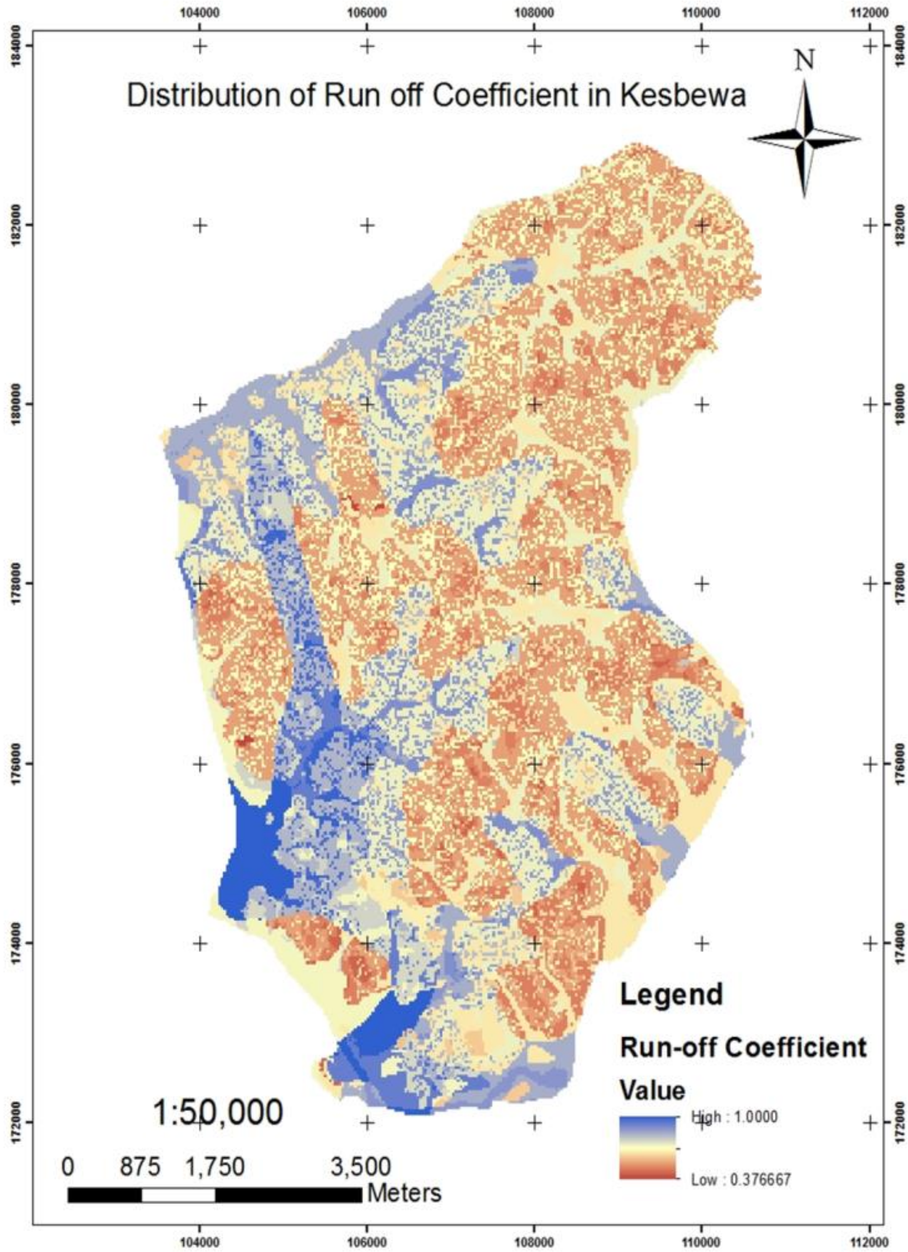
MONITORING THE EFFECTS OF URBAN AND PERI-URBAN AGRICULTURE AND FORESTRY ON RUNOFF AND INFILTRATION OF STORM WATER IN KESBEWA URBAN COUNCIL, SRI LANKA



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Contents

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Acronyms and abbreviations

DEM	:	Digital Elevation Model
GIS	:	Geographical Information Systems
GPS	:	Global Positioning Systems
KUC	:	Kesbewa Urban Council
MSL	:	Mean Sea Level
RS	:	Remote Sensing
UDA	:	Urban Development Authority
UHI	:	Urban Heat Island
UPAF	:	Urban and Peri Urban Agriculture and Forestry

1. Introduction

1.1 Background

Colombo (Sri Lanka) residents consume in average 826 gallons (about 3755 litres) of fresh water a day and about 85 percent of households in Sri Lanka have access to safe drinking water (Department of Census and Statistic Poverty in Sri Lanka, 2010/2011). For groundwater replenishment, Sri Lanka depends largely on recharge water from infiltration of precipitation from the surface to groundwater through permeable surfaces. The rate of infiltration is determined by soil characteristics including ease of entry and crust of the soil surface (permeable versus sealed surfaces), texture of the soil, , compaction, aggregation and structure, water content, organic matter, number, size and continuity of pores, storage capacity of and transmission rate through the soil.

However, as a consequence of urbanisation, forested areas and grass-lands are increasingly converted to commercial, residential or industrial uses. This process implies a conversion of former permeable surfaces to impermeable surfaces such as concrete, asphalt, building roofs, and compacted areas. Changes in the quantity and location of impermeable surfaces have important implications not only for groundwater recharge, but also for storm water management, especially during high intensity and extreme rainfall events which are increasingly more prominent in Sri Lanka. The increase in built-up surfaces thus contributes to an increase in flooding and flash flooding frequency due to reduced infiltration and reduction of flow resistance.

Techniques that promote infiltration and storage of water in the soil, such as permeable pavements, uncompacted soils and increasing the ground and vegetation cover in urban areas can be incorporated into new and existing residential and commercial developments to reduce the volume of storm-water runoff from urban and peri-urban areas (Cohen and Wijsman, 2014).

Urban and Peri-urban Agriculture and Forestry (UPAF) is one strategy through which to restore natural environmental features to the urban environment and can provide hydrological benefits with regards to flood alleviation and protection of water quality. Productive and green areas can positively influence infiltration and decrease in surface run-off.

The amount of surface run-off (Figure 01) reflects the difference between the amount of precipitation and infiltration into the ground water system (Guidelines for the Integrated Management of the Watershed, http://www.unep.or.jp/ietc/publications/). As for infiltration, run-off varies with rainfall intensity and frequency, with slope, surface condition, land use and vegetation cover and hydrological soil type (see Figure 01). Part of the infiltrated water is stored in the soil (see Figure 02) and manifested as increased soil moisture.

