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INDIGENOUS LANDSCAPE BASED PRACTICES FOR STORMWATER RESILIENCE IN TANZANIA (The Case of Moshi Rural District)

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ABSTRACT

This article aims at investigating indigenous landscape based stormwater control skills and practices in the Tanzanian rural setting and availing lessons for urban stormwater management. The currently used urban stormwater engineering techniques have proven failure as evidenced by unpredictable destructive floods and loss of lives and properties during rain seasons. The study dwells on water resilience and landscape based stormwater management practices and skills. Landscape urbanism theory was used as a lens through which the research theme can be gravitated. Moshi Rural District was picked as a case because of its richness of application of conservation of nature and use of natural materials to control surface runoff. The case area was walked though and data collected through observation, mapping and interviews. The empirical findings were: A tree as a plant community and how it delays stormwater, use of diverse native grass and herb cover as an ecological community in lawns, use of vegetative lawn borders with diverse plants instead of concrete curbstones, use of vegetative property borders with multiple cascading canopies and thick varied low vegetation, living roads attained through the use tough grass instead of pavement, conservation of the riparian landscape through native plants and natural landform, mulching of farms to capture stormwater, conservation of natural granite boulders, riverside rocks and riverbed sand, usefulness of plant materials beyond stormwater management that creates sustainable landscape, conservation of riverbeds and riversides to ensure stormwater delay and resilience, and trapping of road stormwater for irrigation. Plant materials facilitate in the crashing of raindrops to reduce impact on the earth surface, evaporation, transpiration, delay of surface runoff and infiltration, and underground water recharge. The indigenous stormwater control practices successfully do away with threats of floods through green infrastructure focusing at nature conservation, imitating nature, promoting infiltration, and safe conveyance of the surplus to the natural drains. Landscape based stormwater control engages in the use of vegetation as holistic measures of control. The repeatedly applied practices produce similarity amongst landscape entities and regional identity. Natural landscape based stormwater control system can inform climate change mitigation and adaptation, urban green architecture, landscape urbanism and landscape sustainability. Residents holistically conserve and imitate natural landscape features. The innate landscape based stormwater control skills and practices reside in residents' processes of existential experiences. Indigenous landscape based stormwater control takes on board the use of locally available materials, customary concepts, hands-on demonstrations, and functioning techniques. Native landscape practices have shown ability to stabilize soil against soil erosion, prevent flooding and adapt to stormwater associated stress and thus qualify as resilient practices. The landscape based stormwater control and the associated benefits such as livelihoods, fuel, and livestock fodders have resulted into sustainable and resilient landscapes. Indeed, the applications of natural stormwater control are water sensitive and low impact developments. Inspired with the rural lessons, it is possible to employ "stormwater based urbanism" whereby the urban landscape is bestowed with capacity to maintain its basic structure and to provide ecosystem services in a dynamic world of social, economic and environmental conditions. Through the use of stormwater as a natural capital, use of native plants and application of indigenous skills of stormwater control and use, the lessons can be conceptually and practically adopted in various rural areas and cites regardless of their respective climatic differences.

KEYWORDS Indigenous stormwater control practices, water resilience, green infrastructure, landscape based stormwater management and landscape based stormwater control.

The concept of stormwater management system as a site amenity is not new. Bookout, (1994); Ferguson and Debo, (1994); Tunney,(2001) cited in Echols and Pennypacker,(2008) argue that skillfully designed detention systems (typically naturalized ponds) have long been recognized for their aesthetic and community value. Stokman, (2008) gives a challenge that, "rather than leaving this field to engineers, the profession of landscape architecture should use this window of opportunity to take a leading part in the reconstruction and development of urban infrastructure systems taking the landscape as a starting point." In line with stormwater management, Stokman (2008:57) urges, the profession of landscape architecture to take a major role to urban infrastructure for stormwater management by giving a reason to which this study capitalizes: "*The strength of landscape architecture lies in its ability to extend our current understandings of infrastructure, linking the performance of natural processes with engineering and urban design strategies"*. For the efficient urban water resilience Stokman,(2008) argues that " by reuniting the built and natural we may find new logics towards a more resilient development of infrastructural landscapes as a base of sustainable urban and regional form."

A long stand alone conventional engineering solution for stormwater management practice has proved insufficiency thus calling for a complementing approach. This is witnessed in urbanized cities such as Dar es Salaam where flooding is inescapable despite enlarging efforts of drainage channels. (see Figure 1)

Figure 1: *Enlarged stormwater channels along Morogoro Road in Dar es Salaam. Floods are still devastating infrastructure, buildings and deaths.* ***Source:*** *Global publisher 2014*

How to cope with the increasing runoff volumes is a matter of debate due to costs increments associated with conventional stormwater management systems. The world has begun to consider alternative means to help check the phenomenon. According to Roy et al., (2008) the perception of stormwater runoff has also been changed from strictly a liability to having a value as a water resource. Roy et al. note that the management of stormwater has similarly shifted accordingly.

The Water resilient Green cities of Africa WGA-project (2013-2017) introduces the concept of Landscape based Stormwater Management (LSM) that, has been gradually developed as a response to various stormwater management challenges in Europe, the United States, and Australia over the last three decades, under names such as Sustainable Urban Drainage Systems (SUDS), Low Impact Development (LID), and Water Sensitive Urban Design (WSUD). The basic idea is to delay and infiltrate stormwater runoff locally in the City, rather than discharging the water through sewer systems (WGA,(2013-2017). Despite the resourcefulness of stormwater runoff, Roy et al.,(2008) note that debate is increasingly centered on how to achieve improved ecosystem health outcomes through stormwater management. According to SWITCH, (2006-2011), Stormwater as a resource in integrated urban water management provides a deeper analysis of decision making processes involved in managing urban stormwater, with a particular focus on the identification of opportunities for reusing stormwater and its potential to contribute to meeting the needs of other sectors of the urban water cycle.

