The **WINAND STARING CENTRE** for Integrated Land, Soil and Water Research

Assessment of soil nutrient depletion in Sub-Saharan Africa: 1983-2000

Volume III: Literature review and description of Land Use Systems

J.J. Stoorvogel
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Report 28

n (The Netherlands), 1990

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ABSTRACT

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On request of FAO a methodology was developed to assess the state of soil nutrient depletion under agriculture in Sub-Saharan Africa for 1983 and the year 2000. The nutrient balance is described with five input and five output factors, which result in a nutrient loss rate. Production figures and data on fertilizer consumption for 1983 and projections for the year 2000 were provided by FAO. Data on nutrient balances as well as additional country information were collected from the literature. Nutrient depletion rates for Sub-Saharan Africa are approximately 20 kg N, 10 kg P_2O_5 and 20 kg K_2O per ha on average up to a maximum of 40 kg N, 20 kg P_2O_5 and 40 kg K_2O per ha in East Africa.

Keywords: nutrient depletion, nutrient balances, soil fertility, Sub-Saharan Africa.

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The WINAND STARING CENTRE is continuing the research of:
Institute for Land and Water Management Research (ICW), Institute for Pesticide Research, Environment Division (IOB), Dorschkamp Research Institute for Forestry and Landscape Planning, Division of Landscape Planning (LB), and Soil Survey Institute (STIBOKA).

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VOLUME III: LITERATURE REVIEW AND DESCRIPTION OF LAND USE SYSTEMS

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1 INTRODUCTION

The Department of International Cooperation of the Winand Staring Centre for Integrated Land, Soil and Water Research, was requested by the Land and Water Development Division (AGL) of FAO, to assess the state of soil nutrient depletion in Sub-Saharan Africa,

a. in the recent past (1983);
b. in the near future (2000).

This assessment should provide, on a country basis, data on the net removal (depletion minus accumulation) of nutrients from the rootable soil layer. The present study, being of a general, exploratory nature, is entirely devoted to the macronutrients nitrogen (N), phosphorus (P), and potassium (K). Even though it is appreciated that secondary and micronutrients also limit crop production, they are not included at the present time.

The development of a method for this assessment is the focal point of this study. Production figures (1983) and forecasts (2000) were provided by FAO, per crop and per country, and further specified per mainly climate-based 'Land/Water Classes' (LWC). Similarly, data on fertilizer consumption were made available but only as country totals. In addition to the data provided by FAO a plethora of literature was studied. This Volume presents the results of this review. Data referring to the individual input and output factors are given in Chapter 2. Data refering to the countries included in this study are given countrywise in Chapter 3.

General information on this study and results per Land/Water Class and country can be found in the Main Report (Volume I). Nutrient balances per crop and LUS are given in Volume II. The programs developed for this study are listed and explained in Volume IV.

2 METHODOLOGY

The model is developed to assess the rate of nutrient depletion under agriculture in Sub-Saharan Africa. To perform this assessment ten different flows of nutrients are to be quantified.

Table 2.1 Input and output factors governing nutrient flows in the soil (in kg/ha,yr).

Input		**Output**	
IN 1	Mineral fertilizers	**OUT 1**	Harvested product
IN 2	Manure	**OUT 2**	Crop residues
IN 3	Deposition	**OUT 3**	Leaching
IN 4	Biol. N fixation	**OUT 4**	Gaseous losses
IN 5	Sedimentation	**OUT 5**	Erosion

2.1 Mineral fertilizers

Weighing factors are based on known fertilizer applications for some countries as described in Chapter 3 and on expert consultations.

2.2 Manure

2.2.1 Review

The chemical composition of farm yard manure is described by several authors. Tables 2.2-2.8 give the data which are used for this study.

Table 2.2 Chemical composition of airdry farm yard manure according to Cooke (1982) (%)

		N	**P_2O_5**	**K_2O**
Malawi	Open khola	0.95	0.69	1.52
	Covered khola	1.28	1.10	2.76
Tanzania		1.50	0.69	
	African Kraals	0.5-0.9	0.6-1.0	1.6-2.7

Table 2.3 Chemical composition of fresh farm yard manure according to Fairbridge and Finkle (1979, cited by Landon, 1984) (%)

	moisture content	N	P_2O_5	K_2O
(range)	8-86	0.3-2.2	0.0-2.1	0.5-1.4
(mean)	76	0.6	0.3	0.6

Table 2.4 Chemical composition of the dry matter of farm yard manure according to Oenema (1980, cited by Noll and Janssen, 1983) (%)

		N	P_2O_5	K_2O
Kenya	Corral manure	1.1	1.7	2.0

Table 2.5 Chemical composition of airdry farm yard manure according to Pichot et al (1981) (%)

		N	P_2O_5	K_2O
Burkina Faso	1966		0.5	
	1970	2.3	0.5	5.4
	1971	2.5	0.5	5.2
	1978	1.5	0.6	1.9

Table 2.6 Chemical composition of airdry farm yard manure according to Richard (1976, cited by Pieri, 1985) (%)

	N	P_2O_5	K_2O
Mali, cotton area	1.2	0.7	1.8

Table 2.7 Chemical composition of airdry farm yard manure according to Pieri (1986) (%)

		N	P_2O_5	K_2O
Madagascar	(range)	0.4-1.0	0.2-0.4	0.4-0.8
	(mean)	0.7	0.3	0.6

Table 2.8 Chemical composition of fresh farm yard manure in Rwanda according to FAO (1986) (%)

	N	P_2O_5	K_2O
cattle	0.2	0.15	0.2
goats	0.15	0.15	0.3
sheep	0.2	0.15	0.3
pigs	0.28	0.30	0.18

2.2.2 Procedure

Two forms of manuring are considered in the present study. Manure collection in storage places (e.g. bomas and kraals) and on-the-spot manuring by livestock feeding on crop residues.

