

Effect of Water Harvesting on Species Diversity and Overall Rangeland Recovery in Kagera Microcatchment

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ABSTRACT

Plant species diversity was investigated on ridges with and without water harvesting structures. The effect of water harvesting technology on the soil properties and rangeland recovery was also investigated. The experimental sites are located in Kifamba, Kakuuto County Rakai District. Plant species were recorded on a 50m horizontal transect aligned on the main transect running S-N on a 20 m lag. The quadrat method was used to sample grasses and herbs, whereas shrubs and trees were sampled on twenty five meter plots on consecutive horizontal transects. Soil physical and chemical properties, plant biomass and ground cover were determined along the landscape. Results indicate that, ridges with water harvesting structures had higher species diversity than those without water harvesting structures ($p < 0.05$). The plant diversity on ridges with water harvesting (Shannon Diversity index) was $H' = 4.46$, while the diversity of ridges without water harvesting was $H' = 3.93$. The two types of ridges were significantly different ($p < 0.001$) in terms of the diversity of plant species. The results further reveal that the introduction of water harvesting structures did not induce a landscape position pattern in the distribution of species, but that of grass biomass, despite the uniformity of chemical properties along the landscape ($p < 0.05$).

Keywords: Ecology, Rangeland restoration, Species diversity, Land productivity.

management (NRC 1994). Degraded range lands (Busby *et al.*, 1995) can be reversed by altering the grazing season, stocking intensity and animal type which can restore the growth of forage plant populations. It can also be done through rotational grazing and withdraw of herbivores (Westoby, *et al.*, 1989) at certain seasons or after favourable climatic events ; non selective grazing (Acocks, 1964) and an increase in the browser : grazer ratio (Walker, 1980). Reversal of range land degradation may also involve the removal of domestic live stock and culling of other abundant herbivores as well as vegetation manipulation. This may latter involve reseeding combined with burning, herbicide treatment , or selective bush cutting (Gibbens *et al.*, 1992; Passera *et al.*, 1992). Barrow, (1991) notes that, to ensure profitable range land rehabilitation, there is need to first rehabilitate the physical environment by reducing erosion, increasing water infiltration, improving the water holding capacity of the soil, protecting the soil surface from the sun and frost, ameliorating salinisation and creating micro sites suitable for the seedlings of perennial plants. Barrow further comments that, when vegetation is completely lost, the only economically feasible management option at this stage appears to be non pastoral use of the area. In the rehabilitation of the rangelands, different water harvesting methods can be employed. These include, contour bunds, contour ridges, negarim micro catchment, semi-circular bunds, trapezoidal bunds, contour stone bunds, permanent rock dams and water spreading bunds. In the rangelands of the Kagera micro catchment, contour bunds are used to rehabilitate the degraded range lands. Therefore the major aim of the study was to find out the influence of water harvesting on plant species diversity, plant biomass production and cover in the degraded range lands of the Kagera Basin.

MATERIALS AND METHODS

This study was carried out in Kakuuto county Rakai District and the study area covers approximately 2100 km². The district is located between 0 ° 35'- 1 ° 00' S and 31 ° 15'-31 ° 48' E. Three replicates of ridges with and without water harvesting structures were randomly selected. The main transect run south north, from the foot slope to the summit of the ridge. The horizontal transects of 50m (25m either side of the main transect) were laid at 20m intervals. On the horizontal transect three; 1x1m quadrats were selected randomly by use of random numbers.

The slope was divided into three sections. These included; the upper, middle and lower. These sections covered areas of the main transect in proportions

equal to 1/5, 2/5, and 2/5 of the length of the main transect. (Achan *et al.*, 1999). The study compared two sites, one with water harvesting and the other without water harvesting. It is assumed that the two sites were similar at the time water harvesting was introduced.

Grasses and herbs were assessed on the horizontal transects using 1*1 m² quadrats selected randomly by use of random numbers. Plants specimens were collected, labeled, pressed, and dried for identification at the Makerere University herbarium. Shrubs and Trees were assessed on the one side of the area demarcated by the main transect and two consecutive horizontal transects. The sample plot size was 20 x 25m.

Species diversity of the recorded species was determined using the Shannon and Simpsons indices of diversity.

Cover was estimated following FAO cover estimation method. Biomass was harvested and the dry weight determined according to sections.

Soils were sampled at depth of 0-15 cm and 15-30 cm and analyzed for OM, pH, exchangeable P, exchangeable bases like K, Na, Ca, and texture using methods described by Okalebo, *et al.* (1993).