Landscape based Stormwater management elements

The concept of landscape based stormwater management (LSM) deems at halting adverse environmental problems and restoring the lost green due to urban physical development using different approaches capitalizing on stormwater as a resource. However, retrofitting urbanized cities with LSM approaches has challenges and some complexity. Fryd et al., (2011) and Ingvertsen et al., (2011) say the complexity is primarily due to incomplete knowledge on geo-hydrological conditions for infiltration, limited space and diverging interests among stakeholders. However LSM advocates natural avenues of reducing effects of stormwater runoff in urbanized areas by acquiring appropriate approaches that enhance *evaporation, evapotranspiration, infiltration, conveyance and filtration* by proper landscape management *blue-green* being the central focus. According to the (CDS, 2002) the key objective of any stormwater management is to minimize threats of floods, though in so doing holistic environment is nourished. "Working with the natural environment and processes has been found to be safer, more sustainable and easier to maintain in the long term than more traditional engineering approaches aimed at controlling these processes"(CDS Guideline, 2002).

Introduction

This article aims at investigating indigenous landscape based stormwater control skills and practices in the Tanzanian rural setting and availing lessons for urban stormwater management. Kilema Ward in Moshi Rural District was picked to demonstrate best indigenous practices of stormwater management through evaporation, transpiration, infiltration and conveyance which are fundamental variables of landscape based stormwater management. The variables of investigation were analyzed through landscape urbanism lenses with the intention of identifying ecological ecosystems and landscape resilience to stormwater. Dwelling on the idea of bringing nature to built urban infrastructure as raised by Stokman, (2008), Pauleit et al., (2011) complements by the concept of green infrastructure (GI) that can bridge-up gaps among different disciplines. The term '*Infrastructure*' gives a common platform for ecologists, landscape architects, urban planners, engineers, and social scientists to collectively address the major challenges of contemporary urban development, such as the restructuring of waste and stormwater systems, reintegration of wastelands into the urban fabric to restore characteristics of ecosystem services in urbanized areas under the capital of stormwater.

The approaches such as SUDS are therefore accompanied by the prospect of increased resilience to climate change and, more importantly, by a possibility of accelerating the transition of cities towards sustainability (Van de Meene et al., 2011; Frantzeskaki et al., 2012) in Mguni et al., (2014). The Water Research Commission (WRC,2012) identifies key variables of the SUDS approach as the effective management of: stormwater runoff quantity, quality and the associated amenity and biodiversity where each level contributes to a more improved, sustainable drainage system.

Theory of Landscape urbanism

Landscape Urbanism is a theory of urban planning arguing that, the best way to organize cities is through the design of the city's landscape, rather than the design of its buildings. Scholars and practitioners of urban design and urban planning are positively debating on the theory while others are fundamentally criticizing by comparing it with other preceded urban design concepts. Agata Zachariasz, advocates that *"landscape urbanism has become more prominent; it is a theory, which assumes that the best manner of planning and organizing the structure of a city consists in designing of the landscape thereof rather than buildings"* Zachariasz (2014:340). Christopher Gray looks at the coupling of landscape with urbanism, he sees a promising blend by arguing that landscape urbanism seeks to reintroduce critical connections with natural and hidden systems and proposes the use of such systems as a flexible approach to the current concerns and problems of the urban condition (Gray, 2011). This is a kind of urbanism that gives room for legibility, flexibility, scalability that anticipates change, open-endedness, and negotiation (Thompson, 2012); Corner, (1999) in Waldheim, (2006)). Anchoring to the *current concerns* as mentioned by Gray, Repishti points out that the world is consciously inclining towards environmental concerns while landscape urbanism has become an autonomous discipline, developing its own mode of practice and ideology (Repishti, 2012).

It is prudent to look into the concept of Ecological resilience, which correlates with resilience in ecosystem as put by Gunderson (2000). The study associates the resilience in ecosystem with the landscape resilience concept focusing on stormwater, and reflects on how Landscape urbanism theory overarches them. Braatz, 2012 defines the word "resilience" as it encompass the following attributes of a system: the ability to cope with stress, the capacity to recover from the effects of disturbance and the capability to adapt to stress and change. The term "resilience" can be utilized in a wide spectrum of systems to measure their stability after circumstantial disturbances applied to them. However the resilience perception differs for the situation holding multiple systems. Thus, *"ecological resilience refers to the width or limit of a stability domain and is defined by the magnitude of disturbance that a system can absorb before it changes stable states"* Gunderson L., (2000).

Francesco Repishti, (2012) argues that *"Although the landscape has historically always played a role in the form of the city, landscape urbanism goes beyond the design of parks, public spaces and gardens"* By going beyond the design, Repishti tries to reveal the power behind the designs, which this study presumes both resilience capability, and capacity of services to the general ecosystem the design can offer as addressed in landscape urbanism. Weller, (2008) further argues that the project of landscape urbanism, apart from being naturally linked to the landscape art experience, it formulates a process rather than a plan. The process character allows landscape urbanism's attachment to time factor as flexible urban settings and design elements, dynamic and responsive, operating under the medium of landscape to fulfill ever-evolving demographic, environmental, political, and social needs of a contemporary city (Waldheim, 2006:37, Repishti, (2012), Mossop, in Waldheim, (2006)). James Corner (1999), in his essay *Terra Fluxus* in Waldheim, (2006), establishes four basic themes governing landscape urbanism: *process over time, staging of surfaces, operation or working method and imaginary.* Landscape urbanism advocates considering traditional concepts, representations, and operative techniques (Corner, 1999), ability to adapt these techniques to the environment that they are in (contextualization). The strength of practices illuminated with theories is measured through their capacity to cope with stormwater stress, ability to recover from the effects of stormwater disturbances and the capability to adapt to stormwater stresses and changes. Durack (2004:1) in Thompson (2012:440) argues that the landscape urbanism concept calls to turn the traditional practice of urban design inside out, *starting with open spaces and natural systems to structure urban form,* instead of buildings and infrastructure systems.

The statement of the problem of the study dwells on the fact that there are areas where stormwater is successfully and exhaustively managed through the use of native skills, native practices through plant materials to produce multipurpose green infrastructure but such native potentials are taken for granted by engineering and landscape architecture professionals. Therefore, there is a strong need of analyzing the processes of coming into being, the green infrastructure for stormwater handling. The main objective of the study is to explore residents' applications of green infrastructure in stormwater management and see how such practices and skills can inform landscape based stormwater management skills and technologies as well as landscape urbanism in the contemporary world.

The specific objective of the study is to identify native green skills and practices towards stormwater management in the rural communities. The study also aims at identifying plausible and exhaustive everyday native techniques of delaying, capturing, infiltrating, evapo-transpiring of stormwater. It also aims at revealing residents' **intuitive natural skills** and **cultural practices** as well as **tacit knowledge** in handling stormwater in the upper stream areas. This is "*an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident*" and therefore case method strategy is appropriate.

