

Exosystem: privatisation

The general focus of privatising services is improving collection and disposal. Whilst an effort to better meet the needs of informal settlements, experience has shown that service quality can be compromised through devolution. It is therefore essential for exosystem institutions to retain involvement in a monitoring, regulation and quality control capacity.

Assessing the social objectives against privatisation rests on key questions of, for example, will the potential savings made by subcontracting be seen by investment back into the community from which the savings are made? What is the job security, compensation, and local content of employees of private entities? Is the private company rooted within the community or is it external? These questions define some of the potential social benefits of privatisation, and the flipside contentions.

The main financial benefit is the potential cost reduction of contracting local companies, this has simultaneous economic productivity benefits in terms of employment opportunities and the use of small enterprises. The environmental protection economic objective is not a priority in this case, with the efficiency/ employment trade off inevitably also favouring efficiency.

Privatisation does not necessarily change technological systems aside from the cases in which appropriate transport is the key factor in subcontracting. Reporting capabilities may be required between the municipality and its subcontractors in order to maintain regulation.

Exosystem: infrastructure upgrading

Infrastructural upgrading is an undertaking which aims to meet multiple needs of informal settlements. In particular, this report discusses the upgrading of roads – thus prioritising the lower end of the waste hierarchy, disposal and collection. As has been gathered from the interviews with officials, municipal budgets are stretched and often do not include informal settlements due to the assumption of a transit status. This means that any likely scenario for upgrading would need financial contributions from locals. Politically, this necessitates facilities such as microfinance being available, as well as legality of the land and planning permissions. With the correct institutional support, the objectives of motivating community participation; involving the private sector through subcontracting; and building municipal capacity, have the potential to be realised through this approach.

One of the key social advantages of infrastructure upgrading is moving towards equity of service by removing the physical factors that limit service possibilities within informal settlements. The approach is also responsive to local priorities by being a means of dealing with drainage and mobility as well as SWM.

As SWM does is not a revenue generating activity in informal settlements, it is likely to be difficult to identify sources from which capital could be mobilised. The financial incentives of the approach are long term and secondary impacts of the initial project; savings made in healthcare from solid waste related diseases; better access to jobs through increased mobility; and potential formalisation of property for collateral are all examples of economically positive outcomes. These may however prove to be a hard sell to potential investors, including local residents.

In terms of the environmental trade-offs, the infrastructure approach places more weight on environmental protection and service efficiency than on lowering service costs and creating employment. The generation of economic activity would be as a result of the long-term effects described above, and in so far as workers are needed for the design and implementation of the infrastructure. Considering the physical upgrades as technology, this approach does use this to facilitate public private partnerships, both in the planning and development stages, and in the use of roads and other new structures. Finally, the technology aims to limit pollution and flooding, thus realising another technological objective.

The matrix (Table 3) below is a summary of the evaluations of multiscale approaches to SWM and drainage or flood risk management. The colours assigned to each intersection show whether the approach adhered to the majority of MSWM framework objectives for a given factor (green); some of the objectives (yellow); or none of the objectives (red). The establishment of cooperatives, infrastructure upgrading, and integrated service provision are therefore the three approaches which respectively adhere most closely to the MSWM framework objectives. However, it is also crucial to take the feasibility of such approaches in the given context of Havelock into careful consideration.

		Political	Institutional	Social	Financial	Economic	Technical
Microsystem	Participation in behaviour change						
	Innovation through physical upgrading						
Mesosystem	Cooperatives: litter picking, stream cleaning						
	Communal bins/ skip						
Exosystem	Economic Instruments						

	Integrated service provision						
	Privatisation/ decentralising services						
	Infrastructure upgrading						

Table 3: Comparison of solutions according to the MSWM framework

Conclusion

Conclusion on frameworks

The literature review conducted for this project established the importance of a multiscale approach to addressing SWM and resulting drainage issues in informal settlements. By unpacking the complex behaviours, interactions, and service provisions that culminate in these challenged, target areas for solutions were able to be identified. Organising and reviewing case studies of proposed solutions as socioecological factors allowed for a clearer understanding of the ways in which these would be disseminated and received at different scales.

Using two frameworks allowed for a rigorous evaluation process whereby qualitative data was both organised and scrutinised. Though originally intended for application to child development, Bronfenbrenner’s framework proved applicable to the Solid Waste Management system. By centring the individual or ‘microsystem’, the framework presents an interactive perspective of SWM and drainage management, tracing the interactions of all levels of society with waste and water. This also meant that the causes of inadequate SWM and flooding could be honed into, and thus targeted solutions identified. Though only applied to Havelock informal settlement in this project, the methodology of using Bronfenbrenner and Schubeler et al.’s frameworks to identify the most pertinent solutions to SWM, and even wider environmental issues is easily replicable. This would allow for community rooted solutions to environmental issues to be conceived and tailored to the contexts and localities being studied. The MSWM framework in particular also allows for the specific inhibiting factors in an approach to be identified, and thus pre-empted.

Recommendations for SWM and drainage management in Havelock

Analysis of the data collected in and about Havelock gave an insight into the community's situation and challenges, as well as the wider environments in which they live. Between the local and municipal perspectives, the evolution and perpetuation of general service and infrastructure deficiencies, including SWM and drainage, became clear to understand.

Evaluating potential solutions at each societal scale against the MSWM framework was useful for comparing the relative feasibility and effectiveness of each approach. It was concluded that the establishment of cooperatives, infrastructure upgrading, and integrated service provision presented the most promising options for changing the status quo of solid waste dumping and flooding in Havelock. It should be noted that these approaches occur at the mesosystem and exosystem levels, suggesting that sustainable change is instigated via the more collective methods. It is also important to note that legal frameworks and financial capital are perhaps that most pressing limiting factors to implementing these solutions and should not be understated.

A pertinent suggestion for further research would therefore be into the household incomes, potential funding streams, and willingness to pay of Havelock residents and other informal settlement dwellers. A quantitative cost-benefit analysis of the better approaches identified would also provide interesting insight into the barriers or benefits to investing in these approaches.

RECOMMENDATIONS TO PRACTITIONERS AND POLICY MAKERS

For practitioners and policy makers generally working in improving environmental conditions in developing contexts, the main value of this work lies in providing a potential roadmap for approaching and unpacking a complex, multi-layered situation. In the ethos of participation and local ownership, the methodology recommended in this project considers the individuals that make up a community at the heart of potential solutions. This approach is very applicable to policy makers considering environmental justice issues. This is due to the tracing of waste as it is metabolised through societal systems; highlighting spatial and distributive justice concerns.

