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Assessment of the Soil Information and Analysis of Related Land Constraints to the Selected Detailed Town Planning Schemes in Morogoro Municipal

Dickson B. Pori[1]*, Proches Msigula[1], Hussein Boniface Massawe[2]

[1]Department of Agricultural Engineering, Sokoine University of Agriculture, Morogoro, Tanzania
[2]Department of Soil and Geological Sciences, Sokoine University of Agriculture, Morogoro, Tanzania
Email: *dicksonpori@yahoo.com

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Abstract

In Tanzania, land use and planning are under the land authority. They are responsible for ensuring sustainable land use and management in urban and rural areas. Nevertheless, lack of adherence to the soil to detailed soil properties and land use constraints by urban planners, urban explosions in different areas in Tanzania, particularly Morogoro have been a big issue of concern as it poses danger to the environment and also to themselves as urban areas they are also vulnerable to land use constraints such as flood, erosion, water logging, erosion hazards and rock outcrop. This study aims to assess the available soil information and analyze land constraints related to the Selected Detailed Town Planning Schemes in Morogoro Municipal so as to address failures of the current urban planning approach. Detailed soil information provided by the municipality and literature of previous studies were accessed. A total of six land use constraints: poor drainage and waterlogging, rock outcrop, erosion hazard, flood hazard, soil depth and surface slope were analyzed in this study to map major land use constraints in the study area. A geospatial analysis approach was used to combine these constraints so as to map total land use constraints and asses the spatial distribution of the constraints. Finally, detailed land use schemes accessed from the Morogoro land management authority were digitized and overlayed on the constraints map. Detailed schemes approved in areas of Mkundi have shown to be a success as these areas have the lowest land use constraints whilst areas of Kilakala, and Mlimani has been a failure due to high slope, erosion hazards and shallow soil, the middle part of Morogoro including the new Kingalu market have been a failure and costly due to flood and water logging mitigations.

Keywords

Soil-Related Constraints, Sustainable Urban Development, Remote Sensing Applications

1. Introduction

The effective and sustainable planning and designing of the use of urban land need overlaying each land unit condition with the specific usage fit on that land site conditions (Mozumder & Tripathi, 2014). In Tanzania, planning procedures are guided by the urban planning legislation which requires the development of a general planning scheme to direct urban development (Halla, 2002). Recent adjustments have seen technicians and consultant firms collaborating with government departments concerning urban development such as land, environmental and natural resources departments to develop detailed urban planning schemes which embodied the regional Master plan scheme (Kimbi et al., 2001; Ram et al., 2017).

In Morogoro urban, like other Tanzania urban areas, the detailed schemes have been prepared with the specific requirements and potential impacts of different land uses. Collaboration between multiple government departments and consulting firms has made the process of urban planning in Tanzania a rather participatory process with multi-stakeholders involvement (DECCW, 2010; Di Martire et al., 2012). This participatory approach to urban-wide planning is based on the adoption of the concept Strategic Urban Development Planning Framework (SUDPF) which stands for priority sets and dynamism in the decision-making process regarding the planning process (Major et al., 2002; Kruglanski et al., 2018). With the SUDPF concept preparation and executions in the planning process relays on the interpretation of the legal land guidance and requirements for the case of Tanzania is the Tanzania Land Act of 1999 (Semko, 1997).

Consultation of multiple stakeholders enables the assessment of various factors that influence land use dynamics and suitability (Li & Yeh, 2000). This participatory approach enables the identification and considerations of the ability of the particular piece of land that can be described as the physical characteristics of land to safely and effectively support land use without degradation of land, water and other natural resources.

Assessment of physical characteristics of the land on supporting the land uses that is, assessing the uses which best fit between the physical requirements of the use and the physical qualities of the land, the potential hazards and limitations associated with specific uses on specific land, the inputs and management requirements associated with specific land use (Wang et al., 2019; Zambon et al., 2018). This information is most important to land-use planners in land management authorities (Halla, 2005). They assist in the initial urban and regional planning processes. It also aids in decisions making to granting consent to development applications and apply accompanying conditions. The information will assist land managers and advisers, including local government bodies, catchment management authorities and farmers to identify appropriate specific uses and intensity of use (Lusugga Kironde, 2006). It will also assist development proponents and consultants in determining project feasibility, appropriate design and necessary environmental impact control measures.

Morogoro Municipal Council is the capital district of the Morogoro region, Tanzania. This municipality contains over 440,109 inhabitants within a 540 km^2 region. The population growth rate (2002-2012) of Morogoro Municipal is 3.5% per annum contributed largely by the birth rate and until most recently by immigration from Dodoma and Dar-es-Salaam rapid urbanization (Shao et al., 2020; Simon et al., 2020).

Urban expansion and built-up area are directly proportional to the population increase (Hanjra & Qureshi, 2010). Studies on Morogoro urbanization have revealed that population expansion is correlated with urban development. Simon et al. (2020) used built-up area expansion as a parameter for the analysis of the urban expansion rate in Morogoro Municipal, the results of this study concluded that built-up area was the only land use class that was constantly expanding at the expense of other land cover classes such as cultivated land, woodland and forest covers.

Furthermore, studies on the quality and condition of urban settlements around the globe have revealed that disasters that plague most urban settlements have been implicated by human-induced factors as much as it is naturally occurring factors. The most convicted human-induced factor is poor planning of the urban land use distributions. In Morogoro Municipal, poor urban planning has been caused by the inaccessibility of the land constraints information and other land disaster-related information (Ashagre et al., 2018; Sumari et al., 2019). In that case, the reliability and availability of the land capability information will improve the decision-making process of the land use officials in Morogoro and consequently, the condition of the municipal will be improved.

This study was designed to make soil information and soil-related constraints available for the land officials and urban planners in Morogoro Municipal by integrating the existing town planning schemes and the analysed soil-related constraints and information. Specifically, the objective of this study is two-fold.

1) To assess the available soil information and the existing Detailed Town Planning Schemes, and

2) To analyse and map soil-related constraints within the selected town planning schemes.

2. Empirical Literature Review

According to the book of Environmental Land Use Planning and Management by John Randolph, 2004 Introduce the broader concepts of environmental planning and describe management approaches these approaches include collaborative environmental management, land conservation, environmental design, government land use management, natural hazard mitigation and ecosystem and watershed management.

Part II of the book focuses with land analysis methods these method includes geospatial data and geographic information system, soil, slope analysis, assessment of storm water quality and quantity, land use and ground water protection, ecological assessment for vegetation, wetland and habitats and integrated analytical techniques like land suitability analysis, carrying capacity studies and environmental impact assessment. In the management of land use, John suggested the increase of state, county and municipal government roles in management of urban growth through zoning and innovation performance standard for controlling the location and impact land development to the environment.