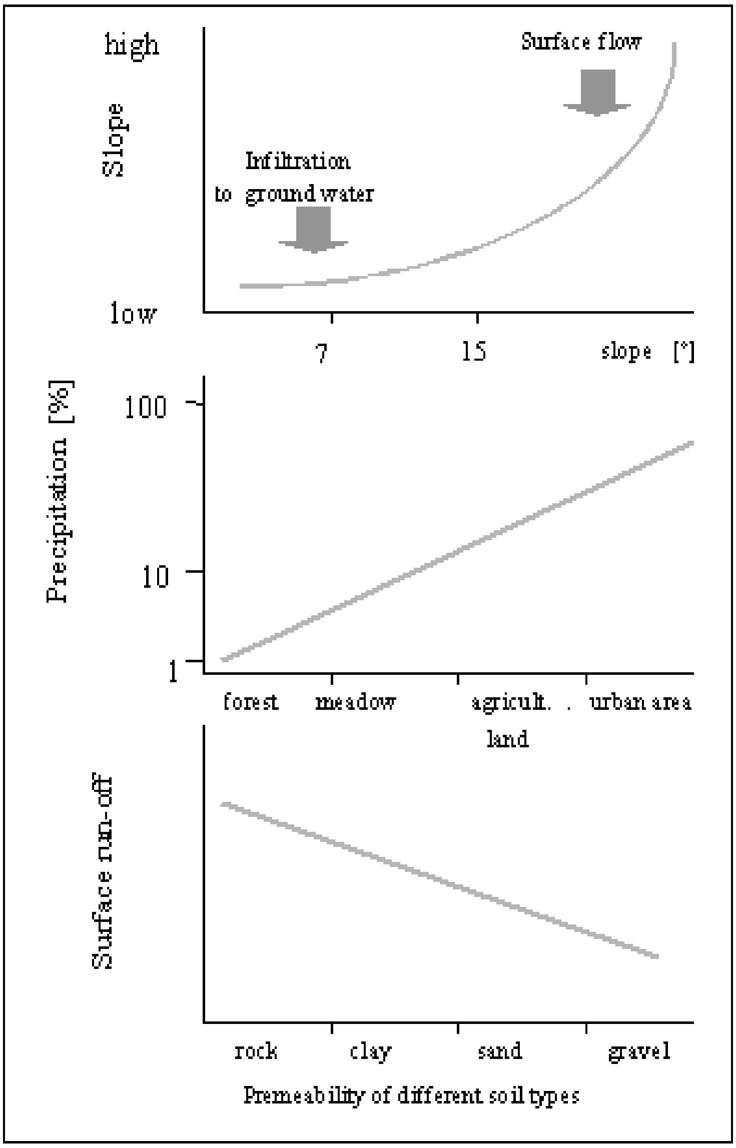

Figure 01: Factors affecting surface run-off

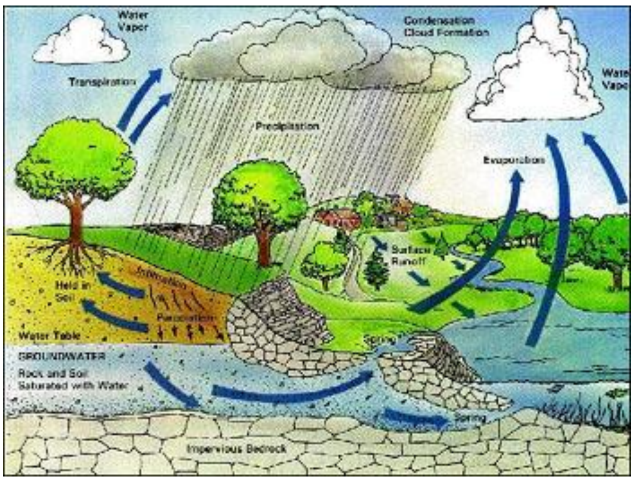

Figure 02: Infiltration and surface run-off process
Source: http://www.villageofhoward.com/182/Infiltration

1.2 The run-off coefficient

The run-off coefficient (ΔC) is the proportion (%) of the rainfall that appears as storm water run-off from a certain surface. Negative ΔC values for any time period will indicate a net decrease in run-off and an increase in infiltration/storage of storm water within a given surface area (which may positively contribute to reducing the risk of floods). Run-off coefficients represent one of the principal means to characterise run-off for different periods and areas (Wanielista and Yousef, 1993). The run-off coefficient varies with slope, surface condition, vegetation cover and soil type. Surfaces that are relatively impervious like streets and parking lots have run-off coefficients approaching one. Surfaces with vegetation and flat lands to intercept surface run-off and those that allow infiltration of rainfall have lower run-off coefficients. Vegetation creates more porous soils by both protecting the soil from pounding rainfall, which can block natural gaps between soil particles, and loosening soil through root action. This is why forested areas have the highest infiltration rates, and lowest run-off coefficients, when compared to other land use categories (Thompson *et al*, 2010).

All other factors being equal, an area with a greater slope will have more storm water run-off and thus a higher run-off coefficient than an area with a lower slope. Soils that have a high clay content that do not allow much infiltration have relatively high run-off coefficients, while soils with high sand content have higher infiltration rates and lower run-off coefficients. Roads, roofs and other (close to) impermeable surfaces have high run-off coefficients.

Run-off coefficients are used to determine flood control channel construction and possible flood zone hazard delineation. A high run-off coefficient may indicate areas with risk of flash floods during extreme rainfall events (Hartmann, 2011).

1.3 Vulnerabilities to increasing flood risk in Colombo district

Flooding has been one of the most costly disasters in terms of both property damages and human casualties in Sri Lanka. Records show major flood events in Sri Lanka for the years 1913, 1940, 1947, 1957, 1967, 1968, 1978, 1989, 1992, 2003 and 2010 with severe loss of human lives and damages to public and private properties and the environment (Ratnayake and Jayasekara, 2009).

Floods can be categorised as local/urban, riverine, coastal and flash floods (World Meteorological Organization 2008). Out of those, riverine and urban floods are the most common in Sri Lankan urban and suburban areas, especially in Colombo and its surrounding urban areas, such as Battaramulla, Kotte and Kesbewa urban area. Colombo's situation is quite similar to other Asian cities. In the period between 1994-2004, Asia accounted for one third of 1,562 flood disasters and nearly 60,000 were killed in these floods (Arambepola and Iglesias, 2009).

In 2010, Colombo was inundated by two major floods in the months of May and November. These floods cost millions of dollars in economic losses due to business interruption, in addition to severe damages inflicted on public and private property (The Metro-Colombo Urban Development Project Sustainable Flood Risk Management for the Colombo Metropolitan Area, 2013).

The recurrent floods in the Colombo Metropolitan Region are due to a combination of factors, including reduction of retention areas in and around the city due to legal and illegal constructions, dumping of waste in drainage canals, lack of regular maintenance of the drainage system and commercial development in wetland reservations. Reduction in open areas and increase in more paved areas due to rapid development has resulted in faster surface run-off. This was aggravated as former storm drains were paved over to make place for roads (Kapilaratne and Kavinda, 2011). These activities have reduced Colombo's capacity to cope with high intensity rainfall that has become more frequent and intense with climate change (University of Moratuwa, 2012).

Recently, however the authorities such as the Urban Development Authority, Sri Lanka (UDA), the Ministry of Defence and Urban Development-Irrigation Department of Sri Lanka and Colombo Municipal Council have started taking steps towards flood prevention. These include amongst others the rehabilitation of drainage channels and former rice fields (Dubbeling, 2014), next to other infrastructure improvements.

It is expected that Urban and Peri-urban Agriculture and Forestry (UPAF) can mitigate flood risks by increasing storage capacity as well as infiltration. In the present study, an investigation has been carried out to identify and assess run-off coefficients for different UPAF and other urban land uses, to better understand UPAF's potential to enhance storm water infiltration and reduce the surface run-off in the study area.

1.4 Objectives of the study
The main objective of this study was to estimate and examine the spatial pattern of run-off corresponding to different land use types of the Kesbewa Urban Council (KUC), located at 25 km from Colombo and one of its fast-growing suburbs.

2. Study site and methods

2.1 Study area
Kesbewa Urban Council (KUC), with a surface area of 50.39 $km^{2,}$ is located in the Colombo district in the Western province in Sri Lanka (Figure 03). KUC lies on the Colombo-Horana main road about 20km away from Colombo- the commercial capital of Sri Lanka, and is part of the Colombo urban fringe that has been rapidly increasing in population. It is also characterised by high and rapid conversion of agricultural to urban land uses. The KUC is located in the Low country Wet zone which is classified based on the altitude from the mean sea level and annual rainfall (Department of Meteorology, Sri Lanka). The KUC study area is characterised by four rainy seasons; with a first Inter-monsoon period from March to April, the Southwest Monsoon period from May to September, the Second inter-monsoon period from October and November and the Northeast monsoon period from December to February (Figure 04). During the Southwest monsoon period, the area receives more than 500 mm rainfall/month, while during the second inter-monsoon and the northeast monsoon periods the area receives more than 200mm average rainfall per month (Department of Meteorology, Sri Lanka).