Research Method:

Reconnaissance in the entire Moshi Rural District was undertaken to identify a case area, which is information-rich enough to comprehensively fulfill all the research objectives. The selected case was taken as a representative case. In order to avoid bias multiple data sources were employed and triangulated. Data collection techniques applied included observation, plant materials identification, in-depth interviews and lived experience. Observation involved noticing or watching and recording residents' green practices and skills of handling storm water in the landscape. Photographs registration and sketching were used to document the practices and as tools for analysis.

The in-depth interview was based on focused group discussion with two main groups: the first involved fourteen elders, both males and females balanced in number, aiming at extracting the real life behind existing environmental set up. The second involved fourteen youths, males and females comprising of 50% each, with the goal of discovering the future trajectory of the present practices in the case area. In-depth interviews revealed the processes of coming into being of green infrastructure for stormwater handling, actors/champions of stormwater management, regulations and bylaws, challenges and opportunities of the green infrastructure in the rural setting. Moreover, in-depth interviews brought into focus storm water delay methods, stormwater capturing methods, stormwater infiltration, stormwater evaporation, evapo-transpiration and stormwater safe discharge as well as the associated benefits.

The case area was mapped based on geo-digitization of satellite images 2015 indicating existing settlements development state through GIS. This was complemented by digitized topo-sheets affirming development pattern in relation to topographical landform. Land features such as retention ponds were located on maps based on the GPS coordinates taken during empirical data collection (see Figure 4:8). Local, regional and national documents were studied to make out associated policies, regulations, bylaws, and seculars, relating to stormwater management.

The case study method was recommended because of its "capacity to dwell on real-life contexts, the capacity to explain causal links, the importance of theory development in the research design phase, a reliance on multiple sources of evidence, with data needing to converge in a triangulating fashion and the power to generalize to theory." This investigation is with reference to the indigenous stormwater management practices through application of soil-water-plant systems that slow down and capture stormwater, infiltrate a fraction of it into the ground, evaporate a portion of it into the air, and at times discharge a part of it into the natural drains. The investigation demonstrates watershed with diversity of plants ranging from super tall, tall intermediate, shrubs to crawlers, each type with varied texture and form. There is diversity of grass ranging from very sturdy to very soft all used by residents to serve multiple functions. Rivers are flanked with sloping terrains which are terraced to accommodate subsistence farms and rural housing. Residents abundantly demonstrate indigenous stormwater practices and techniques which dwell on long and short term benefits of stormwater management through proper integration of soil-water-plant systems. This is basically stormwater management through green infrastructure. An area where stormwater management through green infrastructure has been exhaustively practiced by natives and shown maximum effectiveness and resilience was picked. Researcher's lived experience guided the selection of Kilimanjaro Region and in particular Moshi Rural District and its river watersheds to be the case study area because it is more information-rich than the rest. In the case area there are varied stormwater management practices which dwell on conservation of natural plants, protection of natural landforms and application of green skills and technologies in stormwater management which is very close to the contemporary LSM techniques which are hinged on application of green infrastructure. The study focuses on protection of soils against soil erosion and landslides and restoration of underground water, soil moisture, relative humidity, wetlands, riverbanks, and riverbeds. Moreover, the study analyzed how green infrastructure is applied to mimic the natural water cycle. The study went beyond the utility aspect of green infrastructure and address socio-economic benefits and enhancement of community safety and quality of life.

Case location and features

Kilimanjaro Region, bearing the name of the snowcapped highest mountain in Africa at 5895m from the sea level, lies south of the Equator between latitudes 2°25'and 4°15', and longitudes 36° 25' 30" and 38°10'45" east of Greenwich (Planning Commission Dar es Salaam and RCO-Kilimanjaro 1998).

Fig.2: *Maps showing location of Moshi Rural District in Kilimanjaro Region.* ***Source:*** *www. researchgate.net*

Fig.2a: *Moshi Rural District highlighted in red.* ***Source:*** *Population Distribution by Administrative Units, United Republic of Tanzania, 2013*

The Kilimanjaro Region consists of seven districts (See Figure 2 above) one of which is the Moshi Rural District which is our case district. Moshi Rural District is administratively divided into 31 wards whereby North *Kilema is our case ward.*

Moshi Rural district has a population of 466,737 inhabitants. Its altitudes ascend from 500m to 3000m above the sea level (IUCN, 2005).

The highland zone of Kilimanjaro region is characterized by undulating succession nature of hills, valleys and canyons and lies between 1,000 and 1,800 □meters above sea level. IUCN, (2005) points out that the rainfall patterns are fundamentally related to altitude.

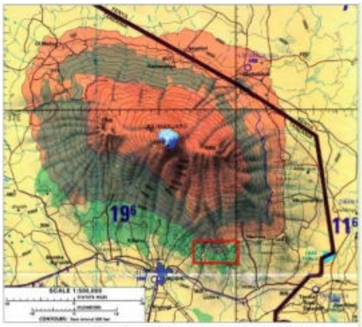

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Figure 3: *Map of Mount Kilimanjaro indicating the Case Study location in red box on the southern slopes.*

However, Hermansen, (2008) gives an insight that temperature, precipitation and humidity from the dry plain upwards along the altitudinal ascent through the agrarian slopes, the forested belt lying between 1600 and 3000m a.s.l furthering via the heath and dry alpine zones to the glacier at the summit of Mount Kilimanjaro, have a significant variation. ***Water Sources***

The Rainfall distribution is ultimately dominant on the southern slopes of Mount Kilimanjaro mainly situated in the highlands of Moshi rural District. Bart and Pomel,(2006) argue that Southern slope takes about 60-65% of the annual precipitation during main rain season whereas Eastern part (Rombo) takes about 43%. This study dwells on Marangu and Kilema/ Kirua Wards located at the altitude range of 1400m to 1600m a.s.l.