- manure collection

Although fertilizer researchers apply up to 5000 kg manure per ha, this is not common on African farms. Experts on this subject considered amounts up to 1500 kg/ha realistic (divided in classes of 0, 500, 1000 and 1500 kg/ha,yr). To calculate the amount of nutrients applied to the fields, data on the chemical composition of the manure is required. The composition of farm yard manure which is used in this study is given in Table 2.9.

Table 2.9 Dry weight and chemical composition of manure in the Land/Water Classes (in % of fresh weight)

LWC	dry weight	N	P_2O_5	K_2O
LR, UR, IR PR (dry climate)	75	0.48	0.40	0.65
GR, NF PR (wet climate)	50	0.42	0.35	0.55

- on-the-spot manuring

If livestock feeds on crop residues which have been left on the field, some of the manure input is realized 'during grazing'.
Three questions now need to be answered to arrive at a calculation:

1. What is the fraction of the crop residues that is grazed?
2. How many hours a day do the animals spend on the grazed field?
3. What is the fraction of the nutrients that remains inside the animals?

The answers have been stipulated as follows:
1. This differs for each LUS and is indicated as such in its description (for LUS UR-L.2 in Senegal, it is 80%);
2. 12 hours (fixed value for all LUS);
3. 10% (fixed value for all LUS).

2.3 Wet and dry deposition

2.3.1 Review

Data on nutrients supplied by wet and dry deposition derived from literature are summarized in Table 2.10.

2.3.2 Procedure

Considerable amounts of nutrients are supplied to soils by the processes of wet and dry deposition. Due to a very uneven distribution of data over the continent, the calculation procedure is split into two, relating to:
1. areas within Harmattan influence (West Africa): the literature (Table 2.9) provides sufficient point data to allow interpolation.
2. areas outside Harmattan influence: data on the factors themselves are scarce, but there is a correlation with rainfall; regression analysis for the different nutrients resulted in the equations listed below. They are used to calculate the contribution to soil fertility by **IN 3** for areas outside Harmattan influence.

IN 3 (N) $= 0.14 * \text{rainfall}^{1/2}$

IN 3 (P_2O_5) $= 0.053 * \text{rainfall}^{1/2}$

IN 3 (K_2O) $= 0.11 * \text{rainfall}^{1/2}$

(**IN** in kg/ha,yr; rainfall in mm/yr).

Table 2.10 Nutrients supplied by wet and dry deposition (kg/ha)

Source and location	Rainfall (mm)	N	P_2O_5	K_2O
(Nye, 1961 cited by Poels, 1987)				
Ghana	1850	16.3	0.93	21.2
(Mathieu, 1976 cited by Poels, 1987)				
Ivory Coast	1320			<8.0
(Meyer and Pampfer, 1959)				
Zaire, Yangambi	1546	5.4		
(Jones and Bromfield, 1970)				
Nigeria, Samaru	1219	4.5		
(Roose, 1980 cited by Pieri, 1985)				
Ivory Coast, Korhogo	1350	12.2	3.0	4.9
Burkina Faso, Saria	860	5.4	4.8	4.1
(Pieri, 1982 cited by Pieri, 1985)				
Senegal, average of 4 sites	836	0.5	3.0	4.9
(Wilkes et al, 1984 cited by Mortimore, 1989)				
Nigeria (north, only dust)		3.1	3.9	30.1
(Lal, 1981 by Styczen, 1989), Harmattan dust				
Nigeria, Samaru	1041	3.3	0.2	1.8
(Richard, 1963)				
Ethiopie, Addis-Abéba	1333	9.4		
(Bille, 1977)				
Senegal	213	1.6	0.5	
(Villecourt, 1975)				
Ivory Coast	1300	5.3		
	1250	4.3		
(Cooke, 1982)				
Ivory Coast		21	5.3	6.9

2.4 Biological N fixation

2.4.1 Review

Data on N fixation (kg N /ha) derived from literature and used in this study are given in Tables 2.11-2.13.

Table 2.11 N-fixation for different crops according to Tisdale et al. (1985) for non-tropical areas (kg N / ha)

Crop	Range	Average
Cowpeas	65 - 130	101
Peas	34 - 157	81
Soybeans	65 - 179	112
Peanuts		47
Beans		45

Table 2.12 Estimates of biologically fixed N in food crop production systems in the tropics (Different authors cited by Greenland, 1985) (kg N / ha)

Production system	Fixation	Remark
A.Semi-arid tropics		Residual soil N only
Non-legume crops	0-10	Need adequate P and
Grain legumes	10-40	favorable rainfall
B.Humid tropics		Residual soil N only
Non-legume crops		
- without mulch	0-10	
- with mulch	10-30	
Grain legumes	10-50	Need adequate P
C.Wetlands		
Fully irrigated rice	40-80	

Table 2.13 N-fixation for soybeans and groundnuts under different rainfall conditions (Wetselaar and Ganry, 1982 cited by Pieri, 1985)

Rainfall	Crop	Yield (kg/ha)	N-fixation (kg N/ha)
sufficient	Soybeans	2315	55
	Groundnuts	1420	66
deficient	Soybeans	835	58
	Groundnuts	1126	21

(Munyinda et al, 1988):
Zambia: percentage of N derived from atmosphere for soybeans was in the order of 65 to 70% .

(Tisdale et al, 1985):
The quantity of nitrogen fixed by properly nodulated legumes averages about 75 % of the total nitrogen used in the growth of the plant.

(Roger and Reynaud, 1979 cited by Wetselaar, 1981):
N-fixation in a paddy field in Senegal varies between 2 and 30 kg N/ha,crop.

2.4.2 The procedure

Based on information from the literature and the expert consultations, three stipulations are presented, depending on total N demand by crops as laid down in Table 2.15.

