Current Urban Studies, 2022, 10, 787-820
https://www.scirp.org/journal/cus
ISSN Online: 2328-4919
ISSN Print: 2328-4900

Integrated Analytical Hierarchical Process and Geographical Information System for Allocation of Compatible Land Uses along Uluguru Mountain Slopes

Simon Msami Seja, Bonifas Mbilinyi, Proches Hieronimo

Department of Agriculture Engineering, Sokoine University of Agriculture, Morogoro, Tanzania
Email: sejasimon@yahoo.com

How to cite this paper: Seja, S. M., Mbilinyi, B., & Hieronimo, P. (2022). Integrated Analytical Hierarchical Process and Geographical Information System for Allocation of Compatible Land Uses along Uluguru Mountain Slopes. *Current Urban Studies, 10,* 787-820.
https://doi.org/10.4236/cus.2022.104045

Received: October 20, 2022
Accepted: December 27, 2022
Published: December 30, 2022

Abstract

The northern slope of the Uluguru mountain, that falls under the sovereignty of Morogoro's urban area, has steadily become populated and connected with uncontrolled human activity, which has had a harmful effect on the ecosystem. The rapid conversion of natural forests to farms and settlements has a severe effect on biodiversity and the land's productive capacity. In order to assist the identification of compatible land uses for managing degradation and restoration of degraded land, as well as ensuring the long-term use of natural resources, this study applied the integration of Geographical Information System and Analytical Hierarchical Process. The land resources of the research area were identified using a Geographical Information System to guide in the evaluation of various land uses' suitability. Land resource values were generated from different sources of data whereby elevation, slope, temperature, rainfall, soil properties, soil moisture index, and land surface temperature classifications were obtained. The land resource classification values throughout the study area were used to create land mapping units. The results of the criteria classification were integrated into questionnaires together with proposed compatible land uses obtained from the literature review. These well-structured questionnaires were used to retrieve expert opinions on land use allocation from environmental beneficiary institutions in the area. The influence of criteria on each suggested land use was assessed accordingly based on the score provided by Saaty's scale. The weight of each criterion at each land mapping unit toward proposed compatible land uses for mapping purposes was calculated using the Analytical Hierarchical Process (AHP) technique. The weighted criteria produced by the AHP technique were integrated into GIS using the weighted overlay method to produce a map that reflects expert judgments on mountain slope planning for long-term natural resource management. A literature review reveals that conservation agriculture, agroforestry, and forest land use types are compatible in the management of natural resources in the area, while settlements have to be integrated to accommodate the existing situation. The integration of GIS and AHP produced a plan that consists of conservation agriculture that covers the majority of the study area (50%) and is generally found in the foothills of the mountains up to land mapping unit 3. Agroforestry is the second-largest land use, accounting for 19% of the study area and being concentrated in the second and third land mapping units. Settlements, which occupy 17% of the study area and are mostly located at the foothills of the mountain, are the third most covered land use. Finally, forest land use is distributed at the top of the research area, inside land mapping units 4 and 5, and accounts for 13% of the total study area. According on the findings of this study, a sustainable land use plan is recommended. Economic activity that could assist in the management of natural resources would be advantageous to both parties. Planning of the mountainous slopes within urban areas that are not designated as conservation zones should be done with great care, and only economic activities that assist management of natural resources should be permitted.

Keywords

AHP Model, Land Use/Cover, GIS, Land Map Units, Uluguru Mountain

1. Introduction

The degradation of natural resources on Uluguru mountain slopes has been ongoing for years (Jones, 1996; Rutatora et al., 1996; Yanda & Munishi, 2007); human activities acts as a driving factors that energize depletion of natural resource continuously. The impacts have been affecting availability of sufficient water supply in Morogoro, Pwani and Dar es Salaam (Massawe et al., 2019) and obviously the well-being of future generation. Clearing of land along Uluguru mountain slopes due to human activities exposes the surface to the effects of raindrops and strong wind which are the source of water and wind erosion respectively. As stated by (Bridges & Oldeman, 1999; Burgess et al., 2002), water erosion is the most common type of degradation, followed by wind, nutrients decline, salinization and compaction; hence vegetation cover is critical in controlling loss of soil nutrients and biodiversity in the area.

Organized land uses can be helpful tool on mitigating environmentally distorting activities along the mountain slopes, scientific analysis of topographic factors and weather could assist on determining appropriate land use to allocate as advised by experts from local environmental stakeholders institutions. Assigning weights of importance to various criteria for land use allocation on different map units is challenging, so a technique that makes weight estimate possible is inevitable. This study made use of an Analytical Hierarchical Process (AHP) technique in criteria's weight estimates. This technique has been used in various studies (Duc, 2006; Mustafa et al., 2011; Kazemi Rad & Haghyghy, 2014; Everest et al., 2021).

The main basic assumption of sustainability is to ensure the most appropriate land use giving consideration of land's resources and stakeholder's demands (Prakash, 2003). Land properties of the study area were critically analysed by using Geographical Information System (GIS) based on remote sensing data obtained together with literature review while stakeholder demands were collected through well-structured questionnaires and analyzed through Analytical Hierarchical Process (AHP). The integration of GIS and AHP facilitated decision of spatial data in relation with attribute data for land use compatibility mapping (Cengiz & Akbulak, 2009).

The AHP is an inbuilt method of decision making used in solving problem that requires multi criteria findings to formulating and analysing decisions (Saaty & Sodenkamp, 2008). AHP approach allows quantitative and qualitative variables to be numerically evaluated and complex issues to be systematically analysed within the hierarchy framework (Cengiz & Akbulak, 2009). AHP relies heavily on experts and stakeholders' judgment on the various criteria and their perceived impacts on site suitability based on the main theme of the research. Incorporating experts and stakeholders' opinions on matching capacity of the land and compatible land uses makes the approach more transparent hence gives a chance of being endorsed in collaboration with spatial modelling on facilitating land use allocation for natural resource management and natural hazard's risk management (Siddayao et al., 2014). Based on experts' and stakeholders' opinions, the AHP method works by dividing the main problem into criteria for the use of data that cannot be analysed as a whole (Saaty & Sodenkamp, 2008). Splitting the problem into criteria contributes to simplifying the main problem into more details and making it into a more easily understood arrangement (Cengiz & Akbulak, 2009). This approach consists of three steps, which are to develop suitability hierarchical criteria, to establish priorities between elements of the hierarchy by means of pair-wise comparisons, and to test the logical consistency of pair-wise comparisons.

To obtain the influence of criteria in achieving the theme of the research, the criteria are compared by using a pair-wise comparison matrix and the score of one criteria against another was defined by a suitability evaluation scale known as the Saaty scale (Saaty & Sodenkamp, 2008).

From the pair wise comparison matrix which is carried out by using the theory of scale (Cengiz & Akbulak, 2009), the relative importance of criteria at each level is compared. The unit geometric mean extracted from each comparison matrix are used as a weight coefficient for criteria (Krejčí & Stoklasa, 2018) to obtain the value of suitability of each land use for each land map unit at the stage where AHP is used in combination with Geographical Information System

(GIS). To check the consistence of pair wise comparison at each level of the hierarchy, the parameter called consistency ratio is used whereby variation of not exceeding 10% is allowed (Duc, 2006). The weight values obtained from AHP was used in GIS software via weighted overlay to obtain suitability map.

Analytical Hierarchical Process has some advantages compares to other site suitability analysis techniques as stated bellow (Ullah & Mansourian, 2016). It gives a more depth analysis of the factors affecting site suitability by decomposing the suitability analysis problem into hierarchical levels which can be easily understood when are in small units.

1) It relies more on expert opinions or observation about factors that affecting suitability and their strength/influence on facilitating the theme of the research which are then converted into weight.

2) The process is more transparent and can be easily understood hence more likely to be accepted when it comes to land use suitability analysis.

In the integration of AHP and GIS, the AHP facilitates a framework for decision making process while GIS acts as a spatial analysis tool for land suitability. GIS facilitates input, storing, retrieving, manipulating, analysing and outputs of spatial and attribute data. Through GIS, many spatial data can be handled through layers and linkage with attribute data plays a major role in land use allocation process (Duc, 2006).

Due to urbanisation pressures and daily human demands, management of natural resources in mountainous areas has been a challenge in Tanzania. There have been numerous studies focused on mountainous natural resource management in the country, but most have focused on agriculture practice, participatory rural appraisal, and conservation education (Bhatia & Buckley, 1998; Rutatora et al., 1996; Mbaga-Semgalawe & Folmer, 2000; Komba, 2015; Manase, 2016; Msangi, 2016) without much consideration of the constraints and ability of the land. This study considered the integration of AHP and GIS to facilitate management of natural resources since it gives room to understand the landscape characteristics through analysis of land resources and enables accommodating experts' knowledge on allocating compatible land uses in the area's planning to achieve the desired goals considering the on-going depletion of the Uluguru Mountains' natural resources.

The concept of achieving sustainability, protection, and proper use of natural resources attributed by this study will benefit current and future generations not only by providing ideas that could benefit on the availability of clean water and a healthy living environment, but also by achieving the goals of national policies such as the National Environmental Policy (2021), the Water Sector Policy (2002), the National Forest Policy (1998), and the National Land Policy (1995).

Eventually this study was intended to answer these questions; 1) Is land use allocation viable in supporting environmental sustainable developments? 2) Will land use allocation meet the need for present and future generation?

2. Material and Methods

2.1. Study Area

The study area is located at the northern slope of Uluguru mountain, its boundary commence on the eastern part situated at the Latitude of 6˚48'00"S and Longitude of 39˚45'00"E up to the western part at Latitude of 6˚55'41"S and Longitude of 37˚38'44"E (Figure 1). The attitude is approximately 495 m above mean sea level at the foothill of the mountain and about 1750 m at the point it border with Uluguru forest reserve. The coverage of the area of study is approximately 6928 Ha. The area has average minimum and maximum temperature of 16˚C and 33˚C respectively with minimum and maximum annual rainfall of 821 mm and 1505 mm respectively (Ernest et al., 2017).

2.2. Data Collection and Analysis Procedure

2.2.1. Land Resources Data and Satellite Images Acquisition

Data required for assessment of land resources of the study area was obtain from various reliable sources as shown in Table 1.

Land sat of the year 2020 were retrieved from United States Geographical Survey website (https://earthexplorer.usgs.gov/) by using a path and row that covering our study area as the details shown in Table 2.

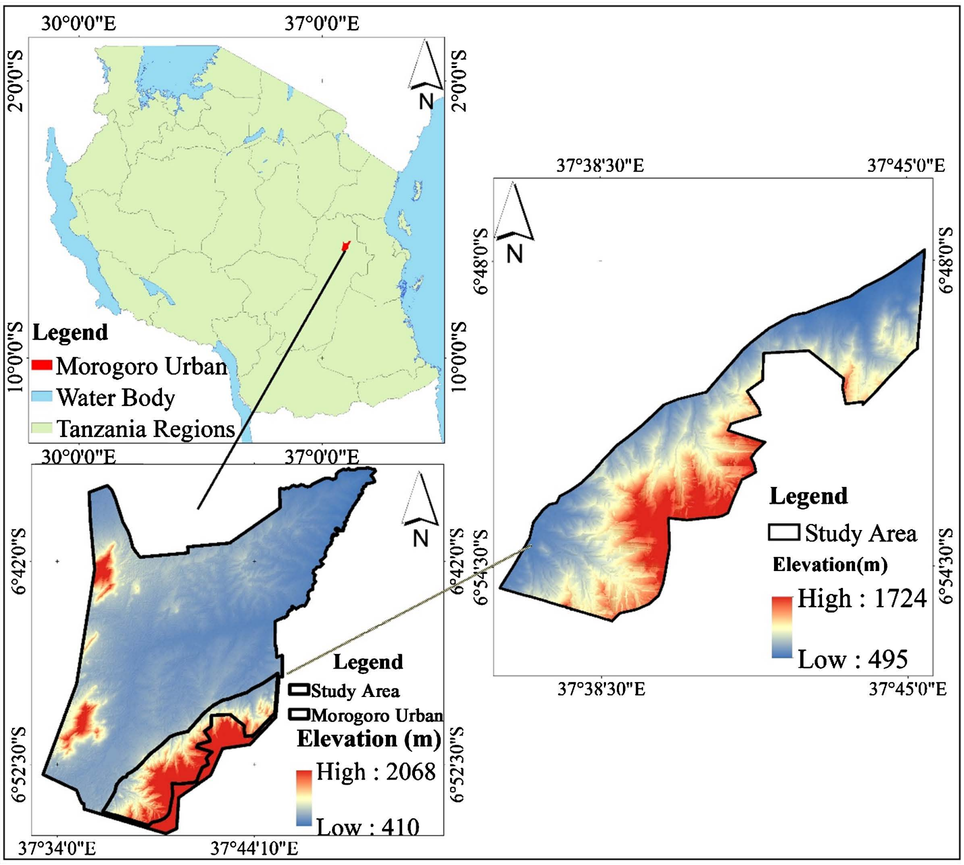

Figure 1. Description of the study area.

