# Environmental sustainability of construction practices in informal settlements

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## Abstract

**Purpose** – Construction practices used in the development of self-help housing and upgrade of informal settlements are believed to have negative effects on the natural environment. This paper examines this idea by conducting a study on purposely selected informal settlements located in Mbabane, Kingdom of Eswatini, to determine the environmental sustainability of construction practices used in these areas and to offer an approach that can mitigate the environmental degradation witnessed in informal settlements.
**Design/methodology/approach** – The study comprised of three major components – literature review, situational analysis and research output. A literature review informed the extent of the problem and served to identify categories of assessment. A situational analysis of construction practices in informal settlements was done through the use of a structured checklist tool. Pattern matching was used as an analysis to evaluate the environmental sustainability of the identified construction practices.
**Findings** – Empirical results indicate a lack of environmental sustainability in the identified construction practices used. The challenges identified included the wrong choice of building material, inefficiency in energy use, a threat to biodiversity, poor planning and a lack of construction control measures. The research output was a framework encouraging affordable, sustainable and regenerative construction practices believed to be a viable solution to the environmental challenges within informal settlements. It was concluded that current construction practices used within informal settlements lead to negative environmental effects.
**Originality/value** – The framework offered in this study is believed to mitigate the effects on the natural environment in informal settlements.

**Keywords:** Environmental sustainability; Informal settlements; Sustainable construction, Low-cost housing; Regenerative development; Self-help housing

### 1. Introduction

The formation of informal settlements is imposing negative impacts on the natural environment around urban areas (Hansen, Knight & Marzluff 2005:1899), possibly due to uncontrolled construction practices used by informal settlement dwellers or poorly controlled upgrades by governments. The definition of construction employed in this study is cited from

Du Plessis (2002:4) as “the broad process or mechanism for the realisation of human settlements and the creation of infrastructure that supports development,” to capture the broad discussion in sustainability and settlements. Therefore, any activity executed with the purpose of forming a settlement and supporting its operation is termed as a “construction practice.”

Informal settlements are normally located on areas left undeveloped by cities because of accessibility, along waterfronts, along sidewalks and urban infrastructure (Dovey & King 2011). These areas are prone to natural environmental threats of erosion, desertification, water and land pollution. Within these settlements, self-help housing is developed where the residents are the main actors in housing delivery yet they are without a guide on constructing environmentally sustainable self-help housing. Despite that, there are still traces of environmental sustainability especially in the use of materials (Devi et. al 2017), which should be identified and enhanced.

Responses to the housing challenges, including public housing, provision of sites and services, housing production (self-help housing and social housing), building codes and standard reforming, have not been successful except for “informal settlement upgrading” approach which is claimed to be adopted by many non-governmental organisations (Wekesa et al. 2011). None of the programs have addressed the environmental quality of housing needs, as attested by Nassar and Esayed (2017). There is also limited information on interventions with a focus on mitigating environmental challenges and enhancing environmentally sustainable practices in informal settlements.

In order to address the problem of environmental degradation in informal settlements, the paper has an objective of identifying construction practices used in informal settlements, determining their environmental sustainability and further to formulate a framework which can inform a future proposed guide towards the use and enhancement of environmentally sustainable construction practices in the development of neighbourhoods for low-income households.

A structured observation study was done on three selected informal settlements in Mbabane, capital city of Swaziland, to identify construction practices used in informal settlements. The identified construction practices found were evaluated through pattern matching to understand their environmental sustainability, and a framework was proposed to mitigate these environmental challenges.

This paper reviews the problem and current intervention approaches through a literature review. The study method used is presented in detail, describing the setting, sampling strategy, data collection and data analysis used in this study. The results are presented and discussed to inform the proposed measures for sustainable construction and regeneration of informal settlements. The paper is concluded by presenting achievements and limitations of the study.

## 2. Literature review

### *2.1. Environmental impact*

Literature enumerates the following as impacts inflicted by construction practices:

- Carbon emissions from fossil fuels impacting the atmosphere when transporting construction material (Du Plessis and Landman 2002)
- Deforestation with the use of wood to generate energy (Kibwami and Tutesigensi 2016)
- Atmospheric impact from construction materials with high embodied carbon/energy (Bredenoord 2017; Kim 1998; Lawson 2006; Pullen 2010)
- Vegetation loss and a negative impact on the remaining habitat. Vegetation loss changes nutrient and biogeochemical cycles (McKiney 2006)
- Sofianou (2015) states landscape aesthetic deterioration, biotic diversity threats, desertification, forest and open land squeeze, and water contamination as impacts inflicted by informal housing.

The effects are also indirect – the growth of housing leads to the growth of transport infrastructure which introduces more pollutants and interruptions in the natural environment (McCarty & Kaza 2015), and low-density residential development enlarges the footprint of housing development therefore spreading the impact of an individual house over a great portion of land (Hansen et al. 2005). Compactness is therefore an important consideration in the planning of housing which normally occurs in the pre-construction stage as part of the project cycle towards the realization of a settlement (defined as ‘construction’).

In the comparison of informal settlement impacts to formal settlement impacts, it is a general expectation that informal settlements have a lesser ecological footprint since they are believed to use fewer resources and energy (Devi, Lowry and Weber 2017; Du Plessis 2002; Du Plessis and Landman 2002; Kovacic, Smit, Musango, Brent and Giampetro 2016). Grove (2009) supports this view as he argues that informal settlements are compact, use less energy and there seem to be practises of waste reuse and recycling within them. The

energy, water and material consumption of settlements has been proven to increase with the increase in economic development in a study conducted in European countries (Du Plessis and Landman 2002; Jorgenson, Alekseyko and Giedraitis 2014).