1. Of the total nitrogen demand of leguminous crops (soybean, groundnuts and pulses) 60% is supplied through symbiotic N fixation (Rhizobia).
2. Of the total nitrogen demand of wetland rice (LWC NF and IR) 80% is supplied through chemo-autotrophic N fixation (Azolla, other algae), up to a maximum of 30 kg/ha,yr. Higher uptakes are drawn from soil N.
3. All crops benefit from N that is fixed non-symbiotically (Azotobacter, Beyerinckia, Clostridium) or by N-fixing trees that are left on the field (Rhizobia, Actinomycetes).

The latter contribution is partitioned according to LWC in Table 2.14.

Table 2.14 Contribution of scattered trees and of non-symbiotic N fixation to Biological N-fixation (**IN 4**, in kg N/ha)

LWC	**Input**
low rainfall	3
uncertain rainfall	4
good rainfall	5
problem area - >1200 mm rain/yr	5
problem area - <1200 mm rain/yr	2
naturally flooded	2
irrigated area	2

2.5 Sedimentation

(different authors cited by Wetselaar, 1981)
The amount of nitrogen supplied by irrigation water in Asia varies between 6 and 16.5 kg/ha, crop.

2.6 Harvested product and crop residues

2.6.1 A review

Different crops withdraw different amounts of nutrients from the soil. A good deal of literature is available on this subject. The complete listing of raw data on N, P and K uptake in the harvested parts of crops and in their above-ground residues is given in Table 2.15.

Table 2.15 Chemical compositions of products and crop residues for all crops, described in the literature (kg/ton product)

Product			Crop residue			Totals		
N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
WHEAT								
(Singh and Balasubramanian, 1983) - Nigeria								
22.3	9.9	7.0	4.3	4.1	32.0	26.6	14.0	39.0
(Cooke, 1982)								
						20.0	9.6	16.1
(different authors cited by Sanchez, 1976)								
17.6	8.1	5.3	4.4	2.7	24.8	22.0	10.8	30.1
14.1	8.9	4.2	6.7	2.0	12.7	20.8	10.9	17.0
(Westphal, 1985) - France								
18.0	13.3	7.8	12.0	2.3	30.0	30.0	15.6	37.8
RICE								
(IRAT, 1972 cited by Kassam, 1976) - Senegal totals								
						24	11.9	34.0
(different authors cited by Westphal, 1985) - Philipines								
10.0	2.7	2.3	9.0	1.6	44.7	19.0	4.3	47.0
(Siband, 1972 cited by Pieri, 1985) - Senegal								
9.0	7.8	5.5	15.4	10.8	56.6	24.4	18.6	39.8
(Chabalier, 1976 cited by Pieri, 1985) - Ivory Coast								
17.1	15.8	4.3	17.2	7.8	41.2	34.3	23.6	45.5
(Rice Production Manual cited by Williams, 1975)								
11.8	7.3	3.3	10.3	3.9	61.6	22.1	11.2	64.9

Table 2.15 (Cont.)

Product			Crop residues			Totals		
N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
(Ochse et al, 1961 cited by Grist, 1975)								
9.6	5.0	5.1	4.5	2.3	10.5	14.1	7.3	15.6
(different authors cited by Cooke, 1982)								
11.8	8.2	4.3						
						19.0	9.9	56.6
(different authors cited by Sanchez, 1976)								
20.5	9.4	7.1	4.1	1.3	12.7	24.6	10.8	19.8
11.7	8.1	2.7	3.9	1.3	9.3	15.5	9.3	11.9
(FAO, 1986) - Burkina Faso								
13	7	4						
(FAO, 1986) - Madagascar								
17	9	27						
MAIZE								
(IRAT, 1972 cited by Kassam, 1976) - Senegal								
						25	11.9	21.0
(Wielemaker and Boxem, 1982) - Kenya								
						25	9.6	28.1
(Singh and Balasubramanian, 1983) - Nigeria								
21.0	6.6	4.9	4.6	2.5	24.7	25.6	9.1	29.6
(Barber and Olsen, 1968 cited by de Geus, 1973)								
13.7	7.6	4.9	6.5	2.1	20.1	20.2	9.7	25
(Traore, 1974 cited by Pieri, 1985) - Mali								
15.0	11.2	7.7	12.7	3.9	23.5	27.7	15.5	31.2
(Chabalier, 1982 cited by Pieri, 1985) - Ivory Coast								
19	15.4	7.2	15	8.9	34.4	34	24.3	41.6
(different authors cited by Cooke, 1982)								
15.5	6.2	3.3						
(different authors cited by Sanchez, 1976)								
22.0	12.1	15.9	13.2	6.1	19.1	35.2	18.2	35.0
13.9	6.1	8.0	8.1	3.0	10.1	22.0	9.1	18.0
16.1	5.8	5.6	9.1	4.0	14.1	25.2	9.8	19.7

Table 2.15 (Cont.)

Product			Crop residues			Totals		
N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
(Singh et al, 1987) - Nigeria								
						25.3	6.1	32.0
						26.4	5.9	32.9
						26.2	6.4	34.8
(FAO, 1986) - Burkina Faso								
19	10	12						
(FAO, 1986) - Madagascar								
24	12	18						
BARLEY								
(Bajwa et al, 1979) - Libya								
15.5	6.4	7.2	7.0	2.3	25.2	22.5	8.7	32.4
(Cooke, 1982)								
						20.0	8.3	14.5
MILLET								
(Kassam, 1976) - West African Savanna								
						42	20.2	24.9
(Bertrand et al, 1972 cited by Pieri, 1985) - Niger								
20.4	12.4	6.3	29.2	10.5	82.5	49.6	22.9	88.8
(Traore, 1974 cited by Pieri, 1985) - Niger								
18.0	15.1	6.7	11.7	7.6	60.8	29.7	22.7	67.5
(different authors cited by Sanchez, 1976)								
13.6	9.2	56.9						
(FAO, 1986) - Burkina Faso								
19	10	11						
SORGHUM								
(Maroua, 1975 cited by Gigou, 1986) - Cameroon								
14	6.0	3.0	7	5.5	27.1	21	11.5	30.1
(IRAT, 1972 cited by Kassam, 1976) - Senegal								
						12	2.1	13.0
(Wielemaker and Boxem, 1982) - Kenya								
						9	2.5	25.4

Table 2.15 (Cont.)