Table 1. Land resource data used.

S/N	Input data	Description	Format	Source
1.0	Digital elevation model	Topographic information	GIS Raster	https://earthexplorer.usgs.gov/
2.0	Soil map units	Soil information	GIS Raster	Msanya et al. (2001)
3.0	Temperature	Annual temperature data	GIS Raster	https://www.worldclim.org/data/index.html
4.0	Rain fall	Annual rainfall data	GIS Raster	https://www.chc.ucsb.edu/data/chirps (Musie et al., 2019) (Funk et al., 2015).
5.0	Soil Moisture Index	Moisture condition	GIS Raster	$[(LST_{min} - LST)/(LSTmax - LST_{min})] + 1$. (Saha et al., 2018)
6.0	Land Surface Temperature	Earth temperature information	GIS Raster	https://earthexplorer.usgs.gov/

Table 2. Details of satellite image acquired.

SN	Date	Season	Data source	Spatial Resolution (m)
4.0	2020-07-10	Dry	Landsat 8 OLIS	30

2.2.2. Pre-Processing

Raster data obtained from various sources with varying spatial projection and spatial resolution. Resampling function and projection tools in ArcGIS was used to change the raster pixel and all map projection to be the same (to WGS 84 coordinate system zone 37 south). Clouds and cloud shadows of satellites images was removed by using ERDAS and Geomatica 2015 to obtain clear image that covers the area of interest, this method has already been employed by other studies (Tafesse & Suryabhagavan, 2019). All of the images and GIS layers were clipped based on the boundary of the study area. The gap fill process was used to fill the sinks of DEM to ensure proper delineation of basins and streams and remove the void areas.

2.2.3. Image Classification

The corrected images processed via Arc GIS to generate regions of interest for various land uses identified in the study area to facilitate classification by random forest classification algorithm in R software, the method has been widely used and reported in other studies (Liaw & Wiener, 2002; Adam et al., 2014; Feng et al., 2015; Camargo et al., 2019). The Landsat imagery was used as reference in classification process base on features appearance as described in **Table 3**.

2.2.4. Classification Accuracy Assessment

To verifying how accurately the pixel was classified into the proper land use/ cover class, the ground truthing technique was employed. The hand held GPS (Gamin) was used for field data collection (coordinates) while Google Earth was used for unreachable locations whereby a total of 25 points for each land use/ cover type were collected as identified by the interpreter.

Table 3. Descriptions for land use/land cover classification.

S/N	Land use/Land cover class	Description
1	Built up	Settlements and other manmade structures associated with.
2	Agriculture	All lands used for seasonal crops cultivation.
3	Forest	Areas with closed trees and thick canopy
4	Closed woodland	Areas with wood trees with less closed canopy.
5	Open woodland	Area with scattered trees with less cover

2.2.5. Topographic Parameters

Topographic parameters were assessed in two categories, which are slope and elevation, and both were derived from the Digital Elevation Model. The reclassify tool in ArcGIS was used to reclassify DEM into different values of elevation. The slope function in ArcGIS under the spatial analyst tools was used to generate a slope gradient map in terms of percentage.

2.2.6. Weather

Weather parameters were assessed in two categories, which are temperature and rainfall. Temperature and rainfall data from Tanzania's meteorological agency are both in point form, limiting information about their spatial variation for mapping purposes. Raster data for weather parameters obtained from global climates layer website (https://worldclim.org/) were reclassified by Arcgis to obtain pixel values of temperature of the study area.

Rainfall spatial data (Raster) from the Climate Hazards Group Infrared Precipitation with Station data (CHIRPS) were reclassified using ArcGIS software to determine pixel values that cover the study area's boundary.

2.2.7. Land Surface Temperature

This is another variable which was obtained from the earth explorer website (https://earthexplorer.usgs.gov/) in raster format. The data types used were MODIS land surface temperature and emiss V6. Arcgis software was used to reclassify the obtained raster data in order to obtain Land surface temperature pixel values for the study area.

2.2.8. Soil Moisture Index

Soil moisture index was calculated using the formula derived from the relationship between land surface temperature and normalised vegetation index (Saha et al., 2018);

$$\mathrm{SMI} = \left[\left(\mathrm{LST}_{\min} - \mathrm{LST}\right) / \left(\mathrm{LST}_{\max} - \mathrm{LST}_{\min}\right)\right] + 1 \tag{1}$$

where LST = Land Surface temperature, $\mathrm{LST}_{\min}$ = Minimum Land surface Temperature, $\mathrm{LST}_{\max}$ = Maximum Land surface temperature.

2.2.9. Soil Properties

The raster data from the Morogoro land resource inventory study by Msanya

(2001) was adopted and processed by using the polygon to raster tool and clipped to fit the boundary of the study area via ArcGIS software to obtain the soil properties which are within the study jurisdiction to facilitate experts familiarising with the landscape.

2.3. Land Mapping Units

Elevation, slope, soil temperature, soil units, soil moisture index, land surface temperature, and rainfall data derived above were used as input to generate land mapping units. Through ArcGIS software, all criteria were reclassified into five classes of range to achieve uniformity. With the special analysis tool of reclassify, all layers of criteria were used as input, and their attribute tables were grouped into five major classes based on elevations.

Raster layer for each criterion was converted into vector data using raster to polygon command in convention tool to create a uniform data type for overlaying purposes. In order to not alter the attributes of each layer of criteria, intersection overlay tool was used to combine all layers to deliver one unit layer of land with various characteristics at each level of elevation in the study area.

2.4. Analytical Hierarchical Process

The procedure which involves AHP relies much on experts and stakeholder opinions on planning of Uluguru mountain slopes for the purpose of sustain land productivity, reduce land degradation and improve the livelihood of local people. Various studies (Reyes et al., 2005; Kassam et al., 2009; Silici et al., 2011) have been reviewed to propose compatible land uses that can assist environmental conservation while supporting locals economically. Other studies (Yanda & Munishi, 2007) were reviewed to integrate compatible land use obtained with the existing situation.

Opinions were gathered using well-structured questionnaires (**Appendix 1**) focusing on how experts evaluate the planning of the Uluguru mountain slope based on the influence of climate and topographical criteria on compatible land uses derived from literature review. The questionnaire survey was conducted throughout Uluguru environmental beneficiaries institution around Morogoro area, this includes Wami-ruvu basin water board, Tanzania forestry research institute (TAFORI), Uluguru nature forest reserve (NFR) and Eastern arc mountains conservation endowment fund (EAMCEF). With the objective of the research in mind, questionnaires survey were conducted and during the process it was noticeable that degradation along Uluguru Mountain slopes is clearly acknowledged by the experts across interviewed institutions.

Expert opinions on the influence of each criterion in allocating compatible land uses were obtained at each land mapping unit along the study area. In order to determine the influence of criteria at each unit for every proposed compatible land uses, the comparison matrix was used based on the score obtained as defined by 9-point scale measurement (Saaty scale, **Table 4**) whereby each pairwise

Table 4. Saaty's scale.

Intensity of Importance	Definition
1	Equal Importance
2	Equal to moderate importance
3	Moderate importance
4	Moderate to strong importance
5	Strong importance
6	Strong to very strong importance
7	Very strong importance
8	Very strong to extreme importance
9	Extreme Importance

matrix was normalized and calculate geometric mean of each questionnaire for each level of elevation (**Appendix 2**).

2.4.1. Consistency Ratio Index

In reality, expert's opinions are not expected to be consistency due to preference and experience towards proposed land uses. The consistency ratio is computed as follow;

$$(\mathrm{C.I}) = (\lambda_{\max} - n)/(n-1) \tag{2}$$

where: C.I = Consistency index n = number of criteria involved, $\lambda_{\max}$ =Biggest Eigen value.

$$\text{Consistency ratio} = \mathrm{C.I/R.I} \tag{3}$$

where: R.I = Random inconsistency index. R.I is 1.252 (Siddayao et al., 2014; Stein & Mizzi, 2007).

All of the pairwise matrixes were checked to be within an acceptable consistency ratio, C.R ≤ 0.1.

2.4.2. Weighted Overlay

Geometric mean obtained from comparison matrix procedure was used as a weight coefficient for criteria (Krejčí & Stoklasa, 2018) to obtain the value of suitability of each land use for each land mapping unit at the stage where AHP is used in combination with Geographical Information System (GIS). The methodology of the whole study is summarized in Figure 2.

3. Results

3.1. Spatial Classification of Land Resources within the Land Mapping Units

Slope angle in percentage, soil properties, temperature, soil moisture index, land surface temperature, and rainfall data were processed to give different values of

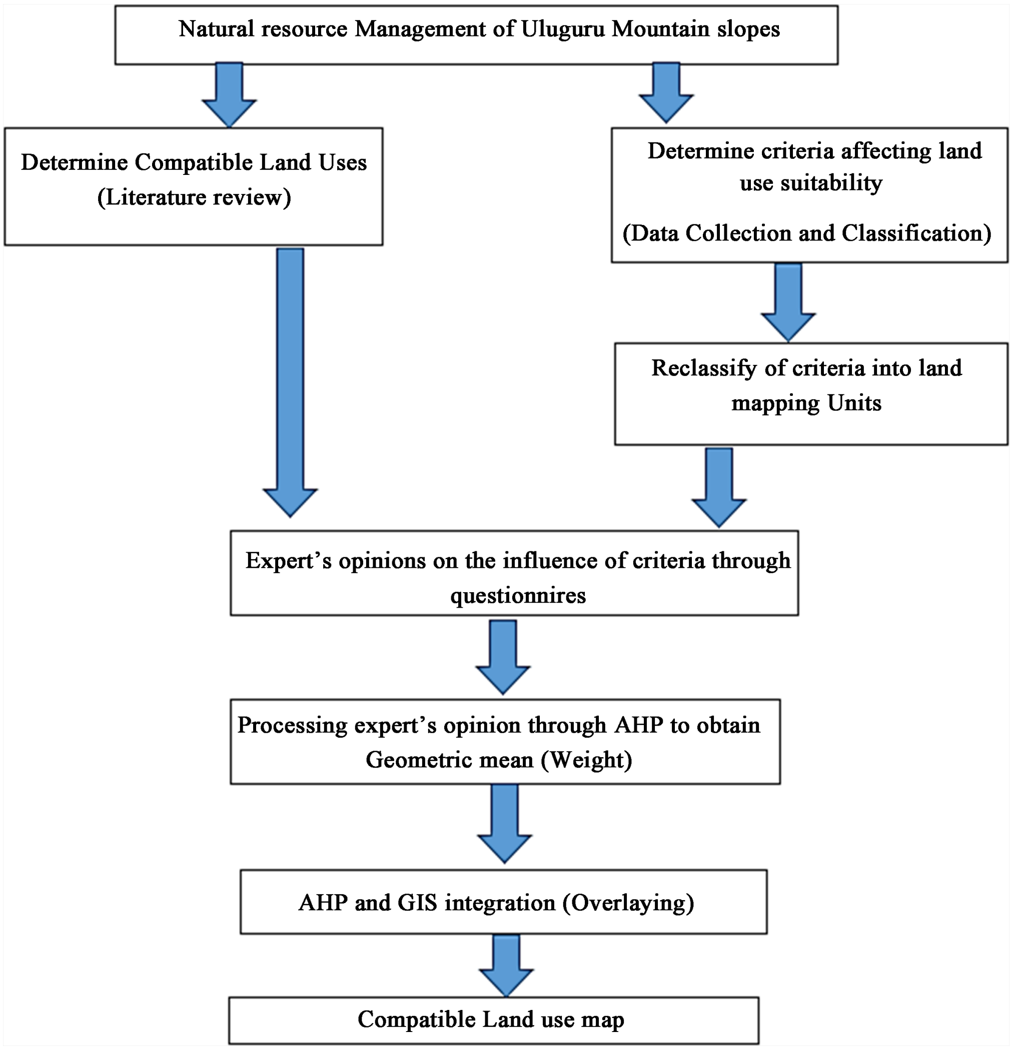

Figure 2. The workflow of the study.

these land resources in the study area. Figure 3 shows spatial variations of each criteria.