Environmental impacts are yet more sensitive in informal settlements as the settlers within them (living in poverty) rely more on the depleting natural resources (like wood) for living (shelter, food, generating income), and they have less choice of the natural environment as they mostly occupy areas of dereliction (Bredenoord 2016; Huby 1998). Winston and Eastway (2008) claim that environmental impacts in informal settlements may lead to negative impacts on physical and mental health of the residents, which makes the attention on their environmental sustainability a matter of urgency.

### *2.2. Current Intervention Approaches*

Literature (Bredenoord 2016; Bredenoord 2017; Devi, Lowry and Weber 2017; Du Plessis 2002; Du Plessis and Landman 2002; Pullen 2010; Sullivan and Ward 2012) has established that informal settlements have an impact on the natural environment hence the number of interventions and theories, especially in developing countries, that have been developed to counteract this problem and housing challenges in general. The most common interventions taken from literature (Balbo 2001; Nassar and Esayed 2017; Wekesa, Steyn and Otieno 2011; UN-Habitat 2005) are shown in Table 1 below.

**Table 1:** Intervention analysis of sustainability components and challenges

| **Intervention** | **Sustainability component focus** | **Challenges** |
|---|---|---|
| **Public housing** | Social | Power given to contractors<br>Relocation does not solve environmental challenges |
| **Sites and services** | Physical | Relocation does not solve environmental challenges |
| **Upgrading brownfield** | All | Implementation |
| **Self-help housing** | Economic | Focus is mainly on economic aspect<br>Power given to dwellers without sustainability knowledge and skills |
| **Social housing** | Social | Economic aspect missing as there are issues of unaffordability<br>Environmental component has no focus |
| **Building codes** | Economic | Focus is only on affordability |

None of the programs have addressed the environmental quality of housing needs on a larger scale (Nassar and Esayed 2017). Upgrading with the aim of developing sustainable informal settlements could minimise the environmental challenges in these areas. A sustainable informal settlement should have all the three sustainability components:

economic, social, and environment. It is noted that' informal settlement upgrading' have been developed to accommodate all components of sustainability (Table 1). The most preferred way to improve environmental conditions in informal settlements is through 'informal settlement upgrading' (Abbot 2002a; Abbot 2002b; Walker 2016; Wekesa, Steyn and Otieno 2011; Devi, Lowry & Weber 2017).

### *2.3. Sustainable housing concept*

Sullivan and Ward (2012) argue that sustainable rehabilitation should address informal self-help housing to solve the challenge of the environmental impact of housing. The sustainable housing concept has been newly introduced in developing countries and falls under the concept of sustainable development which aims to achieve and maintain a dynamic balance between human needs (including shelter) and the ecosystem's limits, which may be limited natural resources required for construction.

Sustainable applications are costly, and that makes them easily adopted among more economically advantaged sectors (Wilson and Dowlatabadi 2007). As a result there are now studies about issues that pertain to affordable and sustainable housing for the urban poor, mostly located in informal settlements (Bredenoord 2016; Du Plessis 2002; Pullen 2010; Sofianou 2015). Bredenoord (2016) suggests that low income households require affordable housing, and assumes that sustainable housing can become a vehicle in providing that kind of housing. The authors recognise that cost is one of the primary constraining factors which determine the feasibility of a sustainable intervention in low-cost housing (Sullivan and Ward 2012:315).

Several authors (Bredenoord 2016; Pullen 2010; Sullivan & Ward 2012) have advised on measures and interventions to achieve sustainable housing for low-income households (Table 2 below). The literature seems to focus directly or indirectly on "energy efficiency, water efficiency, construction materials, construction methods, dwelling sized and waste management" in the provision of sustainable housing. These measures require enhancement with the shift from the concept of doing less or *net-zero* to a concept of *net-positive* – in view of the need to change the perception that a building has an impact on the environment to where it adds value to its context (Robinson & Cole 2015:134). These new approaches to building design (net positive approach to sustainability) which are departing from dominant sustainability narratives are known as regenerative sustainability.

**Table 2:** Examples of sustainable housing measures

| Categories | Bredenoord (2016) | Arman (2009) and Pullen (2010) | Sullivan and Ward (2012) |
|---|---|---|---|
| **Planning/ environmental features** | Proper house orientation such that there is proper ventilation, minimal heat, making possible to assemble solar panels and collectors at a later stage<br>Tree lined streets to lower temperature;<br>Availability of parks playing grounds and footpaths<br>Well sized housing plots<br>Environmentally acceptable sanitation solutions<br>Use of septic tanks; | Appropriate location of the house<br>Suitable house size and quality<br>for dwellers<br>Area/plot reducing the loss of biodiversity<br>Area maximising low-energy transportation options<br>Good waste management systems<br>Water conservation (grey water<br>re-use, rainwater storage and reuse) | Proper orientation of the house (simple cross-ventilation and kitchen ventilation)<br>Water conservation (rainwater harvesting)<br>Good waste management systems (Contract recycling, passive composting, active composting, vermiculture) |
| **Design and Construction** | Locally available materials<br>Insulated walls and roofing<br>Roof overhangs by verandas<br>Small scale solar panels and/or collectors<br>Shading of vegetation<br>Recyclable building materials | Sun shading<br>Energy efficiency<br>Renewable and recyclable building materials<br>Conventional, Alternative, Pre Fabrication and Internal Thermal Massing construction methods | Foil/reflective film in windows, replacing filters<br>In-sink aerators, water efficient showerheads, toilet lid sink, water pipe insulation<br>Compact fluorescent bulbs and passive water heating |

## 3. Methods

The three major components of this study are literature review, situational analysis and research outputs. This study followed mixed methods research design as it mixes quantitative and qualitative data collection and analytical methods. The method is influenced by the pragmatism philosophy as the study's research questions and context are the driving forces determining the most appropriate methodological choice, which is the approach by pragmatists (Nastasi, Hitchcock & Brown 2010).