Further work to corroborate, evaluate, and refine the suggested methodology of combining frameworks would apply the approach to diverse contexts as well as other environmental challenges.

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Appendix 4: Small-scale farming design for Namibia Stop 8

An abridged version of Xuexin Li's MSc dissertation submitted as part of the UCL MSc Engineering for International Development entitled 'Small-scale farming in Namibia Stop 8, Durban, South Africa'

Design objectives

The growing system is designed for individual household vegetable supply, and it can be potentially used for food exchange and additional income, as the farming skills and knowledge develop along this process. Namibia Stop 8 is a settlement with formal housing, municipality metered water supply and pre-paid electricity. According to preliminary data and stakeholder questionnaires collected previously on site, households would spend their spare time on taking care of the plants, available space is limited. However, all of the interviewees expressed their interest in farming. The objectives of design will be including:

- Easy operation and maintenance
- Convenient installation and storage
- Cost-effective (minimised capital cost)
- Keep away from potential contaminants from the ground
- Hygiene water for irrigation
- Efficient irrigation
- Suitable for small-scale household farming

The assumptions made in the design are:

- Roof conditions of the housing will not affect the hygiene of rainwater collected.
- Households will be given trainings for basic farming knowledge, which would not explain in depth in this research.
- Seeds can be bought, sponsored by the municipality or share between households.
- Crop selections are based upon the farmers' expectations. Vegetables suggested in this design is only for initial stage of small-scale farming.
- Simulation model uses a 3 by 3 metres house, with a roof area of circa $9m^2$.
- 2 litre bottles are adapted in this model.

Household small-scale growing system: design overview

The proposed growing system is a portable bottled system that contain functions of germination and growing. Figure 4 illustrates the installation of farming system for individual household. The gutter for rainwater harvesting is supported by a wooden shelf underneath it, the shelf is also for hanging the farming system. The water collected from the roof is stored in the top row of bottles, then excess water will go to the end of the gutter and flow into the storage tank on the ground. This tank is also for collecting the water drained from the plant bottles. The water in this tank can be manually feed back to the top row water bottles for irrigation. This tank can be filled with water for fish breeding, when the sales of the vegetables increase and affordable for fish farming. Similar to aquaponics, quality of vegetable can be beneficial from this nutrient water.

This system is specially designed for small-scale agricultural activities, with fast growing vegetables. Its nature of portability constraints the size of individual devices. All bottles demonstrated in this design are the commonly available 2 litre PET bottles (i.e. water or soft drinks bottles), which have height of 320mm and diameter of 104mm. This design is therefore suitable for shallow-rooted leafy greens, considering bottle size cannot adapt large plants.

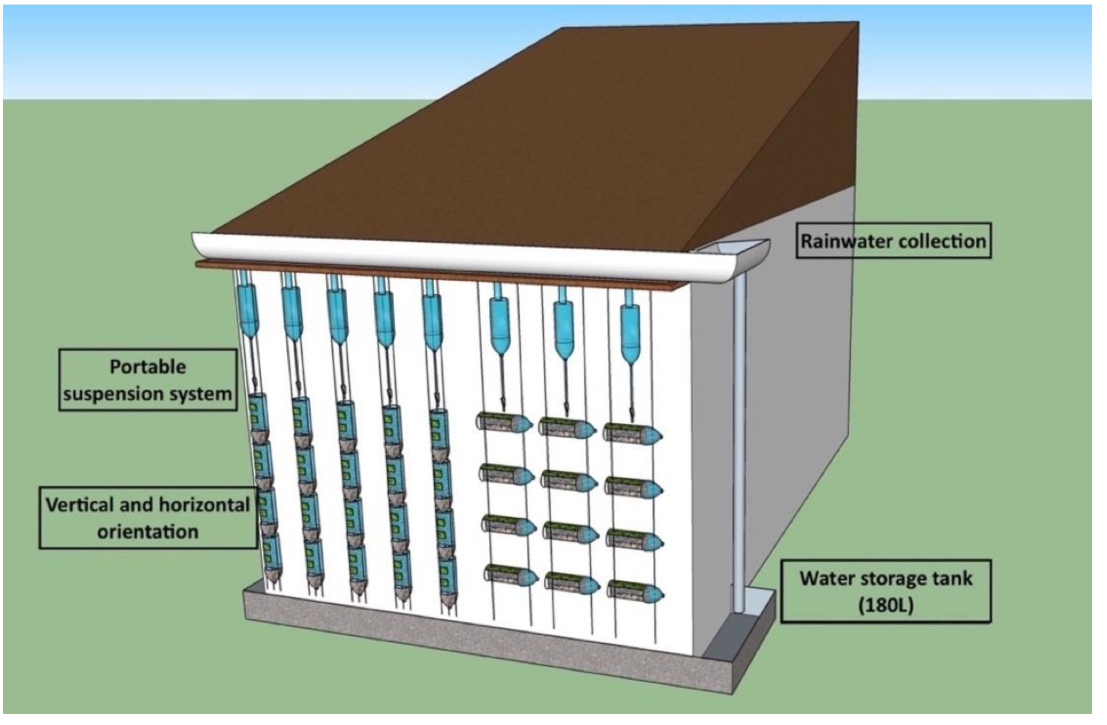


Figure 4 Schematic view of portable growing system.

Figure 5 presents the detailed function of each growing series. Each series includes an irrigation bottle and growing bottles. All bottles have hooks attached at the back, so that the bottles can be mounted to the net and detached for enhanced flexibility. The rainwater diverter directs rainwater from gutter to each irrigation bottle. Bottles that have volume of 2 litres or above are recommended, ensuring sufficient bottle diameter for plant roots propagation.