Since criteria vary as elevation increases, the elevation classification of the study area was used as the base for land mapping units formulating. The highest and lowest elevation was found to be 1772 m and 499 m respectively. The obtained land mapping units range from lowest to highest as 499 - 702 m, 702 - 882 m, 882 - 1094 m, 1094 - 1341 m and 1341 - 1772 m. An elevation of an area influences variation of land resources, thus these land units were found to have different properties in terms of land surface temperature (LST), Soil Moisture Index (SMI), slope, precipitation, soil units and temperature. Land resource parameters of these land units are detailed explicated in Table 5.

3.2. Compatible Land Use Obtained

Through a literature review, it was revealed that agroforestry, conservation agriculture, forest and settlements were selected to serve both natural resource

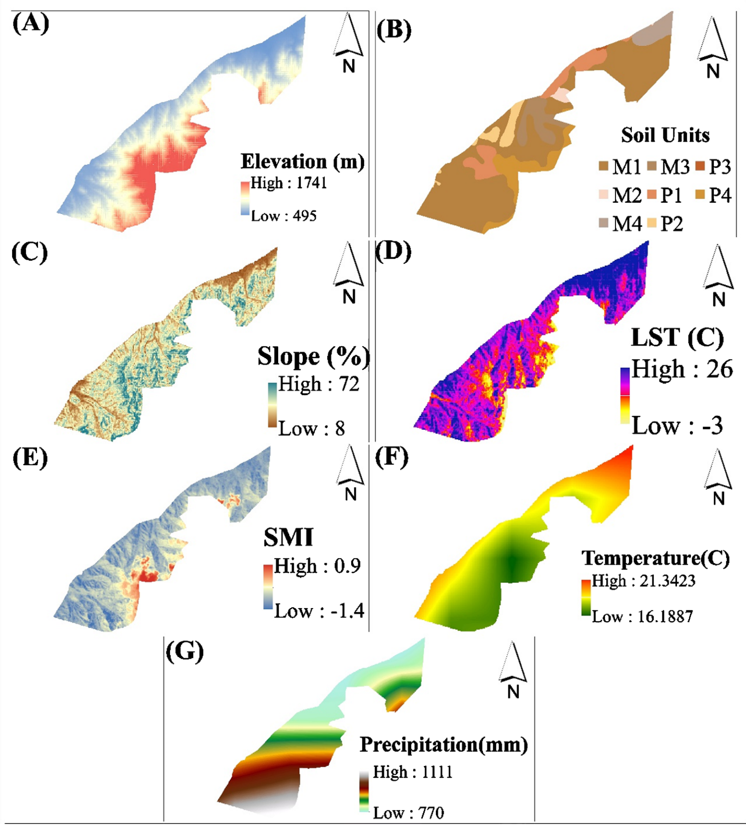

Figure 3. Classification of criteria in the study area. Elevation (A); Soil Units (B); Slope angle(C); Land Surface Temperature (LST) (D); Soil Moisture Index (SMI) (E); Temperature (F); Rainfall (G).

Table 5. Summary of land unit parameters.

Parameters	LU1	LU2	LU3	LU4	LU5
Elevation	499 - 702 m	702 - 882 m	882 - 1094 m	1094 - 1341 m	1341 - 1772 m
Soil units (**Appendix 3**)	P4, P1, P3, P2 and V2, V1	M2 and M3	M2, M3, M4 and M1	M3,M2 and M1	M202, M201
Landform	Foot hills and flood plains	Moderate dissected to strongly dissected ridges slopes	Moderate to strong dissected ridge slopes	Moderate to strong dissected ridges slope	Moderately to strong dissected ridge slopes
Temperature	17.9˚C - 21.3˚C	17.9˚C - 19.1˚C	16.2˚C - 17.8˚C	16.2˚C - 17.8˚C	16.2˚C - 17.8˚C
Rainfall	770 - 886 mm	770 - 886 mm	886 - 953 mm	886 - 953 mm	1023 - 1111 mm
LST	10˚C - 26˚C	7˚C - 10˚C	3˚C - 10˚C	3˚C - 7˚C	−9˚C - 3˚C
SMI	0.101 - 0.735	0.73 - 0.885	0.885 - 0.887	0.87 - 0.91	0.91 - 0.97
Slope	8% - 12%	12% - 20%	20% - 28%	28% - 38%	38% - 72%

LU is land mapping unit, LST is land surface temperature, and SMI is Soil moisture index. These obtained criteria were used to create an understanding of the landscape characteristics for experts to evaluate the planning of the study area.

management and accommodating existing neighborhoods in planning of the area. These compatible land uses attained together with land resources assessed facilitated the obtaining of expert opinions by using questionnaires, which were processed via AHP and accomplished the weight of influence of each criterion on allocating every proposed compatible land use at each level of elevation.

3.2.1. Compatible Land Use Allocation on Land Mapping Unit 1

Geometric mean of criteria obtained from pairwise comparison matrix for each proposed land use is indicated in Table 6.

Based on the results analysed from AHP preference weight ratio, suitability maps were produced for each land unit (based on elevation). The ratios of suitability on this Land map unit for settlement, conservation agriculture, agroforestry and forest were 45.74%, 49.78%, 4.49% and 0%.

3.2.2. Compatible Land Use Allocation on Land Map Unit 2

Geometric mean of criteria obtained from pairwise comparison matrix for each proposed land use indicated in Table 7.

Based on geometric mean of expert opinions that processed by AHP method, the compatible land use allocation on land map unit 2 produced the ratio of 6.87%, 46.29%, 46.42% and 0.41% of coverage for settlement, conservation agriculture, agroforestry and forest respectively.

3.2.3. Compatible Land Use Allocation on Land Map Unit 3

Geometric mean of criteria obtained from pairwise comparison matrix for each proposed land use indicated in Table 8.

Obtained geometric mean used in weighted overlay in GIS to produce a proposed land use with area coverage of 0.67%, 84.46%, 11.32% and 3.54% for settlement, conservation agriculture, agroforestry and forest respectively.

Table 6. Geometric mean of criteria for each land use.

	Slope	Temperature	Rainfall	Soil	SMI	LST
Settlement	0.1701	0.0879	0.1975	0.1414	0.0732	0.0411
Forest	0.0647	0.0696	0.0897	0.0620	0.0474	0.0334
Agroforestry	0.0164	0.0696	0.1179	0.1000	0.0915	0.0353
Conservation Agriculture	0.0517	0.08258	0.1324	0.1015	0.0816	0.04404

Table 7. Geometric mean of criteria for each land use.

	Slope	Temperature	Rainfall	Soil	SMI	LST
Settlement	0.1160	0.0719	0.091	0.0623	0.0459	0.0521
Forest	0.0228	0.0672	0.0486	0.0436	0.0405	0.0525
Agroforestry	0.0623	0.0551	0.1497	0.0811	0.0818	0.0817
Conservation Agriculture	0.1170	0.0754	0.1392	0.1377	0.074	0.0391

3.2.4. Compatible Land Use Allocation on Land Map Unit 4

Geometric mean of criteria obtained from pairwise comparison matrix for each proposed land use indicated in Table 9.

The AHP produced results that gave compatible land use area coverage distribution ratio of 4.34%, 10.11%, 3.83% and 81.72% for settlement, conservation agriculture, agroforestry and forest respectively.

3.2.5. Compatible Land Use Allocation on Land Map Unit 5

Geometric mean of criteria obtained from pairwise comparison matrix for each proposed land use indicated in Table 10.

The compatible land use distribution ratio on this land map unit obtained through AHP is 0.47%, 5.70%, 6.27% and 87.55% for settlement, conservation agriculture, agroforestry and forest respectively.

3.2.6. Overall Compatible Land Use

Spatially, the geometric mean obtained was used to map compatible land uses in the area at each level of elevation as shown in Figure 4.

Table 8. Geometric mean of criteria for each land use.

	Slope	Temperature	Rainfall	Soil	SMI	LST
Settlement	0.0441	0.0433	0.0287	0.0346	0.0350	0.0288
Forest	0.0155	0.044	0.0186	0.0490	0.0307	0.0333
Agroforestry	0.0880	0.0799	0.1754	0.1250	0.0622	0.0537
Conservation Agriculture	0.0667	0.0523	0.0981	0.0640	0.0955	0.04288

Table 9. Geometric mean of criteria in each proposed land use.

	Slope	Temperature	Rainfall	Soil	SMI	LST
Settlement	0.0277	0.0620	0.0904	0.0457	0.0412	0.0347
Forest	0.127018	0.0889	0.1931	0.1583	0.0890	0.0339
Agroforestry	0.0420	0.0675	0.1034	0.1154	0.0410	0.0602
Conservation Agriculture	0.0372	0.1067	0.1145	0.1228	0.0772	0.0348

Table 10. Geometric mean of criteria in each proposed land use.

	Slope	Temperature	Rainfall	Soil	SMI	LST
Settlement	0.03464	0.074319	0.081777	0.042192	0.081708	0.038932
Forest	0.2051	0.1092	0.2920	0.1236	0.0953	0.0480
Agroforestry	0.0079	0.0915	0.0408	0.0620	0.1384	0.1341
Conservation Agriculture	0.0775	0.1531	0.1103	0.0515	0.0461	0.0312

Land use allocated on each land mapping unit was combined to produce the compatible land use map of the study area, which comprises 11.35 km^2, 33.32 km^2, 12.91 km^2, 8.72 km^2 and 66.3 km^2 of settlement, conservational agriculture, agroforestry and forest respectively (Figure 5).

3.2.7. Existing Land Use

1) Classification accuracy

The accuracy assessment process as shown in Table 11 gave the output of 85.6% overall classification accuracy and 82% of kappa statistics.

2) Classification output

Through the classification process of satellite image of the year 2020, five land use classes were identified, which are: built-up area; closed woodland; open woodland; agriculture; and forest, as shown in Figure 6.

Existing land uses obtained from LULC Classification show that agriculture occupies the majority of the study area, which is 44.73 km^2 (65.36%), followed by

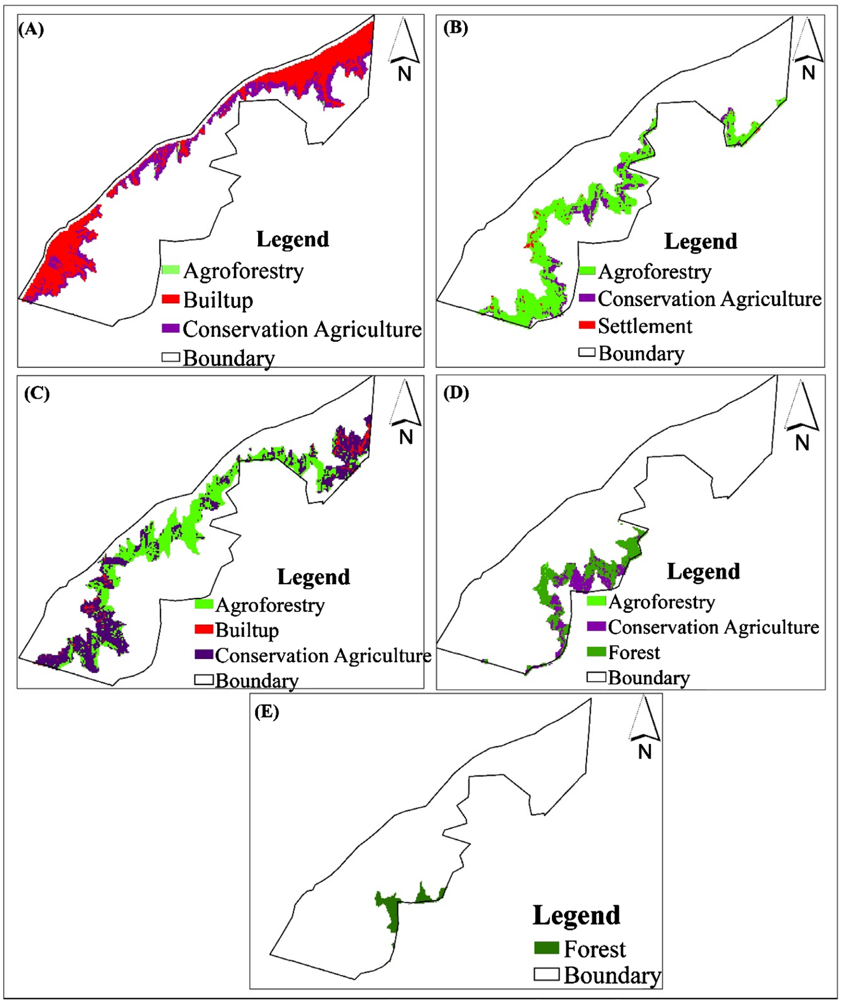

Figure 4. Spatial distribution of compatible land use on each land unit. Land Mapping Unit 1 (A); Land Mapping Unit 2 (B); Land Mapping Unit 3 (C); Land Mapping Unit 4 (D); Land Mapping UNIT 5 (E).