Saturated hydraulic conductivity (K_{sat}) was determined using a tension infiltrometer (Ankeny *et al.*, 1988; Prieksat *et al.*, 1992). Infiltration tests were carried out on each transect and for three suction heads: 30, 50, 80 mm. Wooding's (1968) solution for steady state flux from a circular source in conjunction with Ankeny *et al.*, (1991) method was used to determine the hydraulic conductivity associated with steady state flow (K_{sat}) attained for a pair of suction heads. Assuming the conductivity-potential relationship can be described by Gardner's (1958) exponential function, the relationship between the steady state flux rates Q_j , and the suction heads (h_j) is of the form:

$$\alpha = (\text{Ln } (Q_1/Q_2) / (h_1 - h_2))$$

provided that α remains constant for the head ranging from h_2 to h_1 . K_{sat} was determined for each two pairs of heads (30-50 mm) and (50-80 mm).

The overall soil K_{sat} value at a given site was estimated by averaging the computed (K_{sat}) for the two pairs of heads for that specific site. Each K_{sat} value was computed following the equation:

$$K_{sat} = Q / (\exp(\alpha h) * (\pi r^2 + 4r/\alpha))$$

Where r is the radius of the circular ponds.

RESULTS AND DISCUSSION

Plant species diversity

A total number of 164 plant species belonging to 37 families were recorded on ridges with and without water harvesting structures. The Poaceae (29 spp.), Fabaceae (18 spp.), Asteraceae (14 spp.) and Euphobiaceae (12 spp.) families were the most important since they contributed the highest number of plant species. However, ridges with water harvesting structures presented higher species richness than those without water harvesting structures ($p < 0.05$).

Ridges with water harvesting structures had a total number of 105 plant species belonging to 32 families (Table I). Some of the plant species on ridges with water harvesting belonging to the Poaceae family included, *Bracharia bryzanta*, *Chloris pycnatrix* and *Panicum maximum*. Those belonging to the Fabaceae family included, *Desmodium asbcendens*, *Dolichos oliveri* and *Zonia setosa*. Some plant species of the Asteraceae family included, *Ageratum conyzoides*, *Vernonia aericulata* and *Dichrocephala integrifolia*. The ones belonging to the Euphobiaceae family included, *Phyllanthus numuloriifolia*, *Acalypha crenata* and *Euphorbia hirta*.

The following are some of the rare ones represented by one plant species: *Capparis fascularis* (Capparidaceae), *Asparagus africana* (Asperagaceae), *Carrisa edulis* (Apacynaceae) and *Gomphocarpus physocarpus* (Asclepidaceae).

Ridges with water harvesting structures had a total number of 57 plant species belonging to 20 families. The Poaceae family presented the highest number of plant species on ridges without water harvesting structures (Table I).

They included, *Hapachne schimperi*, *Bothriochloa inscupa* and *Sporobolus pyramidalis*. Other important families included, Fabaceae represented by *Crotalaria spp.*, *Indigofera arrecta*. Those belonging to the Euphobiaceae family included, *Flueggea virosa*, and *Phyllanthus numularifolia*. (Table I). The rare ones represented by one individual in a family included, *Alternanthera pungens* (Amaranthaceae) and *Clerodendrum myriciodes* (Verbanaceae) (Table I).

Table I: Species list for ridges with water harvesting

Species.	Family.	Growth form	WHS	NWHS
<i>Desmodium asbcendens</i>	Fabaceae	S	+	+
<i>Solanum macrocarpum</i>	Solanaceae	S	+	
<i>Teclea nobilis</i>	Rutaceae	T	+	+
<i>Zyzygium guineense</i>	Myrtaceae	T	+	-
<i>Asparagus africanus</i>	Asparagaceae	S	+	+
<i>Bracharia bryzantha</i>	Poaceae	G	+	+
<i>Phyllanthus numolariiifolia</i>	Euphorbiaceae	S	+	+
<i>Trilepisium madagascariensis</i>	Malvaceae	S	+	-
<i>Abutilon maceritianum</i>	Malvaceae	S	+	+
<i>Chloris pychnotix</i>	Poaceae	G	+	-
<i>Sida acuta</i>	Malvaceae	H	+	-
<i>Acacia gerrardi</i>	Mimosaceae	T	+	+
<i>Panicum maximum</i>	Poaceae	G	+	-
<i>Comelina benghalensis L.</i>	Commelinaceae	H	+	
<i>Cissampelos mucranata</i>	Meacisperrnaceae	H	+	-
<i>Serna mimosefolia</i>	Caesalpinaceae	S	+	-
<i>Oxalis corniculata Senna</i>	Oxalidaceae	H	+	-
<i>Themeda triandra L.</i>	Paoceae	G	+	+
<i>Lycopersicum esculerutum</i>	Solanaceae	H	+	-
<i>Mimosa pigra</i>	Mimosaceae	S	+	-
<i>Acacia gagentica</i>	Mimosaceae	T	+	-
<i>Aldia spp.</i>	Rubiaceae	T	+	-
<i>Asystasia guhata</i>	Acanthaceae	H	+	-
<i>Pennisetum polystachyon</i>	Poaceae	G	+	-
<i>Kyllinga alba Nees</i>	Cyperaceae	H	+	+
<i>Alternanthera pungens</i>	Amaranthaceae	H	+	+
<i>Solanum macrocarpum</i>	Solanaceae	S	+	-
<i>Sporobolus pyramidalis</i>	Poaceae	G	+	+
<i>Commelina africana L.</i>	Commelinaceae	H	+	
<i>Solanum incanum</i>	Solanaceae	S	+	
<i>Acalypha crenata</i>	Euphorbiaceae	S	+	-
<i>Physalis peruviana</i>	Solanaceae	H	+	-