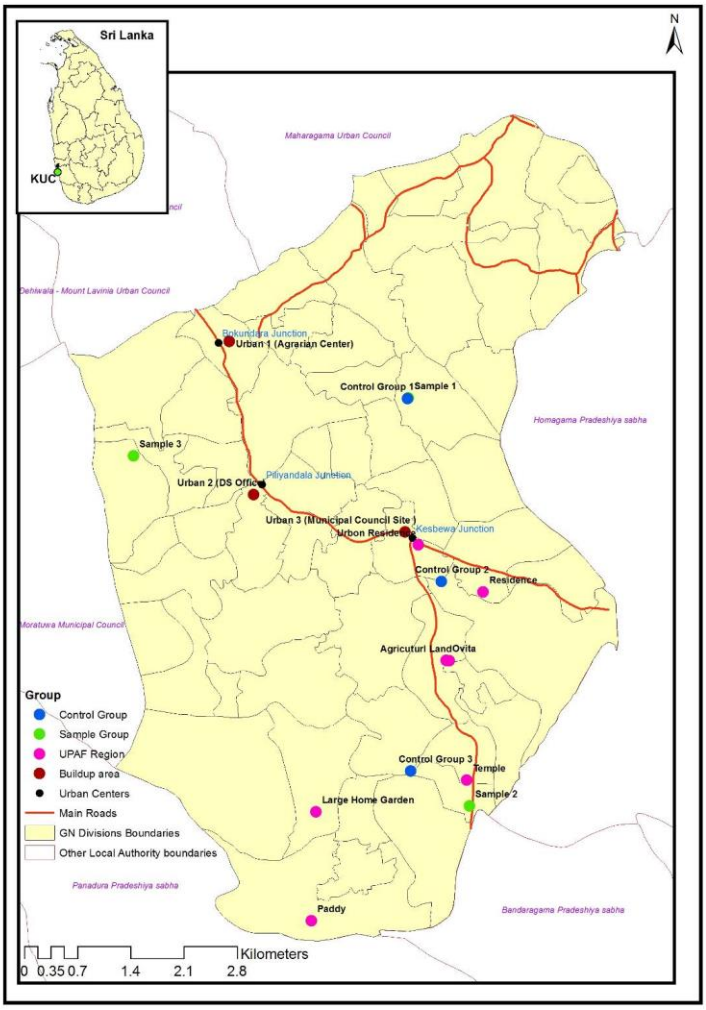

Figure 03: Kesbewa Urban Council (light yellow) area

Source: Urban Development Authority, Sri Lanka

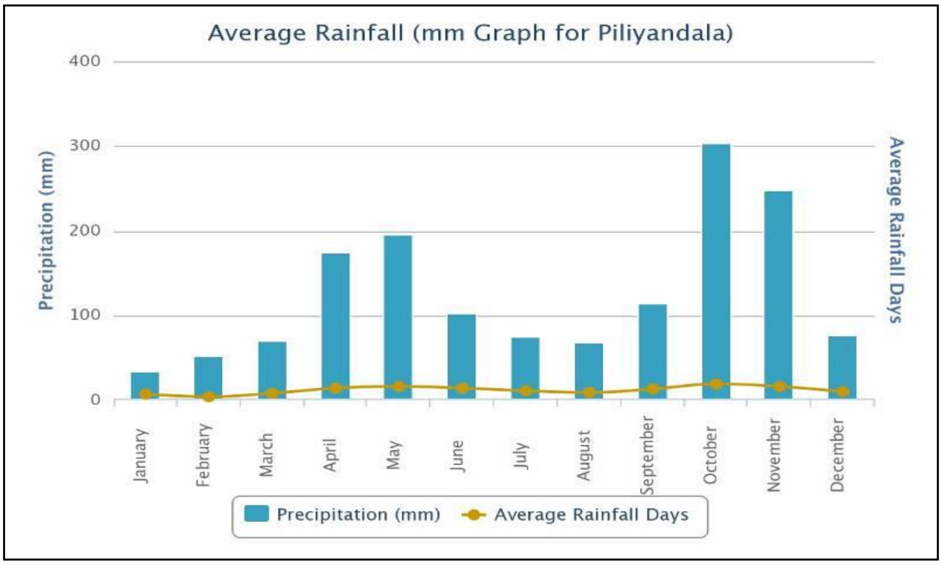

Figure 04: Average rainfall of Kesbewa Urban Council (Piliyandala area in the KUC urban core), Sri Lanka from 2008 – 2013. *Source: World Weather Online, 02.12.2013*

The average air temperature of the KUC area for the last 5 years (2008 to 2013) was 28.05 ^{0}C, ranging from 31.33^{0}C (Maximum) temperature to 24.50^{0}C (Minimum) with some significant deviations. During the Southwest Monsoon period (May to September), average temperature is relatively low when compared with the first inter monsoon period and the northeast monsoon period (Figure 05). The hottest season is January to March. During 2008 to 2013, the KUC area has shown an increasing trend in air temperature (Figure 06), which is partially contributed to the rapid urbanisation and related Urban Heat Island impact in the KUC area (University of Colombo, 2014).

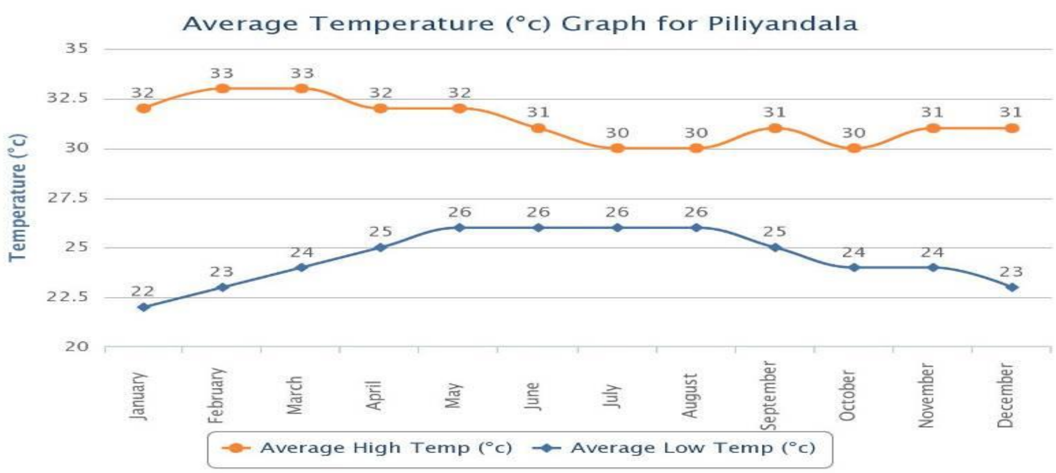

Figure 05: Average temperature ranges for the Kesbewa Urban Council area
Source: University of Colombo, 2014

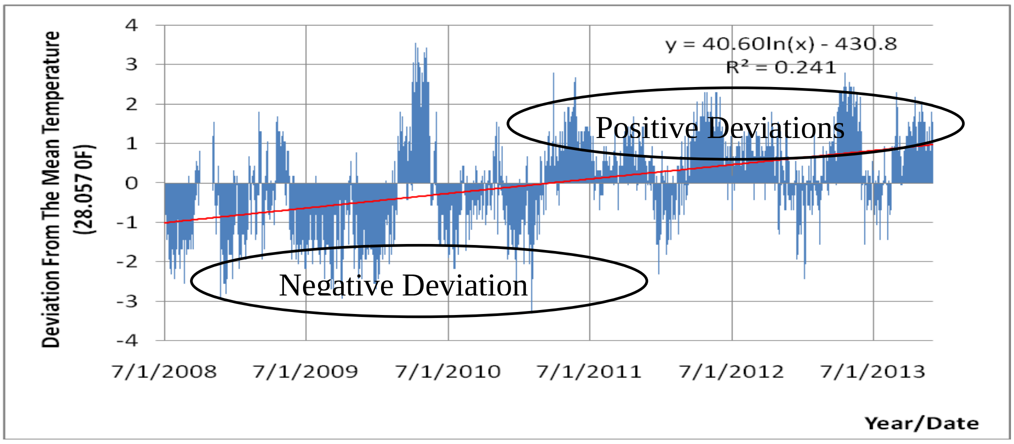

Figure 06: Air Temperature variation in Piliyandala City area, Sri Lanka.

Source: www.worldweather.com/ 2013

The 2012 population of the KUC area was estimated at 243,842 inhabitants, with an average population density of 3,488 inhabitants per square kilometre, ranging from 1,057 to 7,858 inhabitants per square kilometre. There were 21,634 housing units and average housing density was 1, 327 per square kilometre, ranging from 320 to 2,212 units per square kilometre (Department of Census and Statistics Sri Lanka, 2013). Over the past years, KUC has emerged as an attractive residential area for commuters from many parts of Sri Lanka.

Low-lying areas in the KUC suffer from regular food damages during the periods of heavy rainfall (May to September, Southwest Monsoon period) as shown in Figure 07 (with areas in orange to red showing highest frequency of floods).