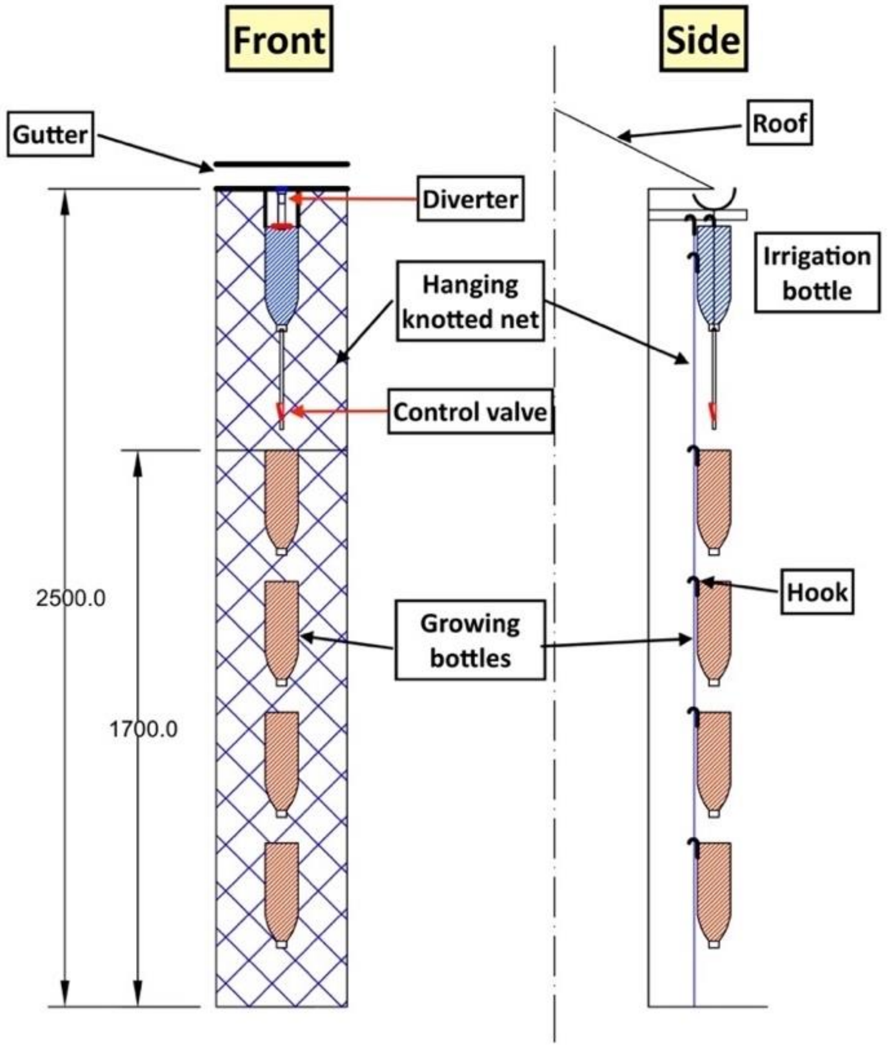


Figure 5 Front view and side view of individual series.

Irrigation system

The irrigation system shown in Figure 6 consists of top row irrigation bottles, connecting components and irrigation components. Diverters are installed on gutter to harvest rainwater from the roof. It is a connecting part between gutter and hose. Figure 7 gives the detailed drawing of the diverter. Rainwater flows in the diverter, through the $\emptyset 20mm$ hose and stored in the irrigation bottle. A silicone washer is attached at water inlet, it is closely wrapped around the hose to make the bottle hermetic when the valve is close. As a result, excess water travels in gutter and directed to the ground tank. At the bottleneck, there is a connector installed on the lid to bond the lid and an elastic rubber tube for dispensing water. Details of connector is shown in Figure 8. These parts can be detached from the bottle.

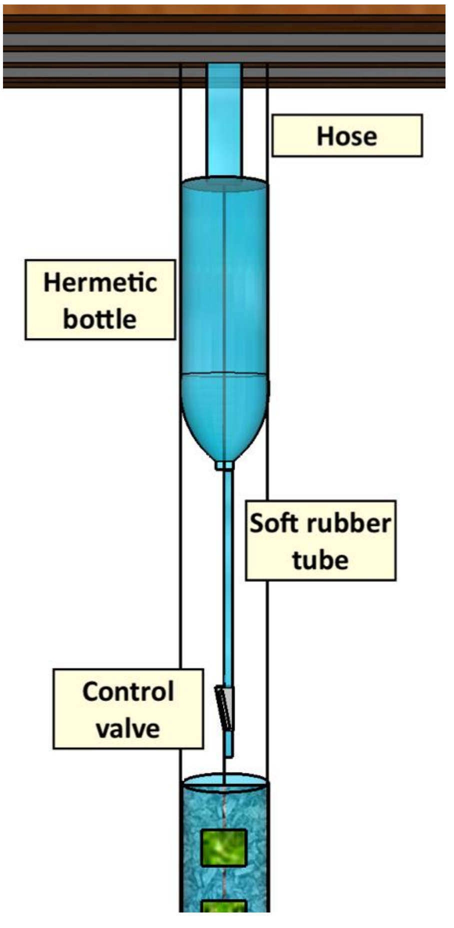


Figure 6 Irrigation system overview.

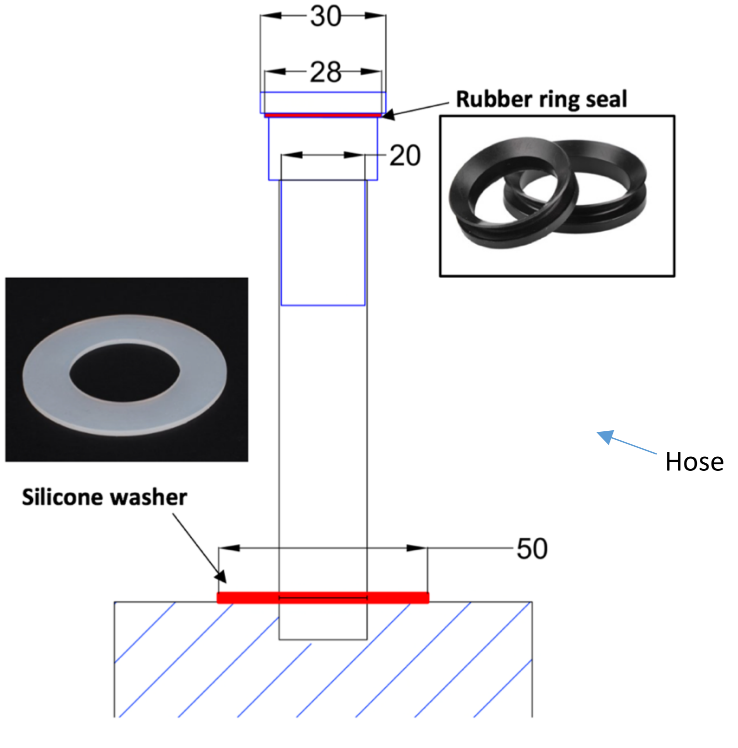


Figure 7 Detailed drawing of diverter.