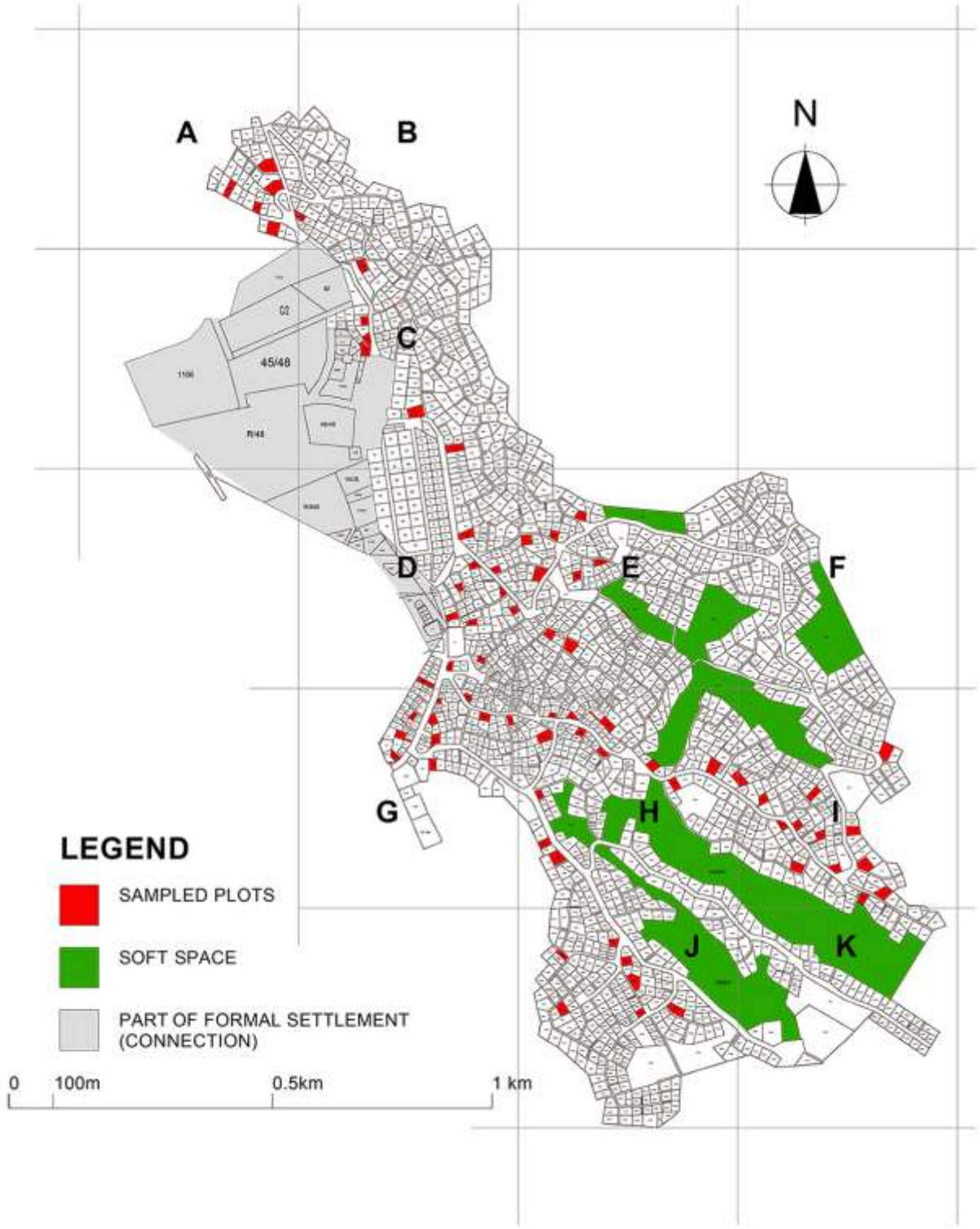


**Figure 1**: Msunduza map showing sampled plots

### *3.1.* **Research Setting**

Swaziland, newly known as The Kingdom of Eswatini from the year 2018, is a small, developing, landlocked monarchy in Southern Africa, bordered by two countries - The Republic of South Africa and Mozambique. This study was set at Msunduza (Figure 1), Nkwalini and Mahwalala (Figure 2) informal settlements all which fall in Mbabane, the capital

city of Swaziland. Literature indicates lack of studies done on informal settlements and their challenges in this country. The three informal areas were chosen for the study as they were prioritised for upgrade through the Urban Development Program in Swaziland. Msunduza is the most densely populated and oldest informal settlement in Swaziland therefore the study assumes it will give the most accurate information on informal settlements in this country.