Product			Crop residues			Totals		
N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
(Kassam, 1976) - Senegal								
						30	7.1	17.0
(Gigou, 1976 cited by Pieri, 1985) - Cameroon								
13	18.3	6.0	7.0	8.0	30.1	20	26.3	36.1
(Arrivets, 1976 cited by Pieri, 1985) - Burkina Faso								
16.5	13.5	4.3	18.5	17.9	47.7	35	31.4	52
(different authors cited by Sanchez, 1976)								
17.6	1.8	4.2	5.3	0.8	2.1	22.9	2.6	6.4
14.9	2.5	3.6	7.2	1.0	1.7	22.0	3.5	5.3
(FAO, 1986) - Burkina Faso								
22	5	5						
OTHER CEREALS (average of all cereals)								
POTATOES								
(Kassam, 1976) - tropics								
						4.4-5.0	1.6-2.1	4.2-7.8
(Flach, 1979 cited by Westphal, 1985) - dry weight								
15.5	5.5	26.0						
(Wielemaker and Boxem, 1982) - Kenya								
						4.0	1.8	7.2
(Obigbesan and Agboola cited by Cooke, 1982) - Nigeria, dry weight								
13.8	5.5	24.0						
(different authors cited by Sanchez, 1976)								
4.3	1.9	8.0						
1.8	0.7	6.1	1.6	0.3	4.1	3.3	1.0	11.0
(FAO, 1986) - Madagascar								
7	2	10						

Table 2.15 (Cont.)

Product			Crop residues			Totals		
N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
SWEET POTATOES								
(different authors cited by Kassam, 1976)								
4.7	1.4	7.3						
(Westphal, 1985) - dry weight								
8.8	4.8	13.9						
(Wielemaker and Boxem, 1982) - Kenya								
						5.1	2.1	9.6
(different authors cited by Sanchez, 1976)								
4.4	0.7	6.1						
(FAO, 1986) - Madagascar								
5	2	9						
CASSAVA								
(Dufournet et al, 1957 cited by de Geus, 1973)								
3.6	0.9	5.3	2.4	0.7	1.8	6.0	1.6	7.1
6.8	1.8	4.2	4.1	1.4	1.4	10.9	3.2	5.6
17.3	8.0	3.6	13.5	6.9	1.8	30.8	14.9	5.4
(Kassam, 1976)								
						7.1	3.2	11.4
(Westphal, 1985) - dry weight								
4.5	3.4	15.9						
(Wielemaker and Boxem, 1982) - Kenya								
						3.0	1.6	7.0
(Obigbesan and Agboola cited by Cooke, 1982) - Nigeria, dry weight								
3.9	2.1	11.9						
(Arraudeau, 1967 cited by Williams, 1975)								
						7.2	3.2	11.4
(different authors cited by Cooke, 1982)								
2.3	0.7	7.1						

Table 2.15 (Cont.)

Product			Crop residues			Totals		
N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
OTHER ROOTS								
(Sobulo, 1972 cited by Kassam, 1976) - yam, Nigeria								
4.6	0.7	3.5						
(Westphal, 1985) - yam, dry weight								
11.6	3.2	18.1						
(Obigbesan and Agboola cited by Cooke, 1982) - yam, Nigeria, dry weight								
14.2	4.4	21.6						
(different authors cited by Cooke, 1982) - yam								
3.5	0.6	4.3						
PLANTAIN								
-								
CANE								
(de Geus, 1973)								
2.0	0.8	4.2						
(Westphal, 1985)								
0.7	0.5	1.4						
(Wielemaker and Boxem, 1982) - Kenya, per ton sugar								
9.2	4.8	22.6						
(Barnes, 1964 cited by Williams, 1975)						0.7	1.1	1.7
(different authors cited by Cooke, 1982)								
0.5	0.7	1.7						
(different authors cited by Sanchez, 1976)						0.8	0.5	1.5
PULSES								
(Kassam, 1976) - cow-pea								
57	10.1	20.0						
(Wielemaker and Boxem, 1982) - Kenya						25	8.0	21.1

Table 2.15 (Cont.)

Product			Crop residues			Totals		
N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
(different authors cited by Sanchez, 1976)								
28.1	7.3	7.2						
(FAO, 1986) - Madagascar, beans								
64	21	50						
VEGETABLES								
(de Geus, 1973) - Kenya, tomatoes								
208	66.5	412						
(Wielemaker and Boxem, 1982)								
2.8	0.9	4.0						
BANANAS								
(Westphal, 1985)								
1-2	0.3-0.5	2.5-6.0						
(Joseph, 1971 cited by Williams, 1975)								
0.8	0.5	7.1	1.6	0.7	14.3	2.4	1.2	21.4
(Cooke, 1982)								
1.7	1.1	6.0						
(different authors cited by Sanchez, 1976)								
1.9	0.5	6.5	2.0	0.3	2.7	3.9	0.8	9.2
CITRUS								
(Westphal, 1985)								
1.2-1.8	0.3-0.6	2.3-3.1						
(Wielemaker and Boxem, 1982) - Kenya								
2.7	0.7	8.1						

Table 2.15 (Cont.)

