canopy cover they afford, which in turn, affect leaf litter and decomposition properties in the topsoil.

Soil quality indicators derived from spectra

Table 4.3.1 suggests that several indicators of soil quality have changed considerably since the NSS survey in 1989. While it appears that clay content has declined the most since 1989, these values are misleading because the 2003 values were calculated *after* the soils had been passed through a 2 mm sieve, whereas, the 1989 values represent clay content prior to sieving. Organic carbon values have declined since 2003 at a fairly constant rate ($r^2 = 0.53$), while the tendency for the Northern region to have higher values than the Central/Southern regions is still apparent. Potassium levels have also declined since 1989, although without linearity. It is important to recognize, however, that soil sample sites are not the same as in 1989 and that the 1989 samples were taken in February during the hot, dry season.

Table 4.3.1 Changes in soil quality indicators since 1989 (NSS survey) by region/soil type

Soil type	% Clay		% Org. C		% N		C/N		Exch. K (me/100g)	
	1989	2003	1989	2003	1989	2003	1989	2003	1989	2003
RU1	55	21.7	4.0	3.44	0.24	0.23	17	15.4	2.48	1.40
RU2	67	23.2	3.2	2.78	0.17	0.17	19	16.6	1.64	1.11
M	47	30.2	3.5	3.00	0.18	0.18	20	16.7	1.47	1.28
RL1	57	27.1	3.2	2.04	0.16	0.16	20	13.1	2.21	1.01
RL2	63	30.8	3.0	2.81	0.17	0.19	18	15.2	2.03	1.06
L1	42	30.7	3.0	2.89	0.18	0.19	17	15.1	2.44	1.21
A	35	25.9	2.8	2.26	0.35	0.16	8	15.5	3.90	1.21

* 1989 values are from February and taken from one sample site, whereas, 2003 values are from June and represent the average of all sample sites within a soil type.

Figures 4.4.5 and 4.4.6 represent clay and organic matter content averages for all land use types (bush, graze, fields) within each soil type for input into the soil loss equation described in the next section (the actual values used in the equation and to generate these figures appear as appendix).

Table 4.3.2 shows variations in soil quality indicators among fields of different soil types. Although values in this table represent the averages of all fields in a given soil type (regardless of conservation measure usage), trends for soil types that are highly suitable for cultivation parallel those of crop productivity. For instance, RL1 fields reported the lowest crop yields and also have the lowest contents of N and K. Similarly, RU1 outperformed RU2 in both maize and wheat productivity as well as in levels of N and K. In general, clay content increases and C_{org} decreases with increasing degree of erosion; thus it appears that RL1 may have experienced a slightly greater degree of soil erosion than RU2, which in turn has experienced a greater degree than RU1. Table 4.3.3 shows differences in soil quality indicators by field type, independent of soil type.

Table 4.3.2 Averaged soil quality indicators for fields within each soil type

	Soil type	% Clay	% Org. C	% N	C/N	Exch. K (me/100g)
Highly suitable	A	26.1	2.41	0.17	14.9	1.18
	RU1	23.2	3.29	0.23	14.5	1.40
	RU2	23.6	2.85	0.17	16.7	1.10
	RL1	26.6	2.00	0.16	13.1	1.01
	L1	31.1	2.83	0.19	14.9	1.21
Marginally suitable	RU3	28.0	3.26	0.23	14.3	1.29
	M	32.5	1.76	0.11	15.4	1.10
	RL2	27.9	2.76	0.19	15.1	1.08
	L2	28.8	3.47	0.13	31.2	1.16
	V	26.4	1.21	0.12	12.4	1.11
Village		27.0	2.65	0.18	15.9	1.13

Table 4.3.3 Averaged soil quality indicators by field type

Crop(s)	% Clay	% Org. C	% N	C/N	Exch. K (me/100g)
Wheat	23.5	2.73	0.18	15.9	1.13
Maize	28.3	2.32	0.17	15.7	1.10
Maize/beans	25.7	2.79	0.22	13.1	1.03
Maize/PPs	29.5	1.91	0.14	13.8	1.12
Beans	29.5	3.07	0.18	19.7	1.21

Tables 4.3.4 – 4.3.5 show how different management practices affect soil quality indicators. The use of contour ridges is accompanied by significantly lower clay content ($p < 0.02$, $n = 15$) and C/N ratios ($p < 0.02$, $n = 14$), in addition to higher contents of both C_{org} and N. Tillage by ox-plough is also significantly correlated to lower C/N ratios than tillage by tractor ($p < 0.001$, $n = 21$). No significant correlations were found with K and the use of these positive management practices.