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<i>Ageratum conyzoides</i>	Asteraceae	S	+	-
<i>Celosia trigyna</i>	Amaranthaceae	S	+	-
<i>Sida cuneifolia</i>	Malvaceae	S	+	-
<i>Euphorbia hirta</i>	Euphorbiaceae	H	+	-
<i>Psidium guajava</i>	Mytaceae	T	+	-
<i>Cassia occidentalis</i>	Caesalpiniaceae	S	+	-
<i>Vernonia aericulata</i>	Asteraceae	H	+	-
<i>Rhus natalensis</i>	Anacardiaceae	T	+	-
<i>Triumfetta annua</i>	Tiliaceae	S	+	-
<i>Physallis capillaris</i>	Euphorbiaceae	S	+	-
<i>Lantana camara</i>	Verbenaceae	S	+	-
<i>Annona senegalensis</i>	Annoniaceae	S	+	-
<i>Acalypha bipartica</i>	Euphorbiaceae	S	+	-
<i>Gomphocarpus physocarpus</i>	Asclepidaceae	S	+	+
<i>Oxalis latifolia</i>	Oxalidaceae	H	+	-
<i>Dichrocephala integrifolia</i>	Asteraceae	H	+	-
<i>Solanum nigrum</i>	Solanaceae	S	+	-
<i>Bidens pilosa</i>	Asteraceae	S	+	-
<i>Dolichos oliveri</i>	Papilionaceae	H	+	+
<i>Bothriochloa crusculpha</i>	Poaceae	H	+	+
<i>Conyza sumatrensis</i>	Asteraceae	H	+	+
<i>Momordica freisiovonum</i>	Cucurbitaceae	H	+	-
<i>Hura crepitans</i>	Euphorbiaceae	H	+	-
<i>Ocimum gratissimum</i>	Lamiaceae	S	+	-
<i>Rhus vulgaris</i>	Anacardiaceae	T	+	+
<i>Asytasia guhata</i>	Acanthaceae	H	+	+
<i>Desmodium trifolium</i>	Fabaceae	H	+	+
<i>Phyllanthus corpillaris</i>	Euphorbiaceae	S	+	-
<i>Indigofera arrecta</i>	Fabaceae	H	+	+
<i>Kyallinga bulbosa</i>	Cyperaceae	G	+	-
<i>Ipomoea spp.</i>	Convolvaceae	H	+	-
<i>Kyllinga pumila</i>	Cyperaceae	G	+	-
<i>Marytemis senegalensis</i>	Celastraceae	T	+	-
<i>Dovyalis macrocalyx</i>	Flacourtiaceae	T	+	-
<i>Helicrysum gerberifolium</i>	Asteraceae	H	+	-
<i>Cymbopogon nardus</i>	Poaceae	G	+	-