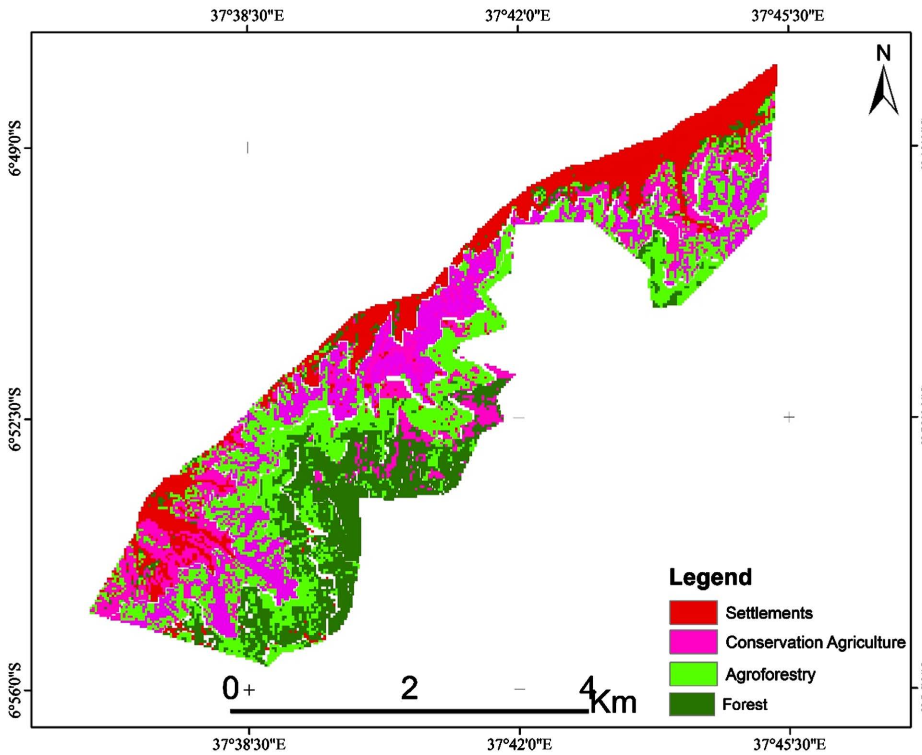

Figure 5. Compatible land use map of the study area.

Table 11. Accuracy assessment results.

	Forest	Built up	Agriculture	Closed Woodland	Open Woodland	Overall accuracy	Kappa statistics
P	96	100	84	92	80	85.6	0.82
U	83	96	100	79	95		

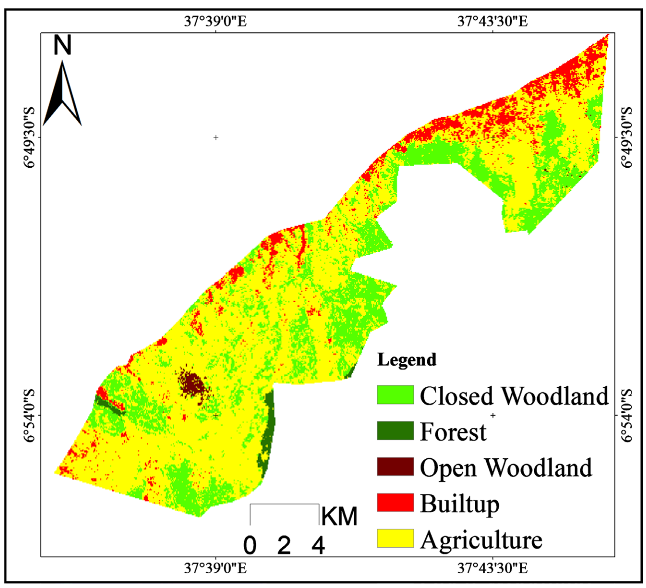

Figure 6. Land use/land cover classification of the year 2020.

Open woodland, which occupies 16.29 km^2 (23.8%), built up occupies 6.14 km^2 (8.97%), forest occupies 0.83 km^2 (1.21%) and closed woodland occupies 0.45 km^2 (0.66%).

4. Discussion

From the outcomes, the weight of the criteria obtained from expert opinions, 17.12% of the study area seemed to be suitable for settlements. The majority of the area that has been identified to be conducive for settlements is located at the Land mapping unit 1 and 2 of the study area. This area possesses a gentler slope and a higher temperature than other parts of the study area, which makes it more compatible for settlements compared to other land map units (Zheng et al., 2021). Compared to the existing land uses, this area has been largely utilised with non-conservation agriculture practise and unplanned settlements (Yanda & Munishi, 2007), whereby more than 61% and 71.8% of land mapping units 1 and 2 respectively are utilised by cultivation, while 21.85% of land mapping unit 1 is covered by unplanned settlements (**Appendix 4**).

The major land use type in the study area among proposed compatibles was conservation agriculture, which occupies 50% of the study area. Expert opinions identified land mapping units 1 - 3 as the most suitable areas for conservation agriculture based on soil type, elevation, slope, and weather conditions (Msangi, 2016). This is an area which has been mostly used for non-conservation agriculture practice (Yanda & Munishi, 2007), whereby its area coverage is 61.07%, 71.8%, and 65.21% on land mapping units 1, 2, and 3 respectively (**Appendix 4**).

The second most proposed compatible land use is agroforestry, which occupies 19.5% of the study area. Agroforestry has the potential to help restore tree loss while also benefiting the environment and the economy by increasing agricultural productivity, ecosystem facility, and human well-being (Ruheza et al., 2012). This land use type was proposed to be more suitable for land mapping units 2 - 4 considering existing criteria. The assessment of existing land uses has revealed that these land mapping units 2 - 4 are mainly used for non-conservation agriculture and most of the area which is not utilised is covered by open woodlands (**Appendix 4**).

Lastly, forest land use type was proposed to cover 13% of the study area, and it was recommended to be more suitable at the highest elevations within land map units 4 and 5. This is the part of the study area with the steepest slope, necessitating the use of forest cover to mitigate the effects of erosion agents. According to assessed existing land uses, land mapping 4 and 5 consist of 63.3% and 61.6% of non-conservation agriculture, respectively (Yanda & Munishi, 2007; Ngondo et al., 2022). It shows some agreement on land mapping unit unit 5, where there is 19.32% of existing forest.

These proposed land use allocations in the study area have taken into account erosion management. Proposed land use categories at the highest elevation have a great potential to increase land cover to protect the land against erosion agents, as recommended by the land resource inventory suitability assessment for the major land use types in Morogoro urban district, Tanzania (Msanya et al., 2001).

5. Conclusion

Identifying the best land use of Uluguru mountain slope to avoid resource depletion due to population increase and economic activities could be a useful strategy for the mountain's future. Through AHP and GIS integration, expert opinions gathered were processed and gave an outcome that considered the future wellbeing of the mountain for the benefit of coming generations.

Due to the fact that development and conservation are needed at the same time as it is evidently that the area is dictated by human activities, while expert's opinions reveal that it is high time for conservation measures, the sustainability land use plan is inevitable. Planning of economic activities which could serve the management of natural resources would be beneficial on both fronts.

Planning of the mountainous slopes that are within urban areas and are not declared as conservation areas should be declared as special planning areas and utilised under special care in such a way that only economic activities that support management of natural resources should be allowed.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

Adam, E., Mutanga, O., Odindi, J., & Abdel-Rahman, E. M. (2014). Land-Use/Cover Classification in a Heterogeneous Coastal Landscape Using RapidEye Imagery: Evaluating the Performance of Random Forest and Support Vector Machines Classifiers. *International Journal of Remote Sensing, 35,* 3440-3458. https://doi.org/10.1080/01431161.2014.903435

Bhatia, Z., & Buckley, P. (1998). Nature Kenya/East African Natural History Society. *Journal of East African Natural History, 87,* 339-347.

Bridges, E. M., & Oldeman, L. R. (1999). Global Assessment of Human-Induced Soil Degradation. *Arid Soil Research and Rehabilitation, 13,* 319-325. https://doi.org/10.1080/089030699263212

Burgess, N., Doggart, N., & Lovett, J. (2002). The Uluguru Mountains of Eastern Tanzania: The Effect of Forest Loss on Biodiversity. *Oryx, 36,* 1-13. https://doi.org/10.1017/S0030605302000212

Camargo, F. F., Sano, E. E., Almeida, C. M., Mura, J. C., & Almeida, T. (2019). A Comparative Assessment of Machine-Learning Techniques for Land Use and Land Cover Classification of the Brazilian Tropical Savanna Using ALOS-2/PALSAR-2 Polarimetric Images. *Remote Sensing, 11,* 1600. https://doi.org/10.3390/rs11131600

Cengiz, T., & Akbulak, C. (2009). Application of Analytical Hierarchy Process and Geographic Information Systems in Land-Use Suitability Evaluation: A Case Study of Dümrek Village (Çanakkale, Turkey). *International Journal of Sustainable Development and World Ecology, 16,* 286-294. https://doi.org/10.1080/13504500903106634

Duc, T. T. (2006). Using GIS and AHP Technique for Land-Use Suitability Analysis. In *International Symposium on Geoinformatics for Spatial Infrastructure Development in Earth and Allied Sciences* (6 p.). Polytechnic University of Ho Chi Minh.

Ernest, S., Nduganda, A. R., & Kashaigili, J. J. (2017). Urban Climate Analysis with Remote Sensing and Climate Observations: A Case of Morogoro Municipality in Tanzania. *Advances in Remote Sensing, 6,* 120-131. https://doi.org/10.4236/ars.2017.62009

Everest, T., Sungur, A., & Özcan, H. (2021). Determination of Agricultural Land Suitability with a Multiple-Criteria Decision-Making Method in Northwestern Turkey. *International Journal of Environmental Science and Technology, 18,* 1073-1088. https://doi.org/10.1007/s13762-020-02869-9

Feng, Q., Gong, J., Liu, J., & Li, Y. (2015). Flood Mapping Based on Multiple Endmember Spectral Mixture Analysis and Random Forest Classifier—The Case of Yuyao, China. *Remote Sensing, 7,* 12539-12562. https://doi.org/10.3390/rs70912539

Funk, C., Peterson, P., Landsfeld, M., Pedreros, D., Verdin, J., Shukla, S., Husak, G., Rowland, J., Harrison, L., Hoell, A., & Michaelsen, J. (2015). The Climate Hazards Infrared Precipitation with Stations—A New Environmental Record for Monitoring Extremes. *Scientific Data, 2015,* 1-21.

Jones, S. (1996). Discourses on Land Degradation in the Uluguru Mountains, Tanzania: Evolution and Influences. *Journal of Rural Studies, 12,* 187-199. https://doi.org/10.1016/0743-0167(96)00014-9

Kassam, A., Friedrich, T., Shaxson, F., & Pretty, J. (2009). The Spread of Conservation Agriculture: Justification, Sustainability and Uptake. *International Journal of Agricultural Sustainability, 7,* 292-320. https://doi.org/10.3763/ijas.2009.0477

Kazemi Rad, L., & Haghyghy, M. (2014). Integrated Analytical Hierarchy Process and GIS for Land Use Suitability Analysis. *World Applied Sciences Journal, 32,* 587-594.

Komba, S. C. F (2015). *Investigation of the Potential of Conservation Tillage Practices on Soil Erosion Control on the Slopes of the Uluguru Mountain Ranges* (114 p.). Dissertation, Sokoine University of Agriculture.

Krejčí, J., & Stoklasa, J. (2018). Aggregation in the Analytic Hierarchy Process: Why Weighted Geometric Mean Should Be Used Instead of Weighted Arithmetic Mean. *Expert Systems with Applications, 114,* 97-106. https://doi.org/10.1016/j.eswa.2018.06.060

Liaw, A., & Wiener, M. (2002). Classification and Regression by Random Forest. *Review News, 2,* 18-22.