Product			Crop residues			Totals		
N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
OTHER FRUIT								
(de Geus, 1973) - pineapple								
0.8	0.3	2.4						
(Westphal, 1985) - pineapple								
0.2	0.3	2.4						
(Wielemaker and Boxem, 1982) - Kenya, pine-apple								
						3.8	0.9	8.3
(Wielemaker and Boxem, 1982) - Kenya, papaya								
2.7	1.1	3.3						
(Guidian, 1970 by Williams, 1975) - pine-apple								
3.4	2.1	6.3						
OIL CROPS								
-								
PALM OIL								
(de Geus, 1973)								
2.8	1.1	5.3						
(different authors cited by Westphal, 1985)								
2.8	2.5	6.4						
(Hartley, 1977) - Nigeria								
2.9	1.4	4.1	2.6	0.9	2.0	5.5	2.3	6.1
(Hartley, 1977) - Zaire								
3.0	1.1	3.7	3.7	1.6	1.9	6.7	2.7	5.6
(Ng and Thamboo, 1967 cited by Williams, 1975)								
6.5	2.3	9.9						
(Cooke, 1982) - Malaysian								
2.9	1.1	4.5	4.8	1.3	8.2	7.7	2.4	12.7
(different authors cited by Sanchez, 1976)								
6.0	1.3	9.2						

Table 2.15 (Cont.)

Product			Crop residues			Totals		
N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
SOYBEANS								
(Godin and Spensley, 1972 cited by Kassam, 1976)								
60	35.1	80.0						
(different authors cited by Westphal, 1985)								
60	16	12-18						
(Larcher, 1983 cited by Pieri, 1985) - Senegal								
67.4	28.9	26.7	14.2	6.4	17.0	81.6	35.3	43.7
61.3	31.9	33.6	8.3	5.7	15.2	69.6	37.6	48.8
(Cooke, 1982)								
61.8	14.7	20.6	30.3	8.2	19.6	92.1	22.9	40.2
GROUNDNUTS								
(different authors cited by Kassam, 1976)								
						51-63	8.9-11.0	20.0-25.1
(Westphal, 1985) - Senegal								
45.5	5.5	15-17						
(Wielemaker and Boxem, 1982) - Kenya								
						67	19.0	70.2
(Gillier, 1964 cited by Pieri, 1985) - Senegal								
38.0	9.6	8.8	7.7	1.8	9.4	45.7	11.4	18.2
(Pouzet, 1974 cited by Pieri, 1985) - Senegal								
37.5	15.4	10.4	14.9	6.0	12.3	52.4	21.4	22.7
(Bockelee Morvan (?), cited by Pieri, 1985) - Senegal								
34.2	14.9	9.4	13.0	4.6	10.4	47.2	19.5	19.8
38.9	15.1	10.2	27.9	9.4	39.6	66.8	24.5	49.8
(different authors cited by Cooke, 1982) - kernels + shells								
37.5	6.3	7.3						
(FAO, 1986) - Burkina Faso								
38	5	8						
SUNFLOWERS								
(Westphal, 1985)								
24	8.0	6.6						

Table 2.15 (Cont.)

Product			Crop residues			Totals		
N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
(Wielemaker and Boxem, 1982) - Kenya								
						47	15.4	56.3
SESAME								
(Kassam, 1976)								
						50	14.0	60.0
(different authors cited by Westphal, 1985)								
30	30.5	8.1						
COCONUT								
(de Geus, 1973) - figures per 7000 nuts								
91	41.0	137						
(Tandon, 1988) - figures per 7000 nuts								
50	24.1	75.1						
(different authors cited by Westphal, 1985) - figures per 7000 nuts								
92	94	165						
(Cooke, 1982), dry copra								
44	27.5	48.2						
(different authors cited by Sanchez, 1976), dry copra								
50	13.8	40.2						
CACAO								
(Urquhart, 1961 cited by Williams, 1975)								
24.0	27.5	22.9						
(Adams, 1962 cited by Williams, 1975)								
64	18.3	24.1						
(different authors cited by Cooke, 1982) (residues = husks)								
21.7	11.5	22.0	18.3	3.9	49.6			
(different authors cited by Sanchez, 1976) - dry beans								
20	10.1	12.1						

Table 2.15 (Cont.)

Product			Crop residues			Totals		
N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
COFFEE								
(de Geus, 1973)								
35	6.9	50.0						
(Tandon, 1988) Arabica								
34	5.0	48.0						
(Tandon, 1988) Robusta								
35	7.1	39.0						
(Wielemaker and Boxem, 1982) - Kenya								
						67	2.1	10.5
(Williams, 1975)								
75	13.3	112						
(Cooke, 1982) - per ton made coffee								
38	18.3	60						
(different authors cited by Sanchez, 1976)- dry beans								
25	3.9	19.3						
TEAS								
(Tandon, 1988)								
40	11.5	24.1						
(Wielemaker and Boxem, 1982) - Kenya								
14	2.3	8.4						
(Cooke, 1982) - dried leaves								
46	8.7	27.8						
TOBACCO								
(Kassam, 1976)								
53	13.1	76.3						
(Wielemaker and Boxem, 1982) - Kenya								
						60	25.2	96.4

Table 2.15 (Cont.)

Product			Crop residues			Totals		
N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
COTTON								
(de Geus, 1973)								
71	28.6	30.4	117	51.8	134	188	80.4	164
(Kassam, 1976) - Senegal								
48	17.0	32.0						
(Wielemaker and Boxem, 1982) - Kenya								
92	34.4	100						
(Deat et al, 1976 cited by Pieri, 1985								
- Cameroon								
17.2	18.3	10.8	21.2	20.6	49.6	38.4	38.9	60.4
18.3	19.2	11.1	7.1	10.3	37.5	25.4	29.5	48.6
- Ivory Coast								
22.5	18.8	14.1	13.7	6.6	27.2	36.2	25.4	41.3
- Benin								
16.6	32.5	7.5	13.4	18.1	29.0	30.0	50.6	36.5
(FAO, 1986) - Burkina Faso								
22	8	11						
FIBRES								
(Wielemaker and Boxem, 1982) - Kenya, jute								
5	1.4	7.6						
RUBBER								
(de Geus, 1973)								
6.3	3.0	5.2						
(Tanden, 1988)								
7.5	3.0	6.0						
(different authors cited by Cooke, 1982) - dried rubber								
6.4	2.1	4.4						
FODDER								
(Jaiebo and Moore, 1964 cited by Sanchez, 1976) - Kudzu								
26.1	6.2	24.0						
(Jaiebo and Moore, 1964 cited by Sanchez, 1976) - Stargrass								
29.2	4.7	21.6						

2.6.2 Procedure

Average values for the chemical composition of each crop (excluding outliers) are given in Table 2.15. In order to obtain an estimate of OUT 1 and OUT 2, the data in this table have to be combined with the production figures provided by FAO. The chemical composition of the crop residues varies widely. For some crops the differences were such that ranges are given instead of averages. Part of the range can be explained by different management levels, which are the main reason for variations of the harvest index (product/residue ratio). For the higher management level (high harvest index) the lower value of the range is used, whereas for the lower management level the higher value of the range is used. The range covers the average value plus or minus half the standard deviation. Outliers were excluded from the calculations.