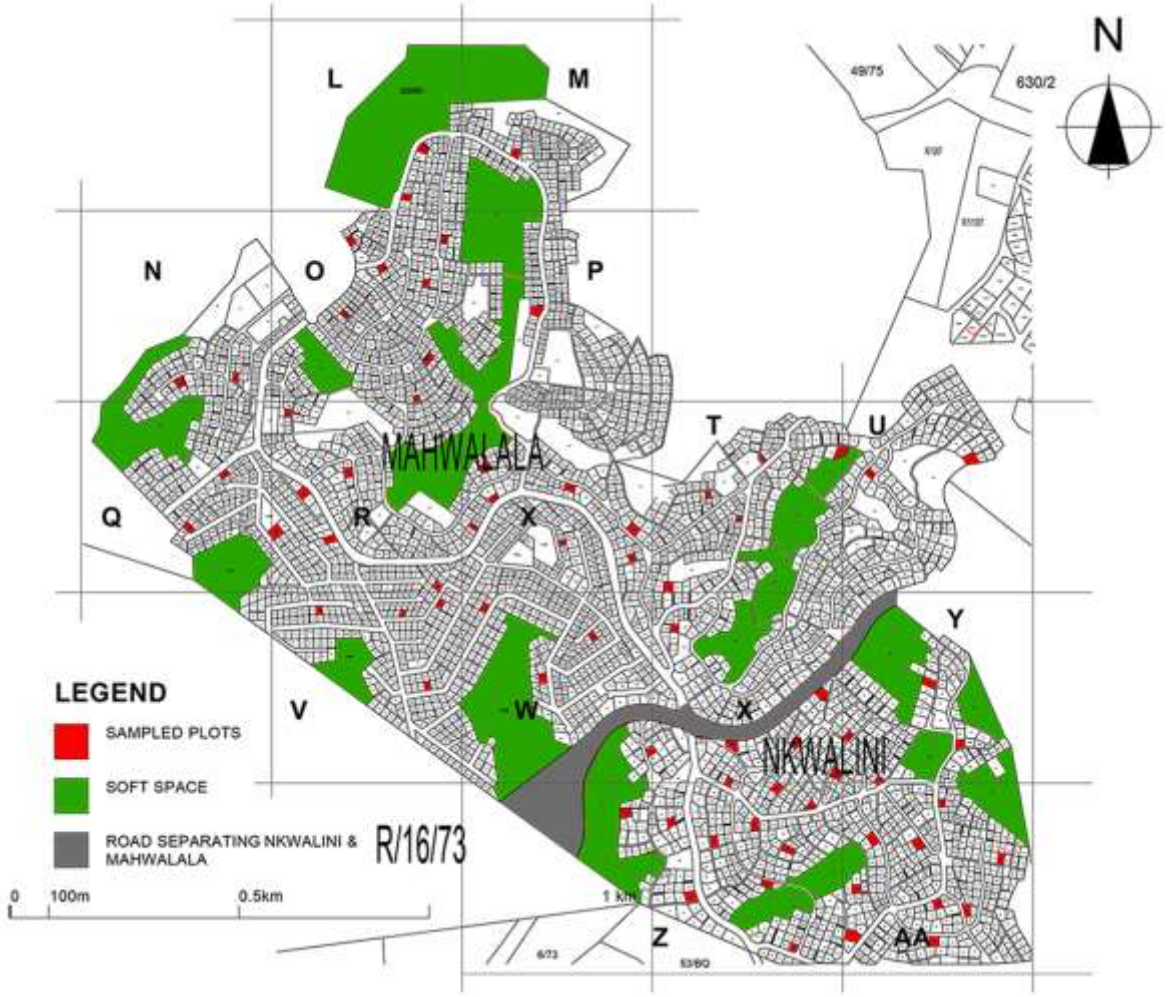


**Figure 2**: Mahwalala and Nkwalini map showing sampled plots

### *3.2.* **Sampling and target group**

The target population for this study was 1605 houses: 748 at Msunduza, 160 at Nkwalini and 697 at Mahwalala. The study was framed on residential houses (unit of analysis) within homesteads, where the main house was selected for study per sampled homestead. Systematic random sampling (probability sampling), which involves the researcher choosing the sample at regular intervals from the targeted sample (Saunders 2016), was used in this study. With the aim of the quantitative study being identification of construction practices used in informal settlements by just getting reasonable evidence of the practices used, a statistical confidence level of 80 percent and confidence interval of 5 percent was considered

sufficient to give accurate results as the focus of the study is not much on the level of use of the practices. Therefore, the targeted sample for this study consisted of 140 houses in the study area – 60 at Msunduza (Figure 1), 50 at Mahwalala and 30 at Nkwalini (Figure 2), to give the intended confidence level and interval. The results were compared to a previously done study by MHUD (2008) to confirm some of the findings.

With the help of a topographic map of the area, the houses were numbered with a unique number and the first house was selected using a random number. Every fifth house was then chosen until the 140 sample size was reached.

### *3.3.* **Data collection**

Categories of assessment identified in literature and used in the research instrument are: building infrastructure, waste management, efficient use of land and transportation. Observational studies using a structured checklist instrument was used to capture the data on construction practices used in informal settlements in two levels – building infrastructure and settlement planning. In the building infrastructure level, a checklist was used for collecting data per building, on materials, energy and waste management practices used. The structured checklist instrument was personally filled out by the researcher for every house in the sampled population to ensure a 100 percent response rate.

Observational studies with the use of a photographic camera and observation schedules were also done to record and capture the planning, condition of the environment, and physical traces of the environmental impact. Bechtel and Zeisel (1987:123) state that photographs are useful throughout a study because of their illustrative qualities. Bechtel and Zeisel (1987) further states that maps and diagrams help in giving a better understanding of how a whole area is used at once, than analysing statistical information.

### *3.4.* **Data analysis**

Data analysis for this study was divided into two – quantitative analysis to identify construction practices used in informal settlements, and qualitative analysis to evaluate the environmental sustainability of the identified construction practices. The statistical data collected through the use of a structured checklist was analysed using a computer program called Statistical Package for Social Sciences (SPSS). Tables and bar graphs were used to present the data. An open ended sort of inquiry (which required written responses), was also included in the checklist to allow for recording of unanticipated practices and further get

deeper understanding of the setting, and it was also analysed through quantitative content analysis.

The identified construction practices were then evaluated through pattern matching. Pattern matching is described by Saunders (2016) and Yin (2014) as a deductive explanation building approach which tries to construct an explanation by predicting a pattern of outcomes based on theoretical propositions to give an explanation of what is expected from the analysis of data. The expected outcomes (environmental sustainability of construction practices) were determined from literature and compared with data collected through the checklist to determine existing sustainable practices for enhancement, and unsustainable practices which require improvement.

## 4. Results and Discussion

Figure 3 presents a summary and comparison of the identified construction practices through quantitative analysis within selected categories, used in all three informal settlements. The general use of the practices is shown in percentages in each settlement.

Table 3 presents construction practices identified through observational studies at neighbourhood level.

