

# Land Characteristics, Run-Off and Potential for Rainwater Harvesting in Semi-Arid Areas of Tanzania

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## Abstract

*Effective utilization of rainfall in semi-arid areas is very much dependent on land characteristics, land use, and management practices. Important land characteristics include soil type, soil hydraulic properties down the profile, soil variation along the catena, slope and vegetation cover. In most semi-arid areas of Tanzania, three soil types dominate the catena. The top of the catena is normally occupied by Lithisols. The middle part is usually subjected to erosion and is occupied by a complex of soils but usually Cambisols/ Arenosols/ Ferrosols. Soils with vertic properties commonly Vertisols are found at the bottom of the catena. The relative proportions of the three sections in a given catena, how they are used and managed, determine the amount of runoff, erosion and the potential for rainwater harvesting (RWH). These factors also have a very important influence on the ability of the soil to receive, store, redistribute and release rainwater. This paper presents case studies from sites in Mwanga, Same, Morogoro and Maswa Districts, Tanzania to elaborate the role of these factors in RWH. It is concluded that the landscape is an important factor in determining yield, control and management of runoff, and hence potential for RWH. The catena is a natural set-up for rainwater harvesting where the top section acts as natural generator of runoff and the bottom section as natural receiver.*

Key words: Land characteristics, catena, land use, runoff, erosion, rainwater harvesting

## Introduction

The districts where the RWH research projects were based (Mwanga, Morogoro, and Maswa) are mainly semi-arid (De Pauw, 1984). Semi-arid parts of the country are the areas mostly affected by land degradation (Kikula, *et al.*, 1999; Christiansson, 1981). Causes of land degradation are site specific and consequently the measures to counter them should also be site or farming system specific.

In the semi-arid areas of Tanzania, the fundamental problems facing agriculture and livestock production are declining soil fertility and

inadequate soil-moisture. Human activities on the land have had a negative impact on soil properties. Soil factors are such that a lot of run-off is generated and hence erosion is very common and rainwater is not utilized effectively. Some of the factors are inherent to the soil while others are brought about by the topography of the land.

The most readily observable influence of land characteristics on soil properties and development is that moving surface water almost always carries some solid particles with it and produces erosion or change in relief. Sloping areas tend to be drier, from the standpoint of infiltrated water, than level areas.

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A catena is considered as a natural set-up for land use planning and hence for rainwater harvesting. The top section acts as a natural generator of runoff and the bottom two sections act as natural receivers (Figure 1). Important land characteristics on the catena include soil type, hydraulic properties down the profile, soil variation along the toposequence, slope and vegetation cover. The relative proportions of the three sections in a given catena, how they are used and managed, determine the amount of runoff, erosion and the potential for rainwater harvesting (RWH). The top, middle and bottom parts of the catena may vary greatly in their relative sizes.

In most semi-arid areas of Tanzania, three soil types dominate the catena. The top of the catena is normally occupied by *Lithisols*. These are usually coarse sandy soils with poor moisture retention properties. A complex of soils but usually *Cambisols*/ *Arenosols*/ *Ferrosols* occupy the middle part, which is usually subjected to erosion. Soils with vertic properties commonly *Vertisols* are found at the bottom of the catena. Water and products of weathering, including nutrients accumulate at the bottom. Soils with vertic properties are the most im-

portant and are locally called *mbuga* which means 'plains'. Land is called *mbuga* if it has the following characteristics:

- It lies at the bottom of catena, has a flat topography,
- It is relatively darker and more fertile than surrounding soils,
- It is flooded during the rains, and
- It is sticky when wet, and cracks when dry.

In general, the high content of expanding lattice clay is of primary concern in the management of *mbuga* soils. Agronomic uses of *mbuga* vary widely, depending on the climate. The high clay content and associated slow permeability of these soils when wet, makes them desirable for farming practices that require retention of water in the soil for long period.

This paper describes land characteristics, soils, extent and causes of degradation, extent of rainwater harvesting and constraints to increased use of RWH in three case studies conducted in three districts, which are predominantly semi-arid.