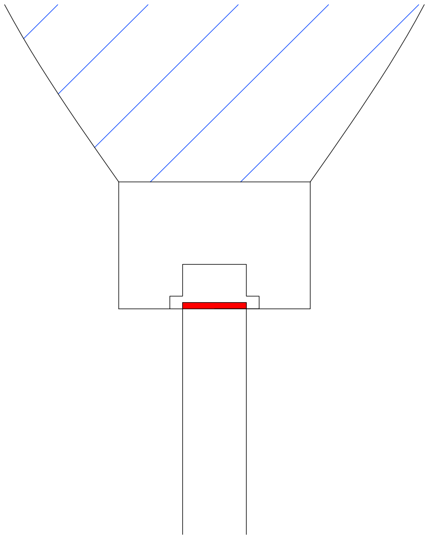


Figure 8 Detailed drawing of bottleneck connector.

In most of the advanced urban farming projects, precisely controlled drip irrigation and sprinkle irrigation are commonly used and considered as water efficient. In this design, a flow control valve is installed near the end of the soft rubber tube, the speed of water drops can be manually adjusted according to types of crops.

The detailed description of the flow control valve can be found in Figure 9. The trapezium shape valve has a shaft that is able to move along the track, in order to control the flow rate. When the shaft moves to the bottom, it is press against the rubber pipe and stop the water. This design is similar to the control valve for intravenous drip device at the hospital.

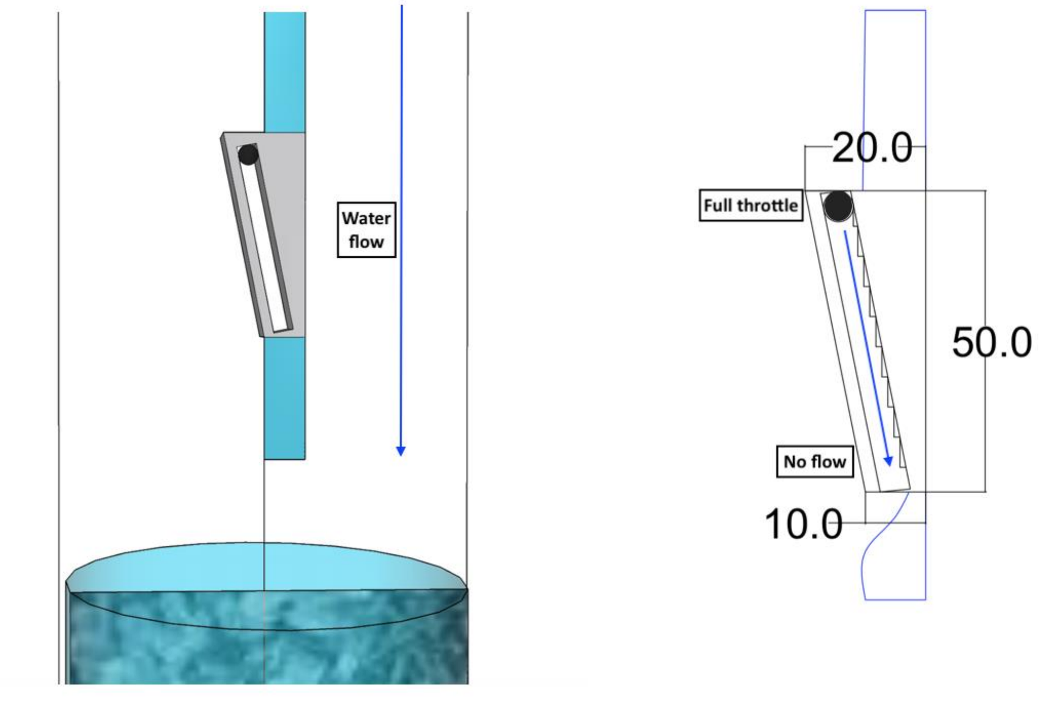


Figure 9 Schematic and detailed drawing of controlled valve.

Cultivating bottle

Well drained soil is crucial to this farming device. There is a mesh sheet at the bottleneck to prevent the stones from falling. From the cross-section view of the vertically oriented bottle in Figure 10, there are cobblestones or large stones at the bottom is for faster draining. The core is made up of sand and gravel mixture, there are layers flake stones throughout the core. This is designed for evenly and quickly distribute water into the soil and deliver the water to the bottles below. Vegetables can be planted around the bottle with openings.

There are bottles with different orientation. It is suggested that the horizontal bottles should be used as propagator (Figure 11), water tend to stay in the bottle for longer time. Keeping the soil wet is essential for seeds germination. As the plant sprouts and grow larger, the plants can be replanted to the vertical bottles.

The targeted plants in this system should combine the following characteristics, fast growing and prolific. Fast growing vegetables such as herbs, spinach, lettuce and other salad greens. Prolific vegetables such as tomatoes, can be grown at the bottom row.