According to Hounjet (2006) nowadays, most of urban development occurs in areas where soils are weak and heterogeneous. Hence, they conducted a pilot study for a location near Rotterdam showed that when engineering-geological information is integrated in the planning process, sensitive structures like roads and sewers can be allocated in areas where soil conditions are relatively good. Maintenance costs for sensitive structures decrease considerably.

The study is based on the use of GIS to combine different qualities of soil and characteristics of structures (roads, sewers, parks, industrial areas and houses). For each structure the best engineering geological locations are indicated and this information is used to create an optimal urban planning design.

The methodology of using soil conditions in urban planning is quite simple and appealing. It must be noted that land use planners and all stakeholder of lands have to take into account more serious on the issue of soil characteristic. However, the consequences of ignoring this information can be disastrous when a municipality has to deal with endless maintenance costs for roads and sewers.

According to Joerin and Marius (2000), Land-use planners often make complex decisions within a short period of time when they must take into account sustainable development and economic competitiveness. A set of land-use suitability maps would be very useful in this respect. Ideally, these maps should incorporate complex criteria integrating several stakeholders' points of view. To illustrate the feasibility of this approach, a land suitability map for housing was realised for a small region of Switzerland. Geographical Information System technology was used to assess the criteria requested to define the suitability of land for housing (Payet & Obura, 2004). The use of Geographical Information Systems (GIS) and Multi Criteria Decision Analysis (MCDA) can help planners handle this complexity.

The recent literatures complete proposing the combining GIS and MCDA which meet the above mentioned objectives either partially or entirely.

3. Methodology

3.1. Description of the Study Area

3.1.1. Location

The study area is Morogoro Municipality which is one of the nine districts in Morogoro Region the municipality is the capital of Morogoro region with 29 wardsand it cover 260 square miles which is 0.74% of the total area of Morogoro region (Matthews et al., 2008). The recently estimated population of Morogoro urban is approximate to 440109 with the growth rate of 3.85%. Population increase goes in hand with urban expansion and human development which may take various forms in which for the case of Morogoro Municipal linear and nucleated settlements have been major form of urban development with few cases of scattered settlements (Sumari et al., 2020).

The study areapresented in **Figure 1** was selected because of its property been the centre joining the National Business City (Dar-es-Salaam) and Capital City of Tanzania, Dodoma, making it most likely to grows exponentially particularly intensified due to Rural-Urban migrations (Gillah et al., 2014).

3.1.2. Topography

The topography of Morogoro Municipal is quite interesting, dominated and influenced with the Eastern Arc Mountains especially Uluguru Mountains which

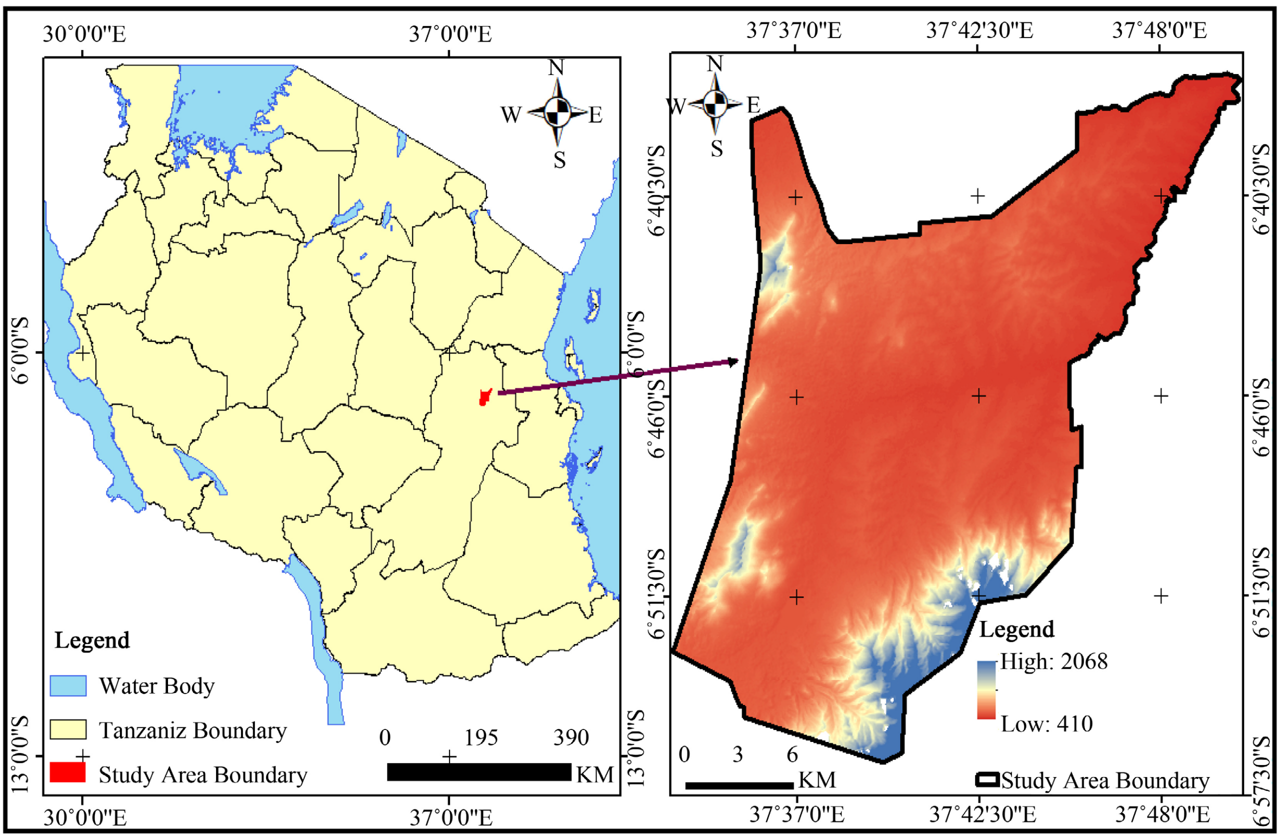

Figure 1. Study area.

are accountable for the steep slopes and drainage patterns in the area. The mountain's peaks are green suggesting undisturbed forest ecosystem, whilst slopes are fertile and have nice weather the hill foots are exploited for agriculture and human settlements. This topography also influence land form features, soil depth and texture in which steep slopes have characterised with rock outcrops and very shallow soils compare to flood plains on the flat surfaces.

3.1.3. Land Use and Development

The most dominant land use classes Morogoro Municipal are woodlands and forest which nevertheless are endangered to be replaced by urban settlements and agriculture classes as studies suggests a huge expansion from 2000-2016 by 2.86% to 8.02% for urban settlements respectively (Makwinja et al., 2021; Sumari et al., 2019, 2020).