There are two rain seasons in the Region, from March to May is the main season and October to December experiences lesser amount (Hermansen, 2008). The annual average precipitation falls between 1250 and 2000mm, and the lowlands receiving 500-600 mm (IUCN, (2005). Kilimanjaro,(1998)). Rainfall is bimodal, occurring mainly between March and June, with short rains in November-

Water resources in Moshi Rural, Hai and Rombo districts originate primarily from rain in the mountain area and from the melting snow on the mountain slopes, forming numerous streams flowing down the mountain (Hermansen, 2008; Mbonile, (2005). However. Hermansen argues *"the contribution to the runoff from the glacier is probably minimal (Hermansen, 2008)."*

According to IUCN, 2005 Moshi rural areas obtain water mainly from springs and rivers and ground water sources. The area has a total of 67 water sources out of which 53 are springs supplying its water to 30 gravity-fed water schemes. The 53 springs are mostly covered by a healthier riparian of natural forest and are protected by the District Council with a closer collaboration with the local communities through trees planting around the springs. IUCN, (2005). *"The Pangani Basin's water originates largely from rain falling on the mountains of Meru, Kilimanjaro, and Pare"* (Mbonile, 2005). Focusing onto the lowlands of Moshi rural, Mbonile substantiates that they have underground water and springs, which are recharged by rain from the upper lands (Ibid).

Vegetation

Vegetation varies dramatically through the basin (Figure 6), ranging from forests on mountain slopes, to arid grasslands, and reflects differences in altitude and precipitation (IUCN, 2005).

According to Hemp's altitudinal vegetation division as cited in Hermansen, (2008:12) in ascending order, include plantations below the forest, forest remnants in gorges and along riverine found below 1800m a.s.l, forest division, and shrubs above the forest division (Hemp, 2006). Hemp substantiates further that the altitude between 1000 to 1300m a.s.l, is very rich in biodiversity (Hemp, 2006 as cited in Hermansen, 2008:12).

Cultivation patterns reflect the rainfall and vegetation patterns of the region with most cultivation being on the lower mountain slopes around Mount Kilimanjaro..." (IUCN, 2005). Human interference to natural vegetation encroaches the forest reserve by cutting down trees for various domestic uses, and pave land for agriculture and new settlements (Hermansen, 2008:12; The population density is 650 people per square kilometre The Chagga's agricultural administration, orders were issued by the native Authority throughout the Mountain banning farming near river banks. The adjoining owners were content to regard the riparian as a land available for communal grazing (Lerise, 2005).

Throughout the Moshi Rural District, the boundaries between wards are rivers, which are characterized by upper streams, midstreams and lower streams each with common features cutting across the entire district. All the rivers are flanked with riparian areas which are mainly occupied by natural vegetation with adjacent farms which are at least 60m away from the centre of the respective river as per NEMC regulations. In some cases the regulations is not strictly observed albeit remarkable green river belts spanning from the slopes of Mountain Kilimanjaro downward to the plains in the low lying lands.

Figure 4: *Map of the Case area showing the existing development on hills leaving valleys under a conserved green structure and perennial rivers.* ***Source:*** *GIS expert, Ardhi University 2016*

Empirical Findings: Native Concepts of Stormwater Management

A tree as a plant community and how it delays stormwater

A tree has different strata of canopy and each level reduces the speed of water falling on it. Subsequently water falling on the ground will have lost most of its speed and momentum and therefore hit the ground with minimum impact. The delayed storm water is given time to infiltrate at source. Moreover, the uneven tree-barks that are sometimes indented hold an amount of water from the vertical run off and keep the tree-stem-surfaces moist (see Figure 5). The moist surfaces support plant communities like lichens, moss, ferns and orchids which reduce the impact of the vertical runoff and keep much of it within the woven mat or network formed by their root like structures. The tree bark with corky material also absorbs water and releases it gradually while retaining much of it. Lastly the base of the tree acts as a barrier to the surface run off reducing the speed and amount moving beyond it.

Figure 5: *Tree as a community of various plant species (parasites) on its stem.* ***Source:*** *(Authors , 2016)*

Use of diverse native grass and herb cover as an ecological community in lawns

In order to capture stormwater, infiltrate a fraction of it into the ground, evaporate a portion of it into the air, and at times discharge a part of it into the natural drain residents make sure that their social spaces around buildings are covered with a variety of herbs which include Catharanthus roses, Indigofera volkensii, Felicia muricata, Desmodium intortum, Dichondra repens, Begonia sp., Drymaria cordata, Richardia scabra, Zerbina sp., Oxalis cornuta, Pellaea viridis (fern), Oxalis latifolia. The rootstock of varied grass and herbs on the lawn consolidate the soil against erosion.(see Figure 6)

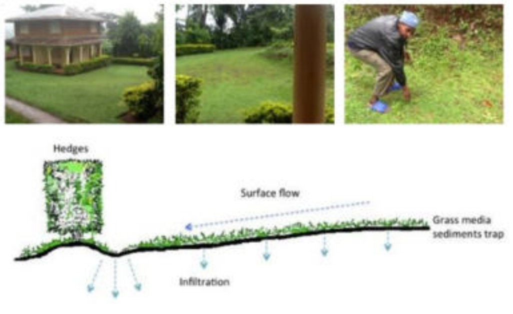

Figure 6: *Lawn at the compound of a resident in Kilema-Makame Chini village. On the right the resident showing composite plant species for the lawn naming them and their importance in local language (Chagga).* ***Source:*** *Authors, 2016*

Use of vegetative lawn borders with diverse plants instead of concrete curbstones

In order to make sure any discharge after capturing, infiltration, and evaporation is released from the lawn without any tresses of soil erosion and landslide, residents ensure that the social spaces are bordered by cascading canopies which are made up of trees, shrubs, low shrubs and herbs (See Figure 6). The boundary trees include Persea americana (English name, avocado), Bridelia micrantha (native name, mwarie), and Grevelia robusta (mwerezi). The boundary shrubs include Eriobotrya japonica (mwelio shrub), Micrococca trichogyne (low shrub) and Duranta repens (low shrub).

Use of vegetative property borders with multiple cascading canopies and thick varied low vegetation

The property boundaries are marked by a variety of plants with multi-level canopies which facilitate cascading and breakage of big raindrops into smaller drops as well as delay of the rainwater to the ground. Alongside the vertical movement delay, the momentum of the raindrops is significantly reduced and as they reach the strongly interwoven flora boundary at the ground level infiltration takes place. Moreover the multi-level canopies act as wind barriers for the coffee plant flowers and the slim banana plants (Figure 7).

