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MAKUENI DISTRICT PROFILE:
SOIL FERTILITY MANAGEMENT

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Preface

Drylands Research Working Papers present, in preliminary form, research results of studies carried out in association with collaborating researchers and institutions.

This working paper is part of a study which aims to relate long-term environmental change, population growth and technological change, and to identify the policies and institutions which are conducive to sustainable development. The study builds upon an earlier project carried out by the Overseas Development Institute (ODI) in Machakos District, Kenya, whose preliminary results were published in a series of *ODI Working Papers* in 1990-91. This led to a book (Mary Tiffen, Michael Mortimore and Francis Gichuki, *More people, less erosion: environmental recovery in Kenya*, John Wiley, 1994), which was a synthesis and interpretation of the physical and social development path in Machakos. The book generated a set of hypotheses and policy recommendations which required testing in other African dryland environments. Using compatible methodologies, four linked studies are now being carried out in:

Kenya	Makueni District	
Senegal	Diourbel Region	
Niger	Maradi Department	*(in association with ODI)*
Nigeria	Kano Region	*(in association with ODI)*

For each of these study areas, there will be a series of working papers and a synthesis, which will be reviewed at country workshops. An overall synthesis will be discussed at an international workshop in London in 2000.

The Kenya series updates the previous study of Machakos District (which included the new Makueni District) and examines this more arid area in greater depth. The Research Leader for these studies is Michael Mortimore. The Leader of the Kenya Team is Francis Gichuki of the University of Nairobi. Michael Mortimore, Mary Tiffen or Francis Gichuki may be contacted at the following addresses.

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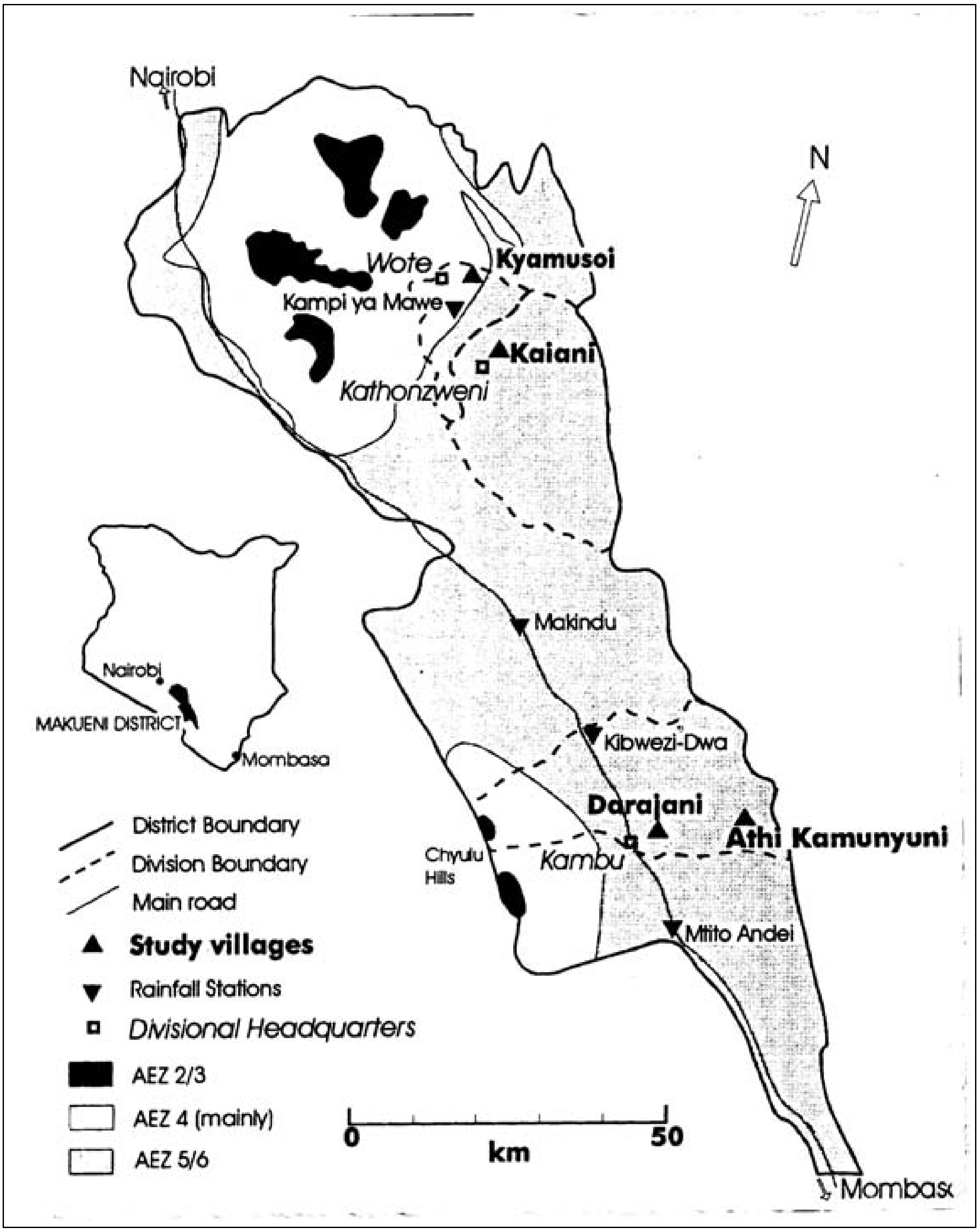
Preface map