Table 2.16 N,P and K content of harvested product and crop residues (in kg/ton harvested product)

Crop	Harvested Product			Crop residues (minimum - maximum)		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Wheat	22.3	9.9	7.0	4.3	4.1	32.0
Rice	11.6	7.8	4.1	9.0-13.6	3.6-7.0	34.0-51.8
Maize	16.8	9.4	5.7	7.6-11.8	3.0-5.8	23.0-28.4
Barley	15.5	6.4	7.2	7.0	2.3	25.2
Millet	19.2	13.7	6.5	16.1-24.6	8.4-9.8	66.3-77.1
Sorghum	14.5	12.6	4.5	8.1-13.5	7.8-13.2	30.5-39.5
O cereals	16.7	10.1	5.8	8.2-13.6	4.2-6.4	27.0-38.6
Potatoes	4.4	3.0	8.3	2.3	1.6	5.4
S. potatoes	4.8	1.8	8.8	2.1	2.7	3.9
Cassava	4.2	1.1	5.1	2.4-6.8	0.7-3.5	1.6- 1.8
Other roots	4.6	0.7	3.5	1.9	1.1	3.7
Plantain	0.7	0.2	4.1	1.2	0.7	7.7
Beet	not relevant for Sub-Saharan Africa					
Cane	0.6	0.5	1.4	0.3	0.7	0.4
Pulses	20.0	7.8	13.3	10.4	2.3	15.7
Vegetables	9.0	2.1	3.1	3.2	3.2	9.4
Bananas	1.2	0.7	5.4	1.6	0.7	14.3
Citrus	1.8	0.5	2.8	0.6	0.5	5.3
Other fruit	2.0	0.5	2.4	1.8	0.5	5.9
Oil crops	2.6	1.1	5.3	0.3	1.4	6.5
Palm oil	2.9	1.6	4.9	3.3- 4.1	1.2- 1.4	2.5- 5.5
Soybeans	62.1	25.1	24.0	13.0-22.2	6.3- 7.3	16.4-18.2
Groundnuts	37.2	13.7	9.8	12.2-19.6	2.8- 8.2	11.6-24.2
Sunflowers	24.0	8.0	6.6	23.0	7.3	49.6
Sesam	30.0	14.0	8.1	15.0	12.4	25.3
Coconut	61.0	16.5	11.8	27.0	13.1	30.4
Cacao	40.0	19.5	23.1	19.9	10.8	39.9
Coffee	35.0	6.0	20.2	4.3	8.7	11.1
Tea	35.0	8.7	16.1	0.1	0.0	0.0
Tobacco	56.0	18.8	87.2	0.1	0.0	0.2
Cotton	18.7	22.2	10.8	11.4-16.4	11.1-16.7	31.4-40.2
Fibres	5.0	0.9	7.2	2.1	1.6	10.8
Rubber	6.9	2.7	5.5	1.0	0.5	4.8
Fodder	6.8	3.0	5.7	0.0	0.0	0.0
Other crops	not relevant for Sub-Saharan Africa					

2.7 Leaching

2.7.1 Review

Table 2.16 Literature data on leaching in Sub-Saharan Africa

N	P_2O_5	K_2O	annual rain	fertilizer $N-P_2O_5-K_2O$	Fertility class	
(kg/ha,year)			(mm)	(kg/ha)	(FAO, 1978)	
(Chabalier, 1985) - Ivory Coast						
4.4			1049	50-50-100	1	(Maize and Cotton)
16			1082	50-50-100	1	(Maize)
(Charreau cited by Charreau, 1972) - Senegal						
13	9		660	0 - 0 - 0	2	(Rotation)
12	12		660		2	(Rotation)
6	10		660	0 - 0 - 0	1	(Rotation)
5	12		660		1	(Rotation)
(Roose and Birot, 1970 cited by Charreau, 1972) - Ivory Coast						
79	76		1569			(Cacao)
(Godefroy et al, 1970 cited by Charreau, 1972) - Ivory Coast						
235	296		1758 + 262 irrigation			(Bananas)
(Gigou, 1986 b) - Cameroon						
4.5	1.9		737	50-68-75		(Sorghum + Cotton)
7	1.8			100-68-75		(Sorghum + Cotton)
5.5	1.7			50-68-75 +5 ton pailles		(Sorghum + Cotton)
(Pieri, 1982 cited by Pieri, 1985) - Senegal						
0.3	0.3		507			(Millet)
25.1	5.2					(Groundnuts)
(Gigou, 1982 cited by Pieri, 1985) - Cameroon						
0	0		705			(Sorghum)
2.1	1.7		683			(Cotton)
(Chabalier, 1984 cited by Pieri, 1985) - Ivory Coast						
6.1	2.4		633			(Maize)
7.1	2.0		532			(Cotton)

Table 2.17 The loss of fertilizer-N through leaching (Chabalier, 1985)

Fertilizer	**Percentual loss**
Urea	47-60
Nitrate	9-24

2.7.2 Procedure

The literature was extensively reviewed (Section 2.7.1) and it provided, together with expert consultations, clues for correlation. Multiple regression resulted in the following equations for N and K:

OUT 3 (N) =
2.3 + (0.0021 + 0.0007 * F) * R + 0.3 * (**IN 1+IN 2**) - 0.1 * UN

OUT 3 (K_2O) =
0.6 + (0.0011 + 0.002 * F) * R + 0.5 * (**IN 1+IN 2**) - 0.1 * UK

In which:

R	rainfall (annual average, mm),
F	soil fertility class (1 low; 2 moderate; 3 high),
IN 1 + IN 2	total application of fertilizer and manure (LUS-specific, in kg/ha,yr),
UN, UK	total uptake of N and K_2O respectively (in kg/ha,yr).