Figure 7: Cascading canopy levels of plants defining territorial borders of individuals compounds. Source: Authors , 2016

The boundary trees include Albizia petersiana (mruka), Grevelia robusta (mwerezi), Persea americana (avocado), Bridelia micrantha (mwarie), Garcinia volkensii (muasai), Acacia mearnsii (wattle, mangoi), Trema orientalis (muengere), Eriobotrya japonica (muelimu), muisi, Commiphora zimmermannii (mfifina), Rauvolfia caffra (msesewe), and Olea capensis (mchio). The boundary shrubs include Toddalia asiatica (Mkananga), Eriobotrya japonica (mwelio), Bouganvilea spectabilis, Lantana camara, Bridelia micrantha, Macaranga kilimandscharia, Ficus sur, and Psychotria sp. Boundary low shrubs include Micrococca trichogyne, Turaea robusta, and Toddalia asiatica. Boundary herbs include Pellaea viridis (fern), Rubus rosifolius (climbing herbs-strawberry), Justicia flava, and Conyza bonariensis. Boundary grasses include Eragrostis tenuifolia and Eragrostis minor.

Living roads attained through the use of tough grass instead of pavement

In order to make sure stormwater is captured, infiltrated and slowly discharged by the roads, residents make sure that the portion of a road which is intended for intense use (vehicular and pedestrian movements is covered by tough grasses namely Eragrostis tenuifolia and Dactyloctenium aegyptium while the other portion which is not meant for intense use is covered by herbs namely Richardia scabra, Ageratum conyzoides, Galinsoga parviflora, Phylanthus amarus, Asystasia gangetica and Justicia flava and Kyllinga alba (sedge, ndago). At the edge of the road, Lantana camara shrubs are found. However, at the middle of the road there is roughly between 30 and 45centimetre wide bare footpath resulting from constant pedestrian movement (See Figure 8).

Figure 8:*Characteristic living roads of the area on fog-day.* ***Source:*** *(Authors , 2016)*

Conservation of the riparian landscape through native plants and natural landform The main vegetation of the riparian includes native and exotic trees, shrubs, high and wide leafed herbs, small herbs and grasses. Trees in the riparian include Grevillea robusta (mwerezi), cupresus lusitanica (cypress, mtarako), Eucaptus saligne (eucaptus, msonobari), Olea capensis (loliondo, mchiyo), Garcinia volkensii (muasai), and Syzygium intermedium (mzambarau mwitu). Shrubs in the riparian include Coffee arabica (kahawa), Croton macrostachyuns (mfurufuru), Markhamia platycalyx, Buddleia polystachya, Datura suaveolens (wide leafed shrub inside water), Ficus sur (mkuyu), Senna septemtrionalis, and Musa paradisiaca (banana, mgomba). Herbs in the riparian include Ageratam conyzoides (ifuna), Commelina bengalensis (ikengera), Pteris catoptera (fern), Pellaea viridis (fern), Rubus rosifolius (strawberry, mawero), Justica flava Conyza bonariensis, and Rubus rosifolius(strawberry).

Figure 9: *A thick riparian of Mae River.* ***Source:*** *Authors , 2016*

There are two types of riparian namely ravine riparian, and gentle riparian. The ravine riparian is morphologically narrow valleys or gorges or gullies or canyons or rift whatever deemed fit but is generally steep and dangerous for human inhabitation (see Figure 9). In some cases ravines are conserved as natural forests (see

Figure 9) while in other cases they are a mixture of natural and planted forests with exotic plants (see Figure 10). Ravines are mainly occupied by a thick mixture of trees, shrubs, low shrubs, herbs and grass which totally cover the entire land (see Figure 9) and thus capture and infiltrate storm water which eventually surface again in form of springs which are the major sources the existing rivers in the district.

Figure 10: *Riparian forest of natural and exotic trees of Mae River.* ***Source:*** *Authors, 2016*

The second type of riparian is gentle riparian which is basin like along the river. In most cases the area adjacent to the river is relatively flat while the furthest away areas are relatively steep. The steep slopes are planted with Digitaria sp. (nyasi) which has tough rootstocks which hold soil particles together and thus prevent soil erosion. The Digitaria leaves are cut and used as animal fodder and thatch while allowing another sprout. Gentle slopes are terraced into different small parcels with Zea mays (maize), Solanum tuberosum (Irish potato), Ipomoea batata (sweet potato), and Brasica oleracea (sukumawiki, cabbage sp). Flat terrain adjacent to the river is planted with Tripsacum luxam or (Setaria splendida, or Guatemala or steria) which is a remarkable animal fodder (see Figure 11).

Figure 11: *The Tripsacum luxam plants at the Riparian Forest of Mshiri River.* ***Source:*** *Authors , 2016*

Mulching of farms to capture stormwater

Mulching as a system of delaying stormwater which involves accumulation of dead plant material especially leaves and stems of different species which decay naturally. Mulch is corky in nature and thus captures stormwater, allow a portion to infiltrate, allow another portion to evaporate, allow another portion to be available for consumption by plants and the associated evapo-transpiration and steadily discharge the remaining into nature. Mulch in farms as well as in conserved forests and protected riparians is green manure that is self replenishing as it hosts plant species which include: **herbs** namely Oxalis cornuta, Justicia flava, Ageratum conyzoides, smilax anceps (climbing herb) and Pteris catoptera fern; **Shrubs** include Ficus sur (mkuyu), Macaranga kilimandscharia, Lantana camara and Commiphora zimmermannii (mfifina); and **trees** include Albizia petersiana (mruka), and Bridelia micrantha. The ground surface which is covered by mulch always wet and spongy and it acts like a carpet which controls excessive evaporation of the soil water content during the dry seasons. On the carpet we have cascading canopies which start with yam palm leaves underneath coffee trees; coffee trees underneath banana leaves; banana leaves underneath coffee shading trees which include Albizia petersiana (mruka), Grevelia robusta (mwerezi), Persea americana (avocado), Bridelia micrantha (mwarie), Garcinia volkensii (muasai), Acacia mearnsii (wattle, mangoi), Trema orientalis (muengere), Eriobotrya japonica (muelimu), muisi, Commiphora zimmermannii (mfifina), Rauvolfia caffra (msesewe), and Olea capensis (mchio)

Figure 12: *Mulching in farms as a typical practice to residents of the Kilema.* ***Source:*** *Authors, 2016*

In the conserved landforms and riparians, trees and shrubs generally grow in groves and rarely singly. Just like in the farms, multiple canopies break raindrops into tiny droplets, which eventually fall on the corky and spongy like soil cover, which captures stormwater and rainwater and allows gradual infiltration those surfaces as springs, which contribute abundantly to river waters. In the conserved landscapes as well as in farms, at any moment in time no soil surface is left bare and the moisture content is always preserved throughout the year.