Nairobi
N
Wote
Kyamusoi
Kampi ya Mawe
Kaiani
Kathonzweni
Makindu
Nairobi
MAKUENI DISTRICT
Mombasa
Kibwezi-Dwa
Darajani
Athi Kamunyuni
Chyulu Hills
Kambu
Mtito Andei
District Boundary
Division Boundary
Main road
Study villages
Rainfall Stations
Divisional Headquarters
AEZ 2/3
AEZ 4 (mainly)
AEZ 5/6
0
50
km
Mombasa

Abstract

This study forms a part of a broad ranging study of farmer investment in semi-arid Makueni District, Kenya, in which soil amelioration is understood as an investment in enhanced bioproductivity. In order to investigate the impact of management practices on soil fertility, 77 samples were taken from the top 20 cm of cultivated and uncultivated soils on 39 farm holdings in the four villages of Kyamusoi (Wote Division), Kaiani (Kathonzweni Division), Darajani and Athi Kamunyuni (Kibwezi Division), which all lie in Makueni District.

The samples collected in the four villages were analysed for total carbon (percent), total nitrogen (percent), and total phosphorus (ppm), and their texture was classified. Taking all 77 sample sites together, few of the samples had better than low organic carbon and nitrogen, and few of the samples contained sufficient phosphorus. Uncultivated (bush) soils have significantly more organic carbon than cultivated soils, but no significant advantage in terms of nitrogen and phosphorus. A comparison of the average values obtained in the wetter sites (Kyamusoi and Kathonzweni) and the drier sites (Darajani and Athi Kamunyuni) showed no differences attributable to climatic agency.

There is very little addition of either organic or inorganic fertilisers in the study area, because they are generally too costly, risky and impractical for many farmers. In view of the potential importance of crop-livestock integration as a strategy for improving the fertility of cultivated soils, correlations were computed between a number of landholding, fertility and livestock variables on 31 farms in the four villages. The only significant relationship found that directly linked livestock with improved fertility of cropped soils was between the level of phosphorus and the number and density of livestock. Thus there is little evidence yet that animals are being used to support intensification in the farming systems of semi-arid Makueni.

Résumé

Ce travail s'inscrit dans le cadre d'une étude plus vaste sur les investissements paysans dans le district semi-aride de Makueni, au Kenya. Dans ce contexte, l'amélioration des sols est considérée comme un investissement pour une meilleure bioproductivité. Pour pouvoir analyser l'impact de différents modes d'exploitation sur la fertilité des sols, 77 échantillons de la couche supérieure (20 cm) de sols cultivés et non cultivés ont été recueillis dans 39 exploitations de 4 villages du district : Kyamusoi (division de Wote), Kaiani (division de Kathonzweni) ainsi que Darajani et Athi Kamunyuni (division de Kibwezi).