3.1.4. Climate

Morogoro Municipal is along the equatorial zone. Being a tropical region, Morogoro experience bimodal rainfall seasons. A heavy rain seasons are locally called *Masika* dominating late March to early May and the light rain seasons are locally called *Vuli* normally between Novembers to December.

3.2. Data and Data Source

The study used the Landsat images which were sourced from the USGS site (https://www.usgs.gov/, repossessed on August 03, 2020) acting as the main foundation of the data for the enduring land constraints indication for the study areas, covering the four eras for four decades (1990, 2000, 2010 and 2020). Cloud correction and Multispectral Scanner (MSS) Satellite images and cloud free Thematic Mapper (TM) and the Enhanced Thematic Mapper (ETM+) satellite images that improved the resolution of the images into 30m by 30m (**Table 1**).

Table 1. Data and data source.

Data	Source of the Data	Description of the Data
Soil	Global soil database by FAO www.fao.org/land-water/land	Soil characteristics
Weather	Tanzania Meteorological Agency (TMA)	Rainfall, temperature, humidity, pressure
Satellite imagery	USGS Earth explore website https://www.usgs.gov	Landsat 8
River streams shapefile	Tanzania National Bureau of Statistics (NBS) (https://www.data4sdgs.org/partner/national-bureau-statistics-tanzania)	Extracted using ArcSWAT Water bodies shapefile
River Basin Parameters	Wami-Ruvu basin Authority	For Wami river

Data processing and extraction such as band composition, mosaicking of the images, image re-projection and re-sampling was performed using the image processing image known as ERDAS imagine 2015 and ArcGIS 10.5 before the whole process of analysis. A void filled Digital Elevation Model (DEM) and the Landsat 8 images were masked and geometrically corrected to Morogoro Municipal boundary. Additionally, the summary of the body breakdown methodologies is in Figure 2.

3.3. Assessment of the Available Soil Information and the Existing Detailed Town Planning Schemes

The assessment of the soil information was done by reviewing the available data of the Morogoro soil properties as provided by the Tanzania National Bureau of Statistics (NBS) and the study output by Msanya et al. (2001). The acquired information is summarized in Table 2 based on the dominant landforms, relief, parent rock materials, and the morphology and chemical properties.

Detailed Planning Schemes (Town Planning Drawings) of selected neighbourhoods were scanned. Images covering the period between 2010-2020 of registration and approval were collected from regional office of lands, in JPG and TIF format planning division of Morogoro region.

The detail planning schemes of the selected neighbourhoods were organized and Georeferencing using qgis plugin (georeferencer). The images were Georeferenced in Projected Coordinate System of Arc_1960_UTM_Zone_37S based on the coordinate's grids within the drawing map to lie within the boundary of Morogoro urban wards. The Georefenced images were then converted from

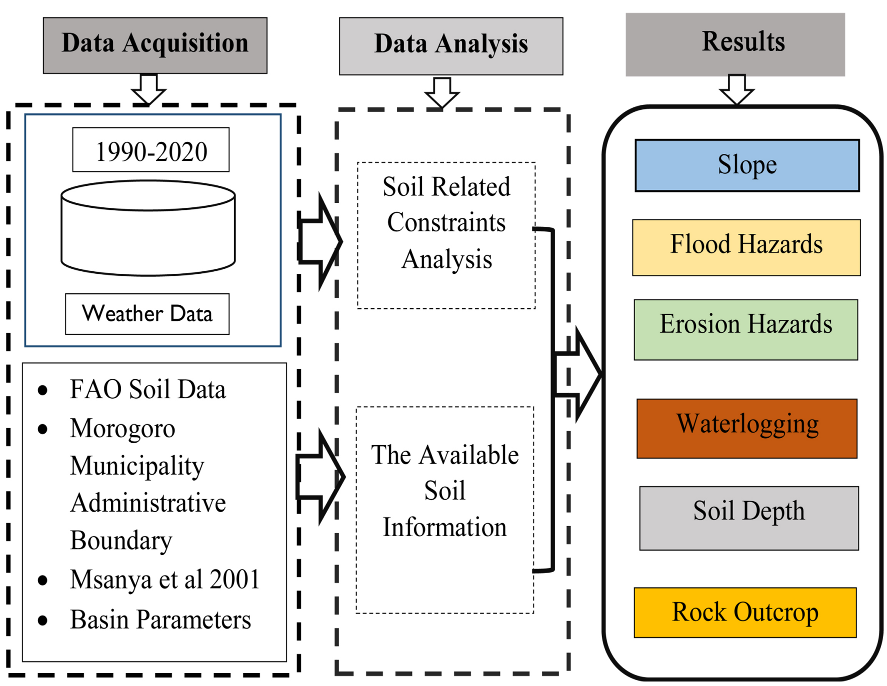

Figure 2. Methodological flowchart (Gillah et al., 2014).

Table 2. Soil information summary.

Name	Description
Mountains	• These are soils developed on hornblende pyroxene granulites with some banded pyroxene granulites • Developed on muscovite–biotite migmatites
Piedmonts	• Developed on colluvium derived from hornblende pyroxene granulites and micaceous gneiss • Developed on colluvial/alluvial deposits derived from pyroxene granulites and micaceous gneiss • Developed on colluvial/alluvial derived from biotite muscovite migmatites.
Peneplains	• Developed on muscovite biotite migmatites • Developed on colluvium with variable mineralogical composition • Developed on muscovite biotite migmatites
Valleys	• Developed on alluvial-colluvium with variable mineralogical composition

hardcopy to digital data through digitization process in arc map and create a vector line data for all hardcopy of the scanned images.

3.4. Analysis of the Soil-Related Constraints within the Selected Town Planning Schemes

Land constraints assessment is done in such a manner that will provide information about the physical potential of the soil and its sustainability to support a particular land use activity without jeopardizing water and land resources and considering the cost of improving particular Land constraints. The assessment considers two key principles which are risk management and quantitative cost (Rizwan et al., 2009). Soil factors surface slope, erosion hazards, water logging, flood hazards, rock outcrop, and soil depth were considered in this study in order to determine Land constraints in each area of Morogoro Municipal. In this study, acquired data were analysed and processed in ArcMap 10.5 and Google earth engine to map various land constraints respectively poor drainage or waterlogging, shallow soils, and the mainly as described on the sub-sections below (Maas et al., 2019).

3.4.1. Surface Slope

According to this study, one of the key factors influencing the primary soil quality and properties is the surface slope.

Land use activities and planning depend on the slope of the surface area. In Morogoro Municipality land use activities appear to be becoming more difficult due to the increase in slopes (Idiong, 2007).

In the research area, it appears that steep slopes make many human activities more difficult; therefore, development in steep locations requires leveling down and slope stabilization during site preparations prior to building construction (Anand & Oinam, 2020). Because the locations are difficult to access, moving heavy loads or machinery becomes almost certainly impossible.