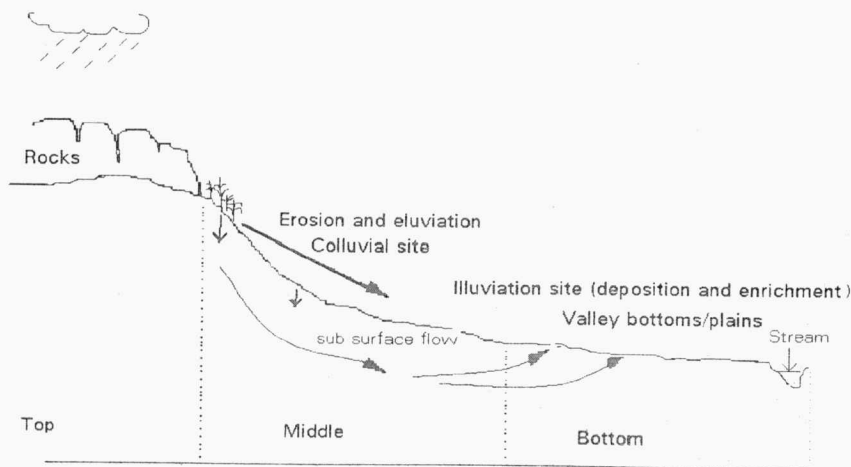


Figure 1: Water movement in a generalised catena

## Methods

### Location

The study was conducted in three areas, namely; (i) Western side of the Pare Mountains in Same and Mwanga Districts. This study area is referred to as the Western Pare Low Lands (WPLL), (ii) Maswa District, and (iii) Morogoro District.

The WPLL are located on the western part of the former Pare District (now Mwanga and Same Districts) and stretch eastward from Kifaruru to Hedaru villages. The study area is located at latitudes 37° 36' to 38° 00' S and longitudes 3° 36' and 4° 36' E. It lies at an altitude ranging from 500 to 1200 m.a.s.l. The study reported in this paper covered nine villages; namely: Kifaruru, Kiruru-Ibwe Ijewu, Kisangara, Lembeni, Mgagao, Mwembe, Bangalala, Mgwasi and Hedaru.

Maswa District in Shinyanga region is located approximately at latitudes 2° 50' to 3° 38' S and longitudes 33° 30' to 34° 15' E. The district lies at an altitude of 1200 to 1300 m above sea level. The study was carried-out in the villages of Shishiyu, Dulung'wa, Lali, Kinamwigulu, Kidema and Mwabayanda.

In Morogoro, the study involved an assessment of the existing agro-ecological zones for the area located in the northern slopes of the Uluguru mountains. The focus area lies between latitudes 6° 47' and 6° 61' S, and the longitudes 37° 38' to 37° 41' E.

### Collection of information

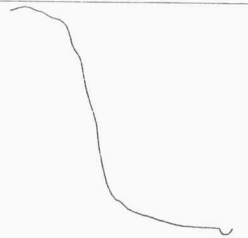
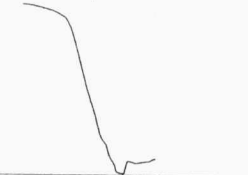
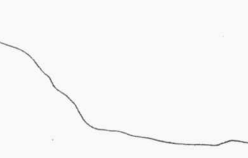
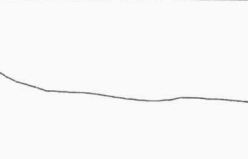
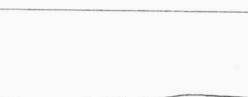
The information used to assess the effect of the catena on potential for RWH was obtained in three different ways.

- (a) Assessment of agro-ecological zoning as done by De Pauw (1984). This was used to provide an overview of the general toposequence in the study areas.
- (b) Reconnaissance soil surveys and limited semi-detailed soil survey of the sites where experimental fields were located. These surveys were done according to approach described by Dent and Young (1981). This also covered all the three study areas.
- (c) Rapid and participatory rural appraisals in the selected villages for Maswa and WPLL. The appraisals involved the collection of multiple type of information. Only the information on landscape characteristics and its effect on the management of rainwater are presented in this paper. This type of information was mainly obtained using the transect walk approach. Information was also obtained through group discussions and workshops. The tools used are described in details by other authors, for example Chambers *et al.* (1989).

## Results and Discussion

The characteristics of the catena determines the potential for rainwater harvesting. The catena found in the three study areas can be categorized into four main groups as elaborated in Table 1. The findings of this study are discussed in this section on the basis of these categories.

**Table 1: Schematic presentation of landform and its effect on runoff generation and rainwater harvesting**

Land Form	Attributes and RWH potential
(a) 	Very steep catchment, run-off in deep gullies and moves fast. Difficult to use in the pediment but spreads naturally further down in the lowland plains where it is opportunistically used by farmers. A good example is Kifaru village in Mwanga.  High potential for RWH.
(b) 	Very steep, a lot of run-off, no area at the bottom to use it. Common in Morogoro north of the Uluguru Mountains.  Poor potential for RWH.
(c) 	Runoff generating area well matched with receiving area. Common in some parts of Maswa District.  High potential for RWH.
(d) 	Small area generating limited run-off, large area on which to use it. Demand of water exceeds supply. Common in many areas of Maswa District.  Medium potential for RWH.
(e) 	Too flat to generate run-off.  Low potential for RWH.