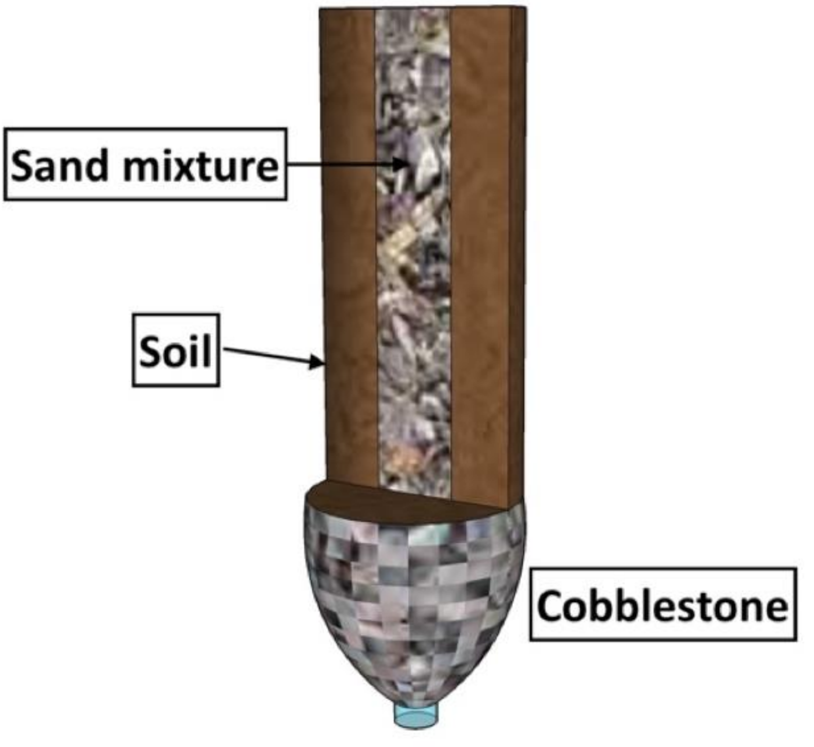


Figure 10 Cross sectional view of grower.

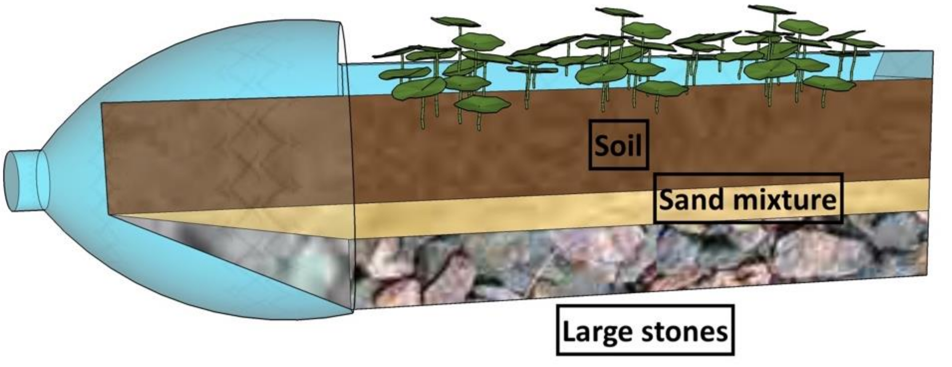


Figure 11 Cross sectional view of propagator.

Device construction and validation methods

System construction

This section includes the set-up procedure of a grower. It is designed to hang against the wall in a vertical orientation and using three sides of the bottle for plants. The tip of a sweet potato is trimmed and planted in the propagator for sprouting. Once it sprouts, it can be replanted to the grower, which is used for demonstration below.

Tools: Small shovel, scissors, sharp knife, cardstock, mesh cloth, cling film.

Materials: 2-litre PET bottle (recommended), cobblestones, sand, gravels, flake stone, moist soil.

Procedures:

- Removed the bottom of the bottle, placed a mesh cloth at the bottle neck to prevent the stones from falling. Using the scissors and knife to cut two openings on each side.
- Filled the bottom with cobble stones and topped with a thin layer of soil. Rolled up the cardstock to a 5cm tube and hold vertically to the soil layer (Figure 12).

Figure 12 Cobblestone and soil base.

- Prepared sand mixture and flake stones. Entirely fine sands absorb water and dehydrate the soil, the sand should mix with small stones to get rid of a portion of water. The sand and stones mixture would keep a certain amount of water in the core to keep soil moist, and stones can facilitate the draining to keep soil from too wet (Figure 13).

Figure 13 Sand and stone mixture.

- Filled the cardstock tube with sand mixture. Prepare flake stones as layers in the middle of the tube. Place flake stone horizontally, and these stones will direct the water to the soil.
- When the cardstock tube is filled with sand mixture, filled the gap between the tube and bottle with fertile soil, as shown in Figure 14.

Figure 14 Fill outer core with soil.

- Removed the cardstock tube, the top view should show a sand core surrounded by soil, as in Figure 15.

Figure 15 Top view of grower.

- When transplanting in the plants or seeds that the bottle will need to be placed horizontally, use the cardstock the cover the top end to prevent the sand from spread out. Use the cling film to wrap the sides of the bottle to stop the soil from falling out. Place the bottle horizontally to carefully put the plants in.
- In this demonstration, a sweet potato root is planted in the bottle. It took about a week to sprout. After 2 to 3 weeks, it can be transplanted to the bottle (Figure 16). This device is for shallow root plants, it is not expected to harvest any sweet potatoes, the leaves are fast-growing and edible.

Figure 16 Plant transplanted to the growing bottle on 10th August 2018.

- The paper can be used as a moisture indicator (Figure 17), to testify whether the plants received proper irrigation. Inserted the paper into one of the openings as an irrigation indicator. The indicator can represent the moisture level in the soil, preventing the plant from under- or over-watering. The indicator is viable in the initial growing period, because young plants require sufficient water at the beginning. As the plant grow larger, its requirement on moisture level will gradually goes down as it can sustain the water for a longer time, keeping the same moisture content at this stage could make the roots eroded by excessive water.

Figure 17 Moisture indicator.

System validation

In order to review the performance of cultivating device built in the previous section, a weekly monitoring plan takes place to record the plant growing condition and water consumption under different weather conditions. This section includes the procedure and equipment for carry out monitoring plan.

The purpose of this monitoring plan is for less-experienced farmers to regulate farming activities upon plants' characteristics. The abiotic factors, including climate, water and soil, of growing environment influence the plant development. Plants respond to its growing environment, and hence flaws can be easily spotted and solved in the early stage.

Meanwhile, the design is also sent to Nick Alcock for comments on feasibility of device application in the settlement. Nick Alcock is a staff member form Aqualima Trust (Aqualima, 2013) that carried out sustainable development projects in informal settlements, including rainwater harvesting, bio-digesters and Integrated Water Resources Management (IWRM) etc.. He is also a participant ISULabaNtu upgrading project, currently working on greywater reuse for farming support.