All experimental results showed that there is no, or virtually no, leaching of phosphorus. Therefore, phosphorus leaching is set at zero.

2.8 Gaseous losses

2.8.1 Review

Table 2.18 Total N content in different soils in Sub-Saharan Africa. (different authors cited by Sanchez, 1976)

Soil type	Depth (cm)	Total N (%)
Ferralitic soil (sandy), Zaïre	0-8	0.10
	8-23	0.05
Ferruginous soil (Ultustalf), Senegal	0-6	0.07
	6-13	0.05
	13-31	0.03
Vertisol Gezira, Sudan	0-2	0.03
	2-90	0.02

Table 2.19 Soil organic C decomposition rates in different Land Use Systems (different authors cited by Sanchez, 1976)

Land Use System		Soil organic C decomposition rate (%)
Tropical forests	Ghana (Ustic)	2.5
	Zaïre (Udic)	5.2
Tropical savannas	Ghana (1250 mm rain)	1.3
	Ghana (850 mm rain)	1.2
Clean weeded bare fallow	Zaïre three years under cultivation	12.8
Corn-cassava rotation	Ghana seven years under cultivation	4.7
Crop rotation	Ghana seven years under cultivation	4.0
Continuous peanuts	Senegal six years under cultivation	6.6
Cotton-peanuts rotation	Sudan six years under cultivation	2.5

(Velly et al, 1980):
Nitrogen content in the upper 20 cm of 40 African soils varied between 0.025 % and 0.935 %. Most soils (85 %) fell in the range between 0.03 and 0.32 %. The average nitrogen content was 0.16 %.

Table 2.20 Range in nitrogen content in the upper 20 cm in tropical soils (Pagel et al, 1982)

	% N in the topsoil	kg N / ha
low	0.05	1500
moderate	0.10	3000
high	0.20	6000

(de Bruin et al, 1989):
After the long dry season the soil contains approximately 14 kg N/ha mineral N (0-10 cm). After the intensive first rains the nitrogen flush is about 8 kg N/ha. During the next 20 days, when the soil is intermittently wet and dry net mineralization amounts to 14 kg N/ha. This is followed by a period of about 60 days in which the soil remains wet, during which net mineralization amounts to 26 kg N/ha.
TOTAL MINERALIZATION = 62 kg mineral N/ha
Total N in the soil was originally: 252 kg N/ha
Mineralization (in the upper 10 cm) in one year equals 25% .

Table 2.21 N-mineralization in the upper 20 cm of a Vertisol (in kg/ha) (Hadas et al, 1989)

	Fertilized	Unfertilized
after 2 weeks	12	4
after 4.5 week	30	11
after 8 weeks	40	9
after 11 weeks	55	16

Note: Original organic N content was 810 mg/kg.

(Rhodes, 1988):
4% mineralisation of total organic N in soil

(Pieri, 1985):
Denitrification = 30% of mineral N

2.8.2 Methodology

In general, information on both factors is scarce and unevenly distributed. Therefore, correlations were looked for once again. Multiple regression analysis provided the following equation for the output factor (in kg/ha,yr):

OUT 4 (N) = 'Base' + 2.5 * F + 0.3 * (**IN 1** + **IN 2**) - 0.1 * UN

In which:

'Base': a constant value, covering relative wetness of the

soils specific for Land/Water Classes (Table 2.22).
F : soil fertility class (1 low; 2 moderate; 3 high),
IN 1 + IN 2 : total application of fertilizer and manure (LUS-specific in kg/ha,yr),
UN : total uptake of nitrogen (crop and yield specific, see Table 2.16; in kg/ha,yr).

Table 2.22 'Base' denitrification per LWC (in kg/ha,yr).

LWC	Denitrification
low	3
uncertain	5
good	8
problem - >1200 mm rainfall	12
- <1200 mm rainfall	5
naturally flooded	12
irrigated	11

2.9 Erosion

2.9.1 Review

- Soil fertility

Table 2.23 Range in concentrations of macro-nutrients in the topsoils of tropical soils (Pagel et al, 1982) (in %)

	low	moderate	high
N	0.05	0.10	0.20
P_2O_5 (total)	0.07	0.25	0.80
K_2O (total)	0.4	1.0	1.6

Table 2.23 Range in concentrations of macro-nutrients in the topsoils of tropical soils (different authors cited by Landon, 1984) (in %)

	low	moderate	high
N	0.1	0.3	0.7
P_2O_5 (total)	0.05	0.14	0.23
K_2O (available)	0.005	0.01	0.02

- Enrichment factor

Table 2.24 The enrichment factor of the macro-nutrients according to different authors (Stocking, 1984)

Source	Total N	Avail.P	Exch.K
Rogers, 1941	-	3.3	4.7
Knoblanch et al, 1942	4.2	-	-
Massey & Jackson, 1952	2.7	3.4	-
Massey et al, 1953	1.1	2.2	6.7
Stoltenberg & White, 1953	-	-	12.6
Hudson& Jackson, 1959	2.1	2.4	-
Lal, 1976	1.6	5.8	1.7
Ketcheson & Webber, 1978	-	1.9	1.8
Quansah & Baffoe, 1981	1.5	2.2	1.3
average	2.2	3.0	3.2

Note: most values are derived from temperate climates

(Stocking, 1986) - Zimbabwe:
- Enrichment ratio for nitrogen: 2.4
- Enrichment ratio for phosphorus: 2.7
- Low correlation of enrichment ratio with soil loss.
- 62% of the variation in the enrichment ratio for nitrogen can be explained with the original nitrogen content in the soil. The relationship is negative.
- 53% of the variation in the enrichment ratio for phosphorus can be explained by soil loss, original phosphorus level and lost phosphorus.