Manase, J. (2016). The Adequacy of Environmental Education Techniques and Strategies Employed in Uluguru Mountains Hotspot. *International Journal of Education & Literacy Studies, 4,* 65-70. https://doi.org/10.7575/aiac.ijels.v.4n.4p.65

Massawe, A., Mvena, D. N., & Chambile, E. L. (2019). Effects of Anthropogenic Activities on Availability of Clean and Safe Water: A Case of Uluguru Forest Catchment Areas of Morogoro, Tanzania, *South Asian Journal of Development Research, 1,* 114-123.

Mbaga-Semgalawe, Z., & Folmer, H. (2000). Household Adoption Behaviour of Improved Soil Conservation: The Case of the North Pare and West Usambara Mountains of Tanzania. *Land Use Policy, 17,* 321-336.

Msangi, I. R. (2016). *Adoption of Conservation Agricultural Practices among Smallholder Farmers: A Case Study of Uluguru Mountains, Morogoro District* (79 p.). Dissertation, Sokoine University of Agriculture.

Msanya, B. M., Kimaro, D. N., Kimbi, G. G., Kileo, E. P., & Mbogoni, J. D. J. (2001). *Land Resources Inventory and Suitability Assessment for the Major Land Use Types in*

Morogoro Urban District, Tanzania. Soils and Land Resources of Morogoro Rural and Urban Districts, Volume 4 (78 p.). Department of Soil Science, Faculty of Agriculture, Sokoine University of Agriculture.

Musie, M., Sen, S., & Srivastava, P. (2019). Comparison and Evaluation of Gridded Precipitation Datasets for Streamflow Simulation in Data Scarce Watersheds of Ethiopia. *Journal of Hydrology, 579,* 124-168. https://doi.org/10.1016/j.jhydrol.2019.124168

Mustafa, A. A., Singh, M., Sahoo, R. N., Ahmed, N., Khanna, M., & Sarangi, A. (2011). Land Suitability Analysis for Different Crops: A Multi Criteria Decision Making Approach Using Remote Sensing and GIS. *Water Technology, 3,* 61-84.

Ngondo, J., Mango, J., Nobert, J., Dubi, A., Li, X., & Cheng, H. (2022). Hydrological Response of the Wami-Ruvu Basin to Land-Use and Land-Cover Changes and Its Impacts for the Future. *Water, 14,* 1-32.

Prakash, T. (2003). *Land Suitability Analysis for Agricultural Crops: A Fuzzy Multicriteria Decision Making Approach* (68 p.). MS Theses, International Institute for Geo-Information.

Reyes, T., Quiroz, R., & Msikula, S. (2005). Socio-Economic Comparison between Traditional and Improved Cultivation Methods in Agroforestry Systems, East Usambara Mountains, Tanzania. *Environmental Management, 36,* 682-690. https://doi.org/10.1007/s00267-004-7269-3

Ruheza, S., Tryphone, G. M., Mbwambo, J. S., Khamis, Z. K., Swella, G., & Mushobozy, D. K. (2012). Studies on the Influence of Tree Tenure on the Adoption of Agroforestry Practices in Uluguru Mountains, Tanzania. *International Research Journal of Agricultural Science and Soil Science, 2,* 170-178.

Rutatora, D. F., Mafu, S. T. A., & Lulandala, L. L. (1996). The Importance of Farmer Participation in Rehabilitating Degraded Uluguru Mountain Slopes: The Experiences from Magadu and Towero Villages in Morogoro Region, Tanzania. *African Study Monographs, 17,* 117-128.

Saaty, T. L., & Sodenkamp, M. (2008). Making Decisions in Hierarchic and Network Systems. *International Journal of Applied Decision Sciences, 1,* 24-79. https://doi.org/10.1504/IJADS.2008.017952

Saha, A., Patil, M., Goyal, V. C., & Rathore, D. S. (2018). Assessment and Impact of Soil Moisture Index in Agricultural Drought Estimation Using Remote Sensing and GIS Techniques. *Proceedings, 7,* 1-2. https://doi.org/10.3390/ECWS-3-05802

Siddayao, G. P., Valdez, S. E., & Fernandez, P. L. (2014). Analytic Hierarchy Process (AHP) in Spatial Modeling for Floodplain Risk Assessment. *International Journal of Machine Learning and Computing, 4,* 450-457. https://doi.org/10.7763/IJMLC.2014.V4.453

Silici, L., Ndabe, P., Friedrich, T., & Kassam, A. (2011). Harnessing Sustainability, Resilience and Productivity through Conservation Agriculture: The Case of Likoti in Lesotho. *International Journal of Agricultural Sustainability, 9,* 137-144. https://doi.org/10.3763/ijas.2010.0555

Stein, W. E., & Mizzi, P. J. (2007). The Harmonic Consistency Index for the Analytic Hierarchy Process. *European Journal of Operational Research, 177,* 488-497. https://doi.org/10.1016/j.ejor.2005.10.057

Tafesse, B., & Suryabhagavan, K. V. (2019). Systematic Modeling of Impacts of Land-Use and Land-Cover Changes on Land Surface Temperature in Adama Zuria District, Ethiopia. *Modeling Earth Systems and Environment, 5,* 805-817. https://doi.org/10.1007/s40808-018-0567-1

Ullah, K. M., & Mansourian, A. (2016). Evaluation of Land Suitability for Urban Land-Use Planning: Case Study Dhaka City. *Transactions in GIS, 20,* 20-37. https://doi.org/10.1111/tgis.12137

Yanda, P. Z., & Munishi, P. K. T. (2007). *Hydrologic and Land Use/Cover Change Analysis for the Ruvu River (Uluguru) and Sigi River (East Usambara) Watersheds* (87 p.). Report to WWF/CARE for the Equitable Payment for Watershed Services Project.

Zheng, X., Wu, J., & Deng, H. (2021). Spatial Distribution and Land Use of Traditional Villages in Southwest China. *Sustainability, 13,* 6326. https://doi.org/10.3390/su13116326

Appendices

Appendix 1. Questionnaire (Expert Opinion)

Objective; Analyze alternative land uses and their influence on strengthening Natural resources management Along Uluguru mountain slope.

Expert Name:………………….

Area of expertise:……………...

Institution:……………………...

1) What is your opinion on the relative importance (influence) of the following criteria on allocating settlement at the foothill of Uluguru sloping mountain (497 - 702 m)?

Settlements	SLOPE (08% - 12%)	TEMPERATURE (17.9˚C - 21.3˚C)	RAINFALL (770 - 886 mm)	SOIL PROPERTIES	SMI (0.101% - 0.737%)	LST (10˚C - 26˚C)
SLOPE (08% - 12%)	1					
TEMPERATURE (17.9˚C - 21.30˚C)		1				
RAINFALL(770 - 886 mm)			1			
SOIL PROPERTIES				1		
SMI (0.101 - 0.737)					1	
LST(10˚C - 26˚C)						1

(Rate by using saaty scale whereby 1 = Equal important, 3 = Moderate important of one over another, 5 = Essential or strong important of one over another, 7 = Very strong or demonstrated importance, 9 = Absolute importance).

2) What is your opinion on the relative importance (influence) of the following criteria on allocating Agroforestry at the foothill of Uluguru sloping mountain (497 - 702 m)?

Agroforestry	SLOPE (08% - 12%)	TEMPERATURE (17.9˚C - 21.3˚C)	RAINFALL (770 - 886 mm)	SOIL PROPERTIES	SMI (0.101% - 0.737%)	LST (10˚C - 26˚C)
SLOPE (08% - 12%)	1					
TEMPERATURE (17.9˚C - 21.3˚C)		1				
RAINFALL(770 - 886 mm)			1			
SOIL PROPERTIES				1		
SMI (0.101 - 0.737)					1	
LST(10˚C - 26˚C)						1

(Rate by using saaty scale whereby 1 = Equal important, 3 = Moderate important of one over another, 5 = Essential or strong important of one over another, 7 = Very strong or demonstrated importance, 9 = Absolute importance).

3) What is your opinion on the relative importance (influence) of the following criteria on allocating Conservation Agriculture at the foothill of Uluguru sloping mountain (497 - 702 m)?

Conservation Agriculture	SLOPE (08% - 12%)	TEMPERATURE (17.9˚C - 21.3˚C)	RAINFALL (770 - 886 mm)	SOIL PROPERTIES	SMI (0.101% - 0.737%)	LST (10˚C - 26˚C)
SLOPE (08% - 12%)	1					
TEMPERATURE (17.9˚C - 21.3˚C)		1				
RAINFALL (770 - 886 mm)			1			
SOIL PROPERTIES				1		
SMI (0.101 - 0.737)					1	
LST(10˚C - 26˚C)						1

(Rate by using saaty scale whereby 1 = Equal important, 3 = Moderate important of one over another, 5 = Essential or strong important of one over another, 7 = Very strong or demonstrated importance, 9 = Absolute importance).

4) What is your opinion on the relative importance (influence) of the following criteria on allocating Forest at the foothill of Uluguru sloping mountain (497 - 702 m)?

FOREST	SLOPE (08% - 12%)	TEMPERATURE (17.9˚C - 21.3˚C)	RAINFALL (770 - 886 mm)	SOIL PROPERTIES	SMI (0.101% - 0.737%)	LST (10˚C - 26˚C)
SLOPE (08% - 12%)	1					
TEMPERATURE (17.9˚C - 21.3˚C)		1				
RAINFALL(770 - 886 mm)			1			
SOIL PROPERTIES				1		
SMI (0.101 - 0.737)					1	
LST(10˚C - 26˚C)						1

(Rate by using saaty scale whereby 1 = Equal important, 3 = Moderate important of one over another, 5 = Essential or strong important of one over another, 7 = Very strong or demonstrated importance, 9 = Absolute importance).

5) What is your opinion on the relative importance (influence) of the following criteria on allocating settlement at the low to middle elevation of the Uluguru sloping mountain (702-882m)?

Settlements	SLOPE (12% - 20%)	TEMPERATURE (17.9 - 19.1)	RAINFALL (770 - 886 mm)	SOIL PROPERTIES	SMI (0.081% - 0.885%)	LST (7˚C - 10˚C)
SLOPE (12%-20%)	1					
TEMPERATURE (17.9 - 19.1)		1				
RAINFALL(770 - 886 MM)			1			
SOIL PROPERTIES				1		
SMI (0.73 - 0.88)					1	
LST (7˚C - 10˚C)						1

(Rate by using saaty scale whereby 1 = Equal important, 3 = Moderate important of one over another, 5 = Essential or strong important of one over another, 7 = Very strong or demonstrated importance, 9 = Absolute importance).

6) What is your opinion on the relative importance (influence) of the following criteria on allocating Agroforestry at the low to middle elevation of the Uluguru sloping mountain (702 - 882 m)?

Agroforestry	SLOPE (12% - 20%)	TEMPERATURE (17.9 - 19.1)	RAINFALL (770 - 886 mm)	SOIL PROPERTIES	SMI (0.081% - 0.885%)	LST (7˚C - 10˚C)
SLOPE (12% - 20%)	1					
TEMPERATURE (17.9 - 19.1)		1				
RAINFALL(770 - 886 mm)			1			
SOIL PROPERTIES				1		
SMI(0.073 - 0.885)					1	
LST(7˚C -10˚C)						1

(Rate by using saaty scale whereby 1 = Equal important, 3 = Moderate important of one over another, 5 = Essential or strong important of one over another, 7 = Very strong or demonstrated importance, 9 = Absolute importance).

7) What is your opinion on the relative importance (influence) of the following criteria on allocating Conservation Agriculture at the low to middle elevation of the Uluguru sloping mountain (702 - 882 m)?

Conservation Agriculture	SLOPE (12% - 20%)	TEMPERATURE (17.9 - 19.1)	RAINFALL (770 - 886 mm)	SOIL PROPERTIES	SMI (0.081% - 0.885%)	LST (7˚C - 10˚C)
SLOPE (12% - 20%)	1					
TEMPERATURE (17.9 - 19.1)		1				
RAINFALL(770 - 886 mm)			1			
SOIL PROPERTIES				1		
SMI(0.081 - 0.885)					1	
LST(7˚C - 10˚C)						1

(Rate by using saaty scale whereby 1 = Equal important, 3 = Moderate important of one over another, 5 = Essential or strong important of one over another, 7 = Very strong or demonstrated importance, 9 = Absolute importance).