In this study the Digital Elevation Model (DEM) was used to derive the slope of Morogoro in percentage Municipal using slope calculation spatial analysis tools in ArcGis 10.5 software.

3.4.2. Erosion Hazards

Erosion problems in Morogoro Municipality are concerned with many land use activities as it involves the removal of the topsoil from one place and deposit the soil particles elsewhere. The major agent of erosion is water in form of surface runoff although there are other factors such as soil type, rainfall intensity, slope gradient, land management practices and soil cover determine the susceptibility of an area to erosion effects (Nortcliff, 1982).

In the erosion site, the removal of the topsoil renders the remaining area less fertile and less productive which also damage roads, crops, and buildings. Depending on the nature of the deposition site, deposition of the eroded soil particles may block river flow, decrease water dam capacity furthermore it may increase risk to flood especially on river banks and dam walls (Melesse et al., 2007).

Soil susceptibility map of Morogoro Municipal was derived from the acquired soil hardness information by the soil database of Morogoro Municipal.

3.4.3. Flood Hazards

In the study, area Flooding may occurs in various forms including flash flooding on narrow valleys of the hill surface, riverine flooding which occurs in more extensive floodplains and lastly coastal flooding dominant on the low lying coastal lands. The occurrence of the flood may damages the crops, buildings and other assets. Floods are threat to human health and human lives in Morogoro Municipality are in danger in the period of flood (Dodds et al., 2006).

3.4.4. Rock Outcrop

Rock outcrop also is an enemy to agriculture and plant growth as it takes up the soil materials making an area less potential to plant growth and cultivation. Cultivation in the rock outcrop is doomed to less crop yield and pasture output per unit area of a land (Emamgholizadeh et al., 2005). Data for the rock outcrop were classified into two classes depending on the data derived from the soil survey data of Morogoro. The two classes are observed outcrop and not observed rock outcrop.

In summary, the evaluation of soil information is to bring a proper attention to the quality of urban soils, their multiple functions and the supply of ecosystem services to the urban population, as the study will raise more awareness about the advantages of soils in the built-up environment, which will integrate the knowledge of urban planning while focusing on the other side of the coin which regards the assessment of the soil constraints. The soil information has been the vigorous module in the planning processes, shimmering directly upon the land use appropriateness (Majekodunmi et al., 2020). However, this integration of the concept in the study area is capable with the presence of the advanced Geospatial Information Science (GIS) and Remote Sensing (RS) techniques which have been found to be useful in addressing the soil constraints. Soil is an important natural resource of which the prolific budding is limited by its fundamental characteristics. Additionally, both the soil constraints and soil information are important for urban planning and management, urban agriculture and to the policy and decision makers (Parida et al., 2008).

4. Results and Discussion

4.1. The Available Soil Information

A general summary of the soil information as provided by Msanya et al. (2001) is presented in **Table 3**. Additionally, in the same study done by Msanya et al. (2001), a total of 25 sample points were studied to analyse the details of the soil properties including the soil pH, texture, organic matter content, chemical properties such as chemical contents and the soil profile of Morogoro. 18 of these sample points are regions of Morogoro Municipal (**Figure 3**).

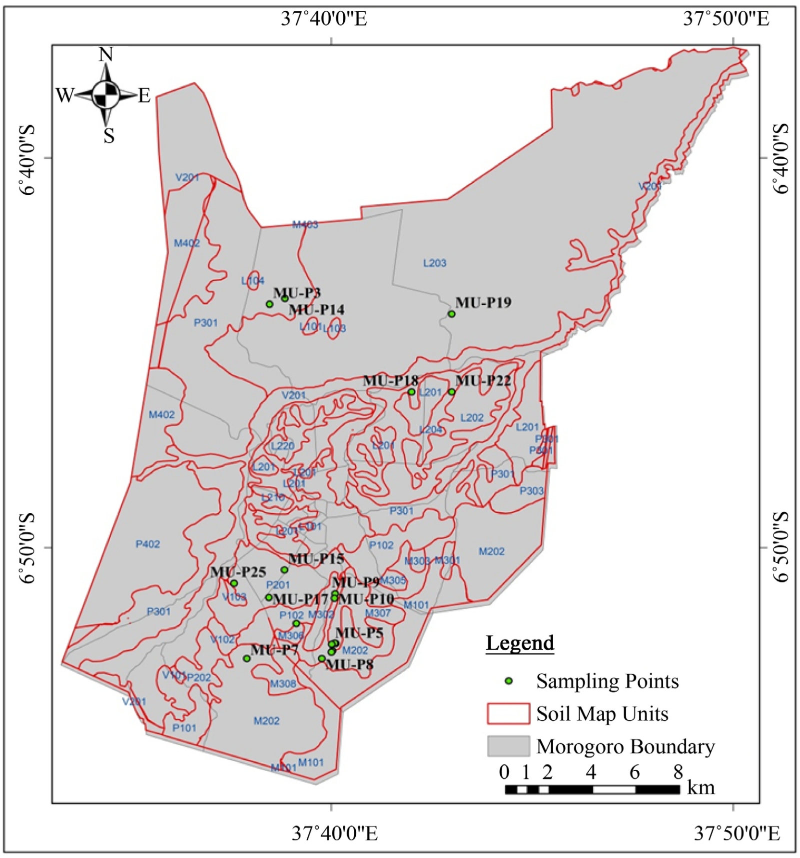

Figure 3. Soil sampling points.

Table 3. Analytical data summary of the soil profiles of various sampling points.

Sample Point	Description
1.	The Major Parent rocks are hornblende pyroxene granulites and gneiss. A mountainous area with a convex Slope of 49%. Stones occupies 10% and the major Erosion types are Inter-rill/sheet/gully/landslide; The area is Well drained.
2.	The soil of an area is yellowish brown deep. The soil profile is well divided into three distinct horizons. Steep slope makes erosion a dominant process on the area and less deposition effects Sandy clay texture is the main texture.
3.	The major composition of the soil is Banded muscovite biotite sediments and superficial sands. Isolated hills make up the dominant landform of an area. 80% slope accounts for the shallow with only two horizons on the soil profile. The soil well drained and slightly weathered rocks.
4.	An area is characterised with a very gentle slope making the soil deeper and poorly drained. Parent rock is dark yellowish brown colluvium.
5.	Biotite gneiss-pyroxinegranulites rock makes up a parent rock. Most dominant landforms are mountainous 55% slope accounts for landslides and erosion activities.
6.	Colluvium rock makes up a parent rock. Landforms are mountainous with slope 65% making an area prone to erosion and rock outcrops. Soil profile is dominated by the sandy clay loam texture
7.	The major landform is Colluvium and the soil is located in mountainous areas. 21% slope accounts for the erosion activities in an area. Cultivation activities by human is the main cause of the increased soil depth for this dark greyish brown soil
8.	A colluvium made lower slope soil feature. 9% slope accounts for the less erosion soil, moderate drainage and a well deep soil.
9.	A mountainous landform with mud clay colluvium over pyroxene granulites parent rock. A complex middle slope of 32% accounts for the severe erosion and well drainage system.
10.	Soil made of a mud clays colluvium over pyroxene granulites parent rock. A middle slope of 32% accounts for the well drainage system and inter-rill, rill, gully erosion activities on the topsoil. A variant of colour particles ranging from red to dark red and dark brown.
11.	Soil particles originated from colluvium mainly mud clays derived from hornblende pyroxene granulites and micaceous gneisses. Hilly landforms with an upper middle slope class 15%. The soil is very deep and a well-drained A surface characteristic of a rock outcrop.
12.	Landforms classified as Strongly dissected ridge crests and slopes. Soil particles made of Horblende pyroxene granulites with some banded pyroxene granulites. Erosion dominated surface activities. Deep soil ranging from strong brown to dark brown soil.