Equipment

- Pre-built cultivating device
- 2 empty containers (volume > 500ml) for water retrieval
- Scale
- Camera
- Notes taking tools

Record initial conditions in the grower

- Plant type
- Plant condition
- Soil type and its moisture level description

Weekly monitoring process

1. Carry out the plan for one day every week. There are two tests in a day, one takes place in the morning and the second one in the afternoon.
2. On the experiment day, remove any irrigation device. No watering required unless told in this test.
3. Prepare a record table for noting down preliminary details and information collected in the below steps.
4. Record weather data: temperature, precipitation status from forecast and from field observation. Include descriptions of sunlight exposure if necessary.
5. Record the location of plant. (i.e. outdoor/ indoor, direct/ indirect exposure to sunlight)
6. Prepare 500ml of water for irrigation with one of the containers.
7. Place the empty container on a scale and set scale to zero.
8. Hold the grower above empty container with scale, and gradually pour the 500ml water to the sand core.
9. Let water slowly drained and record the water outflow volume from scale.
10. Repeat step 6-8 for the second test.

Results

From Nick Alcock's comment and suggestions on the system design (Appendix **Error! Reference source not found.**), he revealed that the greywater reuse for farming is currently under development in the settlement, though it is not linked to the rainwater harvesting system. A similar vertical farming approach without controlled irrigation was applied previously but the maintenance issues were primary concern. The maintenance will be discussed later in this dissertation.

The monitoring plan was conducted in Xinhui, a city in Guangdong, southern China. Hot and humid days dominate throughout the year. During the summer, the average temperature is over 30 ℃, along with frequent tropical cyclones and sometimes torrential rains. The average monthly precipitation of 102 mm (World Weather Online, 2018b) in Xinhui, which is close to Durban's monthly precipitation of 98 mm. (World Weather Online, 2018a) The total amount of water received for plant annually would be alike.

This city is at the confluence of two rivers and flows into the sea, hence the soil has pH lower than 7. The locally available soil is very similar to clay soil, with a sticky and smooth texture. It has a strong ability to hold moisture and organic matters; therefore, the soil can easily form lumps, which leads to a heavy and dense structure. Its characteristics can lead to a fertile soil base for cultivation, but also resulting in potential waterlogging in the soil pockets. Local farmers tend to mix vegetation roots and livestock manure in the soil, making it loosened as well as nutritious.

The sweet potato plant was the test subject. The chunks with shoots was carved and planted in the propagator for maturation. When the sprouts were 5cm to 10cm tall, they were transplanted to the grower before starting the weekly monitoring plans. In consideration of the humid local weather and water-retentive soil, the plant was under regular irrigation every other day.

Table 1 compiled the monitoring information collected over a five-week period. This log included the development of the plants and their appearance discrepancy under diverse climate conditions. Impact from rainfall was reflected by water absorption in cultivating bottle during monitoring process. Noticeably, the more precipitation, the less water absorbed by the grower. It is evident that once the soil was saturated, excess water ran off through the stone-sand core, proving an effective drainage performance. Even though the plants were under high temperature, transpiration of plant was negligible in this test.

Test Date	15th Jul	22nd Jul	29th Jul	5th Aug	12th Aug
Temperature(℃)	28	33	32	33	27
Weather description	Light rain throughout the day	Sunny and dry	Cloudy, no rain seen	Sunny, with intermittent light rain in the afternoon (<30 minutes)	Heavy rain in the afternoon, rain seen in the past week
Precipitation (mm)	8	0.2	8.7	9.4	49.3
Location	Outdoor (morning) and indoor (afternoon)	Outdoor	Outdoor	Outdoor	Outdoor
Water in_1 (ml)	500	500	500	500	500
Water out_1 (ml)	462	457	455	456	477
Water in_2 (ml)	500	500	500	500	500
Water out_2 (ml)	483	478	482	484	491
Water absorbed by plant/day (ml)	55	65	63	60	32
Water appearance	Contain slight soil sediments				
Plant condition	Green	Green	Green	Yellow spots seen on bottom plants	Yellow spotted leaves turned completely yellow

Table 1 Grower draining test results. Precipitation data from World Weather Online (2018b).

During the first three weeks of monitoring, the weather was relatively stable, and the plants remained in healthy condition despite a couple of insect bites, similar to plant condition in Figure 16. In the next two weeks, the intensity and frequency of rainfalls had gone up. Yellow dots on the bottom-row plants appeared from the fourth week of observation. The rainfall continued, and precipitation enhanced to 49mm. In the fifth test, preceding leaves with dots turned completely yellow (Figure 18). It was potentially caused by overwatering by excessive rainfall or nutrient deficiency. Moisture-retentive soil probably kept the redundant water supply in soil pockets and drowned some parts of the roots. The yellow leaves were then wilted and fell off without turning brown. The monitoring recoding stopped after the fifth test.

(a)  (b) 

Figure 18 Plant on (a) four test: 5th August 2018, and on (b) fifth test: 12th August 2018.

Whereas, the rainfall has gone down after fifth test. The update on 25th August shows the roots start growing towards the bottle wall and down to the base drainage layer as in Figure 19(a). The leaves yellowing issue seems to relieve. After two weeks of growing under sunny weather, more shoots were stretching upwards in a green condition, the issues leaves caused by overwatering were entirely wilted and felt off of the plant (Figure 19(b)). Another noticeable finding is that the soil layer went shorter along the process, and the roots have the tendency to grow along the bottle wall. Soil compaction causes a condensed inner structure. Therefore, the roots will either work harder to grow into the soil or find its routes for easy growth. In this case, as the roots continue growing at the outer layer of the soil and the base drainage layer, it would not be able to receive enough water and nutrient for long-term growth.

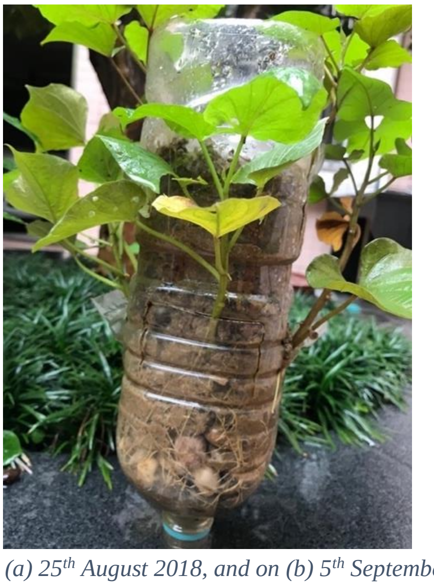
(a)  (b) 

Figure 19 Plant on (a) 25th August 2018, and on (b) 5th September 2018

System maintenance and operation

The advanced vertical farming systems represent reliable and resource-efficient methods for farming, that would minimise maintenance and maximising production yield. Maintenance in agriculture is the process and activities of preserving the farming system in order, involving soil or plant bed preparation, irrigation strategy, taking care of plants throughout the growing cycle, and device maintenance, etc. Keeping the system in working order is essential and indispensable for agro-ecologically viable and sustainable.