Pattern matching was used to evaluate environmental impacts of the identified and evaluated construction practices by identifying possible impacts of construction practices on the natural environment through literature, and matching them with the findings of the environmental impact in the studied informal settlements (Table 4).

The comparison of expected environmental impacts from literature with the findings from the environmental study supports the proposition that informal settlement construction practices have a negative effect on the natural environment as measured through pattern matching (Table 4). Closer examination of the environmental impacts shows that some of the construction practices have minimal sustainability aspects which are environmentally friendly. The results are consistent with the claim by Du Plessis (2002) that informal settlements are sustainable in a special way, as there is full reuse and recycling of building materials and components, which requires enhancement.

The results presented in the tables and figures above, believed to have a major impact on the environment, are discussed in the following sections.

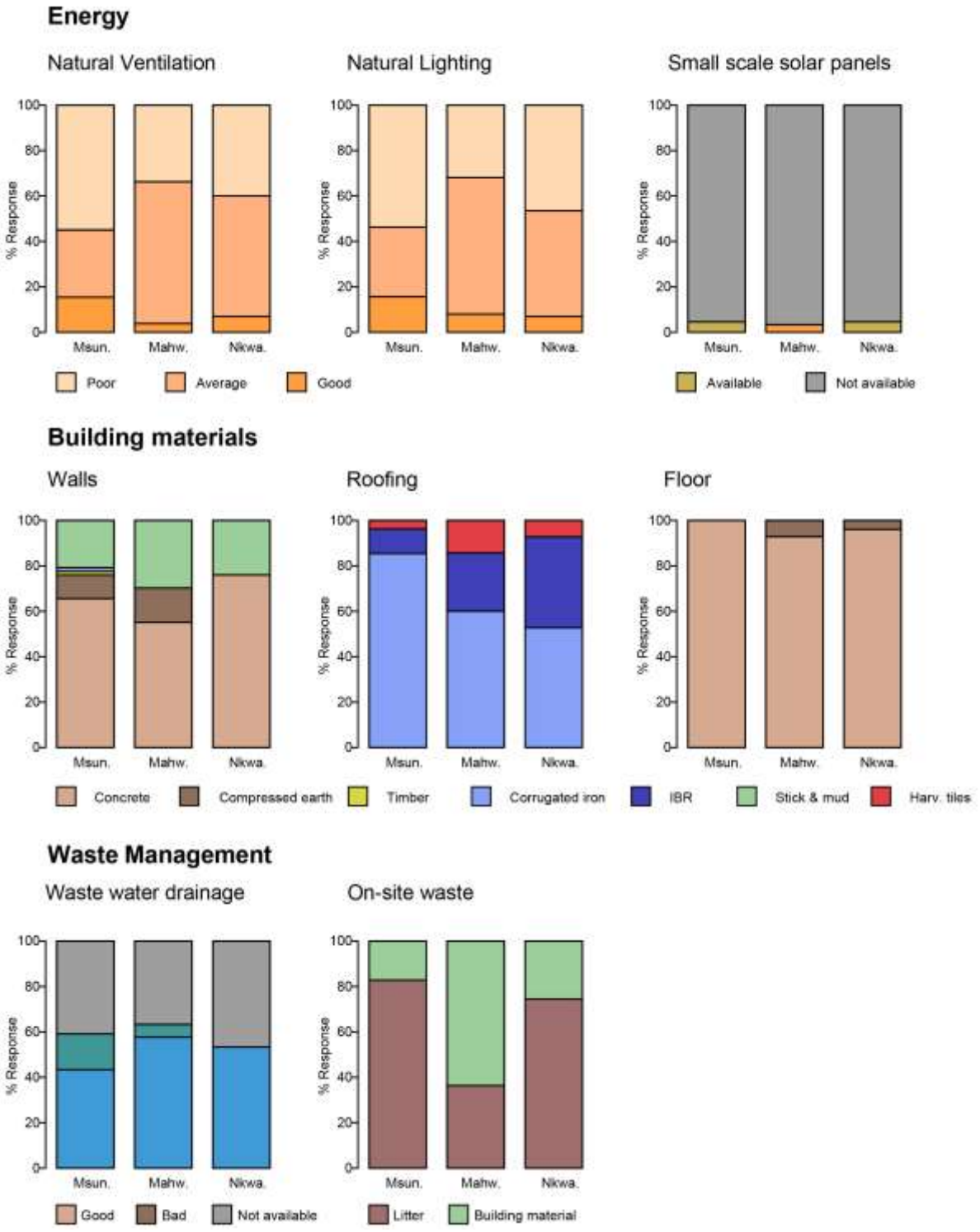


**Figure 3**: Results of identified construction practices used in the informal settlements

**Table 3:** Construction practices observed at neighbourhood level

| | | Msunduza | Mahwalala | Nkwalini |
|---|---|---|---|---|
| **Waste Management** | **Public sewer** | Available | Not available | Not available |
| | **Solid waste** | Waste containers along streets<br>Recycle centre observed | Waste containers observed along streets | Waste containers observed along streets |
| **Land Use** | **Function** | Mixed land use | Mixed land use | Mixed land use |
| | **Soft open spaces** | Available (25.7 ha) | Available (108.9 ha) | Available (40 ha) |
| **Diversity** | **Plots** | Less diversity (range of 200 – 1000 sqm) | Less diversity (range of 200 – 1000 sqm) | Less diversity (range of 200 – 1000 sqm) |
| | **Movement** | No diversity (mainly roadways) | No diversity (roadways only, lacks walkways & bicycle tracks) | No diversity (roadways only) |
| **Movement/ Transportation** | **Movement condition** | Not good | Not good | Not good |
| | **Roads condition** | Not good (lacks maintenance) | Not good (potholes, gullies along untarred roads) | Not good (potholes, gullies along untarred roads) |
| | **Network type** | Looped hierarchical | Looped hierarchical | Looped hierarchical |
| | **Transport type** | Public transport | Public transport<br>Private cars | Public transport<br>Private cars |
| **Services** | **Water source** | Public water system (not accessible to all) | Public water system and Public water supply (not accessible to all) | Public water system (not accessible to all) |
| | **Electricity** | Available but not accessible to all | Available but not accessible to all | Available but not accessible to all |
| **Drainage channels** | | One sided along tarred roads | One sided along on tarred roads | One sided only along tarred roads |