Continued

13.	A dominant landform classified as alluvial fan. Soil particles made of Colluvium derived from horblende pyroxene granulites. The soil is well drained very deep and a slight convex slope of 10%. Yellowish red to deep red soil clays soil dominate an area.
14.	Soil made of sediments from Banded muscovite biotite and superficial sands The dominant landform is alluvial fan with a lower convex slope of 6%. A soil is reddish brown very deep and a well-drained
15.	A low slope (3%) area characterized with nearly flat crest on a peneplain landforms. A deep soil with deposition activities due to low slope with colluvial deposits. The area is excessively drained with pale brown to yellow sand deposits on the topsoil.
16.	A moderately shallow soils with slight sheet erosion and cullovial deposits Gneiss constituents the mother rock, almost flat crest on a peneplain landforms on the middle slope (1%) Brown sandy clay loam texture topsoils.
17.	A middle slope area with flood plain as the dominant landform. Soil particles originating from mixture of alluvial and coluvial deposits. It is a dark brown imperfectly drained and a very deep soil.
18.	A flat terrain surface with a middle slope of 0.5% accounting for the deposition activities. Alluvio-coluvium is the parent rock in form of Alluvio-coluvial deposits. The soil is well stratified, deep and imperfectly drained Brown clay soil deposits dominates

Analysis was done with respect to various horizons of the soil profile. Report of the detailed soil properties is summarized in Table 3.

4.2. Analysis of the Available Soil Data

Analysis was done on the acquired soil data to determine the relative dominance and distribution of various soil types and soil features. Percentage coverage per unit area of a various soil features were calculated from R studio software to determine the most dominant soil features in the study area. Figure 4 shows that Ridge crests and ridge slope features are the dominant soil features in Morogoro Municipal. There is few number of rivers in Morogoro Municipal, the major one been Ngerengere which is not all year around river thus the formation of river terrace is far less regular resulting to a very small area coverage by river terrace (0.4%).

The most area of Morogoro Municipal in dominated with gentle slope especially the northern and central areas of the municipal. It is in these areas where ridge crests and slopes soil features dominate (Figure 5).

4.3. Soil-Related Constraints within the Selected Town Planning Schemes

In this study, a synoptic coverage of remotely sensed techniques was used to study the Land constraints in the study area. The layers were reclassified into the class of five respectively to the rise of the detrimental effects of each feature,

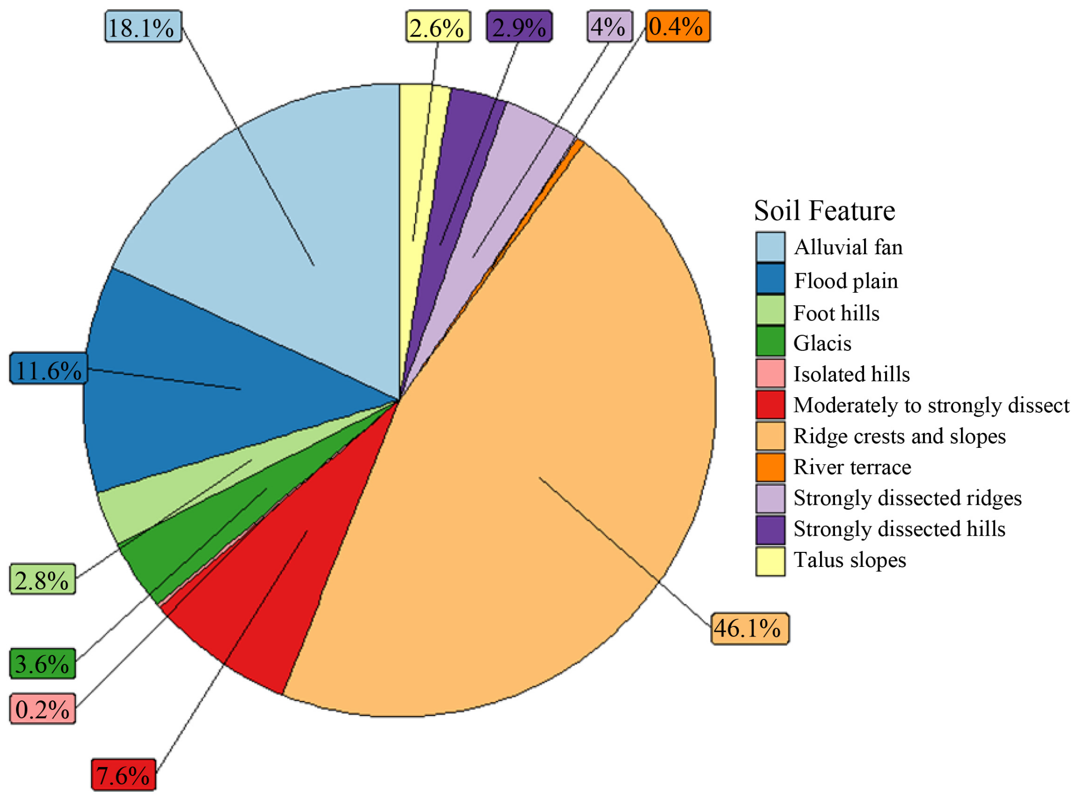

Figure 4. Percentage area coverage of available soil features (Obialor et al., 2019).