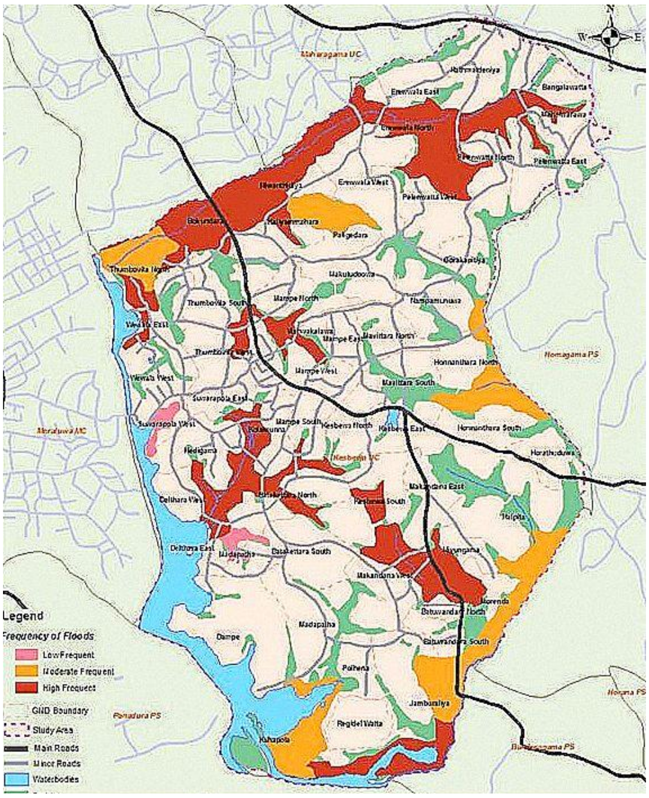

Figure 07: Flood exposure in Kesbewa, Sri Lanka.

Source: Faculty of Architecture, University of Moratuwa (2012). Based on data from the Ministry of Disaster Management, Government of Sri Lanka: Colombo, Sri Lanka.

2.2 Land use in Kesbewa Urban Council area

Kesbewa Urban Council area is strikingly heterogeneous, representing a mix of natural areas located around the city centre and built-up areas found at the city centre in varying densities. With the rapidly growing urbanisation, many of the former agricultural areas were gradually converted to non-agricultural areas, resulting in about 60% of the land now being used for residential purposes and related amenities (Urban Development Authority, 2011). During the period of 2000 to 2010 fourteen percent of agricultural lands have been converted to residential areas (Kekulanannda, 2012). Current land uses in KUC however still include 32% of land being used for agriculture, irrigated with excess water resources from the neighbouring Bolgoda Lake (Figure 08). Relatively large areas of abandoned paddy lands and green spaces exist in Kesbewa. In 2011, Kesbewa counted with 600 hectares of paddy lands, with 32% of the total paddy areas being abandoned. In addition, a total of 410 hectares were used for home gardens, while another 285 hectares remained available for cultivation (Dubbeling, 2014).

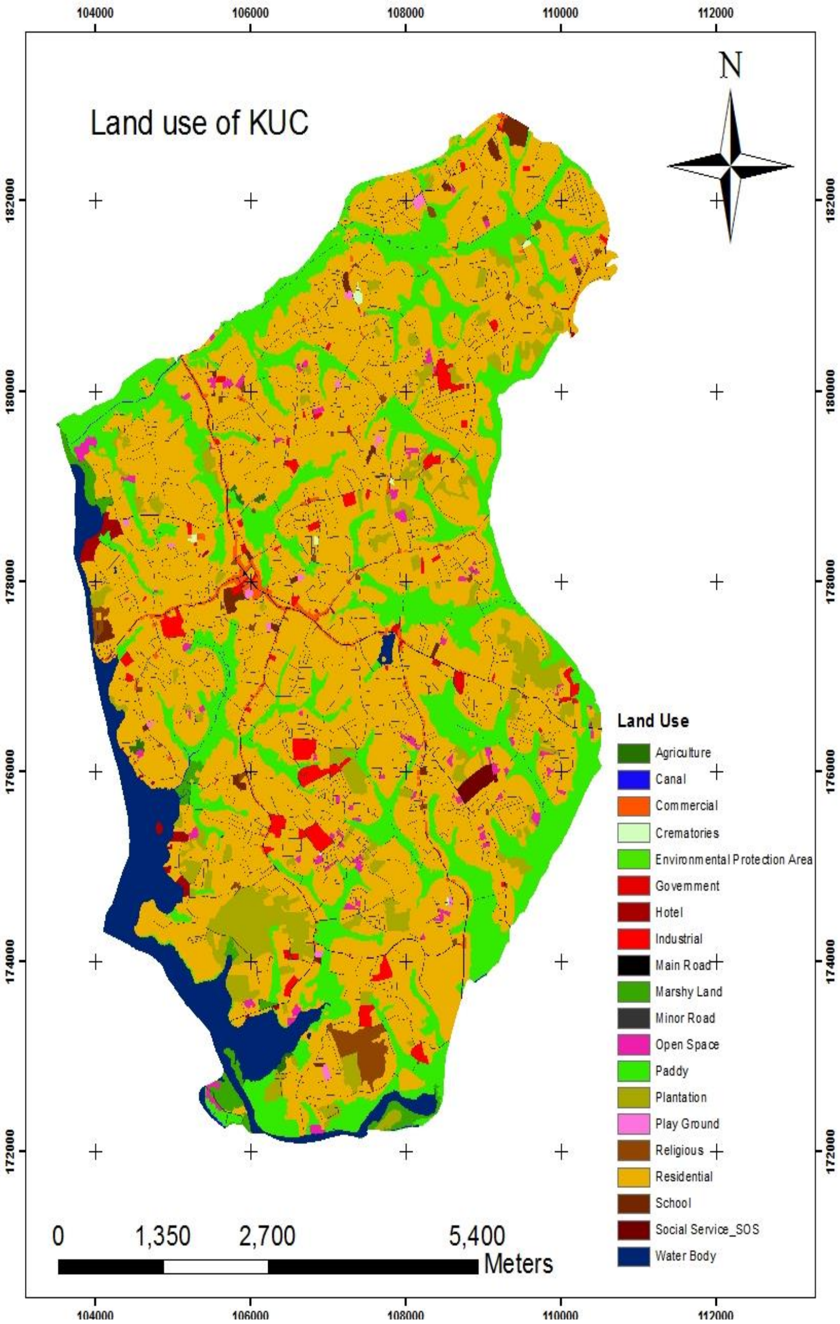

Figure 08: Land use types in Kesbewa Urban Council Area
Source: Urban Development Authority (UDA) Sri Lanka, 2011

2.2.1 Topography and terrain

KUC area falls in the lowest plain of Sri Lanka (Cooray – Geology of Sri Lanka 1984). The elevation of the study area varies from 1 to 38 m, with mild slope patterns as shown in Figure 09.