Dans la zone étudiée, les sols ont une texture généralement assez grossière (allant du sable au loam sablo-argileux mais surtout au sable loameux) en raison de la géologie de la région, où la roche-mère est riche en quartz mais pauvre en phosphore. Du fait du climat chaud et sec, de l'activité des termites et de la faible bioproductivé, peu de litière est produite et elle est vite décomposée, si bien que les teneurs des sols en matière organique et en azote demeurent faibles.

Les échantillons recueillis dans les quatre villages ont été analysés pour obtenir la teneur totale en carbone (pourcentage), la teneur totale en azote (pourcentage), la teneur

totale en phosphore (ppm) et la classe de texture pédologique. Dans la plupart des 77 échantillons, les teneurs en carbone organique et en azote sont demeurées faibles et la teneur en phosphore insuffisante (tableau 2). Les sols non cultivés (de brousse) ont eu une meilleure teneur en carbone organique que les sols cultivés et la différence a été significative, mais aucune différence significative dans les teneurs en azote et en phosphore n'est apparue. Une comparaison effectuée entre les valeurs moyennes obtenues dans les sites à plus forte pluviométrie (Kyamusoi et Kathonzweni) et à plus faible pluviométrie (Darajani et Athi Kamunyuni) n'a fait ressortir aucune différence attribuable aux conditions climatiques.

Dans la zone de l'étude, les apports d'engrais organiques ou inorganiques demeurent très réduits pour les raisons suivantes :

- le coût des engrais est trop élevé par rapport aux revenus des agriculteurs ;
- l'utilisation d'engrais pendant les périodes sèches peut souvent « brûler » les cultures ;
- les paysans élèvent peu de bétail, et produisent donc peu d'engrais organique.

Les apports d'engrais sont ainsi jugés trop coûteux, trop risqués et trop incommodes par beaucoup d'agriculteurs.

En raison de l'importance potentielle de l'intégration de l'élevage à l'agriculture en tant que stratégie d'amélioration de la fertilité des sols cultivés, des corrélations ont été établies entre certaines variables touchant à la superficie des exploitations, à la fertilité des sols et au bétail élevé dans 31 exploitations des 4 villages (tableau 4). La seule relation directe et significative décelée entre l'élevage et une amélioration de la fertilité des sols cultivés a concerné la teneur en phosphore d'une part et la taille du cheptel et le nombre d'animaux par unité de surface de l'autre. Aucune relation significative n'a été trouvée entre la présence de bétail et les teneurs des sols en carbone ou en azote. A ce jour, peu d'éléments prêtent donc à penser que l'élevage serait utilisé en appui à l'intensification des systèmes agricoles dans le district semi-aride de Makueni.

CONTENTS

About the author

Professor J.P. Mbuvi is Head of the Department of Soil Science at the Faculty of Agriculture at the University of Nairobi (Kabete Campus) and participated in the first study of long-term change in Machakos District.

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1 INTRODUCTION

The present study aims to address the effect of cultivation on soil fertility in terms of plant nutrients. It is recognised that fertility losses are as important as the physical removal of soil, and need to be addressed by conservation strategies. The first requirement is to quantify the losses of essential plant nutrients under different management regimes.

The dominant soils of the study area belong to the Ferrolsols and are either rhodic or xanthic, depending on the colour of the soil (red colour rhodic, yellowish xanthic). Few areas have Arenosols (FAO classification).