**Table 4:** Pattern matching of expected environmental impacts (literature) with actual impacts observed in the informal settlements

| Practices (categories) | Environmental impact expected | Environmental impact from settlements |
|---|---|---|
| **Energy** | Carbon emissions from fossil fuels impacting the atmosphere (Du Plessis and Landman 2002) | Observed (assumed) from the public and private vehicles |
| | Deforestation with the use of wood to generate energy (Kibwami and Tutesigensi 2016) | Observed – land cleared to allow for construction and fuel wood |
| | Poor natural ventilation and lighting increases the use of energy, and the greenhouse gas emissions from energy based generation which harm the environment is increased (Khan, Su and Riffat 2008; Mochida 2005). | Observed – statistics show about half of the housing population with poor natural ventilation and lighting. |
| **Materials** | Land pollution from unrecyclable old building material (Kim 1998). | Observed – building material waste was observed as presented |
| | Toxic waste from demolished buildings (Kim 1998) | Not observed |
| | Atmospheric impact from materials with high embodied carbon/energy (Bredenoord 2017; Kim 1998; Lawson 2006; Pullen 2010) | Observed – the materials mostly used like corrugated iron, steel, concrete blocks have high embodied energy, which affect the atmosphere negatively.<br>It is noted though that there are local materials (21%) used with low embodied energy, like compressed earth. |
| **Waste Management** | Land pollution - lightweight litter like plastic bags and film with hazards for animals<br>- chemicals contaminating soil (Kim 1998) | Observed – litter as a form of building materials and lightweight materials along streets and within household premises |
| | Water pollution from toxic pollutant (leachate) | Not assessed |

| Practices (categories) | Environmental impact expected | Environmental impact from settlements |
|---|---|---|
| | Loss of biodiversity as a result of demand for new landfill sites (Ahern 2011). | Observed – landfills were observed at Msunduza and the assumption is that there was a loss of biodiversity |
| **Land use** | Vegetation loss and a negative impact on the remaining habitat. Vegetation loss changes nutrient and biogeochemical cycles (McKiney 2006) | Observed – land cleared to allow for construction processes |
| | Loss of biodiversity (Hansen et al. 2005; Kramer 2013; Sofianou 2015) | Partly observed – assumption is that the loss of vegetation observed reduces the natural habitats, and the primary effect of habitat destruction is reduction in biodiversity |
| | Unfertile soil | Not observed as agriculture is not practised |
| **Density** | Low density extends environmental impact of each house over a large area, extending the footprint of housing development (Hansen et al. 2005; Paulsen and Silverman 2005). | Observed – the settlements have low density of 10 – 12.6 houses per hectare. |
| | - Sprawling of a settlement (low density) increases transport of energy, water, materials, products and people (Du Plessis and Landman 2002). | Clearly before UDP the construction was not controlled, but since government has divided land into plots, expectation is that this will now be sorted. |
| **Movement/transport** | Emissions from fossil fuels that impact the environment negatively as they produce more pollutants and disturbance (Du Plessis and Landman 2002; McCarty & Kaza 2015) | Observed (assumed) – transportation use fossil fuels which produces emission that impacts the natural environment. Lack of bicycle tracks encourages everyone to either use public transport or private vehicles. |

| Practices (categories) | Environmental impact expected | Environmental impact from settlements |
|---|---|---|
| **Services** | The absence of water management and resilient systems result in erosion (Ahern 2010). | Partly observed – gullies along roads as drainage channels are one sided<br>- water disposal on yard caused erosion on steep areas |

### *4.1. Energy*

In the efficient energy design of buildings, natural ventilation is now one of the fundamental methods for consideration as it saves energy in a building by limiting energy consumption of houses (Khan, Sue and Riffat 2008). Research shows that occupants of naturally ventilated informal or low cost housing adapt to their environment, and accept a range of indoor temperatures – cold indoor temperature when it is cold, and hot indoor temperature in hot weather condition, which limits energy use (Simonson 2004). The results on natural ventilation and lighting present over-usage of energy in a section of the houses as half of the buildings are poorly ventilated. With about half of the houses receiving poor natural light, more energy is required to illuminate the buildings. Ventilation was measured by area of window openings to total building area ratio, and natural lighting was measured by the area of glazing and orientation of the building in reference to the Building Standards (1969:35).

The results also show lack of renewable energy sources in these areas as only 3% of the observed houses use small scale solar panels. The main source of energy is electricity as 75% of the houses have access to electricity.

### *4.2. Building Materials*

Steel found in use for window frames in almost all the houses (96%) and as roofing (corrugated iron at 66%) is considered to be highly recyclable as it can be recycled repeatedly without losing its properties. The challenge with steel is that it has high carbon emissions and high energy consumption (Pullen 2006).

Concrete on the other hand, which is used in large volumes in the settlements (65 % for walls and 96% for floor), is said to get scattered and downgraded when recycled, and it does not match with the virgin aggregate. Reuse of concrete is also difficult and probably the reason why it does not appear in the list of sustainable building materials presented by Bredenoord (2016). The manufacturing of cement, which is an ingredient of concrete causes

environmental impacts through pollution and transportation during pre-building stage as cement is imported from neighbouring countries.