8) What is your opinion on the relative importance (influence) of the following criteria on allocating Forest at the low to middle elevation of the Uluguru sloping mountain (702 - 882 m)?

Forest	SLOPE (12% - 20%)	TEMPERATURE (17.9 - 19.1)	RAINFALL (770 - 886 mm)	SOIL PROPERTIES	SMI (0.081% - 0.885%)	LST (7˚C - 10˚C)
SLOPE (12% - 20%)	1					
TEMPERATURE (17.9 - 19.1)		1				
RAINFALL (770 - 886 mm)			1			
SOIL PROPERTIES				1		
SMI (0.075 - 0.885)					1	
LST (7˚C - 10˚C)						1

(Rate by using saaty scale whereby 1 = Equal important, 3 = Moderate important of one over another, 5 = Essential or strong important of one over another, 7 = Very strong or demonstrated importance, 9 = Absolute importance).

9) What is your opinion on the relative importance (influence) of the following criteria on allocating settlement at the middle elevation of the Uluguru sloping mountain (882 - 1094 m)?

SETTLEMENT	SLOPE (20% - 28%)	TEMPERATUR (16.2˚C - 17.8˚C)	RAINFALL (886 - 953 mm)	SOIL PROPERTIES	SMI (-1.44×10^{-8} - 0.872%)	LST (3˚C - 10˚C)
SLOPE (20% - 28%)	1					
TEMPERATURE (16.2˚C - 17.8˚C)		1				
RAINFALL(886 - 953 mm)			1			
SOIL PROPERTIES				1		
SMI(0.885 - 0.887)					1	
LST (3˚C - 10˚C)						1

(Rate by using saaty scale whereby 1 = Equal important, 3 = Moderate important of one over another, 5 = Essential or strong important of one over another, 7 = Very strong or demonstrated importance, 9 = Absolute importance).

10) What is your opinion on the relative importance (influence) of the following criteria on allocating Agroforestry Agriculture at the middle elevation of the Uluguru sloping mountain (882 - 1094 m)?

Agroforestry	SLOPE (20% - 28%)	TEMPERATUR (16.2˚C - 17.8˚C)	RAINFALL (886 - 953 mm)	SOIL PROPERTIES	SMI (-1.44×10^{-8} - 0.872%)	LST (3˚C - 10˚C)
SLOPE (20% - 28%)	1					
TEMPERATURE (16.2˚C - 17.8˚C)		1				
RAINFALL(886 - 953 mm)			1			
SOIL PROPERTIES				1		
SMI(0.885 - 0.887)					1	
LST(3˚C - 10˚C)						1

(Rate by using saaty scale whereby 1 = Equal important, 3 = Moderate important of one over another, 5 = Essential or strong important of one over another, 7 = Very strong or demonstrated importance, 9 = Absolute importance).

11) What is your opinion on the relative importance (influence) of the following criteria on allocating Conservation Agriculture at the middle elevation of the Uluguru sloping mountain (882 - 1094 m)?

Conservation Agriculture	SLOPE (20% - 28%)	TEMPERATUR (16.2˚C - 17.8˚C)	RAINFALL (886 - 953 mm)	SOIL PROPERTIES	SMI (-1.44×10^{-8} - 0.872%)	LST (3˚C - 10˚C)
SLOPE (20% - 28%)	1					
TEMPERATURE (16.2˚C - 17.8˚C)		1				
RAINFALL(886 - 953 mm)			1			
SOIL PROPERTIES				1		
SMI(0.885 - 0.887)					1	
LST(3˚C - 10˚C)						1

(Rate by using saaty scale whereby 1 = Equal important, 3 = Moderate important of one over another, 5 = Essential or strong important of one over another, 7 = Very strong or demonstrated importance, 9 = Absolute importance).

12) What is your opinion on the relative importance (influence) of the following criteria on allocating Forest at the middle elevation of the Uluguru sloping mountain (882 - 1094 m)?

SETTLEMENT	SLOPE (20% - 28%)	TEMPERATUR (16.2˚C - 17.8˚C)	RAINFALL (886 - 953 mm)	SOIL PROPERTIES	SMI (-1.44×10^{-8} - 0.872%)	LST (3˚C - 10˚C)
SLOPE (20-28%)	1					
TEMPERATURE (16.2˚C - 17.8˚C)		1				
RAINFALL (886 - 953 mm)			1			
SOIL PROPERTIES				1		
SMI (0.885 - 0.887)					1	
LST (3˚C - 10˚C)						1

(Rate by using saaty scale whereby 1 = Equal important, 3 = Moderate important of one over another, 5 = Essential or strong important of one over another, 7 = Very strong or demonstrated importance, 9 = Absolute importance).

13) What is your opinion on the relative importance (influence) of the following criteria on allocating settlement at the moderate steep slope elevation of the Uluguru sloping mountain (1094 - 1341 m)?

SETTLEMENT	SLOPE (28% - 38%)	TEMPERATURE (16.2˚C - 17.8˚C)	RAINFALL (886 - 953 mm)	SOIL PROPERTIES	SMI (0.143% - 0.99%)	LST (3˚C - 7˚C)
SLOPE (28 - 38)	1					
TEMPERATURE (16.2˚C - 17.8˚C)		1				
RAINFALL(886 - 953 mm)			1			
SOIL PROPERTIES				1		
SMI(0.87 - 0.91)					1	
LST(3˚C - 7˚C)						1

(Rate by using saaty scale whereby 1 = Equal important, 3 = Moderate important of one over another, 5 = Essential or strong important of one over another, 7 = Very strong or demonstrated importance, 9 = Absolute importance).

14) What is your opinion on the relative importance (influence) of the following criteria on allocating Agroforestry at the moderate steep slope elevation of the Uluguru sloping mountain (882 - 1094 m)?

Agroforestry	SLOPE (28% - 38%)	TEMPERATURE (16.2˚C - 17.8˚C)	RAINFALL (886 - 953 mm)	SOIL PROPERTIES	SMI (0.143% - 0.99%)	LST (3˚C - 7˚C)
SLOPE (28 - 38)	1					
TEMPERATURE (16.2˚C - 17.8˚C)		1				
RAINFALL (886 - 953 mm)			1			
SOIL PROPERTIES				1		
SMI (0.87 - 0.91)					1	
LST (3˚C - 7˚C)						1

(Rate by using saaty scale whereby 1 = Equal important, 3 = Moderate important of one over another, 5 = Essential or strong important of one over another, 7 = Very strong or demonstrated importance, 9 = Absolute importance).

15) What is your opinion on the relative importance (influence) of the following criteria on allocating Conservation Agriculture at the moderate steep slope elevation of the Uluguru sloping mountain (882 - 1094 m)?

Conservation Agriculture	SLOPE (28% - 38%)	TEMPERATURE (16.2˚C - 17.8˚C)	RAINFALL (886 - 953 mm)	SOIL PROPERTIES	SMI (0.143% - 0.99%)	LST(3˚C - 7˚C)
SLOPE (28 - 38)	1					
TEMPERATURE (16.2˚C - 17.8˚C)		1				
RAINFALL (886 - 953 mm)			1			
SOIL PROPERTIES				1		
SMI (0.87 - 0.91)					1	
LST (3˚C - 7˚C)						1

(Rate by using saaty scale whereby 1 = Equal important, 3 = Moderate important of one over another, 5 = Essential or strong important of one over another, 7 = Very strong or demonstrated importance, 9 = Absolute importance).

16) What is your opinion on the relative importance (influence) of the following criteria on allocating Forest at the moderate steep slope elevation of the Uluguru sloping mountain (882 - 1094 m)?

Forest	SLOPE (28% - 38%)	TEMPERATURE (16.2˚C - 17.8˚C)	RAINFALL (886 - 953 mm)	SOIL PROPERTIES	SMI (0.143% - 0.99%)	LST (3˚C - 7˚C)
SLOPE (28 - 38)	1					
TEMPERATURE (16.2˚C - 17.8˚C)		1				
RAINFALL(886 - 953 mm)			1			
SOIL PROPERTIES				1		
SMI (0.87 - 0.91)					1	
LST (3˚C - 7˚C)						1

(Rate by using saaty scale whereby 1 = Equal important, 3 = Moderate important of one over another, 5 = Essential or strong important of one over another, 7 = Very strong or demonstrated importance, 9 = Absolute importance).

17) What is your opinion on the relative importance (influence) of the following criteria on allocating Settlement at the steep slope elevation of the Uluguru sloping mountain (1341 - 1772 m)?

Settlement	SLOPE (38% - 72%)	TEMPERATURE (16.2˚C - 17.8˚C)	RAINFALL (1023 - 1111 mm)	SOIL PROPERTIES	SMI (0.28 - 0.97)	LST (−9˚C - 3˚C)
SLOPE (38% - 72%)	1					
TEMPERATURE (16.2˚C - 17.8˚C)		1				
RAINFALL(1023 - 1111 mm)			1			
SOIL PROPERTIES				1		
SMI (0.91 - 0.97)					1	
LST (−9˚C - 3˚C)						1

(Rate by using saaty scale whereby 1 = Equal important, 3 = Moderate important of one over another, 5 = Essential or strong important of one over another, 7 = Very strong or demonstrated importance, 9 = Absolute importance).

18) What is your opinion on the relative importance (influence) of the following criteria on allocating Conservation Agriculture at the steep slope elevation of the Uluguru sloping mountain (1341 - 1772 m)?

Conservation Agriculture	SLOPE (38% - 72%)	TEMPERATURE (16.2˚C - 17.8˚C)	RAINFALL (1023 - 1111 mm)	SOIL PROPERTIES	SMI (0.28 - 0.97)	LST (−9˚C - 3˚C)
SLOPE (38% - 72%)	1					
TEMPERATURE (16.2˚C - 17.8˚C)		1				
RAINFALL (1023 - 1111 mm)			1			
SOIL PROPERTIES				1		
SMI (0.91 - 0.97)					1	
LST (−9˚C - 3˚C)						1

(Rate by using saaty scale whereby 1 = Equal important, 3 = Moderate important of one over another, 5 = Essential or strong important of one over another, 7 = Very strong or demonstrated importance, 9 = Absolute importance).

19) What is your opinion on the relative importance (influence) of the following criteria on allocating Agroforestry at the steep slope elevation of the Uluguru sloping mountain (1341 - 1772 m)?

Agroforestry	SLOPE (38% - 72%)	TEMPERATURE (16.2˚C - 17.8˚C)	RAINFALL (1023 - 1111 mm)	SOIL PROPERTIES	SMI (0.28 - 0.97)	LST (−9˚C - 3˚C)
SLOPE (38% - 72%)	1					
TEMPERATURE (16.2˚C - 17.8˚C)		1				
RAINFALL(1023 - 1111 mm)			1			
SOIL PROPERTIES				1		
SMI (0.91 - 0.97)					1	
LST (−9˚C - 3˚C)						1

(Rate by using saaty scale whereby 1 = Equal important, 3 = Moderate important of one over another, 5 = Essential or strong important of one over another, 7 = Very strong or demonstrated importance, 9 = Absolute importance).

20) What is your opinion on the relative importance (influence) of the following criteria on allocating Forest at the steep slope elevation of the Uluguru sloping mountain (1341 - 1772 m)?

Forest	SLOPE (38% - 72%)	TEMPERATURE (16.2˚C - 17.8˚C)	RAINFALL (1023 - 1111 mm)	SOIL PROPERTIES	SMI (0.28 - 0.97)	LST(−9˚C - 3˚C)
SLOPE (38% - 72%)	1					
TEMPERATURE (16.2˚C - 17.8˚C)		1				
RAINFALL (1023 - 1111 mm)			1			
SOIL PROPERTIES				1		
SMI (0.91 - 0.97)					1	
LST (−9˚C - 3˚C)						1

(Rate by using saaty scale whereby 1 = Equal important, 3 = Moderate important of one over another, 5 = Essential or strong important of one over another, 7 = Very strong or demonstrated importance, 9 = Absolute importance).