In terms of small-scale farming proposal in this dissertation, the maintenance work including two parts: rainwater harvesting system maintenance and components maintenance. One of the design objectives of the small-scale farming system was low maintenance, and the prospective beneficiaries may have their full-time jobs hence would like to spend minimal time on maintenance process. In general, farmers are responsible for entire maintenance process. While participation and support from experienced farmers, NGOs and municipality are equally important, who would be able to provide training, supervision and funding.

Irrigation system maintenance

Reviewing the latest Durban precipitation data during the past year, the driest months can be seen during June to September. Proposing a rooftop area of $9m^2$ in the simulation model, the minimum water can be collected monthly would be 47 litres, and the maximum water can be collected would be 1674 litres in March. A wall with 3 meters can fit in at least 6 growing series, equivalent to a daily water requirement of 12 litres without manual refilling. June to September are the driest months in a year, the daily water collection is under or around 10 litres per day, which would limit the farming capacity. During dry season, alternative water sources from the stream or filtered greywater can be used for irrigation. In those wet months, the daily collection can range from 23 litres to 56 litres, which will be more than needed.

Month	June (2017)	July	August	September	October	November
Precipitation (mm)	5.2	22.2	42.8	21.9	121.4	174.5
Water from roof (litres)	46.8	199.8	385.2	197.1	1092.6	1570.5
per day (litres)	1.56	6.66	12.84	6.57	36.42	52.35
Month	**December**	**January (2018)**	**February**	**March**	**April**	**May**
Precipitation (mm)	183.9	78.1	111.4	185.9	108.6	118.3
Water from roof (litres)	1655.1	702.9	1002.6	1673.1	977.4	1064.7
per day (litres)	55.17	23.43	33.42	55.77	32.58	35.49

Table 2 Precipitation data from June 2017 to May 2018 in Durban, Data: World Weather Online (2018a).

The components maintenance is about container replacement and parts inspection, including:

- Bottle's lifespan for safe farming is hard to define. The chemical leaching rate within PET bottles are highly depending on its surround environment with countless variables, as discussed in literature review. For instance, PET water bottles can be stored on the supermarket shelf for more than 2 years. Considering the bottles used in outdoor area, exposing to sun and rain, the life expectancy for safety concern should be one year at most.
- All bottles should be thoroughly clean to prevent bacteria contamination before use.
- Drip irrigation system comprises tubes and hoses. Regular inspection on blockage or algae built-up in tubes are required. Inspection can be carried out on a daily or weekly basics.

Overall, small-scale farming solutions are often requiring low maintenance. By checking clogging and adjusting the water flow in the irrigation process, the time spent on maintenance per day is little and easy to conduct, which minimise the impact on the owner's spare time.

Rainwater harvesting system maintenance

Rainwater harvesting system maintenance includes support from organisations and maintenance by owner. Gutter servicing aid may accessible from municipality supporting programme. Aqualima Trust (Aqualima, 2013) is a NGO in South Africa that have implemented rain water harvesting systems and gravity feed low-tech irrigation systems in various projects, including the provision of innovative guttering and equipment service. According to the interview with Nick Alcock at Auqalima Trust by Priti Parikh (I-E), the challenges in implementing projects like rainwater harvesting would be lack of ongoing support, including skills in operation and maintenance. He expressed that the success of urban farming schemes are highly depends on local leadership and participation, external support is needed from NGOs and municipality. For example, some of the urban farming projects operated like a small business, to contract work and labour. The eThekwini municipality also has previous actions in providing help and support for community adaptation projects (eThekwini Municipality, 2010) included rainwater harvesting development. Rainwater harvesting is also mentioned in the municipality's 10 years water plan, (eThekwini Municipality, 2017a) gaining help from municipality for rainwater harvesting tools is viable.

While the self-maintenance for rainwater harvesting can follow advises below:

- The key to maintain rainwater collection is sustaining gutters and drains at unobstructed. Regular de-clogging of leaves or any large abstracts that would affect the collection performance of water storage. To reduce the frequency of maintenance, avoiding the area that is surrounded by trees that may bring debris into the guttering. Time and frequency for maintenance is relatively low.
- Usually there are different types of filters and diverters for rainwater harvesting systems. The first flush diverter gets rid of the initial volume of rainfall that contains impurities and giving the clean water for storage. The filters are often in different mesh sizes, large debris filter needs more frequent clearing, while filter with finer mesh require maintenance after a longer period. The filtering devices is useful for farming and other household activities. When water retrieval from farming system drainage is for higher standard water reuse, filtering maintenance will be involved in future developments.

Natural resources sourcing

Soil and stones at different sizes can be found within settlement and its surroundings. Given the surrounding environment is not contaminated, farmers can source the soil from nearby. Stones play a role of enhancing drainage performance, largest stones with 20 to 40mm in diameter can be used for base layer, smaller stones with diameter of less than 10mm can be mixed with sands in the core. Soil comes with various type that would be suitable for different vegetables. For example, root vegetables such as potatoes, carrots and ginger require loosen structure and sandy texture of soil, which benefits the root growth. There are methods on enhancing soil fertility with available manure or vegetable roots. Guidance of improving soil fertility by the Research Institute of Organic Agriculture (FiBL, 2016) has provided detailed instruction and knowledge of improving the soil fertility. Topics such as what and how to improve soil fertility, production of organic fertilisers and perceiving soil fertility skills are introduced in the guidance.

As mentioned water shortage is one of the concerns. Water usage in drip irrigation is able to reduce the water consumption to minimum. Water can be collected from multiple sources. Settlement information concludes that the water can be obtained from house tap and free water tank or reusing filtered greywater. Rainwater is also an importance source for irrigation. Rainwater harvesting requires equipment as well as services. Equipment including guttering and storage tanks, while services including cleaning up and maintain the gutters and drainage.

Funding and equipment

The portable farming devices comes with components to achieve its mobility. The hook and strings for hanging can be sourced or made by other things. Hangers can be cut and bended to hook for supporting. The net for hanging bottles can be any type of knotted net such as fish net. Containers for farming can be anything with suitable shape or materials, as long as it is thoroughly washed before use. The PET bottle suggested in this design is 2 litres or above, ensuring adequate growing spaces. PET bottles may come from daily consumption or recycle centre. Before using these bottles for farming, carefully check the expiration date on the bottle and wash the bottle thoroughly to prevent bacteria contamination.