The earth blocks and mud with wooden sticks found to be used in small quantities (12% and 21% respectively) are environmentally friendly as they are locally found, retain energy, have very low carbon emissions (low embodied energy) if any, and they are recyclable. Bredenoord (2016), claims that dwellers feel as if the use of these sustainable materials is a sign of poverty. This explains the over reliance on concrete blocks by dwellers of informal settlements. Other materials identified but used in very small quantities, and which their minimal use may have less effect on the natural environment are: timber for walls (0.6%) and window frames (1.7%), Harvey tiles for roofing (8%), and aluminium for window frames (3.1%).

### *4.3. Waste management*

The waste management strategy used in the study areas entails location of waste bins about 500 meters apart along internal streets for ease of access by residents, and municipality transport which empties them when they are full. Litter is observed in the settlements even with these waste management systems in place. The challenge may be in access to the bins as refuse collection is 100m – 1km away from homesteads (MHUD 2008). The exposed lightweight litter observed in all settlements (Figure 4) is believed to cause land pollution and affects fertility of soil.

**Figure 4**: Litter observed along a street at Msunduza

### *4.4. Settlement Planning*

It has been observed with concern that these Installed basic services in informal settlements are not accessible to some of the residents (over 30% in the study) possibly because of financial constraints as a high percentage of residents in the settlements are unemployed (Bredenoord 2016). This claim is consistent with a study done by Devi (2017) who discovered that electricity was extremely restricted to residents of informal settlements because of affordability and administrative constraints. The results show that these residents dispose waste water on streets which causes erosion. Results from the MHUD (2008) study confirm this claim as it stated that poor drainage exacerbated soil erosion in the informal settlements.

The current settlement upgrading approach does not seem to completely eliminate the environmental problems in countries like Swaziland as the findings show that even the approach used by government perpetuates the degradation of the natural environment. This is evidence which calls for measures to improve the current interventions to emphasise on sustainable construction practices or development.

*4.5. Measures*

A framework which can be used as a guideline (or inform a future guideline) towards the use of sustainable construction practices in the development of a neighbourhood for low-income households is required. The challenges observed which might require attention are claimed to be in government's interventions level, settlement planning level and self-help buildings. Therefore, taking from the discussion on the above sections and reviewed literature, the following measures (Table 5) are recommended at building scale and neighbourhood scale:

**Table 5**: Measures for sustainable construction and regeneration of informal settlements in the Kingdom of Eswatini

| Level | Building Scale | Neighborhood Scale |
|---|---|---|
| **1. Settlement Regeneration (Government's role)** | | Installation of sustainable basic services<br>Good governance supporting sustainability & regeneration development practices<br>Encouraging participation during development<br>Establishing sustainable social & economic systems<br>Devise implementation strategies |
| **2. Sustainable Planning (Government's role)** | Use land appropriately<br>Waste management systems supporting recycling and reuse of waste<br>Educating residents | Mixed land use practice<br>Densification<br>Open movement networks<br>Sustainable Transportation<br>Open space systems |
| **3. Sustainable self-help buildings (dweller's role)** | Proper building orientation<br>Energy efficiency (eg. small scale solar panels, sun shading)<br>Sustainable materials (eg. local, low embodied energy, natural)<br>Use already prepared (by professional architects and engineers) | |

| | |
|---|---|
| | construction drawings with inclusion of sustainable practices<br>Anticipate future design evolution<br>Control of construction practices by local authorities<br>Construction methods with minimal environmental impact |
| **4. Resilient systems (Applies to all practices)** | Buildings with less environmental impact at demolition stage<br>Build infrastructure with redundancy<br>Multiple sources for each service (eg multiple renewable energy sources)<br>Systems that adapt under any condition |

At neighbourhood level, the emphasis is on the inclusion and focus on regenerative development practices which add value to the natural environment through restoration of the degraded environment. Participation through collaboration between the community, municipality and land owners is also vital (Wekesa et al. 2011) to ensure success of settlement development. The current systems used for waste management requires enhancement towards a sustainable approach which may sort the waste into biodegradable waste for composting, recyclable materials (steel, paper, glass and rubber) to sale and recycle to sell the products. In so doing the environmental impacts will be reduced.

A shift from the current conventional planning methods to sustainable planning methods to solve the challenge of environmental impact in informal settlements is recommended. Sustainable settlements encourage the use of renewable energy sources, sustainable transport, mixed use development and compactness to limit the use of cars which emit gases harmful to the environment.

Advocates of sustainable housing advises and agrees on the following characteristics to aim for in developing sustainable self-help housing which the study has adapted: proper building orientation to allow for passive ventilation, use of small scale solar panels to encourage renewable energy use affordable to self-help housing dwellers, sustainable materials with low embodied energy to reduce environmental impact. Engaging professional architects guided by revised regulations to include sustainability principles will ensure the use of sustainable construction practices.

Finally the use of resilient systems will ensure that the failure of one system (waste management, drainage, energy and movement systems) will be backed by another system avoiding disturbances that may negatively impact the environment.

## 5. Conclusion

This paper provided empirical data to describe construction practices used in informal settlements, and to further understand their impact to the environment. Through a survey of randomly selected houses within three purposely selected informal settlements, the empirical survey findings supported the arguments of the literature that the construction practices used within informal settlements have a negative effect on the natural environment and that the current interventions require enhancement. However there are a few instances in which the practices were found to be environmentally friendly supporting the claim by literature that informal settlements are sustainable in a unique way.

The findings on the observational study conducted on the overall planning of the settlements by government revealed that basic infrastructure services installed by governments are not accessible to a majority of informal settlement residents because of affordability. Waste containers located along streets are also not accessible to all residents because of long distances from their homes to the locations of the waste containers.

The results highlighted the importance of the proposed framework emphasising control of construction practices used in informal settlements which should encourage properly oriented buildings, use of energy efficient methods and sustainable building materials. The use of building plans with environmentally friendly features that anticipate future design evolution and use construction methods with minimal environmental impact should be encouraged. The study emphasises the need for such a guide which acknowledges sustainability and regenerative development theories to address the housing challenges in informal settlements.