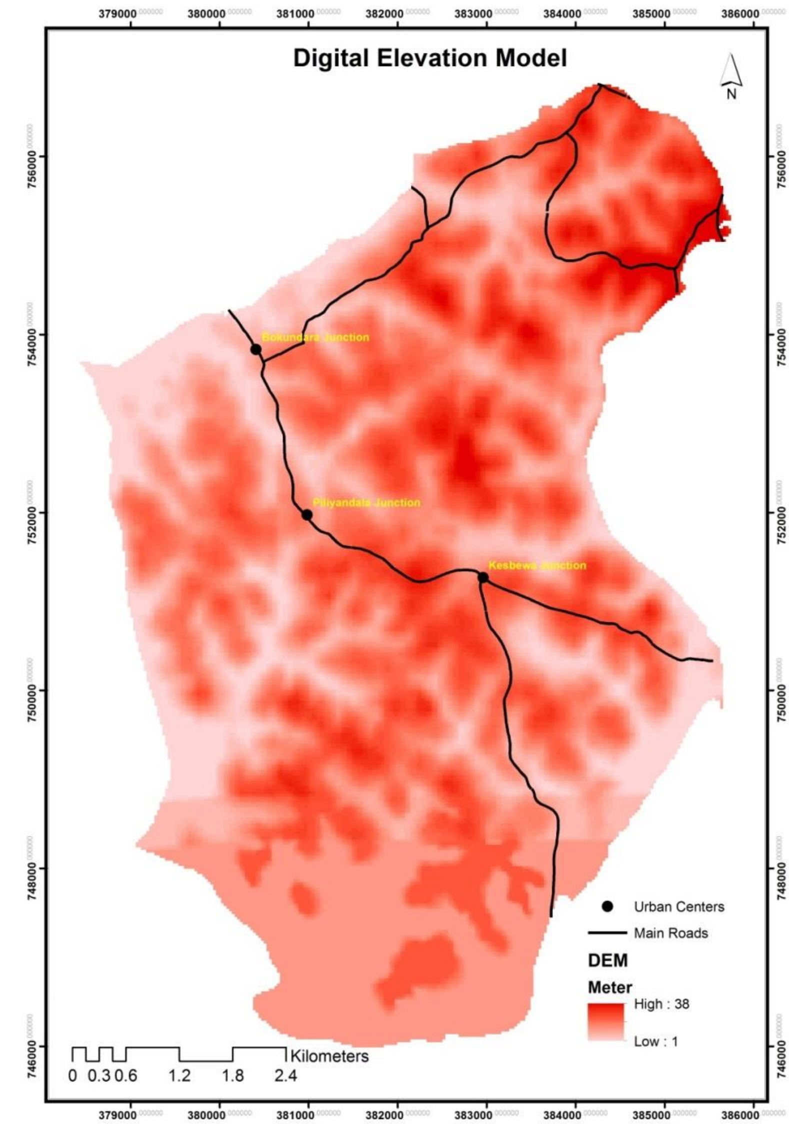

Figure 09: Topography map of the study area

2.2.2 Geology and soil type and quality

A vast area (over 90%) of Sri Lanka is made up of metamorphic crystalline rocks of Precambrian age. The typical rock types of this basement include Biotite gneiss, Hornblende Biotite gneiss, Charnockites, Charnockitic gneisses, Quartzite and undifferentiated Meta sediments. According to the Survey Department soil map, there are two main hydrologic soil types in the project area as described below:

- ***Group B***: Shallow loess; sandy loam; minimum infiltration rate 3.8 - 7.6 mm/hour.
- ***Group C***: Clay loams; shallow sandy loam; soils low in organic content; soils usually high in clay; minimum infiltration rate: 1.27 - 3.8 mm/hour.

2.3 Methodology

The factors affecting urban run-off can be divided into two groups, meteorological factors and biophysical factors. Rainfall intensity, rainfall amount, rainfall duration, distribution of rainfall and direction of storm movement can be considered as meteorological factors. As it is assumed that the impacts of the meteorological factors are uniformly distributed in the study area, this study mainly focused on biophysical factors to evaluate the run-off pattern and to prepare a run-off coefficient map for the Kesbewa Urban Council area. The following biophysical factors were considered:

- Soil types of the study area
- Slope of the study area
- Land use and land cover types of the study area.

To determine the spatial pattern of run-off coefficients and to prepare a run-off coefficient map for the KUC area, ARCGIS Geographical Information Systems software was used, as shown in Figure 10.

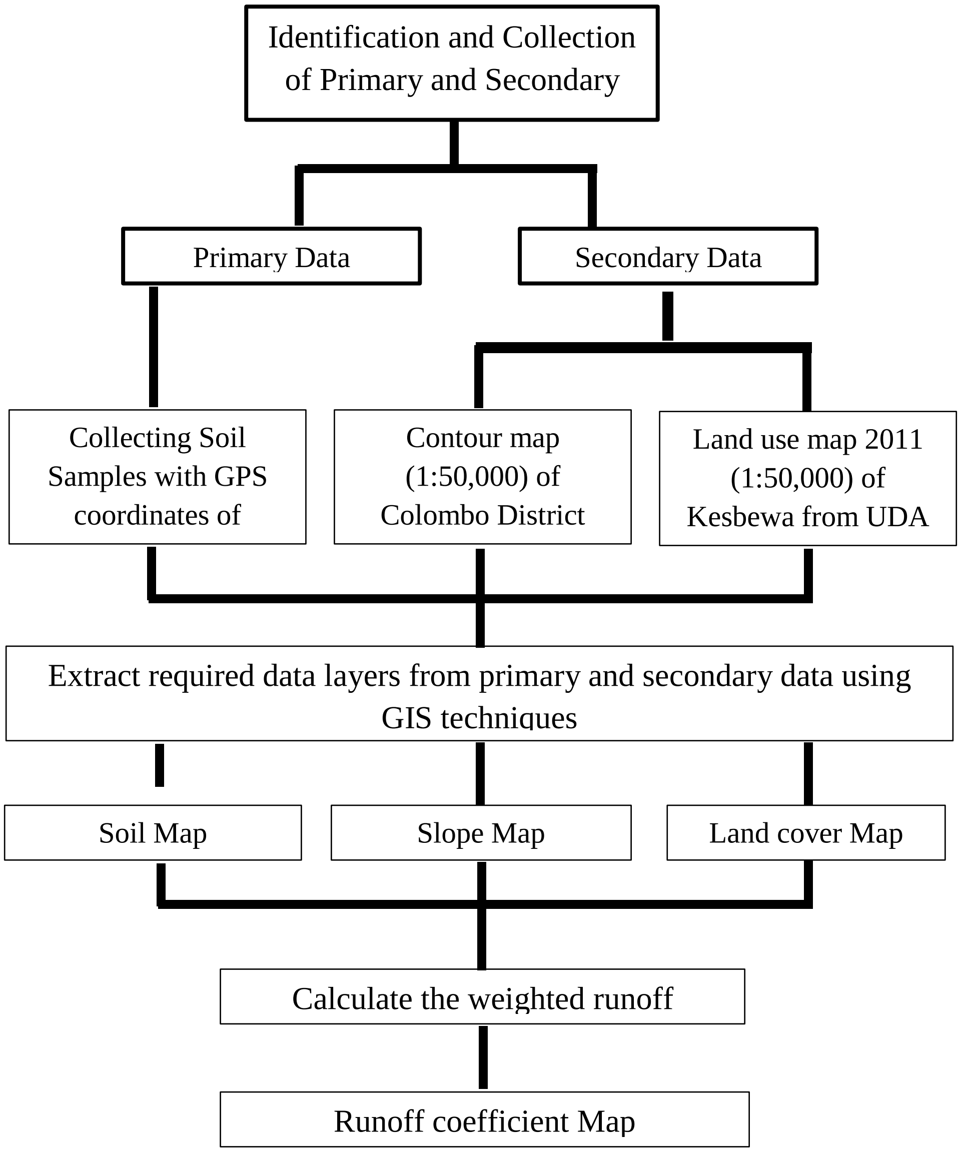

Figure 10: Methodological framework of the study

Source: own elaboration

2.3.1 Data used to determine the run-off coefficient

Data were collected during field work as well as from secondary sources. Slope, land use and land cover maps were obtained from secondary sources. Digital land use data (1:50,000) for 2011 were received from the Urban Development Authority. Together with digital contour data received from the Survey department of Sri Lanka, these were used to extract the slope pattern of the study area. As an appropriate soil map was not available for the study area, a 1:50000 scale soil map was developed using on-ground investigations, base maps such as contour and land use/land cover maps, and expert interviews. Handheld GPS (Global Positioning System) receivers were used to select the locations to determine the hydrological soil types in the area. Geographical Information Systems (GIS) were used to create different spatial data layers and for analysis of the run-off coefficient of the study area.