#### Western Pare Lowlands (WPLL)

According to De Pauw (1984) the WPLL is classified under one major physiographic region, known as Eastern Plateau and

Mountain Block. This is further divided into two smaller physiographic sub-units namely: medium altitude, gently undulating to rolling plains and flat and wide depressions. The medium altitude plain is dominated mainly by

an undulating topography while the flood plain is characterized by flat and wide topographical depressions developed on young alluvium.

The terrain on the upper part is strongly dissected and composed of steep rocky hills and sloping pediments (10 - 40%) developed on intermediate metamorphic rocks (De Pauw, 1984). On the foot of the mountains, there are flat and wide topographical depressions developed on young alluvium. The flat alluvial plains towards river Pangani are poorly drained and contain some pockets of salt affected soils. The landscape of the WPLL study area portrays the characteristics of a catchment with very steep slopes and only a limited area for using the runoff (Figure 2-a). The management of generated runoff is complicated by the concentration through few road and railway culverts and bridges. The effect of too much run-off generated by steep slopes in these areas was also observed by Anderson (1982) and Kisanga (1997).

Mostly, woody bushes cover the steep slopes. However, the slopes are overgrazed during long rain seasons when the lowlands are cropped and therefore unavailable for grazing. The Maasai from neighbouring Arusha region have brought in large numbers of livestock and therefore grazing land is scarce. Felling of trees for fuel wood, charcoal making, timber and poles for house construction and the incessant forest fires and land clearing for crop production have also contributed in the loss of ground cover. As a consequence, high volumes of runoff, which are unmanageable at times are generated. The run-off is very rapid on the steep slopes and it has created deep gullies in the pediment. Such run-off cannot be diverted into crop fields located in the

pediment of the catchment because it flows in deep gullies. Attempts to divert water from gullies have been disastrous. This has been due to inability by farmers to control the amount of water to be diverted and to spread it safely in the cropped area. Several farmers have had to abandon their fields because diverted runoff had created deep gullies across them. Big flows into the lowlands were observed by Bakari *et al.*, (1998). The current trend is for most farmers to use run-off opportunistically by planting crops in low-lying areas where run-off water spreads naturally. Maize and lablab (*dolicos lablab*) are the major crops grown in these areas. The lowlands extend for several kilometers to the Pangani river and their greater use will depend on how the run-off from the mountains is managed.

#### Morogoro

The Morogoro case study is focusing on northern slopes of the Uluguru Mountains (Figure 2 b). The upper part is a strongly dissected mountain plateau with steep to very steep slopes (15 - 30%) and narrow valleys strongly affected by erosion and soil creeps (Rapp *et al.*, 1973; Moberg *et al.*, 1982). The lowlands are well drained undulating to rolling plains (2 - 10% slope) at low altitude (< 750 m.a.s.l). Steep granite inselbergs with moderately sloping foot slopes (2 - 8%) can be seen on the Kihonda - Mkundi lowland areas. Seasonal cropping (maize and vegetables) on the mountain slopes without conservation measures is causing erosion and severe siltation of Mindu dam and valley bottoms. Deforestation and bush fires are the main causes of loss of ground cover on the slopes.

The landscape characteristic is that of very steep slopes and very limited flood plains in

the vicinity of the slopes (Figure 2(b)). The runoff generated on the mountain flow into rivers and flash floods flow quickly to the ocean. The flashy nature of the stream flow was observed in flow studies reported by Rapp et al. (1973). These studies recorded peak flow rates of  $2 \text{ m}^3/\text{s}/\text{km}^2$  and the overall run-off coefficient was about 46%. This represents very high level of runoff generation.

Along the river there are narrow alluvial plains which become seasonally flooded through over-topping of riverbanks. These lands are used to grow various crops including paddy rice. This can be considered a form of rain-water harvesting. However, it must be emphasized that some of the runoff water flowing in rivers is also used for conventional irrigation, further downstream.

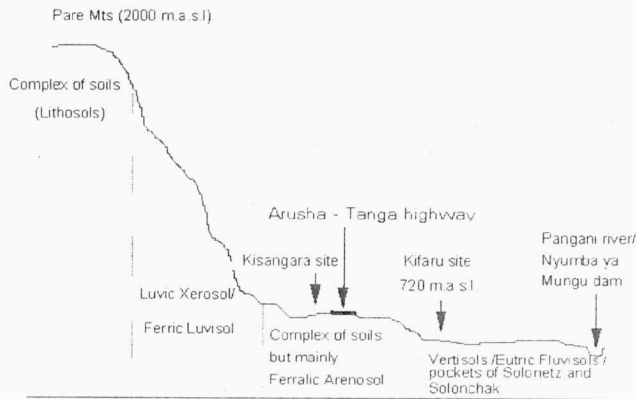


Figure 2(a): Western Pare lowlands - a catena based on soil survey by Rwehumbiza and Diwani (1998), Ngatoluwa et al. (1995) and studies by De Pauw (1984).