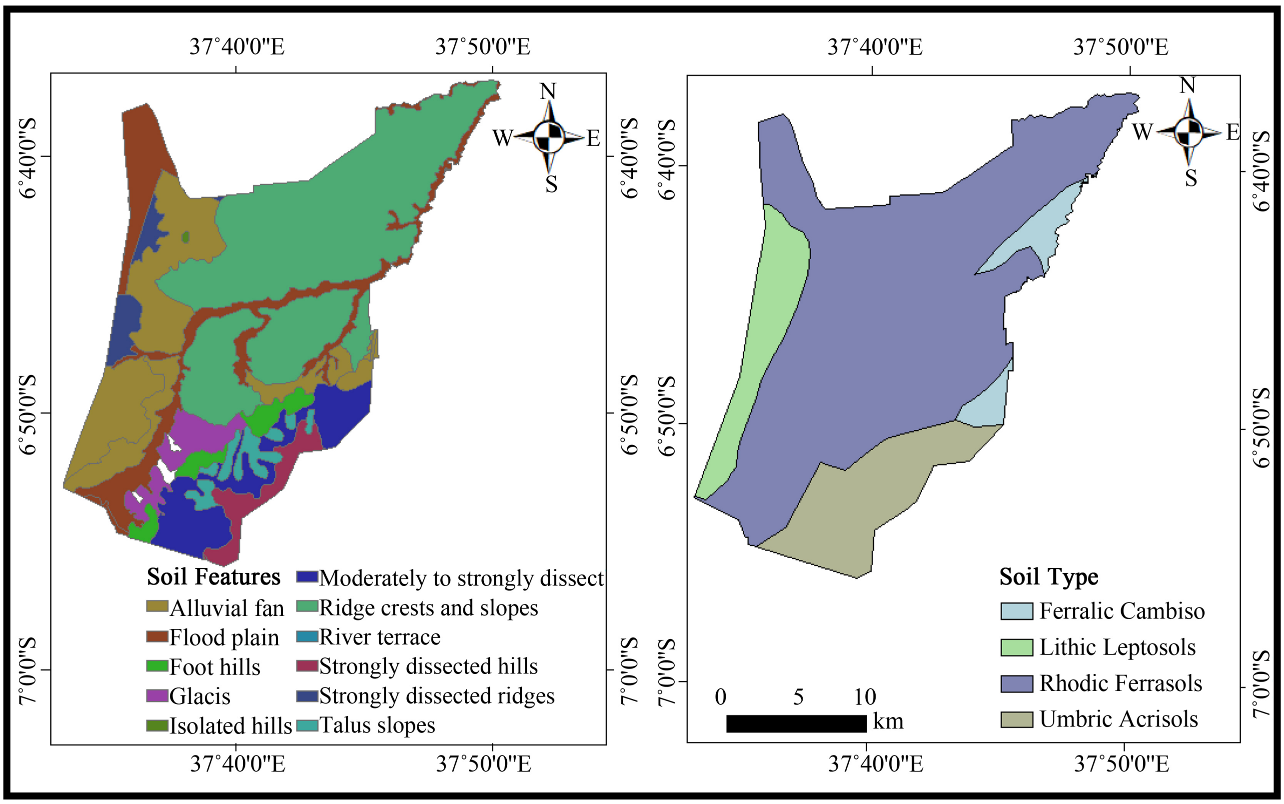

Figure 5. Spatial distribution of soil features.

classes 4 and 5 being the most detrimental or riskier than the proceeding classes. The prepared Land constraints features, data sources, and their descriptions are summarized in Table 4. Selection of the Land constraints was done in consideration of the nature of the study area and the literature review as explained on the proceeding sections.

Figure 6 and Figure 7 summerise the distribution of various land constraints consindered in this study. It is clear that elevation and the topographic pattern of Morogoro is the one that influnce most of the land constraints.

In order to determine total constraints for individual pixels in the study, a spatial analysis on pixel level was done. A raster calculator in ArcGis 10.5 was used to combine the Land constraints layers and summing up to determine the total Land constraints of individual pixels.

Results of the Land constraints are represented on a map (Figure 8). East-Southern parts of Morogoro Municipal including some parts of Mlimani, Kilakala and Bong'ola have the highest constraints than any other places and this is contributed not only by the high attitude, but also a very steep slope (>36%) that inducing erosion at a maximum effect leaving an area with a very shallow soil and rock outcrop.

On the other hand some parts of Lukobe and Kihonda wards have shown to have the lowest Land constraints hence less costly for settlement establishment compare other areas of Morogoro Municipal. These areas are characterized with

Table 4. Land constraints assessment.

Attribute	Class 1 Very Low	Class 2 Low	Class 3 Moderate	Class 4 High	Class 5 Very High	Data Source
Slope (%)	<4	4 - 8	9 - 16	16 - 36	>36	Digital Elevation Model (DEM)
Flood Hazards (Occurrence)	Non-flooded Area	Rarely Flooded	Moderate Frequency		Frequently Flooded	Modified Normalized Difference water index (MNDWI) threshold mapping
Erosion Hazards	Less Eroded Soil		Moderately Eroded Soil		Highly Eroded Soil	Morogoro Soil database
Waterlogging	Very Dry Areas	Dry Areas	Moderately Dry Areas	Hydrated Areas	Very Hydrated	MNWDI from (Landsat 8)
Soil Depth	Very Deep Soil		Moderately Deep Soil		Shallow Soil	Morogoro Soil database
Rock Outcrop	Not Observed				Outcrop Rock	Morogoro Soil database