Table 4.3.4 Averaged soil quality indicators by tillage method for each field type

Crop(s)	% Clay		% Org. C		% N		C/N		Exch. K (me/100g)	
	tractor	ox	tractor	ox	tractor	ox	tractor	ox	tractor	ox
Wheat	21.3	27.5	3.11	2.22	0.18	0.17	17.3	13.0	1.20	1.04
Maize	26.1	30.2	2.18	2.62	0.15	0.17	15.7	15.6	1.08	1.12
Maize/beans	n/a	25.7	n/a	2.79	n/a	0.22	n/a	13.1	n/a	1.03
Maize/PPs	36.4	27.8	2.33	1.80	0.15	0.14	15.2	13.9	0.96	1.16
Beans	30.2	30.1	3.18	2.79	0.19	0.15	16.7	22.2	1.13	1.23

Table 4.3.5 Averaged soil quality indicators by vegetated contour ridges (CRs) for each field type

Crop(s)	% Clay		% Org. C		% N		C/N		Exch. K (me/100g)	
	CRs	none	CRs	none	CRs	none	CRs	none	CRs	none
Wheat	22.0	26.4	2.17	3.14	0.16	0.19	13.4	17.3	1.08	1.18
Maize	27.8	31.4	2.04	2.55	0.17	0.17	15.4	15.8	1.17	1.09
Maize/beans	25.7	n/a	n/a	2.79	n/a	0.22	n/a	13.1	n/a	1.03
Maize/PPs	29.0	30.4	1.69	2.06	0.14	0.14	13.5	14.6	1.10	1.13
Beans	28.2	31.7	2.55	3.39	0.18	0.18	14.2	23.1	1.32	1.15

Correlation of ground truth management practices to ASTER

The use of vegetated contour ridges is correlated to significantly higher SLA-NDVI and lower MSI values ($p < 0.02$, $n = 15$) for all fields in the June (pre-harvest) image, as shown in Table 4.3.6. On the other hand, fields tilled by tractors have higher SLA-NDVI and lower MSI values than those tilled by oxen, although this correlation is not significant. Contour ridges appear to have the greatest impact on maize fields and only minimal impact for wheat fields with both indices. Although vegetated contour ridges resulted in higher SLA-NDVI and lower MSI values in the October image, this correlation is not significant.

Table 4.3.6 Average SLA-NDVI/MSI values for georeferenced fields by management practices

Crop(s)	SLA-NDVI				MSI			
	ox	tractor	CRs	no CRs	ox	tractor	CRs	no CRs
Wheat	0.379	0.489	0.453	0.451	0.165	0.137	0.143	0.146
Maize	0.454	0.423	0.550	0.421	0.148	0.154	0.129	0.156
Maize/beans	0.271	n/a	n/a	0.271	0.187	n/a	n/a	0.187
Maize/PPs	0.477	0.570	0.507	0.489	0.150	0.109	0.147	0.138
Beans	0.446	0.411	0.385	0.434	0.159	0.150	0.146	0.159

* Values are for June image.

4.4 SOIL LOSS ESTIMATES

Two maps showing estimated soil loss risk appear as Figures 4.4.1 and 4.4.2. While georeferenced canopy cover estimates were found to be relatively similar to SLA-NDVI-derived cover estimates in the June image (r^2 = 0.21) and GPS elevations nearly identical to ASTER-DEM elevations (r^2 = 0.93), slope estimates bore much less similarity to ASTER-DEM slope values (r^2 = 0.11). Based on this consideration, Figure 4.4.1 has been selected as the basis for providing most results and recommendations at the qualitative level, however, estimates from this figure are subsequently combined with average slope ranges for each soil type to produce quantitative estimates.

Figures 4.4.3 to 4.4.6 show village maps of the factors included in the USLE (their derivation is described in methods 3.4); Figure 4.4.3 shows the R-factor, 4.4.4 shows slope (for input into the LS-factors), 4.4.5 shows clay content, and 4.4.6 shows organic matter content (these latter two are for input into the K-factor).

Numerical values for soil loss range from 1.3 to 51.1 metric tons/hectare/year with the non-slope equation and 0.2 to 116.6 metric tons/hectare/year with the slopedependent equation. To better conceptualize this, 10 metric tons of soil is the equivalent of 1 mm spread evenly over a hectare. Table 4.4.1 shows the qualitative rankings derived from numerical values generated by the non-slope equation. A factor of 0.792 can be multiplied to these values to calculate soil loss for an average slope of 5º or 2.35 for an average slope of 10º.

Table 4.4.1 Numerical soil loss estimates (A) in 10^3 kg/ha/yr and their corresponding rankings, as derived from the non-slope equation

A	1.3	4.4	6.8	8.7	10.0	11.2	12.4	13.7	15.1	16.2	17.2	18.3	19.5	21.4	24.6
Ranking	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

* Minimum values only.

Table 4.4.2 shows the percentages of each soil type that are of highest and lowest soil loss risk. Figure 4.4.7 contains a soil loss risk histogram for all fields in soils that are highly suitable for cultivation, coupled with previously discussed results for clay, organic matter content, area, and median risk. It also contains average slope values for each soil type and their theoretical effects on annual soil loss. For instance, although RU2 appears to have a lower overall soil loss risk than RU1, RU2 is typically of steeper slope than RU1; thus the average field in RU2 has a greater soil loss risk than the average field in RU1. With subsequent inclusion of average slope ranges, trends in soil loss risk are similar to those of crop productivity (refer back to Table 4.1.1) for the heavily cultivated soil types. This statement is inclusive of fields in the alluvial soil type, which have a relatively low risk estimate and are typically of very mild slope (compounding this low risk estimate).