The following conclusions were drawn from an earlier study of the impact over time on soil fertility in Machakos District (Mbuvi, 1991):

- Areas which have been maintained under natural vegetation, with minimal disturbance, are still fertile lands, well supplied with the necessary plant nutrients.
- Areas which were cultivated at one time and have been fallow for a long time, or which have experienced bush clearance and extensive grazing, but are still under a cover which prevents the soil from being eroded away, have a moderate - to - low supply of plant nutrients.
- Areas under long-term continuous cultivation without inputs, or intensive grazing pressure, have a low supply of plant nutrients. This may be as a result of the removal of the top horizon by erosion. The fertility of cultivated soils depends on their management.
- The soils of the area are naturally low in phosphorus, irrespective of soil management.

2 METHODS

Two methods are available: the longitudinal method and the spatial analogue method. In the first, soils are monitored at a number of controlled sites over a period of time. This requires baseline samples and analytical results of at least a decade ago, if significant changes are to be detected. The second is a fall-back method where baseline materials are not available. Samples are analysed from sites with known management regimes (cultivation, grazing), and compared with samples from control sites under natural vegetation, and the nature of changes through time are inferred from the differences. The first two sample areas were covered by the 1977 Makueni Reconnaissance Survey, which is yet to be published. The remaining areas are not as yet mapped. In the absence of baseline soils data, the second method is used here.

Topsoil samples were collected from cultivated and uncultivated areas of the same farm holdings, of close proximity. The areas had been settled for at least thirty years. All samples were taken from the top layers (0-20 cm). Four points were sampled from each sample site, then mixed to form a composite sample, from which the final sample for analysis was taken. The study villages were Kyamusoi (Wote Division), Kaiani (Kathonzweni Division), Darajani and Athi Kamunyuni (Kibwezi Division).

Two land use regimes were sampled on private farms: (1) cultivated land and (2) uncultivated bush, i.e. (a) land under annual or multiple cropping, with occasional one-year fallows or none, and (b) land under mixed shrubland or open woodland, with grassland used primarily for pasture. The analyses were restricted to soil texture, organic carbon (C), organic nitrogen (N) and total phosphorus (P).

These samples were analysed in the laboratories of the Department of Soil Science at the University of Nairobi. Soil samples were air-dried, then ground through a 2-mm sieve. Those for organic C and total N determination were further ground to pass through a 0.5-mm sieve. Organic C was determined by the Walkley-Black method (Nelson and Sommers, 1982) and organic N by the Kjeldahl method (Bremner and Mulvaney, 1982). For P determination, the vanadomolybdophosphoric yellow method is used (Mehlich *et al.* 1962). These methods are compatible with those used for the earlier Machakos study (Mbuvi, 1991).

3 RESULTS

Table 1: Soil chemical properties

		C (%)	N (%)	P (ppm)	No. of samples
Kyamusoi	Cultivated	0.96	0.16	10.8	12
	Bush	1.23	0.16	9.7	10
Kathonzweni	Cultivated	1.01	0.16	14.8	10
	Bush	1.41	0.16	4.3	8
Darajani	Cultivated	1.05	0.11	17.3	12
	Bush	1.29	0.17	39.1	5
Athi Kamunyuni	Cultivated	0.80	0.12	21.0	10
	Bush	1.14	0.15	21.0	10
All sites	Cultivated	0.96	0.14	15.8	44
	Bush	1.26	0.16	16.27	33
Average	All samples*	1.11	0.15	17.25	77

*Includes 2 samples from dam sites in Kathonzweni.

3.1 Kyamusoi

The soil texture in this sample area ranges from sand to sandy - clay loam. Most of the soils are low in organic matter, N, and P. However, when one compares cultivated with the uncultivated land a difference in C is noted (0.96 verses 1.23). There is no significant difference in N and P.

3.2 Kathonzweni

The texture of the soils ranges from sand to a sandy - clay base. The C content of the soils is slightly better than that of Kyamusoi, but low. Only 20 percent are considered to have a ‘medium’ supply (Table 2). The majority of the samples are deficient in P. The cultivated area has more P than the bush, although still deficient, and the bush has 40 percent more C than the cultivated soils.