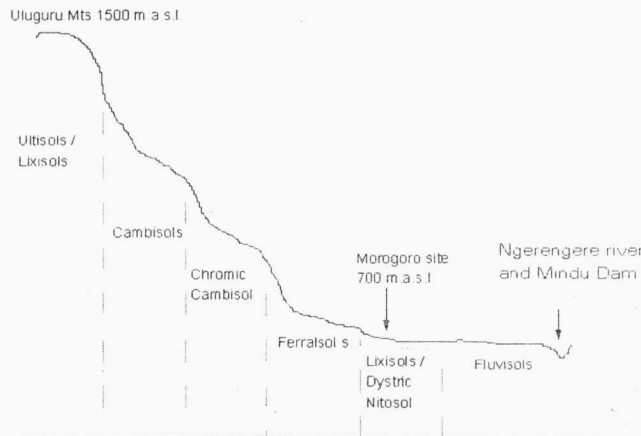


Figure 2 (b): A catena from Uluguru Mts. to Ngerengere river. (Modified from Moberg et al., 1982; with data from Kaaya, 1989).

Maswa

The study area in Maswa is physiographically located on the Central Plateau (De Pauw, 1984). It is characterized by undulating topography and small hills covered by extensive surfaces of rock outcrops which are interspersed by broad valleys (Mahoo et al., 1998). In some cases, the hilltops are covered with thick pockets of trees and shrubs. There is a good understanding by farmers of the soils and the type of crops to be grown.

The largest part of the landscape is flat to gently undulating plains (0 - 3% slope) developed partly on granite, partly on old colluvium and alluvium (De Pauw, 1984). Vertisols, Sodic Planasols and Gleyic Solonetz constitute about 50 - 60% of the soils. The exact extent of each of these soils varies from one area to another. Occurrence of crusts of salts during dry periods is a common phenomenon. There is considerable seasonal waterlogging.

Unlike the WPLL and Morogoro cases, which have very steep mountains overlooking the lowlands, this area has small hills that cover relatively small areas compared to the extensive plains (Figure 2(c)). Rainwater harvesting is wide spread, and most runoff is harvested into banded paddy fields. The generated run-

off is substantial but it is not adequate to meet the water demand of the expanding rice production. Good knowledge prevails among farmers on local techniques of RWH and management in the paddy fields. Run-off is harvested from a wide range of sources including foot and cattle paths, roads and road culverts in addition to that from rock outcrops on the hills. The other major source of water is from seasonal rivers which flow only during the rainy season. In the dry season the major source of water is either from charco-dams, shallow hand dug wells and subsurface water from dry sand riverbeds.

Despite the limited availability of runoff, it is in the Maswa case where there is high degree of rainwater harvesting. The runoff is concentrated in excavated banded fields called *majaluba* and used for paddy rice production. However, shortage of runoff water is one of the major constraints to the paddy rice production as discussed in detail by Meertens et al. (1999). This is a consequence of the relatively larger area on which runoff is used, compared to the smaller runoff generating area, as identified in this study. However, despite this constraint, rice production using rainwater harvesting contributes nearly 50% of the total rice production in Tanzania (Meertens and Lupeja, 1996; MoAC, 1998).

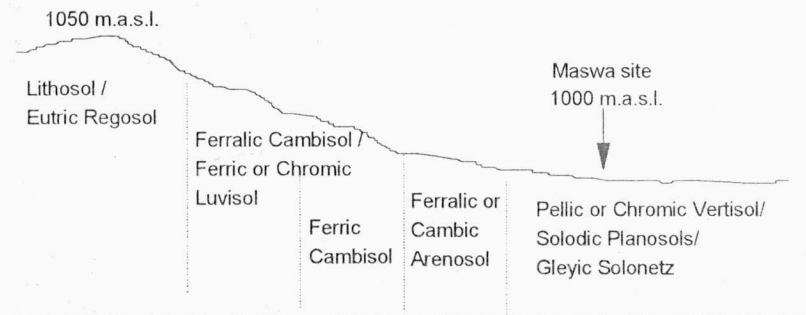


Figure 2(c): A catena across Shishiyu Maswa (constructed with information from Meertens et al., (1999), Mahoo et al., (1998), Ngailo et al. (1994) and, De Pauw (1984)



## Conclusions

A high potential for RWH requires catena that is divided into two parts, one for generating runoff above a fertile and relatively flat area, where crop fields can be located.

The expansion of rice production using RWH as described in the Maswa case study is a testimony to the importance of catena characteristics. Most of RWH practiced or attempted by farmers in the three case study areas utilizes runoff without storage. It is for these reasons that the availability of both too much or too little runoff is not conducive for RWH.

A high potential for RWH is determined by availability of a catchment area to produce sufficient runoff water that can be easily directed into a field having fertile soil with high water storage capacity.

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