2.3.3 Preparation of a soil map for KUC area

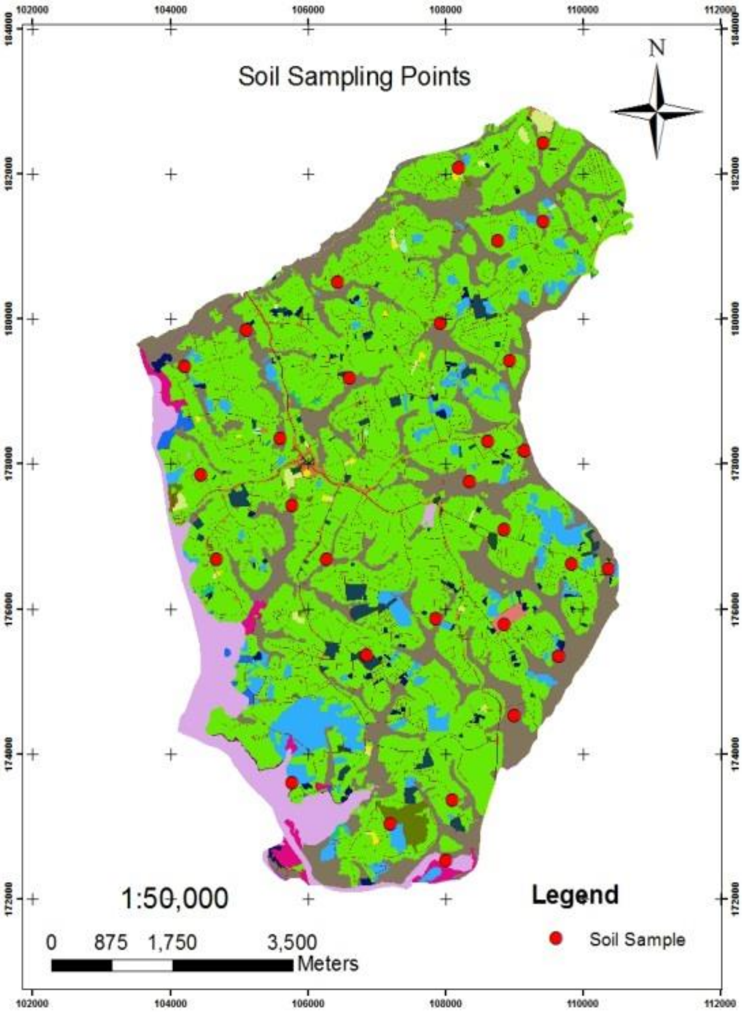

Figure 11: Soil sampling locations
Source : own elaboration

To prepare the soil map of the study area, field data were collected, based on spatial stratified sampling techniques. The study area was divided into 20 strata based on the land use types, and then 25 sample sites were identified representing all the land use categories (Figure 11) and located on site map. Soil samples for analysis of soil types and GPS coordinates of each sample location were collected.

Soil analysis confirmed that only two major hydrological soil types were found in the study area, coinciding with the survey department soil types (Groups B and C) previously described.

According to the characteristics of the soil samples a run-off coefficient was assigned for each sample. Then point data were interpolated using the Inverse Distance Weighted Method (IDW) to convert the point characteristics into surface data.

2.3.4 Preparation of a slope map

A Digital Elevation Model (DEM) was generated by using a 1:50,000 scaled and 5m interval contour map of the Colombo district. To increase the accuracy of the results, using interpolation techniques, a 2m interval contour map was generated and a DEM was created for the entire Colombo district and cropped into a DEM for Kesbewa Urban Council area in order to generate the slope map for KUC as shown in Figure 12.

a b c

a. 1:50,000 scaled, 5m interval contour map of Colombo district Source: Survey Dept. of SL
b. Generated 2m interval DEM
c. Slope map of the KUC area

Figure 12: Steps adapted to preparation of slope map

Finally slope directions and angle (in degrees %) of slope of the study area were assessed and the slope map was classified into three main slope classes as given in Table 01.

Table 01: Slope Categories

Class category	Slope
1 (Low)	< 2%
2 (Moderate)	2-6%
3 (High)	>6%

Source: RUAF Foundation, 2013. Guidelines for monitoring the adaptation and mitigation impacts and co-benefits of UPAF activities

2.3.5 Preparation of a land use and land cover map

There were twenty land use types in the study area. Among them, residential land uses are the most prominent in KUC area followed by paddy lands (Table 02).

Table 02: Land use types and area statistics of KUC area – 2012

Land use category	Area in sq.km	Percentage
Residential	30.10274	59.66
Paddy	9.892944	19.61
Water Body	2.873120	5.69
Plantation	2.733412	5.42
Minor Road	1.196784	2.37
Industrial	0.746368	1.48
Open Space	0.482796	0.96
Marshy Land	0.459324	0.91
Commercial	0.456504	0.9
Religious	0.421460	0.84
School	0.268776	0.53
Main Road	0.209568	0.42
Hotel	0.163864	0.32
Play Ground	0.094796	0.19
Social Service, SOS	0.095836	0.19
Government	0.078956	0.16
Canal	0.052336	0.1
Agriculture	0.052964	0.1
Crematories	0.038828	0.08
Environmental Protected Area	0.032544	0.06
Total	50.45397	100.00

Note: Data has been rearranged from highest to lowest based on percentages

Source: own elaboration, data has been extracted through ArcGIS v10.1

Considering the impermeability of the land use types, 20 land use classes were re-categorised into 6 land cover types: Impervious, Bare land, Plantation, Residential, Paddy or Rice fields and Water Bodies. When there was no significant difference in run-off coefficient between certain land use types, such as wet land and rice fields, these were assigned the same run-off coefficient (See Table 03).

2.3.6 Preparation of the run-off coefficient map

A weighted run-off coefficient value for all the slope categories in the slope map of the study area was assigned using standard values given in Table 03. Then, corresponding weighted run-off coefficient values for the soil categories in the soil map of the study area were assigned (Table 03) for different land cover types. The run-off coefficients for impervious (including open water surface) and paddy fields were set to 1 and 0.9 respectively. Finally, GIS was used to combine the soil map, slope and land cover map into one map (the run-off coefficient map) and then run-off coefficient values were inserted into the map.

Table 03: Run-off coefficient values

Land use / vegetation cover	Peak run-off coefficients C (range)	C suggested Default value (soil class B, Slope class 1: max 2%)	For Soil type classes C and D	For Slope classes 2 and 3
Agricultural land				
Cultivated cropland	0.10 – 0.40	0.15	Add 25% for each higher class	Add 30% for each higher class
Pasture/meadow	0.10 – 0.60	0.25	Add 25% for each higher class	Add 30 % for each higher class
Rice fields	0.9	0.9	-	-
Undisturbed natural vegetation				
Mainly shrubs/scrubs	0.10 – 0.40	0.15	Add 25% for each higher class	Add 30 % for each higher class
Mainly grasses	0.10 – 0.60	0.25	Add 25% for each higher class	Add 30 % for each higher class
Sparsely vegetated	0.20 - 0.60	0.35	Add 25% for each higher class	Add 30 % for each higher class
Wetlands	0.9	0.9	-	-
Forested	0.05 – 0.25	0.10	Add 25% for each higher class	Add 30 % for each higher class
Pavement				
Asphalt/cement	0.75 - 0.95	0.85	-	-
Brick/flagstone/gravel	0.70 - 0.85	0.80	-	-
Compacted non-vegetated land	0.30 – 0.75	0.50	Add 25% for each higher class	Add 30 % for each higher class
Roofs	O.75 – 0.95	0.85	-	-
Water bodies	1	1	-	-

Source: RUAF Foundation, 2012. Guidelines for monitoring the adaptation and mitigation impacts and co-benefits of UPAF activities

It has to be noted however that the assumption is that soils in wet rice fields are already saturated with water; as are water bodies, reason why any additional rainfall water can thus not infiltrate and will immediately run off. However a functioning rice field and a water body allowing for storing different water levels (for example if bordered by small dikes) might contain different levels of water, hence there would be a run-off delay. This may also depend on rainfall intensity. Such storage capacity of rice fields and water bodies should be further determined to assign its real run-off coefficients.

3. Results

3.1 Distribution of hydrological soil types in the study area

There were no large spatial differences in soil types throughout the study area, with basically two different soil types, boggy laterite soil and Clay soils found in the paddy fields and flood plains. The area (m^2) covered by different soil classes is summarised in Table 04.

Table 04: Area covered by different soil classes

Soil Class	Area m^2	Area %
Group B: Shallow loess; sandy loam; minimum infiltration rate 0.15 - 0.30 inches/hour	28720800	56.95
Group C: Clay loams; shallow sandy loam; soils low in organic content; soils usually high in clay; minimum infiltration rate: 0.05 - 0.15 inches/hour	15020100	29.79
Water Bodies	6686100	13.26
Total	50427000	100.00

Source: Own elaboration, data has been extracted through ArcGIS v10.1

As indicated in Table 04 and Figure 13, 57% of the total area is shallow loess soil which has moderate infiltration rates. In addition, 30% of the area is Clay loams, which has low infiltration rates and 13% of the area is made up of water bodies which are assigned the highest infiltration rate (1.0).