Conservation of natural granite boulders, riverside rocks and riverbed sand

Besides conservation of riparian vegetation, there is conservation of geological profiles which include naturally set granite boulders in riverbeds which slow down water speed and allow deposition of sand

Figure 13: *Conserved steep slope riverbanks, undisturbed natural setup of boulders that check water flow speed and create succession of check dams along the river flow. This contribute to the beauty and biodiversity richness of the Mshiri river valley.* ***Source:*** *Authors, 2016*

Moreover, the shoulders of rivers are protected against tilling for farm produce in order to make sure that erosion is avoided. Moreover, sand mining in river beds is strictly prohibited. Therefore, river forms and natural elements are always conserved (See Figure 13).

Usefulness of plant materials beyond stormwater management creates sustainable environment

Generally, trees in Moshi Rural District play multiple roles including territorial marking, wind breaking, animal feed, production of fruits, wood, fuel, and mulch and tearing of big rain drops into droplets with practically low momentum and slow speed which easily ooze into the mulch and the underneath soil. Moreover, all the herbs, grass, shrubs and trees play multiple roles in the everyday lives of the natives. For example, all the herbs, grass used for stormwater management is also animal fodders. All the trees bordering the individual farms are also animal fodders and more than 50% are fruit trees for human use. Albizia petersiana (mruka), and Grevelia robusta (mwerezi) are hardwood trees suitable for construction and furniture. Moreover, all the trees are sources of firewood (See Figure 14).

Figure 14: *Guava tree one of many edible fruits of the Kilema and the setaria grass serving as environmental protectors and providers for food to natives and animals. The photo on the right shows some Setaria grass cut to feed animals leaving short stems for new germination.* ***Source:*** *Authors , 2016*

Conservation of riverbeds and riversides to ensure stormwater delay and resilience

Riverbeds and riversides are characterized with granite rocks and granite boulders of varied sizes and shapes on/or surrounded by sand which is strictly protected by the community against mining. The riverbeds are lined with varied native plants with strong interwoven roots which knit the soil particles together and thus prevent soil erosion. (See Figure 13)

Trapping of road stormwater runoff for irrigation

In Rombo District residents trap stormwater from roadside drains and direct the water into furrows which lead into swales in the adjacent farms.

Figure 15: *Meanders of swales in the farm for irrigation through storm water after being trapped primarily from the road side and from the roof tops of the owners house. Excess of stormwater chains to the neighbouring farms away from the roadsides. This is the typical practice at Shimbi in Rombo District.* ***Source:*** *Authors, 2016)*

The stormwater flowing in a series of swales is allowed to pond up and eventually infiltrate and automatically replenish the underground water and soil moisture content within the farms throughout the year See Figures 15.

The captured stormwater is rich in dark humus which improves fertility and water retention of the soil and therefore important for plant growth as demonstrated by observation in Rombo District (See Figure). In some cases, swales are dug along the green fences in order to ensure that tree roots are not tapping underground moisture content from the adjacent farm. By and large, this practice produces plausible farm produce. One of the respondents Mr. Priscus Basil Mramba ascertained that *when the swales are saturated with stormwater and there the surplus flow is directed to the neighbouring farms which are not lining the roads and this acts are abundantly appreciated by all parties*

Lessons gathered from the indigenous stormwater management practices are classified as follows:

Indigenous soil stabilization against stormwater erosion

Soil stabilization against stormwater erosion is one of the mandatory and cultural activities among the natives of the Moshi Rural District. Before independence (1961) it was the responsibility of the Chagga Chiefs to sensitize their citizens to bring about excavation of terraces, digging of stormwater channels, excavation of roads accompanied with greening, greening of sloping terrains and river banks and planting of farm-perimeter-trees as wind barriers. The instructions were given in the form of poems which were sung in wedding ceremonies and government celebrations

Chagga song	Translation into English language
Oh lale ulele ulele ulele *Mangi kawamba le waie* *Wasoro lukape* ***matuta*** *Matuta mali wa serikali* *Olale ulele ulele ulele.*	Bugle call to the community The Chief announces that Men should make **terraces** Terraces are public properties. Bugle call to the community.
Oh lale ulele ulele ulele *Mangi kawamba le wai* *Wasoro lusume* ***mfongo*** *Mfongo mali wa serikali* *Olale ulele ulele ulele.*	Bugle call to the community The Chief announces that Men should excavate **water canals** Water canals are public properties. Bugle call to the community.
Oh lale ulele ulele ulele *Mangi kawamba le wai* *Wasoro luwaye* ***mashiri*** *Mashiri mali wa serikali* *Olale ulele ulele ulele.*	Bugle call to the community The Chief announces that Men should **plant trees**. Trees are public properties. Bugle call to the community.
Oh lale ulele ulele ulele *Mangi kawamba le wai* *Wasoro lusume* ***parapara*** *Parapara mali wa serikali* *Olale ulele ulele ulele.*	Bugle call to the community The Chief announces that Men should **make roads**. Roads are public properties. Bugle call to the community.
Oh lale ulele ulele ulele *Mangi kawamba le wai* *Wasoro luwaye* ***kahawa*** *Kahawa mali wa serikali* *Olale ulele ulele ulele.*	Bugle call to the community The Chief announces that Men should **plant coffee trees**. Coffee trees are public properties. Bugle call to the community.

Likewise in the urban areas residents can be sensitized by their leaders and experts to make sure that all the earth surfaces which are not paved are covered with turf in order to delay stormwater discharge and improve infiltration for underground water recharge.

Mulching of farms through reuse of thinned and trimmed materials

One of the most dominant features of the Chagga native farms is a covering made from decaying plant leaves, twigs and barks normally used to get better soil, protect the roots of plants in oredr to retain a portion of the stormwater and to delay discharge of stormwater. Mulch is often obtained from trimming and pruning of banana plants, coffee trees and yams. Similarly through sensitization of the urban residents, mulch can without difficulty be deployed for soil erosion prevention, enhanced stormwater infiltration, and improved soil condition.