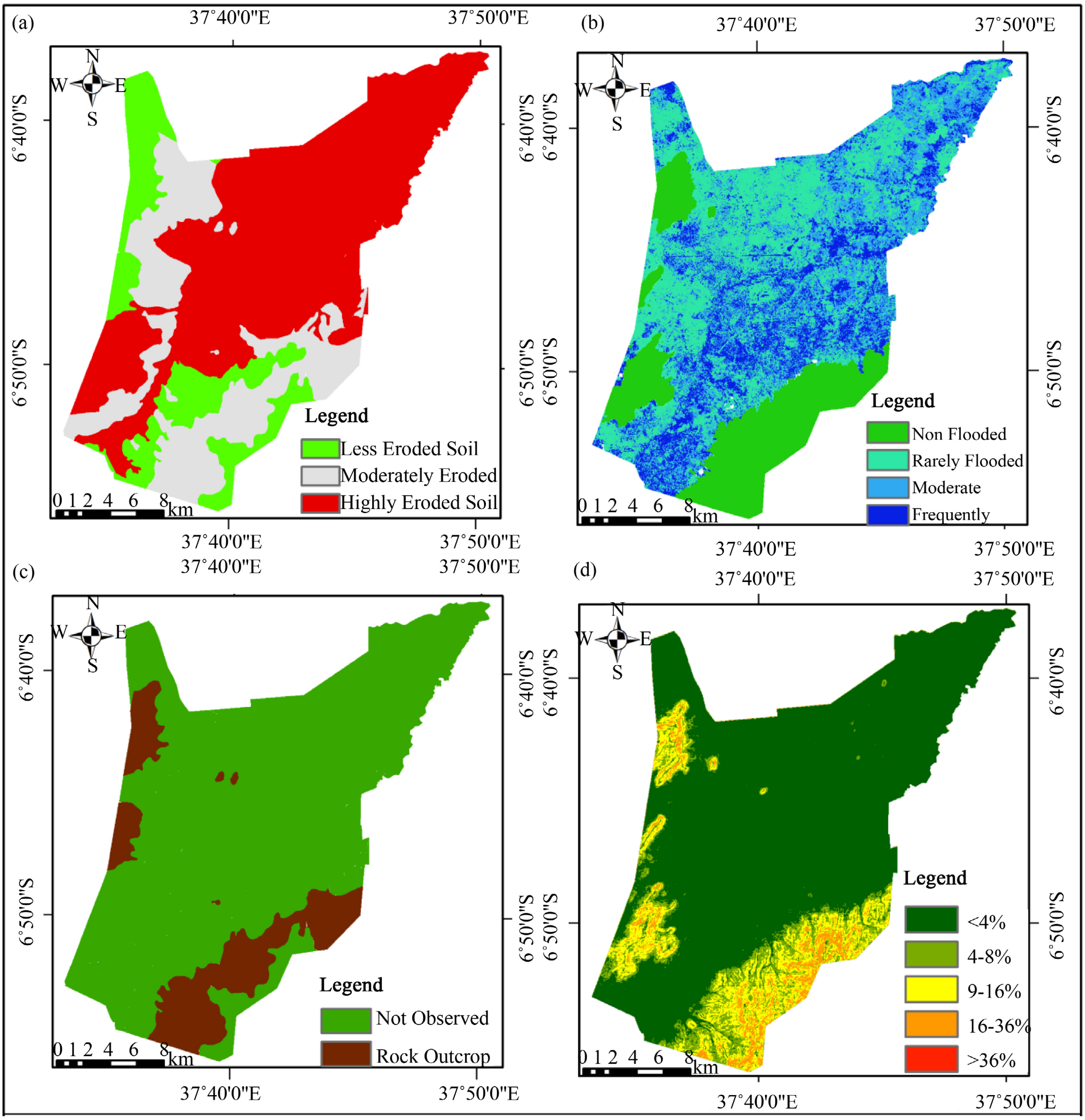

Figure 6. Land constraints: (a) Erosion hazard, (b) Flood risk, (c) Rock outcrop and (d) Slope gradient. Source: Mokarram and Hojati (2016).

a gentle slope, making it stable and less prone to erosion which is ideal for various human uses. Furthermore, these areas are less flooded, moderately dry and have a deep soil. These characteristics make these areas most suitable for human settlements and infrastructure developments.

A belt like structure of high constraints pixels running from South-North Eastern parts of Morogoro cutting through the central part of Luhungo, Mafinga, MjiMpya, Chamwino and Mazimbu is reflecting the presence of water belt.

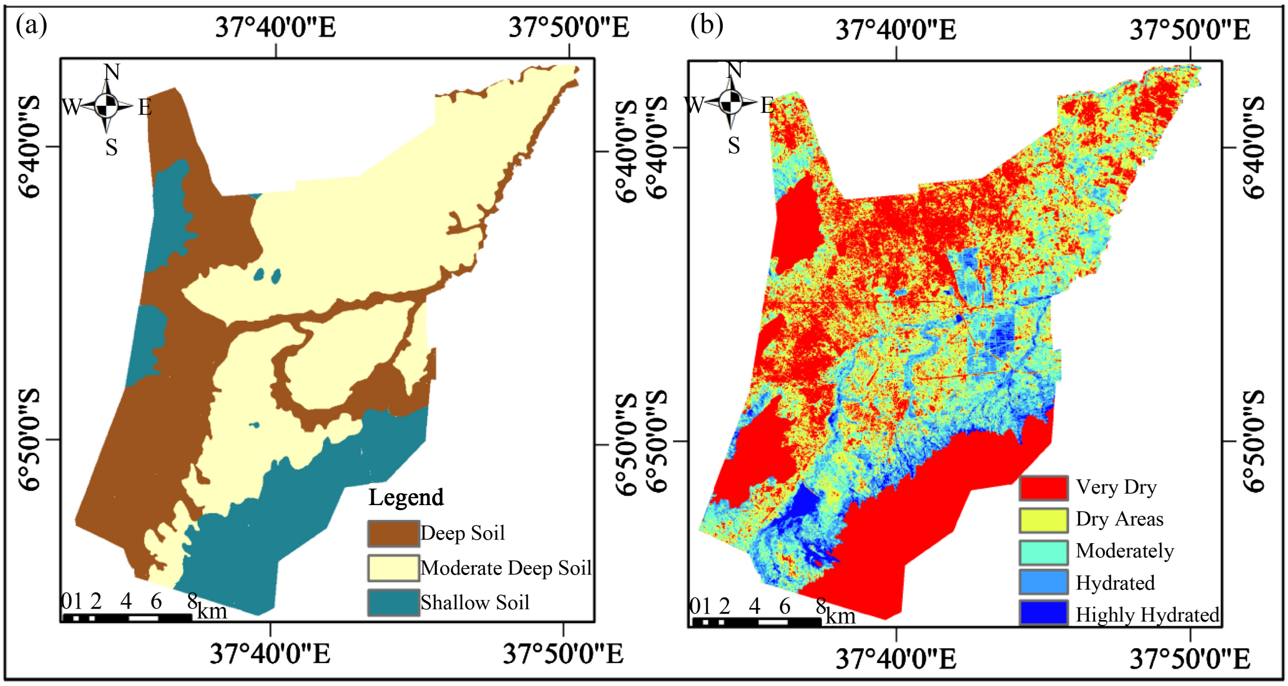

Figure 7. Land constraints: (a) Soil Depth and (b) Waterlogging. Source: Lal (1985).