For other small components like the silicone washers and tube, although they are very cheap for unit price, a large number of units are required for single purchase. Hence it is better to make the purchase a group.

Seek for help or funding from charities, NGOs or municipality is a good way to support these purchasing and even training and maintenance. For instance, the Agroecology programme initiated by the eThekwini programme to promote and support farming activities (Management & Socio-economic Development Department, 2009), or the partnership programmes to provide platforms and techniques for small-scale farming (SSIP, 2016). Components for rainwater harvesting takes up the largest portion among all, because of the purchasing and installation of gutters and storage tanks. Help from NGOs and municipality is vital, who can provide not only part of the funding, but also training and services.

Seeds provision

Dwellers rated seeds obtaining as their top priority for implementing small-scale farming, even more important than free irrigation water. Except the seed funding from municipality or NGOs, seeds can be bought from market or exchange with neighbours. Whereas, during the start-up stage, new farmers are lack of experience in farming activities and knowledge in plant characteristics. Inevitably there will be waste in seeds at the beginning. Hence re-growing plants is an option for start-up farmers. Stalk or root vegetables such as celery, lettuces and sweet potato can be used for re-growing. Sweet potato demonstration in this dissertation used the tip part of the sweet potato for sweet potato leaves, though the bottle is not deep enough to grow sweet potatoes, the leaves have short growing cycles. Soaking the roots of stalk vegetables in water, it grows and can be harvest in 4-10 weeks. Tips and skills on growing various type of vegetables can be obtained from community workshop, or from useful guidance. The Dublin agriculture authority concluded a growing guidance (Alexander, 2017), including soil, seeds and watering control for different vegetables.

Discussion and further work

Urban agriculture is not only representing the state of the art in farming, but also a dedicated approach for poverty and food insecurity alleviation. While there is an escalating attention on informal settlement development, it is evident that small-scale urban farming has increasing implementations in informal settlements, in the context of limited natural resources, environmental vulnerability and high unemployment rate. It is an important role to economic and social development in informal areas. Gaps are defined in guidelines for low-cost small-scale farming and support from organisations and municipality. ISULabaNtu upgrading project is closing up gap, by collecting comparable cases and addressing local needs to develop the environmental system management guidance and establish knowledge base for site improvements. The eThekwini municipality has proactive collaborations with charities and organisations, a greater focus has been contributing to food security of informal settlements and sustainable agriculture for economic development. The eThekwini commitment in their development strategy (eThekwini Municipality, 2017b) to support sustainable farming activities, farming tools provision and providing ten fruit trees per community has reflected urban farming integration to municipality development strategy.

Development is a step-by-step process of experimenting and adapting. The implementation of the proposed small-scale farming approach requires prototype trail, and also practice on field to assess local participation and adaption. The results from prototype weekly test in section 0 revealed that balancing the variables is the key to a sustainable device. The suitable proportion of sands, gravels and stones contribute to a well-drained device, the appropriate soil and its blending with other compost enable a nutritious and permeable base for growing. Improving the small-scale farming system along with collecting local stakeholders' opinions is considered a primary task of the upcoming on-site practice. Equipment and materials sourcing is yet a vague plan. Other than receiving donations and support from formal sources, community-owned and self-purchasing is the way to scale up and sustain. There is yet a significant gap in small-scale farming yield and farming incurred income data within the informal settlements. Having positive assumptions on the farming system vegetable production, that the amount can fulfil household dietary needs and even able to sell surplus produce. During in-field observations, recording the yield data is useful for predicting an accurate income of using this farming system. It is worth predicting the household income in each stages of development. By forecasting the income within certain time frame, the development guidance will be able to provide suggestions on purchasing items to scale up household farms. Such as upgrading rainwater collection with accessories and water storage tank, using solar power for pumping the water and a larger structure to adopt larger variety of vegetables as in Ukulima devices introduced in earlier section, and exploit more space for farming purposes. Further on-site studies are required on material sourcing and purchasing power analysis at different stages.

Small-scale farming in informal settlement is a proactive approach to local economic and social development. The scaling up of urban farming project provides more than food. Its derivatives are including employment opportunities, economic growth and social value. Farming device improvements and scaling up is a way to stimulate profit, while the social benefits come from the interaction and communication between the households. The 'Impact Farm' discussed in earlier section set an example for Namibia Stop 8 to form a communal space in the context of urban farming. The farming deck can be used for educational purposes, and the recreational area can be used for farmers' training, library and meetings. Also, having a community representative to seek partnerships and sponsorships is a more efficient way to accelerate the development process.

Apart from maintaining the physical components for farming, maintaining local farmers' soft skills is another key element to a sustainable agriculture. In the perspective of this dissertation, maintenance is not only about preserving the system in good working condition, but also maintain farmers' skills and communication network. There are plenty of guidelines on small-scale farming that provide soft skills for farmers to begin. The edible landscape guideline (Vikram *et al.*, 2005) has provided instructions on site selection, orientation, and farming tips. Other guidelines include collective farming skills of different types of vegetables (Alexander, 2017) and even brochure for children (Nestle, 2014). Experience and information sharing can be beneficial to social networks, such as WeFarm (WeFarm, 2017), the farmer-to-farmer digital network that served over 300,000 farmers in Africa.

Conclusion

This dissertation has shown the necessity, feasibility and residences' willingness of small-scale agriculture implementation for settlement Namibia Stop 8. Evidence from preliminary research has shown, although eThekwini municipality had initiatives to promote urban farming in low-income areas for self-resilience, there has been lack of developed guidelines and plans for execution. Small-scale farming device with controlled drip irrigation approach in this dissertation has shown the viability of vegetable farming for household consumption, and also a good practice in preparation of a collective scale farming within the community. Model validation test revealed that the prototype is yet to be improved in terms of soil composition and tested on-site for better planting strategy. This design enables further work on small-scale agriculture data collecting, and evaluates its impact on food production, household income and social impact. Small-scale farming may provide opportunities in enhancing environmental, economy and society sustainability. Besides funding and support from NGOs and municipality, training workshops and communication network are the core of successful and sustainable urban agriculture.