3.3 Darajani

The soils in Darajani are predominantly loamy sand - sandy loam - sandy clay loam. Both the organic matter and N are low. About a third of the sample points are sufficiently supplied with P. However, in respect to P, the bush areas are adequately supplied while the cultivated ones are deficient, though better supplied than those of Kyamusoi and Kathonzweni.

Table 2: Plant nutrient sufficiency (percent of samples)

Organic C	Very low (<0.6%)	Low (0.6-1.25%)	Medium (1.26-25%)
Kyamusoi		80	20
Kathonzweni		60	40
Darajani		77	23
Athi Kamunyuni		85	15
Organic N	Very low (< 0.1%)	Low (0.1-0.2%)	Medium (0.21—0.5%)
Kyamusoi		80	20
Kathonzweni		80	20
Darajani		82	18
Athi Kamunyuni		90	10
P		Deficient (<20ppm)	Sufficient (20>ppm)
Kyamusoi		80	20
Kathonzweni		80	20
Darajani		66	33
Athi Kamunyuni		75	25

3.4 Athi Kamunyuni

The predominant soils are sandy clay loam (45 percent) while the remaining are either loamy sand (35 percent) or loam (20 percent). In terms of organic C and N content, these soils are the lowest in all the areas sampled. They are also predominantly deficient in P. However there is one sample point with an exceptionally high P content, both under cultivation and bush. This is due to a nearby outcrop. There is an appreciable difference in organic matter between the cultivated land and bush (42 percent).

Taking all 77 sample sites together, few have better than low organic C and N, and only a few are sufficient in P. Uncultivated (bush) soils have significantly more organic C than cultivated soils, but their superiority in N and P is insignificant.

A comparison of the average values obtained in the wetter sites (Kyamusoi and Kathonzweni) and the drier sites (Darajani and Athi Kamunyuni) shows no significant differences in C or N, but higher values for P in the drier sites. The explanation for this difference, however, is believed to reside in geological (soil parent material) rather than climatic agency.

3.5 Summary

The texture is generally coarse (sandy to sandy clay loam, but predominantly sandy to loamy sand). This is a result of the geology of the area, with parent material rich in quartz. This parent material is also poor in P. The area experiences both hot and dry conditions which quickly decompose any litter fall, hence the low supply of both organic matter and N. Termites are also common and therefore aggravate the shortage of both organic matter and N. Rainfall is also erratic, and therefore provides little vegetative material for decomposition. Thus there is no noticeable difference between cultivated and uncultivated sites in terms of the plant nutrients analysed.

4 SOIL FERTILITY MANAGEMENT

There is very little addition of either organic or inorganic fertilisers in the study area. This can be explained in two ways. (1) Farmers are not financially capable of buying inorganic fertilisers; and when they do use fertilisers in times of low rainfall the crops 'burn'. Thus they are both costly and risky. (2) Farmers keep few animals, thus producing little organic manure, which is poorly stored and therefore low in nutrients. Organic (‘farmyard’) manure is both scarce and inefficiently used.

A comparison between soil properties on farm holdings having livestock and those without is shown for illustrative purposes in Table 3. Holdings endowed with livestock are divided between two categories: more and fewer standard livestock units relative to other farm holdings in the sample.

Table 3: Manure management for nutrients

Sample site and household no.	%C	%N	P.ppm	Livestock units
Kyamusoi				
23 Cultivated	1.19	0.25	8.5	11.2
Bush	1.44	0.20	34.5	
29 Cultivated	0.83	0.06	24.0	0.8
	0.62	0.08	21.5	
Bush	0.55	0.14	4.0	
32 Cultivated	1.03	0.11	7.0	0
Bush	1.34	0.17	10.0	
Kaiani				
40 Cultivated	0.42	0.14	6.5	16.0
Bush	1.66	0.17	1.0	
	1.95	0.22	6.5	
18 Cultivated	2.14	0.17	9.0	4.0
Bush	1.56	0.22	4.0	
22 Cultivated	1.15	0.22	16.5	1.0
	0.67	0.17	6.5	
Bush	0.98	0.14	6.5	
Darajani				
19 Cultivated	0.79	0.11	35.0	5.2
Bush	0.92	0.25	10.0	
9 Cultivated	0.95	0.14	15.8	2.2
Bush	1.73	0.14	16.5	
32 Cultivated	1.17	0.22	11.0	0
Bush	0.53	0.20	18.0	
Athi Kamunyuni				
18 Cultivated	0.56	0.20	840.0	14
Bush	1.46	0.22	560.0	
21 Cultivated	0.92	0.11	15.0	7.2
Bush	0.67	0.14	65.0	
35 Cultivated	1.03	0.08	17.5	0
Bush	1.23	0.14	8.0	