Appendix 2. Geometric Mean of Criteria

Settlement											
	Average	**Average**	**Average**	**Average**	**Average**	**Average**	**Average**	**Average**	**Average**	**Average**	**GM**
SLOPE	0.166223	0.206015283	0.1268807	0.1082114	0.185286	0.187696468	0.107696468	0.1043412	0.2472668	0.446623	0.170110915
TEMPERATURE	0.052662	0.048725357	0.1395197	0.161784	0.162614	0.044992706	0.044992706	0.0497965	0.1871908	0.154908	0.087898631
RAINFALL	0.191324	0.156401241	0.1970026	0.1451871	0.202206	0.26812463	0.26812463	0.2484045	0.1988272	0.1468	0.197480262
SOIL PROPERTIES	0.173268	0.144356645	0.1236699	0.1459231	0.139348	0.16384839	0.16484839	0.1652853	0.0921923	0.123002	0.141351777
SMI	0.080303	0.056031938	0.0492975	0.0524366	0.046791	0.100727424	0.100727424	0.1134268	0.1015454	0.069841	0.073241596
LST	0.03622	0.043469538	0.0556296	0.0564578	0.063755	0.034610382	0.034610382	0.0387456	0.0329774	0.028826	0.041146325
total	0.7	0.655	1	1	1	1	1	1	1	1	0.71
forest											
	Average	**Average**	**Average**	**Average**	**Average**	**Average**	**Average**	**Average**	**Average**	**Average**	**GM**
SLOPE	0.320186	0.015725793	0.0151917	0.0920555	0.122327	0.12507303	0.300073	0.0253974	0.2014196	0.007788	0.06471302
TEMPERATURE	0.045802	0.339676969	0.0533113	0.1529682	0.11206	0.053742682	0.120442682	0.05482	0.0137969	0.038514	0.069634863
RAINFALL	0.10200	0.009724201	0.312	0.0440339	0.100055	0.122534526	0.110412109	0.1025595	0.1417448	0.126183	0.089730368
SOIL PROPERTIES	0.008918	0.077765741	0.1505581	0.0330433	0.100013	0.13749697	0.01049697	0.2130125	0.0431648	0.183859	0.062019152
SMI	0.034467	0.017360341	0.0465124	0.133242	0.054452	0.044124275	0.012124275	0.066568	0.0898607	0.089265	0.047435499
LST	0.035512	0.04044143	0.0076827	0.0474871	0.033763	0.024628517	0.044828517	0.0440427	0.0370131	0.05439	0.033407698
total	1	1	1	1	1	1	1	1	1	1	0.37
agroforest											
	Average	**Average**	**Average**	**Average**	**Average**	**Average**	**Average**	**Average**	**Average**	**Average**	**GM**
SLOPE	0.04391	0.052238306	0.0063444	0.0004903	0.016694	0.044970955	0.054497096	0.0044971	0.1356457	0.007829	0.016384442
TEMPERATURE	0.033546	0.038175809	0.103673	0.036428	0.110086	0.050330907	0.050330907	0.0503309	0.1614787	0.241681	0.069552358
RAINFALL	0.00874	0.134190451	0.1579659	0.2000636	0.257953	0.212529461	0.103529461	0.1235295	0.1380822	0.144723	0.11790801
SOIL PROPERTIES	0.065771	0.133286764	0.1257144	0.1990574	0.006402	0.222534824	0.149534824	0.1695348	0.1009575	0.125408	0.100031262
SMI	0.156092	0.072451704	0.0658824	0.0823363	0.065257	0.122817386	0.142817386	0.1428174	0.062319	0.065647	0.091476041
LST	0.121942	0.055656966	0.0604198	0.0554244	0.063608	0.024290326	0.001290326	0.0292903	0.041517	0.054711	0.035312031
total	0	0	1	1	1	1	1	1	1	1	0.43
Conservation Agriculture											
	Average	**Average**	**Average**	**Average**	**Average**	**Average**	**Average**	**Average**	**Average**	**Average**	**GM**
SLOPE	0.105285	0.066632249	0.0718401	0.0493595	0.009746	0.107569976	0.157569976	0.10757	0.0030603	0.100425	0.051678319
TEMPERATURE	0.042042	0.044959499	0.2009289	0.0459242	0.131096	0.050622068	0.050622068	0.0506221	0.241141	0.206227	0.082581249
RAINFALL	0.103611	0.12268193	0.1358086	0.1814839	0.187783	0.208716221	0.038716221	0.1387162	0.1264411	0.198955	0.132428913
SOIL PROPERTIES	0.158231	0.023670139	0.0123646	0.186969	0.118375	0.237797368	0.257797368	0.2177974	0.103087	0.082338	0.101509024
SMI	0.079128	0.087921744	0.0512133	0.0803541	0.043077	0.102366176	0.132366176	0.1323662	0.079566	0.074573	0.081622027

Continued

LST	0.051703	0.05413444	0.0678445	0.0559093	0.049924	0.032928191	0.032928191	0.0329282	0.0387047	0.037483	0.044041234
total	0.54	0.4	0.54	0.6	0.54	0.74	0.67	0.68	0.592	0.7	0.493860767
agroforest											
	Average	**Average**	**Average**	**Average**	**Average**	**Average**	**Average**	**Average**	**Average**	**Average**	**GM**
SLOPE	0.129156	0.044812	0.122536	0.102491	0.104497	0.00857	0.143777	0.087781	0.013723	0.078693	0.062345
TEMPERATURE	0.113156	0.110752	0.037977	0.046718	0.050331	0.04742	0.0446	0.0563	0.043147	0.044689	0.055079
RAINFALL	0.147601	0.045836	0.143149	0.147151	0.123529	0.137849	0.125372	0.120481	0.370369	0.415634	0.149675
SOIL PROPERTIES	0.046112	0.007679	0.121517	0.13511	0.139535	0.107864	0.100151	0.101976	0.087109	0.156193	0.081
SMI	0.08162	0.074885	0.109306	0.105659	0.142817	0.0842	0.068674	0.09759	0.048013	0.04897	0.081777
LST	0.043855	0.046036	0.051515	0.042871	0.02929	0.054097	0.047425	0.045206	0.057639	0.055821	0.046643
total	1	1	1	1	1	1	1	1	1	0.8	0.476519
Conservation Agriculture											
	Average	**Average**	**Average**	**Average**	**Average**	**Average**	**Average**	**Average**	**Average**	**Average**	**GM**
SLOPE	0.148774	0.175656	0.103159	0.127169	0.08757	0.14033	0.101536	0.039659	0.127539	0.221688	0.116975
TEMPERATURE	0.10861	0.109735	0.108033	0.043598	0.050622	0.075983	0.065243	0.12425	0.058052	0.058477	0.075403
RAINFALL	0.15766	0.106522	0.108535	0.129544	0.128716	0.120799	0.147798	0.103666	0.1493	0.324553	0.139171
SOIL PROPERTIES	0.12225	0.089098	0.109264	0.162022	0.157797	0.118244	0.19974	0.108326	0.176777	0.178313	0.137716
SMI	0.077706	0.085857	0.082094	0.092188	0.132366	0.046738	0.056474	0.111843	0.048663	0.053822	0.074358
LST	0.045001	0.053132	0.067597	0.035479	0.032928	0.039907	0.049209	0.017143	0.039669	0.033147	0.039103
total	0.66	0.62	0.6	1	1	1	1	1	1	1	0.582727
Settlement											
	Average	**Average**	**Average**	**Average**	**Average**	**Average**	**Average**	**Average**	**Average**	**Average**	**gm**
SLOPE	0.113287	0.10074	0.008481	0.110406	0.343459	0.00386113	0.102001	0.062771	0.062771	0.004934761	0.04414508
TEMPERATURE	0.048407	0.04579	0.06369	0.062655	0.066668	0.000763455	0.063297	0.063297	0.063297	0.204819704	0.043340321
RAINFALL	0.102058	0.002229	0.080762	0.132397	0.210694	0.000224617	0.008678	0.01278	0.258678	0.103376585	0.028400868
SOIL PROPERTIES	0.120125	0.100312	0.100026	0.152399	0.104665	0.00086132	0.000108	0.133708	0.103708	0.099028054	0.03458511
SMI	0.063383	0.062708	0.062367	0.000201	0.045138	0.110038715	0.110073	0.111673	0.015673	0.058388931	0.035024301
LST	0.04374	0.036922	0.031675	0.005523	0.042376	0.021234701	0.035312	0.035874	0.035874	0.034288771	0.028825715
total	1	1	1	1	1	1	1	1	1	1	0.214321397
forest											
	Average	**Average**	**Average**	**Average**	**Average**	**Average**	**Average**	**Average**	**Average**	**Average**	**gm**
SLOPE	0.106187	0.124456	0.019456	0.213112	0.000676	0.000268097	0.015944	0.001868	0.016868	0.163855197	0.015532865
TEMPERATURE	0.041317	0.047289	0.04367	0.058467	0.060737	0.029066689	0.041033	0.031557	0.021557	0.100075889	0.043561008
RAINFALL	0.381494	0.012446	0.104373	0.044367	0.003234	0.007271453	0.001861	0.014577	0.001771	0.200363632	0.018607702
SOIL PROPERTIES	0.213823	0.222367	0.009613	0.20187	0.010312	0.008303537	0.100952	0.005581	0.115581	0.153925239	0.048963858

Continued

SMI	0.053384	0.0602	0.051596	0.032677	0.063581	0.033824058	0.002797	0.002879	0.100288	0.07987479	0.030732107
LST	0.043796	0.033242	0.041292	0.045507	0.049119	0.033266165	0.034413	0.010129	0.040129	0.026905253	0.033311245
total	1	1	1	1	1	1	1	1	1	1	0.190708785
agroforest											
	Average	Average	Average	Average	Average	Average	Average	Average	Average	Average	gm
SLOPE()	0.130155	0.119514	0.210051	0.262659	0.207556	0.0000868	0.123701	0.114819	0.314819	0.401244965	0.087965308
TEMPERATURE ()	0.089814	0.030457	0.059278	0.060572	0.062984	0.043418244	0.126234	0.123118	0.129118	0.197399539	0.079926775
RAINFALL()	0.19353	0.220156	0.195068	0.236304	0.21796	0.028746579	0.234306	0.241147	0.241147	0.164709197	0.175435068
SOIL()	0.163151	0.167066	0.195176	0.157947	0.195964	0.134249595	0.093262	0.043741	0.093741	0.110005519	0.12498082
SMI()	0.053472	0.073018	0.060501	0.058989	0.057035	0.007901866	0.076811	0.143995	0.143995	0.087224806	0.062240221
LST()	0.039878	0.05979	0.078826	0.053562	0.058501	0.031468907	0.045686	0.077181	0.077181	0.039415973	0.053683392
total	1	1	1	1	1	1	1	1	1	1	0.584231584
Conservation Agriculture											
	Average	Average	Average	Average	Average	Average	Average	Average	Average	Average	GM
SLOPE()	0.215697	0.11173	0.110551	0.135615	0.003038	0.004800622	0.214801	0.123095	0.123095	0.100906944	0.066653989
TEMPERATURE ()	0.044269	0.059393	0.061124	0.057601	0.053602	0.038586378	0.038586	0.045575	0.045575	0.10051211	0.052338487
RAINFALL()	0.093896	0.006273	0.34848	0.309625	0.207837	0.00631679	0.427632	0.212707	0.082707	0.132014874	0.098138717
SOIL()	0.003441	0.123937	0.151075	0.151127	0.009534	0.124299985	0.1243	0.117202	0.057202	0.11815233	0.063906219
SMI()	0.092811	0.053456	0.08524	0.070395	0.087168	0.103675338	0.103675	0.121552	0.131552	0.141628245	0.095510332
LST()	0.036885	0.04521	0.043529	0.045637	0.038821	0.031005998	0.031006	0.059868	0.059868	0.047446396	0.04288179
total	1	1	1	1	1	1	1	1	1	1	0.419429534
Settlement											
	Average	Average	Average	Average	Average	Average	Average	Average	Average	Average	GM
SLOPE()	0.233007	0.117628	0.044608	0.001141	0.001141	0.000653	0.110653	0.101477	0.111647652	0.131276517	0.026503617
TEMPERATURE ()	0.033579	0.038376	0.043164	0.044717	0.044717	0.040439	0.040439	0.311155	0.113154824	0.111154824	0.060987095
RAINFALL()	0.37203	0.343957	0.129406	0.109561	0.019561	0.007071	0.170712	0.106645	0.078645461	0.101645461	0.090417934
SOIL()	0.162911	0.189373	0.115401	0.100724	0.101724	0.000522	0.110022	0.081283	0.181282738	0.001282738	0.045688146
SMI()	0.105228	0.092145	0.080434	0.085622	0.005622	0.001389	0.117389	0.092851	0.192850891	0.012850891	0.041197419
LST()	0.033246	0.036521	0.046987	0.050234	0.050234	0.029526	0.021526	0.04359	0.043589569	0.013589569	0.034461932
total	1	1	0	0	0	0	1	1	1	0	0.299256143
forest											
	Average	Average	Average	Average	Average	Average	Average	Average	Average	Average	GM
SLOPE	0.188281	0.111348	0.122963	0.244807	0.216453	0.244799	0.124799	0.221597	0.101596701	0.011596701	0.126977018
TEMPERATURE	0.066341	0.0775	0.079078	0.075346	0.08024	0.037762	0.037762	0.145941	0.245940643	0.243940643	0.088858634
RAINFALL	0.252533	0.237537	0.210517	0.329444	0.127131	0.105343	0.405343	0.157892	0.127892198	0.157892198	0.193079645