Conservation of riparians and minimal human interventions

Chagga natives through their local leaders were sensitized to vegetate the river banks, river valleys and the river beds. Sensitization was carried out through meetings and traditional songs which were commonly sung in wedding ceremonies and public holiday festivals. Residents were barred from cultivating the river valleys and steep slopes and compulsorily required to vegetate them for prevention of soil erosion and landslides by means of stormwater. In the 1970s and 1980s, the Kilimanjaro Regional Administration forcibly evacuated all the residents of the riparian areas and resettled them at Kilacha in order to give way for flood free green riparians. Evacuation and resettlement of the Dar es Salaam urban river banks and river valley settlers accompanied with effective vegetation cover may result into green fingers between human built environments or neighbourhoods and thus contribute to strong physical and environmental structures.

Multipurpose stormwater management

All the plant materials deployed to delay stormwater movement and eventually accelerate infiltration are also serving as vital sources of food for humans and fodder for animals. In the Moshi Rural District natives own small coffee and banana farms. 95% of the homesteads practice zero grazing whereby a family owns at least one cow, 5 goats and 5 sheep. Natives keep hens which let free to forage for food in the small farms. The plant materials for boundary setting, protection of fierce winds, edging the terraces and stabilization of the steep slopes and river banks as well as grass-ground cover are all sources of fodder, fruits and cooking fuel. It is apparent that there is a strong need of sensitizing urban residents to plant fruit trees, fodder grasses/shrubs/ trees, and trees for timber and fuel instead of planting trees just for the mere sake of stormwater management. Such an inclusive stormwater management practice may also contribute to enhanced environment, improved health, uplifted economy and ownership of the degraded and abandoned stormwater fields.

Affordable stormwater harvesting for irrigation

Farmers of Moshi Rural District channel stormwater from the road side drains to the adjacent farms and stored in a series of swales and any surplus is agreeably channeled to the adjacent farms. Stormwater harvesting for irrigation is currently a potential agent of food production and agricultural-economic growth. In Dar es Salaam City the allowable development densities are; 40% plot coverage for high density development, 25% for medium density development and 15% for low density development. Through sensitization on adherence to the development standards it is possible to avail land for diverse green stormwater management in both formal and informal settlements.

Native pragmatic codes

The natives of Moshi Rural Districts use inherent stormwater management skills which are employed by every actor and thus become part of the culture. Adoption of the stormwater management skills that work best for the natives produces a contextual blue print of pragmatic rural landscape architecture. The natives concentrate on critical stormwater management problems and the possible contextual solutions and benefits. The natives are open-minded and practical in addressing the challenges and opportunities of stormwater. Natives continuously revisit their management

practices in their everyday lives to the extent of attaining co-existence of residents and stormwater benefits. Local government guardians can sensitize urbanites to prioritize the far reaching nature based stormwater management in order to avoid the capital intensive engineering solutions. This article is not intending to glorify nature based stormwater management at the expense of engineering based stormwater management but rather advocate parallel stormwater control operations for comprehensive control at varied contexts, levels and scales.

Practices which cannot be applied in the urban setting

Total greening of roads in lieu of pavement cannot be applied in the urban settings because of the intense motorist and pedestrian uses of the urban roads. However, urban roads can be constricted to provide roadside rain gardens which depend on stormwater. Planting of trees and grass as an avenue of production of animal fodder is not practical in urban human settlements because land is scarce. In the rural settings, riparians are controlled by the owners of the farms and homesteads abutting them and therefore the aspect of maintenance is culturally addressed. In the urban settings riparians fall under the custody of the National Environment Management Council (NEMC) which does not have its eyes on the riparians and thus attract encroachment for informal development. Riparians can be surveyed, planned and sub-leased to potential investors who can run them as neighbourhood parks or regional parks. However, through advocacy and collaborative stormwater based planning, stormwater based landscape architecture and stormwater based urban design a real-life model of landscape urbanism can be realized.

Reflections

Use of diverse plant material for crop production and control of stormwater facilitates evapotranspiration, delay of surface runoff, infiltration, soil stabilization against soil erosion, and cool environment human health in the warm climate. The infiltrated water becomes favorable for underground water recharge, plants growth and biotic communities living beneath the earth surface. Moreover, infiltration, and discharge of surplus stormwater into rivers and creeks is further delayed through conservation of intercepting volcanic groins and sand. Additionally, the edges of rivers are vegetated with diverse broad-leaf plants and ferns with ability of maximum evapotranspiration.

The indigenous stormwater control practices successfully do away with threats of floods through nature conservation, imitating nature, promoting infiltration, and safe conveyance of the surplus to the natural drains. In this investigation it was evident that stormwater can safely replenish and improve underground water through filtration.

Landscape based stormwater control engage in the use of vegetation as holistic measures of control. During rainfall on vegetated land, prior to reaching the earth, raindrops are intercepted and captured by plants-canopy leaves, branches, trunks, shrubs and grass cover that keep hold of a cumulative volume of rainwater. Rainwater before trickling down the tree trunk surfaces to the ground, or evaporate prior to hitting the ground is accumulated momentarily on canopy leafs and bark surfaces. Through the use of mulch and grass cover, direct soil evaporation is denied access and thus renders to sufficient utilization of stormwater for vegetation growth. "Water that evaporates directly from the soil surface, lessens the quantity of subsoil water, thus renders to little utility for crop production." Mulched and/or grassed soil performs as an insulating layer and thus receives much less energy than a bare soil as surface residues, thence less evaporation. The application of stormwater control through a network of green roads, green territorial buffers, terracing, mulching, planting the slopes and riverbed sides, restoration and protection of riverbeds against sand and stone mining, and trapping road stormwater in swales for irrigation are consistent and rational. The use of natural treatments is the precursor of enduring green infrastructure in the rural areas in Moshi Rural District.

The repeatedly used cultural landscape based stormwater control practices produce similarity amongst landscape entities and regional identity which can be termed as vernacular stormwater management, The indigenous green practices and skills can adopted or modified to suit urban stormwater management systems and straightforwardly contribute to urban green infrastructure and the associated benefits, for example, climate change mitigation and adaptation, urban green architecture, landscape urbanism and urban landscape based stormwater management.