Source: Field survey, 1998.
Livestock units (LUs): 1 cow = 5 sheep or goats

In view of the potential importance of crop-livestock integration as a strategy for improving the fertility of cultivated soils, correlations were computed between a number of landholding, fertility and livestock variables on 42 farms in the four villages (Table 4). A strong association was found between the variables: size of holding, area cropped, number of cattle and number of livestock units (rows 1 - 7 in the table). Thus the larger farms have more cropped land and more animals, and, though larger in size, their cropped sites tend to have more soil C (row 8). Also, the more animals there are, the more C and P is found in the soils of the bush (grazing land) sites (rows 9 and 10).

However, the only significant relationships found (at .05 level) linking livestock directly with the fertility of cropped soils are those between P and the number and density of livestock (rows 11 and 12). No significant relationships were found with C or N. Thus there is little evidence yet of the use of animals to support intensification in these farming systems in semi-arid Makueni.

Table 4: Correlations between soil fertility, landholding and livestock variables in the four villages

Significant at .01 level			
(1)	Total area of holding	Area cropped	.6614
(2)	Total area of holding	Number of livestock units	.5176
(3)	Total area of holding	Number of cattle	.4437
(4)	Area cropped	Number of cattle	.4673
(5)	Number of livestock units	Livestock units/cropped acre	.4503
(6)	Livestock units/total acre	Livestock units/cropped acre	.8906
Significant at .05 level			
(7)	Cropped area	Number of livestock units	.4010
(8)	Cropped area	Percent C on cropped site	.4079
(9)	Percent C on bush land	Number of livestock units	.3832
(10)	P ppm on bush land	Number of livestock units	.3495
(11)	P ppm on cropped land	Number of livestock units	.3674
(12)	P ppm on cropped land	Livestock units/cropped acre	.3394

ANNEX: SOIL CHEMICAL PROPERTIES

Table A1: Soil chemical properties, Darajani

Sample site no.		Lab. nos.	Texture	%C	%N	P.ppm
1a	Cultivated	38	SL	1.11	0.17	15.0
2a	Cultivated	73	LS	0.55	0.20	8.5
3a	Cultivated	34	LS	0.68	0.10	15.5
9a	Cultivated	7	SCL	0.95	0.14	15.8
b	Bush	64	L	1.73	0.14	16.5
13a	Cultivated	20	LS	0.86	0.20	9.0
14a	Cultivated	5	LS	1.54	0.25	16.5
19a	Cultivated	63	LS	0.79	0.11	35.0
b	Bush	71	L	0.92	0.25	10.0
20a	Cultivated	4	LS	1.05	0.11	22.0
24a	Cultivated	11	LS	0.99	0.20	22.0
27a	Cultivated	39	SCL	1.69	0.17	7.0
b	Bush	50	SCL	2.06	0.17	140.0
32a	Cultivated	13	LS	1.17	0.22	11.0
b	Bush	79	SL	0.53	0.20	18.0
38a	Cultivated	57	SL	1.23	0.11	30.5
b	Bush	53	SL	1.23	0.11	11.0