This study was not exempt from limitations, which could be overcome by future research. The geographical location also has an effect on the environmental condition. Further studies in a different geographical location would reinforce the findings of this study.

The main contribution of this study to the international discourse is mainly through the research output, which advocates for control of construction practices in the development of

informal settlements and its housing ensuring the use and enhancement of environmentally sustainable practices, than giving all power to residents to construct their own dwellings.

## References


Abbott, J., 2002a. A method-based planning framework for informal settlement upgrading. *Habitat International*, 26(3), pp.317-333.

Abbott, J., 2002b. An analysis of informal settlement upgrading and critique of existing methodological approaches. *Habitat International*, 26(3), pp.303-315.

Balbo, M., 2001. Shelter: emerging trends and policies. *Habitat Debate*, *7*(3), pp.2-3.

Bechtel, R.B. and Zeisel, J., 1987. Observation: The world under a glass. *Methods in environmental and behavioral research*, pp.11-40.

Bredenoord, J., 2016. Sustainable Housing and Building Materials for Low-income Households. *J Archit Eng Tech*, 5(158), p.2.

Cole, R.J. 2012. Regenerative design and development: current theory and practice. *Building Research & Information* 40(1): 1-6.

Devi, P.P., Lowry, J.H. and Weber, E., 2017. Global environmental impact of informal settlements and perceptions of local environmental threats: An empirical case study in Suva, Fiji. *Habitat International*, 69, pp.58-67.

Dovey, K. and King, R., 2011. Forms of informality: morphology and visibility of informal settlements. Built Environment, 37(1), pp.11-29.

Du Plessis, C., 2002. Agenda 21 for sustainable construction in developing countries. CSIR Report BOU E, 204.

Du Plessis, C. and Landman, K., 2002. Sustainability analysis of human settlements in South Africa. CSIR Building and Construction Technology Programme for Sustainable Human Settlement.

Hansen, A.J., Knight, R.L., Marzluff, J.M., Powell, S., Brown, K., Gude, P.H. and Jones, K., 2005. Effects of exurban development on biodiversity: patterns, mechanisms, and research needs. *Ecological Applications*, 15(6), pp.1893-1905.

Jorgenson, A.K., Alekseyko, A. and Giedraitis, V., 2014. Energy consumption, human well-being and economic development in central and eastern European nations: A cautionary tale of sustainability. *Energy Policy*, *66*, pp.419-427.

Khan, N., Su, Y. and Riffat, S.B., 2008. A review on wind driven ventilation techniques. *Energy and Buildings*, *40*(8), pp.1586-1604.

Kibwami, N. and Tutesigensi, A., 2016. Enhancing sustainable construction in the building sector in Uganda. *Habitat International*, 57, pp.64-73.

Kim, J.J. and Rigdon, B., 1998. *Sustainable architecture module: Qualities, use, and examples of sustainable building materials*. National Pollution Prevention Center for Higher Education.

Kovacic, Z., Smit, S., Musango, J.K., Brent, A.C. and Giampietro, M., 2016. Probing uncertainty levels of electrification in informal urban settlements: A case from South Africa. *Habitat International*, *56*, pp.212-221.

Kramer, M. 2013. Our built and Natural Environments: A technical review of the interactions among land use, transportation, and environmental quality. In Environment protection agency, smart growth program. Washington, D.C: U.S. Government.

McCarty, J. and Kaza, N., 2015. Urban form and air quality in the United States. Landsccape and Urban Planning, 139, pp.168-179

McKinney, M.L., 2006. Urbanization as a major cause of biotic homogenization. *Biological conservation*, 127(3), pp.247-260.

Nassar, D.M. and Elsayed, H.G., 2017. From Informal Settlements to sustainable communities. *Alexandria Engineering Journal*.

Nastasi, B.K., Hitchcock, J.H. and Brown, L.M., 2010. An inclusive framework for conceptualizing mixed methods design typologies: Moving toward fully integrated synergistic research models. *Handbook of mixed methods in social & behavioral research*, *2*, pp.305-338.

Ploeger, H. and Groetelaers, D., 2006. Informal settlements and fundamental rights.

Pullen, S., Arman, M., Zillante, G., Zuo, J., Chileshe, N., & Wilson, L., 2010. Developing an assessment framework for affordable and sustainable housing, *Australasian Journal of Construction Economics and Building*, 10(1/2), pp. 48-64.

Robinson, J. and Cole, R.J., 2015. Theoretical underpinnings of regenerative sustainability. *Building Research & Information*, *43*(2), pp.133-143.

Saunders, M., Lewis, P. & Thornhill, A. 2013. *Research methods for business students.* 7th ed. Harlow: Pearson Education Limited.

Simonson, C., 2005. Energy consumption and ventilation performance of a naturally ventilated ecological house in a cold climate. *Energy and buildings*, 37(1), pp.23-35.

Sofianou, P., 2015. Regeneration of informal settlements towards sustainability: a case study. Proceedings: *From the wisdom of the ages to the challenges of the modern world,* 12-21 May, Sofia, Bulgaria.

Sullivan, E. and Ward, P.M., 2012. Sustainable housing applications and policies for low-income self-build and housing rehab. *Habitat International*, 36(2), pp.312-323.

United Nations. High-level Panel on Threats, Change and United Nations. Department of Public Information, 2004. *A More Secure World: Our Shared Responsibility: Report of the High-level Panel on Threats, Challenges, and Change* (Vol. 5). United Nations Publications.

Wekesa, B.W., Steyn, G.S. and Otieno, F.F., 2011. A review of physical and socio-economic characteristics and intervention approaches of informal settlements. *Habitat international*,35(2),pp.238-2

Wilson, C. and Dowlatabadi, H., 2007. Models of decision making and residential energy use. *Annual review of environment and resources*, *32*.