Continued

SOIL PRPERTIES	0.244156	0.232362	0.138227	0.184254	0.175984	0.112265	0.242265	0.112719	0.112418667	0.112718667	0.158295247
SMI	0.112301	0.089075	0.084009	0.089514	0.066648	0.117655	0.117655	0.076461	0.076460856	0.076460856	0.088954465
LST	0.036388	0.052177	0.045206	0.045634	0.063544	0.022177	0.022177	0.025391	0.025390935	0.025390935	0.033898684
total	1	1	1	1	1	1	1	1	1	1	0.690063694
agroforest											
	Average	Average	Average	Average	Average	Average	Average	Average	Average	Average	GM
SLOPE	0.042571	0.05609	0.073688	0.100816	0.011539	0.112342	0.001429	0.104008	0.044487681	0.111087681	0.041951911
TEMPERATURE	0.057818	0.092326	0.050035	0.011633	0.103554	0.047795	0.110019	0.062159	0.142129476	0.132159476	0.067540929
RAINFALL	0.218665	0.099325	0.103275	0.102422	0.111767	0.21501	0.11	0.110365	0.02000000	0.104247047	0.103402638
SOIL PROPERTIES	0.10066	0.136558	0.103536	0.13267	0.11	0.07124	0.200007	0.123659	0.113659476	0.100649476	0.1153943
SMI	0.045543	0.017256	0.105525	0.102518	0.13426	0.022115	0.012124	0.103621	0.04362079	0.00962079	0.040965043
LST	0.044343	0.098446	0.079937	0.054439	0.030187	0.031527	0.114342	0.047108	0.142107872	0.045107872	0.060191553
total	1	1	1	1	1	1	1	1	1	1	0.429446374
Conservation Agriculture											
	Average	Average	Average	Average	Average	Average	Average	Average	Average	Average	GM
SLOPE	0.003941	0.141657	0.102946	0.018721	0.022123	0.117397	0.16707	0.009922	0.109922276	0.009922276	0.03718367
TEMPERATURE	0.101698	0.127814	0.121724	0.119908	0.097334	0.046978	0.109149	0.100969	0.197969015	0.100969015	0.106690709
RAINFALL	0.002238	0.202116	0.276044	0.167298	0.316595	0.476162	0.120177	0.100885	0.100884517	0.100884517	0.114537557
SOIL PRPERTIES	0.133087	0.110911	0.187383	0.188701	0.171086	0.101115	0.10595	0.093468	0.093468239	0.093468239	0.122821445
SMI	0.06003	0.082708	0.0761	0.058411	0.049928	0.310779	0.063608	0.070223	0.07022334	0.07022334	0.077224447
LST	0.045019	0.034794	0.035804	0.021961	0.042933	0.027569	0.034047	0.037533	0.037532612	0.037532612	0.034825641
total	1	1	1	1	1	1	1	1	1	1	0.493283468
Settlement											
	Average	Average	Average	Average	Average	Average	Average	Average	Average	Average	GM
SLOPE	0.049022	0.002927	0.100192	0.042985	0.041227	0.012345	0.1005951	0.210011	0.019349	0.019349	0.03464
TEMPERATURE	0.035191	0.057086	0.063311	0.06322	0.32206	0.226305	0.0054606	0.043325	0.114325	0.324325	0.074319
RAINFALL	0.220523	0.201414	0.211444	0.230072	0.018055	0.132783	0.1732539	0.232463	0.014363	0.004463	0.081777
SOIL PROPERTIES	0.2113	0.060162	0.057558	0.054101	0.041113	0.045331	0.0587644	0.006536	0.096536	0.006536	0.042192
SMI	0.032272	0.1515	0.079512	0.061114	0.043662	0.124984	0.2041069	0.013689	0.223689	0.163689	0.081708
LST	0.049692	0.04391	0.031983	0.048507	0.043883	0.0385	0.0284394	0.036638	0.036638	0.036638	0.038932
total	1	1	1	1	1	1	1	1	1	1	0.35
forest											
	Average	Average	Average	Average	Average	Average	Average	Average	Average	Average	GM
SLOPE	0.204312	0.295804	0.276344	0.279083	0.111669	0.23561	0.144282	0.237557	0.227557	0.137557	0.205077

Continued

TEMPERATURE	0.107172	0.093836	0.103673	0.108111	0.110086	0.042428	0.1501927	0.148378	0.138378	0.148378	0.10919
RAINFALL	0.271699	0.30074	0.257966	0.340368	0.297953	0.467755	0.2616999	0.257947	0.257947	0.257947	0.291901
SOIL PROPERTIES	0.154694	0.135703	0.135714	0.138815	0.146402	0.130485	0.0830906	0.184679	0.084679	0.084679	0.123588
SMI	0.104236	0.119593	0.065882	0.065194	0.045257	0.090246	0.1229748	0.131803	0.131803	0.131803	0.095266
LST	0.057887	0.054324	0.06042	0.068429	0.063608	0.033476	0.0377599	0.039637	0.039637	0.039637	0.048013
total	0.9	1	1	1	0.8	1	0.8	1	1	0.8	0.873034
agroforest											
	Average	**Average**	**Average**	**Average**	**Average**	**Average**	**Average**	**Average**	**Average**	**Average**	**GM**
SLOPE	0.100112	0.000621	0.014881	0.000314	0.014236	0.114422	0.0023381	0.097644	0.002644	0.003242	0.007883
TEMPERATURE	0.160278	0.012294	0.11252	0.10006	0.122614	0.113426	0.1002328	0.104075	0.112045	0.114075	0.091501
RAINFALL	0.238336	0.3005	0.250003	0.232283	0.102206	0.222065	0.0102279	0.021123	0.004113	0.000153	0.040812
SOIL PROPERTIES	0.012824	0.130859	0.00367	0.109208	0.120348	0.100376	0.1023873	0.100169	0.100569	0.100569	0.062026
SMI	0.056041	0.047196	0.149297	0.260007	0.214791	0.100094	0.1290142	0.142157	0.185337	0.343157	0.13838
LST	0.045409	0.045527	0.15463	0.04446	0.113755	0.100611	0.2502038	0.250202	0.420512	0.438002	0.134064
total	1	1	1	1	1	1	1	1	1	1	0.474665
Conservation Agriculture											
	Average	**Average**	**Average**	**Average**	**Average**	**Average**	**Average**	**Average**	**Average**	**Average**	**GM**
SLOPE	0.124308	0.100833	0.01424	0.016046	0.103651	0.100073	0.1000088	0.111746	0.110546	0.213746	0.077528
TEMPERATURE	0.142268	0.100007	0.200313	0.200009	0.251096	0.02322	0.2039322	0.200038	0.220394	0.237394	0.153139
RAINFALL	0.142631	0.104248	0.105809	0.102847	0.087783	0.141445	0.1000274	0.100059	0.132059	0.100059	0.110265
SOIL PROPERTIES	0.009133	0.100394	0.102365	0.112001	0.100375	0.101418	0.1000886	0.128742	0.000742	0.128742	0.051521
SMI	0.031606	0.046763	0.042213	0.041225	0.013077	0.10871	0.0621409	0.068236	0.048236	0.058236	0.046121
LST	0.050054	0.053972	0.067845	0.06058	0.014924	0.027034	0.037942	0.042823	0.002823	0.042823	0.031221
total	1	1	1	1	1	1	1	1	1	1	0.469795

Appendix 3. Physico-Chemical Properties and Clay Mineralogy of the Soils of Morogoro Urban District

Landform	Soil depth	Soil drainage	Soil texture	pH	OC %	N %	P mg/kg	ESP	CEC cmol(+)/kg	BS %	Clay mineralogy
Uluguru mountain strongly dissected ridge slopes (Units M1, M2, M3)	S-MD	E-W	grSCL, SC-C	5.5-6.0	0.1-1.2	0.01-0.05	1.0-5.0	Tr	4.0-12.0	20-85	kaolinite (84%), gibbsite (7%), illite (5%), mica-vermiculite (4%)
Uluguru mountain foothills (Unit P1)	D-VD	W	SC-C	5.0-6.5	0.5-1.0	0.01-0.10	1.0-2.0	Tr	10.0-13.0	30-65	kaolinite (80%), mica-vermiculite (8%), illite (6%), gibbsite (6%)
Mindu-Lugala hills (Units M4, L1)	S	E	grSL-SCL	5.5-6.5	0.3-0.8	0.03-0.06	2.0-3.0	Tr	7.0-10.0	70-95	kaolinite (55%), illite (35%), smectite (10%),
Mzinga-Bigwa piedmont slopes (Units P2, P3),	VD	W	C	6.0-7.5	0.2-0.60	0.03-0.05	0.4-1.0	Tr	6.0-10.0	80-100	kaolinite (85%), illite (8%), gibbsite (6%), smectite (1%)
Mindu-Lugala piedmont slopes (Unit P4)	VD	E-W	LS-SL	6.0-7.0	0.3-0.4	0.04-0.08	0.7-1.4	Tr	8.0-14.0	80-100	kaolinite (50%), smectite (16%), illite (34%)
SUA-Kingolwira peneplains with undulating slopes (Units L2, L3)	D-VD	W	SC-C	4.5-6.5	0.3-0.7	0.04-0.05	1.2-1.8	Tr	10.0-12.0	25-45	kaolinite (78%), illite (10%), smectite (7%), mica-vermiculite (5%),
Tungi-Mkonowamara peneplains (Units L4, L5, L6)	MD-D	E-W	LS, SL-SCL	4.5-5.5	0.3-0.5	0.04-0.08	1.0-1.5	Tr	9.0-11.0	30-40	kaolinite (48%), smectite (20%), illite (32%)
Valleys with river terraces and floodplains (Units V1, V2)	VD	MW-P	L, CL-C	6.5-8.0	0.6-1.6	0.06-0.10	8.0-9.0	5-37	20.0-30.0	75-80	kaolinite (40%), smectite (26%), illite (30%), gibbsite (4%)

S=Shallow, MD=Moderately deep, D=Deep, VD=Very deep.E=Excessively drained, W=Well drained, MW=Moderately well drained, P=Poorly drainedtr=trace

Appendix 4. Existing and Proposed Land Use on Each Land Mapping Unit

LAND MAPPING UNIT	EXISTING LU (%)		PROPOSED LU (%)		TOTAL AREA OF LAND MAPPIN UNIT (km²)
1	Built Up	22.85	Settlements	45.74	20.7
	Agriculture	61.07	Conservation Agriculture	49.78	
	Close Woodland	0.04	Agroforestry	4.49	
	Open Woodland	15.29	Forest	0	
	Forest	0.75			
2	Built up	2.24	Settlements	6.87	21.30
	Agriculture	71.8	Conservation agriculture	46.29	
	Closed Woodland	1.30	Agroforestry	46.42	
	Open Woodland	24.66	Forest	0.41	
	Forest	0			
3	Built Up	8.17	Settlements	0.67	14.53
	Agriculture	65.21			
	Closed Woodland	0.68	Conservation Agriculture	84.46	
	Open Woodland	24.74	Agroforestry	11.32	
	Forest	1.20	Forest	3.54	
4	Built Up	0.34	Settlements	4.34	7.65
	Agriculture	63.30	Conservation Agriculture	10.11	
	Close Woodland	0			
	Open Woodland	32.86	Agroforestry	3.83	
	Forest	3.50	Forest	81.72	
5	Built Up	0	Settlements	0.47	2.12
	Agriculture	61.60	Conservation Agriculture	5.70	
	Close Woodland	0	Agroforestry	6.27	
	Open Woodland	19.09	Forest	87.55	
	Forest	19.32			