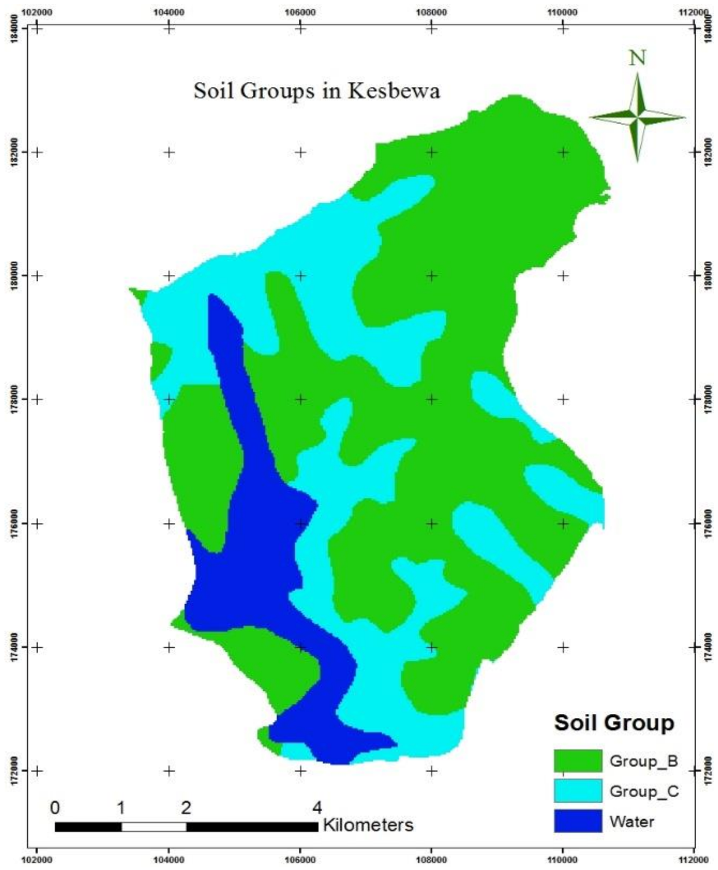

Figure 13: Hydrological soil group in KUC Area

Source: own elaboration

3.2 Slope of the study area

The project area shows a relatively uniform terrain pattern. 99% of the total area slope variation ranges from 1-6 % (Table 05), such uniform slope shape produces significantly greater run-off per unit area than the concave-linear, head, or convex-linear slopes.

Table 05: Area under the different slope categories

Slope category	Count	Area in sq.km	Area %
0 - 2%	4602024	18.40	36.51
2 - 6 %	7870261	31.48	62.42
Over 6%	131274	0.53	01.07
Total	12603559	50.45	100.00

Source: Own elaboration, data has been extracted through ArcGIS v10.1

The slope map created for the entire KUC area is given below (Figure 14).

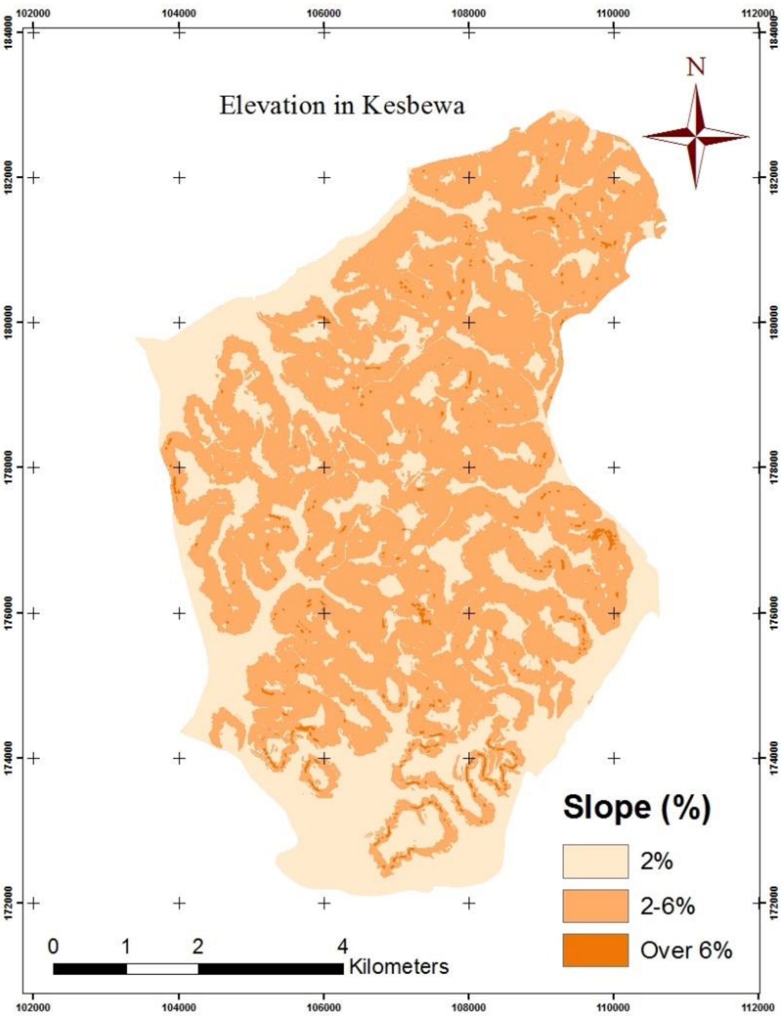

Figure 14: Percent slope for KUC area

Source: own elaboration

3.3 Land cover/land use in the study area

In the Kesbewa study area, the most significant factor determining run-off is land cover type, as impacts of the other two factors (slope and soil) are uniformly distributed over the study area. The land use map with the six main land (ground) cover types is shown in Figure 15 and Table 06.

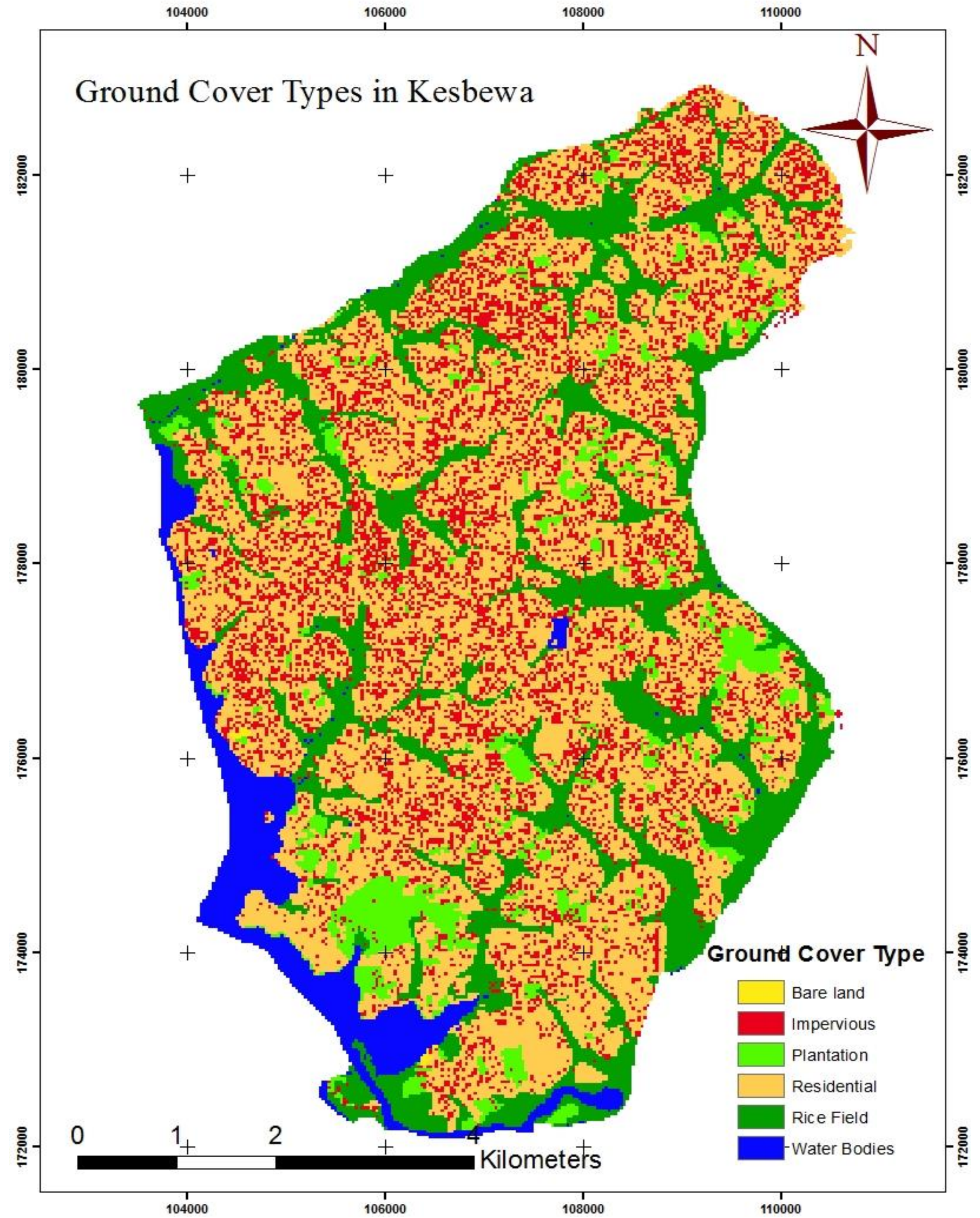

Figure 12: Land use map with six (6) ground cover types. *Source: own elaboration*