<i>Sida ovata</i>	<i>Malvaceae</i>	S	+	-
<i>Aspilia africana</i>	<i>Asteraceae</i>	S	+	-
<i>Desmodium gangeticum</i>	<i>Papilionaceae</i>	S	+	-
<i>Erythrococa bengenisi</i>	<i>Euphorbiaceae</i>	T	+	-
<i>Clerodendrum myriciods</i>	<i>Verbanaceae</i>	S	+	+
<i>Tagetes minuta</i>	<i>Asteraceae</i>	S	+	+
<i>Clausena onisata</i>	<i>Rutaceae</i>	T	+	-
<i>Melanthera scandens</i>	<i>Asteraceae</i>	S	+	-
<i>Capparis fascicularis</i>	<i>Capparidaceae</i>	S	+	-
<i>Flueggea virosa</i>	<i>Euphorbiaceae</i>	S	+	+
<i>Sida rhomboidea</i>	<i>Malvaceae</i>	S	+	+
<i>Grewia simulis</i>	<i>Tiliaceae</i>	T	+	-
<i>Carissa edulis</i>	<i>Apocynaceae</i>	S	+	+
<i>Euphorbia unaquilatera</i>	<i>Euphorbiaceae</i>	S	+	-
<i>Ocimum suave</i>	<i>Lamiaceae</i>	S	+	-
<i>Zornia setosa</i>	<i>Fabaceae</i>	H	+	-
<i>Abildgaardia ovata</i>	<i>Cyperaceae</i>	G	+	+
<i>Aristida adoensis</i>	<i>Poaceae</i>	G	+	-
<i>Loudetia kagerensis</i>	<i>Poaceae</i>	G	+	+
<i>Sporobolus stapfianus</i>	<i>Poaceae</i>	G	+	+
<i>Leonotis nepetifolia</i>	<i>Laminaceae</i>	S	+	+
<i>Crotalaria vatkeana</i>	<i>Fabaceae</i>	S	+	+
<i>Indigofera spicata</i>	<i>Fabaceae</i>	H	+	+
<i>Alysicarpus zeyheri</i>	<i>Fabaceae</i>	S	+	-
<i>Eriosema shirensense</i>	<i>Fabaceae</i>	S	+	-
<i>Indigofera encarginella</i>	<i>Fabaceae</i>	H	+	-
<i>Pycnospora lutescens</i>	<i>Fabaceae</i>	S	+	+
<i>Andropogon schirensis</i>	<i>Poaceae</i>	G	+	-
<i>Eragrostis tenuifolia</i>	<i>Poaceae</i>	G	+	-
<i>Eragrostis racemosa</i>	<i>Poaceae</i>	G	+	+
<i>Ficus sycomorus</i>	<i>Moraceae</i>	T	+	-
<i>Solanum anguivi</i>	<i>Solanaceae</i>	H	+	-
<i>Blighia unijugata</i>	<i>Sapindaceae</i>	T	-	+
<i>Andropogon schirensis</i>	<i>Poaceae</i>	G	-	+
<i>Albizia coriaria</i>	<i>Mimosaceae</i>	T	-	+
<i>Desmodium ramosissimum</i>	<i>Fabaceae</i>	S	-	+

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<i>Alysicarpus rugosus</i>	<i>Fabaceae</i>	S	-	+
<i>Microglossa angolensis</i>	<i>Asteraceae</i>	S	-	+
<i>Microglossa pyrifolia</i>	<i>Asteraceae</i>	S	-	+
<i>Urena lobata</i>	<i>Malvaceae</i>	S	-	+
<i>Laggera alata</i>	<i>Asteraceae</i>	S	-	+
<i>Cyperaceae cyperoides</i>	<i>Cyperaceae</i>	G	+	+
<i>Desmodium setigerium</i>	<i>Fabaceae</i>	H	-	+
<i>Fimbristylis dichotoma</i>	<i>Cyperaceae</i>	H	+	+
<i>Capparisreny thiocapus</i>	<i>Capparidaceae</i>	S	-	+
<i>Pennisetum perpureum</i>	<i>Poaceae</i>	G	+	+
<i>Hypoxis obtusa</i>	<i>Hypoxidaceae</i>	H	-	+
<i>Pterigota becquartii</i>	<i>Steculiaceae</i>	T	-	+
<i>Hyparrhenia spp.</i>	<i>Poaceae</i>	G	+	+
<i>Bothriochloa crusculpha</i>	<i>Poaceae</i>	G	-	+
<i>Cacanium schuenfeathu</i>	<i>Bresseraceae</i>	S	-	+
<i>Justicia exegua</i>	<i>Acanthaceae</i>	H	-	+
<i>Cyperaceae rotundus</i>	<i>Cyperaceae</i>	G	+	+
<i>Loudetia simplex</i>	<i>Cyperaceae</i>	G	-	+
<i>Hoslundia opposita</i>	<i>Lamiaceae</i>	S	-	+
<i>Vitex spp.</i>	<i>Vitaceae</i>	T	-	+
<i>Hapachne schimperii</i>	<i>Poaceae</i>	G	-	+