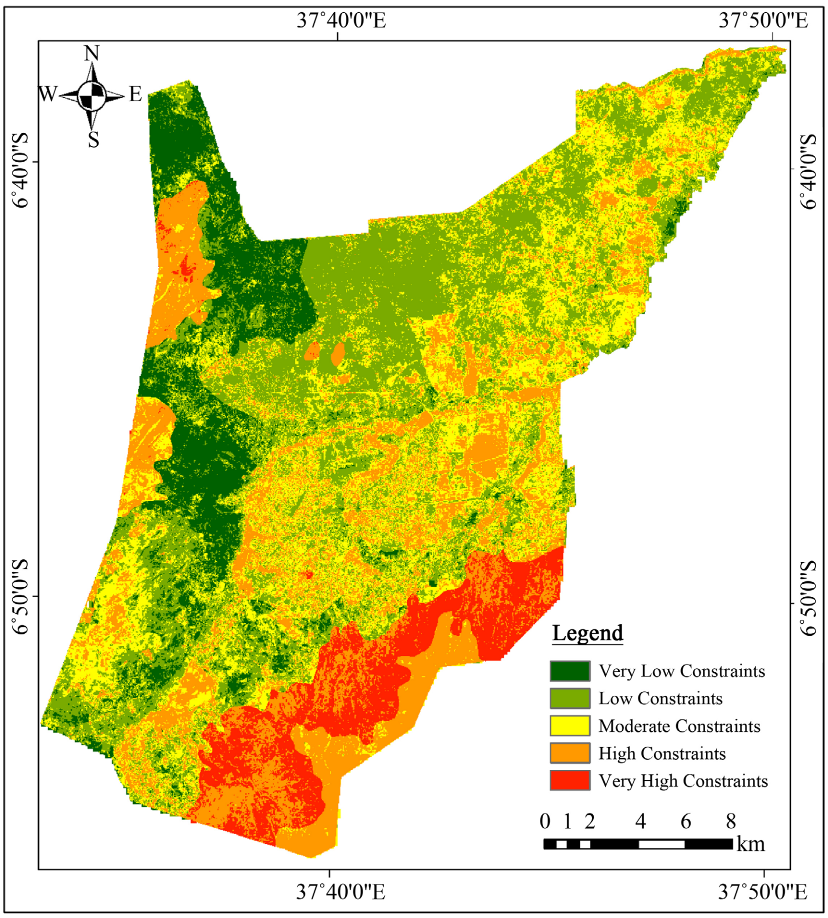

Figure 8. Total land constraints (Kumar et al., 2012).

An ephemeral river, Ngerengere and Morogoro rivers together with Mindu dam are creating a water logging zones which are often affected by the flooding hazards during high rainfall seasons for example that of 2020 April.

Gentle slopes and deep soils (**Figure 8**) in some parts of Mjimkuu, Boma and Bigwa make up for the green pixels of low constraints as shown in **Figure 8**. Low constraints make these areas more suitable and less costly as well.

A distribution map for the planned schemes (**Figure 9**) gives the picture of the distribution of human development activities with respect to the constraints base map. The resultant map shows that majority of the human settlement developments have been on the areas with high and moderate constraints suggesting that there is a significant modification prior to construction for example slope stabilization or in the time of disaster such as flood. Settlements on the middle of Morogoro Municipal are mostly susceptible to flooding during wet seasons because of the water line passing through inform of Morogoro river. These areas are protected are modified through water line stabilization and construction of bridges to direct water away from the human settlements.

South east parts of Morogoro Municipal are characterized with high elevation, erosion hazards, steep slope and rock outcrop. Settlement on Kilakala and Mlimani wards provides challenges prior to settlement development in the case of slope stabilization. Flooding hazard and water logging affects the Northern East part of Morogoro Municipal counting for the high constraints in the respective area. Human development activities in Kihonda and Mkundi wards have to deal with the impacts of these constraints specifically salt erosion and damaging of buildings and construction properties.

Areas of North Western parts of Morogoro Municipal have shown to have the lowest constraints, suggesting that development activities around wards of Mkundi and Mindu are experiencing the least challenges compare to other areas.

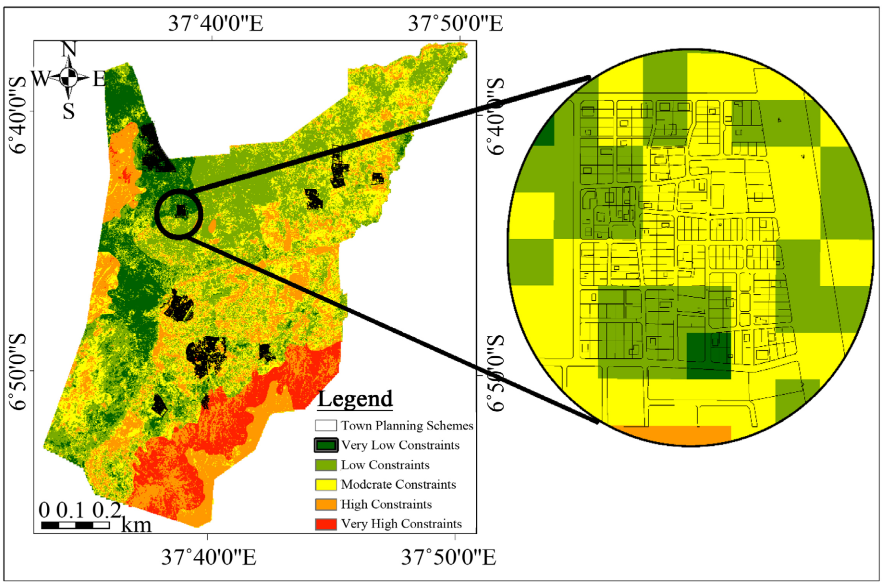

Figure 9. Distribution of planning schemes.

In general, the classification accuracies, including the kappa coefficient, overall accuracy and the producer accuracy were high. For the whole validation and the overall accuracy are around 90% and the kappa coefficients of both being more than 0.85. The global database commonly known as FAO obtained the soil characteristics and the soil properties which proved Morogoro urban having of alluvial fans, foot hills, flood plains, glacier, isolated hills, river terrace, ridge crystals, talus slopes and moderately, strongly dissects, hills and slopes respectively as the soil features (**Figure 4**). The features were sufficient to provide the plentiful soil information including the soil properties; soil pH, texture, organic matter content, chemical properties such as chemical contents.

Additionally, the obtained soil information was appropriate for us to know the soil-related constraints with the sampled Detailed Town Planning Schemes using the GIS and RS techniques. The slopes, erosional and flood hazards, water logging, water depth and rock outcrop were the main attribute for the assessment and evaluation of the soil constraints in Morogoro urban. The soil and its related constraints were classified into five classes; very low constraints, low constraints, moderate constraints, high constraints and very high constraints. However, **Figure 8** demonstrates the concentration of the Detailed Town Planning Schemes in the Central Business District (CBD) areas as it contains low and moderate constraints, while few of them felt in the very low and high constraints proving the low soil information knowledge for the residents dwelling in such areas.

5. Conclusion

Despite all the drawbacks associated with human settlements established in a constrained land, it is still not clear to many residents of Morogoro as well as the authority and specialists of town planning about the distribution and the patterns of various land constraints affecting their land. As a result, even though there are a number of recent publications done to map various constraints in Morogoro Municipal such as floods (Sumari et al., 2019); the means of knowledge transfer through publication alone is not effective as few people in the population are likely to come across the published paper. Still, others may read and understand the paper and still, the problems arise by locating the individual land location on the published map. This calls for the most effective and efficient way to publish results of public matters such as this one of the land constraints, the way that will be convenient to both educated and lay individuals of the society. With that in mind, it is safe to say that a user-friendly real-time web app will be a solution and the most reliable way to communicate the findings of this study.

Conflicts of Interest

The authors declare no conflicts of interest.

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