Table A2: Soil chemical properties, Kyamusoi

Sample site no.	Lab. nos.	Texture	%C	%N	P.ppm
14_{1-} Cultivated	23	LS	1.05	0.22	13.5
14_{2-} Bush	6	LS	1.15	0.14	5.6
14_{3-} Bush	80	SCL	1.32	0.17	2.0
11_{a-} Cultivated	30	LS	1.15	0.17	23.0
b Cultivated	55	S	2.06	0.17	11.0
c Bush	17	S	1.03	0.20	18.0
201 Cultivated	72	L	0.92	0.17	8.5
2 Cultivated	28	SCL	1.15	0.22	6.0
3 Bush	15	LS	1.11	0.22	7.0
231 Cultivated	21	SCL	1.19	0.25	8.5
2 Bush	24	LS	1.44	0.20	34.5
29a Cultivated	60	LS	0.83	0.06	24.0
b Cult	47	SCL	0.62	0.08	21.5
c Bush	27	S	0.55	0.14	4.0
32_1 Cult.	40	SL	1.03	0.11	6.5
2 Bush	35	SCL	1.34	0.17	10.0
41_1 Cultivated	42	SCL	0.99	0.11	7.0
2 Bush	49	S	0.62	0.08	21.5
42a Cultivated	74	L	0.83	0.22	8.5
b Bush	44	S	2.14	0.11	6.6
8a Cultivated	43	SL	1.15	0.17	15.0
b Bush	75	L	1.24	0.25	6.5

Table A3: Soil chemical properties, Kathonzweni

Sample site no.		Lab. nos.	Texture	%C	%N	P.ppm
4a	Cultivated	22	SCL	1.38	0.25	29.0
b	Bush	31	SCL	1.52	0.17	4.0
c	Cultivated	10	S	0.49	0.14	14.0
18a	Cultivated	1	SCL	2.14	0.17	9.0
b	Bush	16	SL	1.56	0.22	4.0
22a	Cultivated	69	SCL	1.15	0.22	16.5
b	Cultivated	77	LS	0.67	0.17	6.5
c	Bush	70	LS	0.98	0.14	6.5
32a	Cultivated	58	SCL	0.79	0.03	25.5
36a	Cultivated	25	S	0.62	0.20	26.0
	Dam Soil	19	SC	1.23	0.20	12.5
	Dam Crusts	59	C	2.82	0.22	22.5
40a	Bush	18	SCL	1.66	0.17	1.0
b	Bush	54	SCL	1.95	0.22	6.5
c	Cultivated	76	S	0.42	0.14	6.5
59a	Cultivated	29	SC	1.48	0.14	4.0
b	Bush	14	SCL	1.48	0.20	7.0
c	Bush	61	SCL	1.37	0.08	2.0
60b	Cultivated	41	SL	0.97	0.11	10.5
a	Bush	56	S	0.78	0.06	3.5

Table A4: Soil chemical properties, Athi Kamunyuni

Sample site no.		Lab. nos.	Texture	%C	%N	P.ppm
3a	Cultivated	3	LS	0.66	0.02	7.7
b	Bush	68	LS	0.64	0.17	25.5
9a	Cultivated	45	LS	0.86	0.08	10.0
b	Bush	46	SL	1.25	0.14	8.5
15a	Cultivated	26	SCL	0.76	0.17	14.5
b	Bush	48	SCL	1.36	0.17	11.0
18a	Cultivated	12	LS	0.56	0.20	840.0
b	Bush	9	SCL	1.46	0.22	580.0
21a	Cultivated	37	SC	0.92	0.11	15.0
b	Bush	67	SCL	0.67	0.14	65.0
24a	Cultivated	8	SCL	1,19	0.14	40.5
b	Bush	62	SCL	0.70	0.08	62.2
27a	Cultivated	32	LS	0.70	0.06	17.5
b	Bush	65	L	1.28	0.08	6.5
29a	Cultivated	51	SCL	1.29	0.11	55.5
b	Bush	2	SCL	1.76	0.20	1.0
32a	Cultivated	66	LS	0.06	0.22	11.0
b	Bush	36	SCL	1.03	0.14	2.0
35a	Cultivated	52	L	1.03	0.08	17.5
b	Bush	33	L	1.23	0.14	8.0

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