Key:

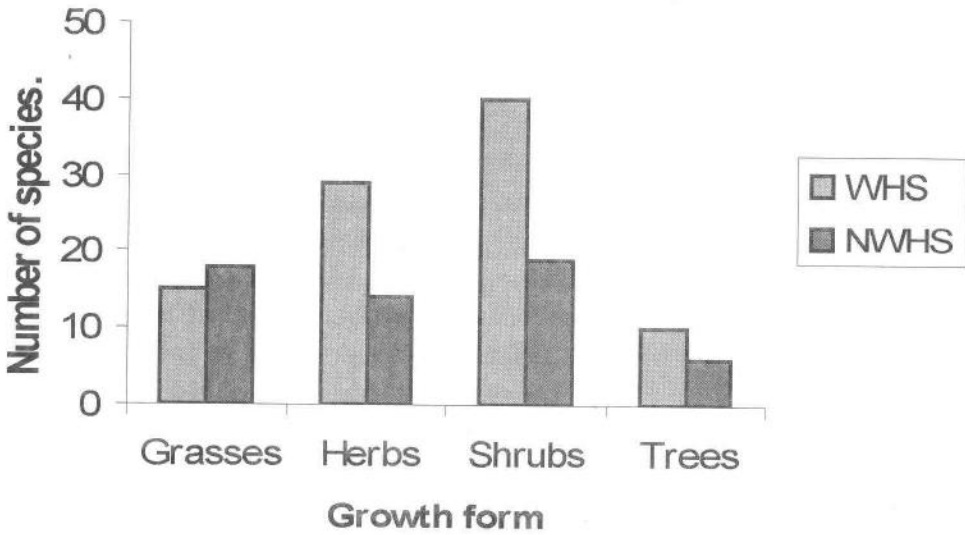
S	=	Shrubs
H	=	Herbs
G	=	Grass
T	=	Trees

Of the 37 families, 17 did not occur on ridges with water harvesting structures. Some included: Moraceae, Rutaceae, Convolvaceae, Celastraceae and Flacourtiaceae. Five of the 37 families were only represented on ridges without water harvesting structures. They included: Sapindaceae, Hypoxidaceae, Steculiaceae, Bresseraceae and Vitaceae.

The diversity of ridges with water harvesting (Shannon index) was $H' = 4.46$, while the diversity of ridges without water harvesting structures was $H' = 3.93$. The two types of ridges were found to be highly significantly different ($p < 0.001$) in terms of the diversity of plant species.

The plant species seen above belong to different growth forms ranging from grasses to trees. Shrubs are most dominant for both types of ridges. These are followed by herbs, grasses and trees for ridges with water harvesting structures and grasses, herbs and trees for ridges without water harvesting structures. The establishment of water harvesting structures seems to encourage the growth of shrubs as compared to grasses where there is no water harvesting structures.

Comparing the two types of ridges, those with water harvesting structures presented higher species number for shrubs and herbs. Grasses were more on ridges without water harvesting structures. Trees were Higher on ridges with water harvesting structures (Figure 1).



WHS= Sites with water harvesting structures.
NWHS= Sites without water harvesting structures.

Figure 1 : Growth forms of plant species compared on the two types of ridges

The introduction of water harvesting structures did not affect the landscape pattern in plant distribution ($p < 0.05$) (Table II). It only increased the diversity of species for all sections. The number of plant species ranged between 57 and 64 on ridges with water harvesting structures and 14 - 22 on ridges without water harvesting structures. Sections of ridges with water harvesting structures had higher number of common species as compared to the corresponding ones without water harvesting structures. ($p < 0.05$) (Table II).

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Table II: Plant species distribution along the toposequence

Section	WHS	NWHS
Lower	64 (28)	16 (0)
Middle	59 (25)	22 (1)
Upper	57 (28)	14 (1)

Total number of species (common species)

Key:

WHS = Water harvesting structures

NWHS = No water harvesting structures

Biomass was found to be treatment dependent. It was higher on ridges with water harvesting structures ($p < 0.05$). The mean weight of biomass was 19.59 t/ha and 7.13 t/ha on ridges with and without water harvesting structures respectively. For ridges with water harvesting structures, the middle part had the highest biomass (27.22 t/ha) compared to other sections of the landscape i.e. 15.3 and 16.3 t/ha for lower and upper sections respectively ($p < 0.05$). For ridges without water harvesting structures, higher values of biomass were recorded at the lower and middle sections (8.6 t/ha in average) ($p < 0.05$) (Figures 2 and 3). This suggests that the middle section recovered relatively faster than other sections of the ridge. Sections of ridges with water harvesting structures had higher biomass compared to the corresponding sections without water harvesting structures ($p < 0.05$). Biomass changes were reflected on ground cover; (86.1%) on ridges with water harvesting structures representing an increase of 69.2% compared to ridges without water harvesting structures. All sections of ridges with water harvesting had higher cover compared to corresponding sections of control ridges ($p < 0.05$). However for all treatment no significant difference was observed between different sections of the ridges ($p < 0.05$). This confirms a uniform cover recovery across ridges.