Table 06: Area covered by six (6) ground cover categories and their percentages

Land uses	Land coverage	Area in sq.km	Percentage %
Rice Field	Paddy	10.35	20.50
Marshy Land/water bodies			
Residential	Religious	25.74	51.0
	Hotel		
	Commercial		
	Government		
	School		
	Industrial		
	Social Service_SOS		
Plantation	Agriculture	2.82	5.50
	Tree Plantation		
	Environmental Protection Area		
Bare land	Open Space	0.62	1.20
	Crematories		
	Play Ground		
Impervious	Minor Road	9.73	19.20
	Main Road		
	Roof	8.32	
Total		**50.45**	**100.0**

As expected, paddy lands were distributed in low-lying areas in Kesbewa and away from the city centre and most of impervious surfaces were clustered in residential areas. Residential areas were distributed in and around the city centre and in comparatively high elevation -land areas (Figure 12).

3.4 Run-off coefficient map

The run-off coefficients values were computed using GIS and a run-off coefficient map was generated combining the slope, soil type, and land-use classes (Figure 13).

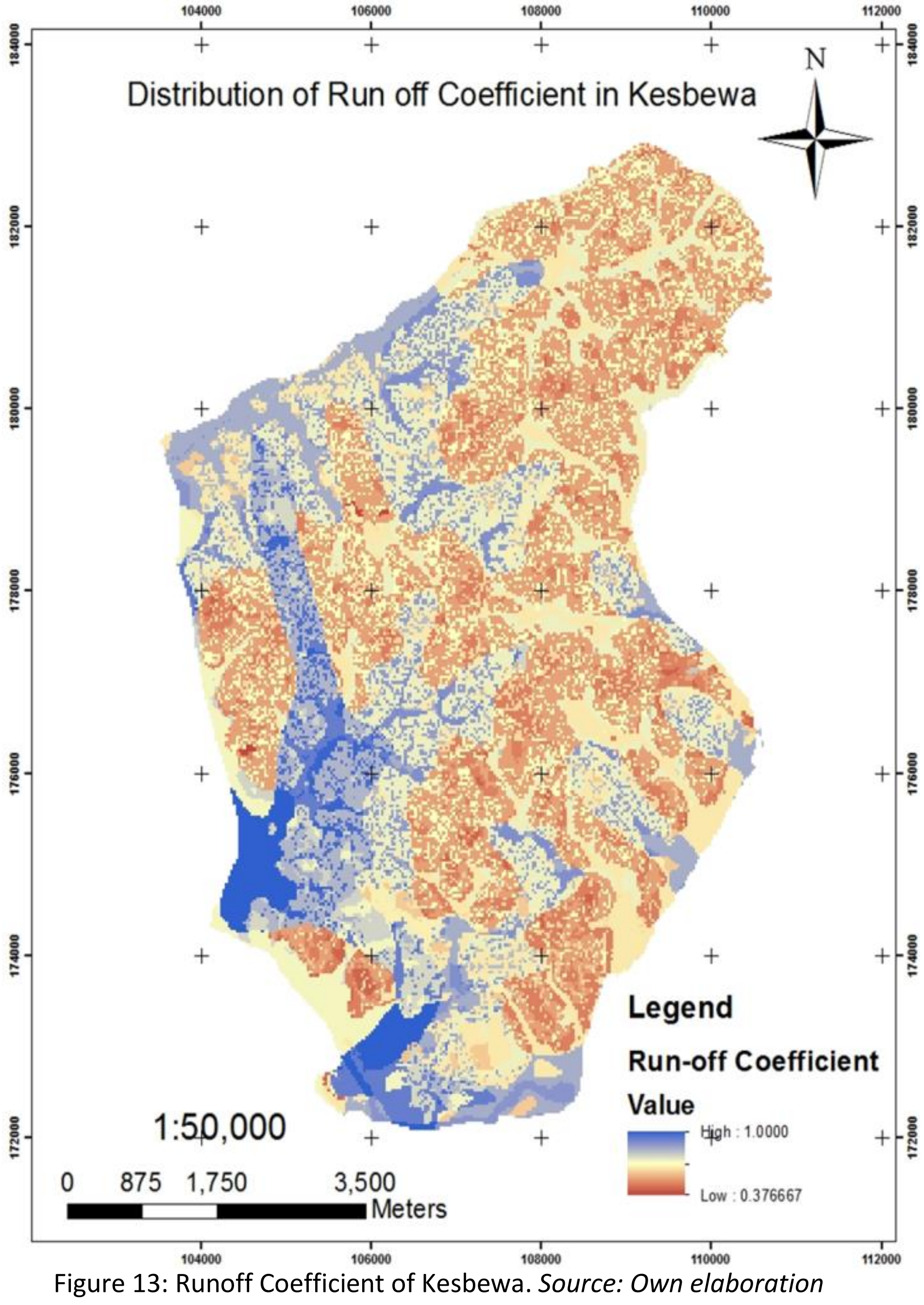

Figure 13: Runoff Coefficient of Kesbewa. *Source: Own elaboration*

The variability in the run-off coefficient pattern is highly correlated with land cover types of the study area. In a future study, and based on this initial data set and set of maps, scenarios could be developed for changing land use/cover types to determine effects on run-off.

4. Discussion

Determination of run-off coefficient is important for flood control and for possible flood zone hazard delineation. To generate run-off coefficients for the study area, three physical factors were considered; slope, soil, and land use/land cover types. As soil types and slopes were rather uniformly distributed throughout the study area, land use types/covers were most directly correlated with variation in run-off coefficients.

A high run-off coefficient indicates potential flash flood and flooding areas during storms and periods of intense rainfall. Depending on the water storage capacity in rice fields and wet lands run-off coefficients can get close to 1 (0.9). Indeed as most paddy lands in Kesbewa are located in low-lying areas and flood zones, any housing in these areas suffers from regular flood damage during periods of heavy rainfall. However, in contrast to abandoned paddy lands, well-maintained and well-drained paddy lands function as buffer zones, storing water and controlling drainage, thus reducing flood risk in nearby areas. It is for this reason, that Kesbewa Urban Council and the Ministry of Agriculture from the Western Province implemented a (pilot) project to rehabilitate abandoned paddy areas in 2012-2013. Future impacts on reduced flood incidences will be monitored (Dubbeling, 2014).

In addition, impermeable surfaces such as concrete, asphalt and building roofs, with high presence in the city centre, are showing comparatively high run-off coefficients in the study area. Residential areas away from the city centre have still maintained larger amounts of green spaces and home gardens, therefore run-off coefficients of these residential areas were not excessively high. KUC and the Western province already implemented a programme aimed at supporting home gardens, by providing training, technical assistance and marketing outlets, for reasons of enhancing food security and urban greening. The potential of these areas for flood risk reduction could further be taken into account.

5. Conclusions and recommendations

Over the past two years another 5% of former agricultural land/green spaces has been converted into residential housing and this trend is only expected to increase. Flood incidences in the past years have demonstrated that Kesbwa is vulnerable for urban floods and inundation. The Kesbewa Urban Council, Urban Development Authority and Western Province could further explore the potential of urban and peri-urban agriculture and forestry to mitigate the flood risk by increasing storm water infiltration capacity and decreasing run-off in different zones in the study area.

The pilot project implemented in abandoned paddy lands could be up-scaled to other areas, as a large amount of abandoned paddy lands are still found in Kesbewa. The Kesbewa Urban Development Plan 2020 that is currently being elaborated could integrate protection zones around low lying areas and the Bolgoda Lake and promote urban agriculture activities in these areas. Existing home gardens could be preserved and new residential housing could integrate plot lay out regulations that would set aside a certain area of each plot for home gardening. The use of green roofs and rooftop gardens could be further promoted in the city centre and new housing settlements.

Building on the established GIS and data sets, future scenario studies –with varying land uses- could be easily implemented to determine potential impacts on run-off. More temporal studies should also be conducted in future, to monitor actual impacts of increasing rainfall and contribution of urban and peri-urban agriculture to actual flood risk reduction.

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