In Moshi Rural District one cannot easily see the frontier between natural and manmade landscape as the two are closely fused together. This notion can easily inspire Landscape Urbanism theory of urban planning arguing that, the best way to organize cities is through the design of the city's landscape, rather than the design of its buildings. Agata Zachariasz, advocates that *"landscape urbanism assumes that the best manner of planning and organizing the structure of a city consists in designing of the landscape thereof rather than buildings"* Zachariasz (2014:340). Turner, (1996) predicts that, *"the city of the future will be an infinite series of landscapes: psychological and physical, urban and rural, flowing apart and together."*

The way indigenous residents holistically conserve the natural landscape and imitate natural landscape in their daily agricultural and stormwater control practices produce enduring and sustainable landscape which can easily linked with the notion of functional art. According to Weller, (2008), landscape urbanism *shifts the landscape architectural project from an art (or craft) of making beautiful landscapes to one of interdisciplinary negotiation and the seeding of strategic, development processes*.The innate landscape based stormwater control skills and practices reside in residents' processes of existential experiences and therefore culturally accepted and owned. Weller, (2008) argues that the project of landscape urbanism, apart from being naturally linked to the landscape art experience, it formulates a process rather than a plan. This means that landscape based transformation dwells on the course of action rather than planning for academic authorship. This is a type of revolution that anticipates "change, open-endedness and negotiation" (Corner, 1999) in Waldheim, (2006).Therefore, in order to attain optimal landscape performance and appearance one must involve residents' lived experiences through collaborative planning and design charrette. In so doing urban development actors/champions through design charrette will learn and practice low-key but effective techniques of stormwater management as a supplementary method to curb floods and other stormwater associated challenges in the urban setting, while enhancing livelihood, aesthetics and better living environment. In order to avoid flooding, residents capitalize on conservation and consolidation of natural systems. "*The loss of natural systems increases the risk of flooding and natural disasters"* Benedict, and McMahon, (2001).

Indigenous landscape based stormwater control takes on board use of locally available materials, customary concepts, hands-on demonstrations, and functioning techniques. Corner, (1999), urges the advocates of landscape urbanism to consider traditional concepts, representations, operative techniques and ability to adapt these techniques to the environment that they are in. He further argues that "the collective imagination, informed and stimulated by the experiences of the material world, must continue to be the primary motivation of any creative endeavor (Corner, 1999). The way Moshi natives survive through giving way to nature in their daily life activities and stormwater control reflects Power and Sekar's (2011) assertion that "*a sustainable landscape is one that aspires to be resource self-sufficient and yield significant reductions in resource consumption and waste production while enabling the built landscape to support some natural ecological functions by protecting existing ecosystems and regenerating some ecological capacity where it has been lost.*" Since the native landscape based stormwater control practices have shown ability to stabilize soil against soil erosion, prevent flooding and adapt to stormwater associated stress we can term such practices as resilient practices. Right through the case area, landscape based stormwater control exhaustively demonstrates ability to retain the natural landform, landscape meanings, composition, and distinctiveness. Walker looks at "resilience" as the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks (Walker et al., 2004). Susan Braatz defines the strength of the word "resilience" as the ability to cope with stress, the capacity to recover from the effects of disturbance and the capability to adapt to stress and change (Braatz, 2012). All the native stormwater control practices effectively handle surface runoff without destruction of landform, vegetation, soil quality and underground water balance and thus stormwater resilient.

The native landscape based stormwater control and the associated benefits such as livelihoods, fuel, and livestock fodders have resulted into resilient landscape systems. According to Suzan Braatz, *"working at the landscape level is conducive to building resilience of land-use systems, natural resources and people's livelihoods in a cohesive way....."*Braatz, (2012).

Landscape based stormwater control is taken as a starting point for any individual or community development on the ground in Moshi Rural District. The environmental impact of landscape based stormwater control is negligible and thus brings up dominance of green fields. It is the usefulness of the green fields to the residents that produce a sense of affinity to naturalness and residents sense of ownership and respect to the enduring stormwater based rural landscapes. The application of natural methods exceedingly demonstrates maximum strength in coping with the increasing runoff volumes without employing engineering techniques. Stormwater control is not understood as a liability but rather as an avenue towards integrated cultural, economic, environmental and utilitarian benefits. Moreover, stormwater control is hinged on plants' ecology, flora and fauna ecology, and eco-system benefits. Indeed, the applications of natural stormwater control are water sensitive and low impact developments.

It is evident that stormwater is the real life means of livelihood and environmental sustenance in Moshi Rural District. Use of diverse plant material for crop production and control of stormwater facilitates evapotranspiration, delay of surface runoff, infiltration, soil stabilization against soil erosion, and cool environment human health in the warm climate. The infiltrated water becomes favorable for underground water recharge, plants growth and biotic communities living beneath the earth surface. Moreover, infiltration, and discharge of surplus stormwater into rivers and creeks is further delayed through conservation of intercepting volcanic groins and sand. Additionally, the edges of rivers are vegetated with diverse broad-leaf plants and ferns with ability of maximum evapotranspiration.

Indigenous landscape based stormwater control takes on board the use of locally available materials, customary concepts, hands-on demonstrations, and functioning techniques. Native landscape practices have shown ability to stabilize soil against soil erosion, prevent flooding and adapt to stormwater associated stress and thus qualify as resilient practices. The landscape based stormwater control and the associated benefits such as livelihoods, fuel, and livestock fodders have resulted into sustainable and resilient landscapes. Indeed, the applications of natural stormwater control are water sensitive and low impact developments.

The stormwater based correlation between landscape endurance and social welfare and the link between ecological reliability and socio-economic benefits orchestrated by Rural Moshi District natives are also underpinned by theorists of landscape sustainability. Wu (2013) states that "*An increasingly dominant view is that biodiversity, ecosystem processes, and ecosystem services are to be sustained, human well being (including economy) are to be developed and thus these two kind of processes are to be closely linked*". In emphasizing further the link between landscape sustainability and development, Forman (1995) who states: "*A sustainable landscape is an area in which ecological integrity and basic human needs are concurrently maintained over generations.* In the same line of thinking Haines-Young (2000) underpins that "*a sustainable landscape is one in which the sum of the benefits (goods and services) people derive from the landscape area are maintained. It is also one in which our liabilities do not increase.*" The cultural stormwater based landscape comprehensively replicates Selman's (2007) characteristics of landscape sustainability which include "*ecological integrity and cultural legibility... and the capacity to reproduce simultaneously, their forms, functions and meanings.*" *Selman's key words are "self regenerative capacity of landscapes; cultural legibility of landscape patterns; and cultural identity and character.*"

The overarching stormwater based landscape sustainability experienced from Rural Moshi District natives is brightly explained by Wu's (2012) assertion that land*scape sustainability is 'the capacity of a landscape to maintain its basic structure and to provide ecosystem services in a changing world of environmental, economic and social conditions."*

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