The observed difference in species richness, biomass and cover is attributed to water harvesting which increased the moisture content of the soil, after soil improvement as illustrated by soil chemical (Table III) and hydraulic properties (Table IV). Ridges with water harvesting technologies had higher values for all parameters ($p < 0.05$) especially P, Na, Ca, Silt, pH, and OM, and showed

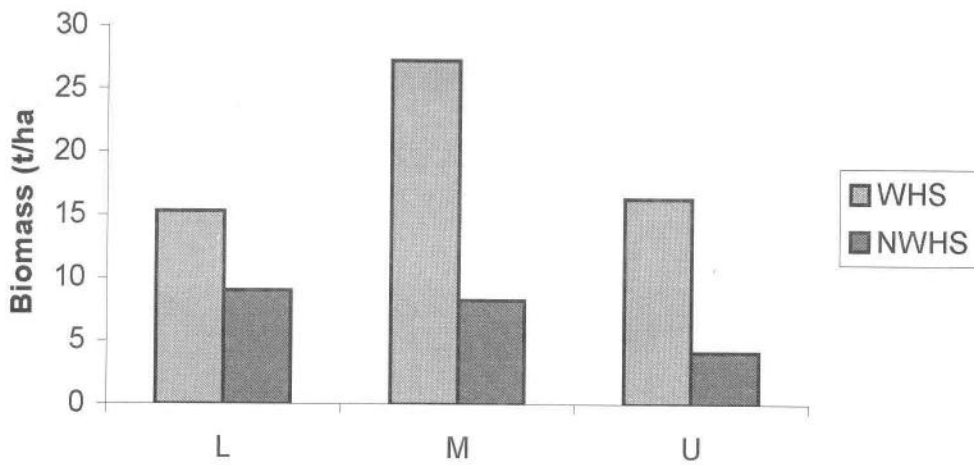


Figure 2: Change in biomass along the landscape on ridges with and without water harvest structures

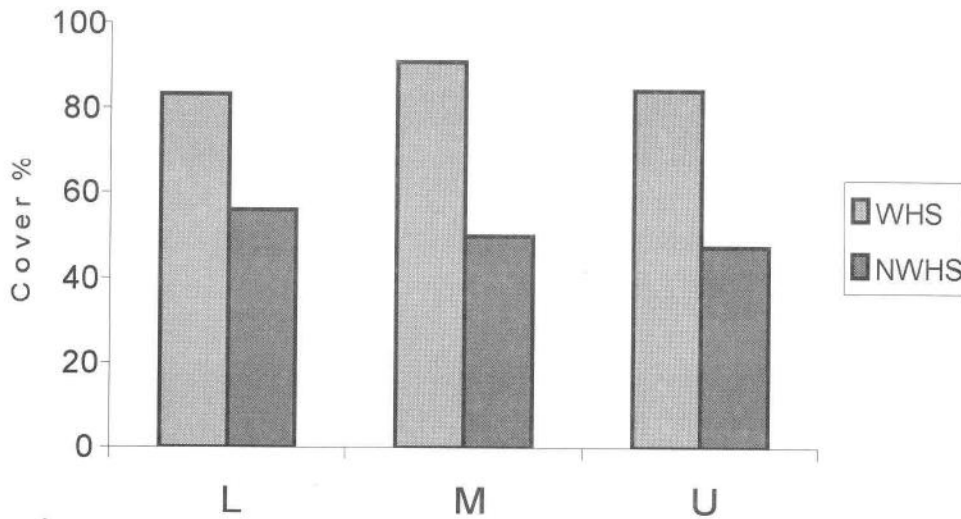


Figure 3: Change in ground cover along the landscape on ridges with and without water harvesting technologies

section variability ($p < 0.05$), while those without water harvesting showed uniformity in OM up to the depth of 0 to 30 cm. Hydraulic properties also were higher on soils with water harvesting structures compared to the control, and had similar pattern as chemical properties along the toposequence.

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Table III: Selected soil properties of ridges with and without water harvesting technologies

Treatment	Section	Depth cm	pH	OM %	P mg/kg	K Cmol/kg	Na Cmol/kg	Ca Cmol/kg	Sand %	Clay %	Silt %	TC
Ridges with water harvesting	Lower	0-15	5.2	15.2	15.1	0.6	0.3	2.5	39.7	27.0	33.3	CL
		15-30	5.1	10.7	15.2	0.4	0.2	1.4	34.7	33.0	32.3	CL
	Middle	0-15	5.3	10.0	16.2	0.5	0.2	2.4	35.7	32.3	32.0	CL
		15-30	5.0	6.53	7.9	0.3	0.1	1.0	31.7	36.3	32.0	CL
	Upper	0-15	5.5	11.2	13.6	0.6	0.3	2.6	36.3	31.7	32.0	CL
		15-30	5.0	7.70	8.9	0.2	0.1	0.8	31.0	35.7	33.3	CL
Ridges without water harvesting	Lower	0-15	4.6	9.4	8.2	0.6	0.1	1.6	37.5	33.6	28.9	CL
		15-30	4.3	8.0	5.1	0.4	0.1	0.6	36.8	35.6	27.6	CL
	Middle	0-15	4.6	8.1	6.0	0.5	0.1	1.0	37.9	34.3	27.8	CL
		15-30	4.4	6.8	3.5	0.3	0.1	0.3	35.9	33.6	30.5	CL
	Upper	0-15	4.5	7.3	5.7	0.4	0.1	0.5	31.5	37.6	30.9	CL
		15-30	4.3	5.7	3.2	0.3	0.1	0.2	28.8	38.9	32.3	CL
Lsd Treat			0.14	3.70	ns	0.03	0.59	ns	ns	ns	2.12	
Lsd Section			Ns	ns	ns	ns	ns	ns	ns	Ns	Ns	
Lsd Depth			0.14	ns	4.73	0.03	0.59	ns	ns	Ns	ns	

Table IV: Hydraulic properties of soils along the landscape

Treatment	Landscape Position	Q (cm ³ /min) h=30 mm	Q (cm ³ /min) h=50 mm	Q (cm ³ /min) h=50 mm	K _{sat} (cm/min)	Alpha (cm ⁻¹)
WHS	Upper	48.1	11.0	5.3	0.19	0.38
	Middle	77.8	32.7	9.3	0.29	0.41
	Lower	88.7	38.8	12.7	0.28	0.37
NWHS	Upper	64.3	20.6	7.9	0.19	0.44
	Middle	22.5	6.7	3.3	0.18	0.41
	Lower	45.6	14.0	5.3	0.21	0.41
Lsd _{treat}		Ns	12.3	3.7	0.05	Ns
Lsd _{pos}		Ns	21.3	Ns	Ns	Ns

CONCLUSION AND RECOMMENDATIONS

The study shows that, water-harvesting structures are effective in improving plant diversity and as a consequence, biomass and ground cover were also enhanced after three years of establishment. The study too shows that, contour bunds can improve significantly the chemical and physical properties of the degraded rangelands. However, there is need for continued monitoring of the rangeland recovery process in order to establish the different recovery phases and their associated plants diversities. The water harvesting technology can be used to rehabilitate the “bare hills” in South-Western Uganda. These barehills generate excessive runoff (Majaliwa *et al.*, In Press) and yet the only practice so far recommended is afforestation. A combination of water harvesting structures and afforestation may lead to faster recovery and hence reduced runoff and pollution of water bodies.

REFERENCES

- Abel, N.O. J. and Blaike P., (1989). Land degradation, stocking rates and conservation policies for the communal rangelands of Botswana and Zimbabwe. *Land degradation and rehabilitation* 1:101-103.
- Abesiga, N. K. C, Magunda, M. K, Huising H. E, and Majaliwa, G. J. M., (2001). Rangeland recovery after establishment of water harvesting structures. Paper presented at the 4th LVEMP Conference in Mukono, Uganda.

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- Achan, P., M.M. Tenywa, M.I. Isabirye, R. Lal, and Lufafa, A., (1999). "Soil and water Conservation in a Banana based Cropping System within the Lake Victoria Basin," In Zake J.Y.K., J.K Tumuhairwe, C. Nkwine, and S. Sessanga. Soil Science, a key to Sustainable Landuse, Proceedings of the 17th Soil Science Society of East Africa(SSSEA) Conference held in Kampala Uganda, September 6-10th, 1999. P. 149.
- Acocks , J. P. H., (1964). Karoo vegetation in relation to the development of deserts. Pages 100-112 in D. H. S. Davis, ed. Ecological Studies in Southern Africa. Dr W. Junk, The Hague, The Netherlands.
- Baker , D. L , and Guthery, F. S., (1990). Effects of continuous grazing on habitat and density of ground foraging birds in south Texas. *J. Range Manage.* 43:2-5.
- Barrow , C. J., (1991). Land degradation. Cambridge University Press New York.
- Bosch O. J. H and Theunissen, I. D., (1992). Differences in the response of species on the degradation gradient in the semi-arid grasslands of southern Africa and the role of Ecotypic variations. Pp. 95-108. In Chapman G. (Ed.). Desertified grasslands: Their biology and management. London. The Linnean Society of London.
- Busby, F. E., Ruyle, M. R., and Joyce, L. A., (1995). Minimum ecosystem function: A strategy to integrate methods to classify, inventory and monitor rangelands. Pp. 101-104. In: West NE (Ed.). Rangelands in a sustainable Biosphere. Proceeding of the fifth International rangelands congress. Vol. 1. Lakewood (Co.) Society of range management.
- Crawley, M. J., (1983). Herbivory: The dynamics of Animal-Plant Interactions. Blackwell, London.
- Dean , W. R. J. and Macdonald, I. A. W. (In press). Historical changes in stocking rates of domestic livestock as a measure of semi arid and arid rangeland degradation in Cape Province , *South Africa. Biol. Conserv.* 58: 257-274.

- Fuls, E. R., (1992). Ecosystem modifications created by parch over grazing in semi arid grassland. *J.Arid Environ.*23: 59-69.
- Friedel, M. H., Foran, B. H., and Stafford, M. D. S., (1990). Where he creeks run or ten feet high: Range land Degradation Modal
- Grainger, A., (1992). Characterisation and assessment of the desertification processes. Pp. 18-32. In Chapman G. (Ed.) In Chapman G. (Ed.). Desertified grasslands: Their biology and management. London. The Linnean Society of London. Inventory and monitor rangelands. Washington DC. National Academy Press.
- Gibbens, R. P., (1992). Application of non-equilibrium ecology to management of Mediterranean grassland . *J. Range Manage.* 45:436-440.
- Heady, H. F., (1995). Rangeland management. McGraw Hill, New York.
- Lamprey, H., (1981). Seeking remedies desert encroachment: *UNESCO-IPAL renewed. Span* 24:1-4
- Le Houerou, H. N., Bingham, R. L., and Skerbek, S., (1988). Relationship between the variability of primary production and the variability of annual precipitation in word and lands. *Journal of Arid Environments* 15: 1-18.
- Le Houerou, H. N., (1989). The Grazing Land Ecosystems of the African Sahel. Springer-Verlag, New York.
- Montana , C., (1992). The colonisation of bare areas in two phase mosaics of an arid ecosystem. *J.Ecol.* 80:315-327.
- NRC (National Research Council). (1994). Rangeland health: New methods to classify, Inventory, and monitor Rangelands. Washington DC National Academy Press.
- Okalebo, J. R.; Gathua, K.W. and Woome, P. L. (1993). Laboratory methods of soil and plant analysis. A working manual. SSSEA. Technical Publication No 1.

Effect of Water Harvesting on Species Diversity and Overall Rangeland Recovery in Kagera Microcatchment

- Schlesinger, W. H., Reynolds, J. F., Cunningham, C. L., Huennke, L. F., Jarrell, W. W., Virginia, R. A., and Whitford, W. G., (1990). Biological feedbacks in global desertification. *Science* 247:1043-1048.
- Tenywa., (1998). The Rwenzori Mountains National Park Uganda. Published by Geog Dept MUK.
- Thomas, D.S.G. and Middleton, N.S., (1994). Desertification: Exploding the myth. Chichester (UK): John Wiley & sons.
- Thurrow, T. L., Bhkbun, W. H., and Taylor Jr, C. A., (1988). Infiltration and interrill erosion responses to selected livestock grazing strategies, Edwards Plateau, Texas. *J. Range Manage.* 41:296-302.
- Walker, B. H., (1980). A review of browse and its role in livestock production in Southern Africa. Pages 7_24 in H. N. Le Houerou ed. Browse in Africa. ILCA, Addis Ababa, Ethiopia.
- West, N. E., (1993). Biodiversity of Rangelands. *J. Range Manage.* 46: 2-13.
- Westoby. (1989). Opportunistic management for rangelands not at equilibrium. *J. Range Manage.* 42: 266-274.