Table 2.25 The relation between farming system and erosion hazard (Okigbo, 1977)

Farming system	Erosion hazard
Bush fallowing	Low
Sedentary agriculture	High on slopes
Mixed farming	Very high, especially in the savannah where there is no adequate cover at the end of the season.
Large-scale plantations	Low in tree crop plantations, such as rubber and oil palms. High in large-scale mechanized food and arable crop farms involving row crops.

2.9.2 Methodology

For the calculation of the amount of nutrients lost through erosion, three components must be known: total soil loss, nutrient concentration in the original soil and the enrichment factor. Research findings on the soil loss through erosion are reasonably well documented for most countries. Based on this information, an estimate of soil loss is given in the description of each LUS. The assumed nutrient contents of eroded soil material of the three fertility classes are given in Table 2.26. The soil fertility classes are indicated in the LUS description. In the present study, the enrichment factor is set at 2.0 for N, P and K, implying that the ratio between the nutrient content of the eroding soil material and the nutrient content of the original soil material is 2.

Table 2.26 Nutrient contents of eroded soil at three levels of soil fertility (in %)

Soil fertility class	N	P_2O_5	K_2O
1	0.05	0.02	0.05
2	0.1	0.05	0.1
3	0.2	0.1	0.2

2.10 Fallow

2.10.1 Review

Table 2.27 Nutrients stored in fallow vegetation in relation to the age of the fallow vegetation (Brubacher et al, 1989) (in kg/ha)

Age of fallow (years)	N	P_2O_5	K_2O
1	56	8.7	114
2	73	11.0	133
3	102	18.3	157

Table 2.28 Nutrients stored in fallow vegetation (Nye and Greenland, 1960) (in kg/ha)

Type and age fallow	N	P_2O_5	K_2O
5 year secondary forest, Belgian Congo (1854 mm rain)	391	54	415
6 year fallow, S. Nigeria (1829 mm rain)	311	62	209

2.10.2 Cropping intensity

The FAO database provides acreages of both harvested land and total arable land for each Land/Water Class. The ratio between the two, expressed as a percentage, is called the 'cropping intensity' (CI). If this ratio is less than 100%, part of the arable land is considered **fallow**. Its hectarage is calculated as follows:

Fallow area= ((100/CI) - 1) * Harvested area (in ha).

During a fallow period, a gradual build-up of nutrients takes place. **IN 3**, **IN 4** and **IN 5** provide external contributions to soil fertility. In addition, part of the plant-available nutrients is retained in the fallow biomass instead of being leached or eroded. During years of fallow, the on-going processes of weathering and mineralization do not increase the total amount of nutrients in the soil, but they replenish the labile pools of the nutrients.
On the other hand, woody species from a fallow are often used as a source of fuel or sold along the roadside (**OUT 1**), a fallow is partly depleted by grazing animals that do not return all they have taken (**OUT 2-IN 2**), and the slash and burn practices prior to cultivation strongly enhance the loss processes **OUT 3-5**. Also, extra input in West-Africa through deposition of dust (**IN 3**) is offset by extra output due to the scarcity of fuelwood (**OUT 1**) in that region.

These considerations, combined with findings in literature and expert consultations , led to the decision to set the nutrient input by fallow at fixed values of 2 kg N, 2 kg P_2O_5, and 1 kg K_2O/ha,yr, irrespective of the LUS.

If cropping intensity equals 100%, the fallow acreage is set at 0 ha. If the cropping intensity exceeds 100%, **multiple cropping** takes place and it is assumed that there is no fallow. In this case the harvested areas and yields of the annual crops are adapted so that the total area equals the arable area and the total production remains the same.

Example
The cropping intensity for the uncertain rainfall area in Senegal is 45% . The total harvested area is 1,436,000 ha. The fallow area will then be 1,755,100 ha.

Considering all exports of nutrients due to burning and use of fallow these values are drastically reduced. Therefore only small increases of nutrients are used. No differences are made between farming systems and Land/Water Classes. In all cases the following values are used:
N: 2 kg/ha,yr
P_2O_5: 2 kg/ha,yr
K_2O: 1 kg/ha,yr

3 LAND USE SYSTEMS PER COUNTRY

In this chapter all the information gathered to describe the land use systems is listed. All countries are described individually and in alphabetic order:

ANGOLA

Table 3.1 Average annual rainfall for the Land/Water Classes in Angola (Instituto Geografico De Agostini, 1976) (in mm)

Land/Water Class	Annual rainfall
low rainfall	300
uncertain rainfall	800
good rainfall	1200
problem area	1600
naturally flooded	1200

(Instituto Geografico De Agostini, 1976):
Few high input plantations and many small farmers.
Mixed farming does not occur

Table 3.2 Major soil types and average soil fertility class for the Land/Water classes in Angola (FAO, 1977b and FAO, 1978)

Land/Water class	Major soil types	Average soil fertility class
Low rainfall	Xh, Qc, Ge, Be, Lf	2
Uncertain rainfall	Qc, Ge, Qf, Xh, Lf	2
Good rainfall	Qf, Fo, Qc, Fx, Ge	1
Problem area	Qf, Fo	1
Naturally flooded	Ge, Gc	3

Table 3.3 Relative soil loss for the Land/Water Classes in Angola (Hakkeling, 1989)

Land/Water class	Relative soil loss
Low rainfall	1
Uncertain rainfall	1
Good rainfall	1,3
Problem area	1,3

Table 3.4 Major crops under different forms of management in the Land/Water Classes for Angola (Pössinger, 1968)

LWC	Management	Major crops
LR	organized	oil palm, cane, fruit, vegetables, sisal
	traditional	cotton, cashew, oil palm, cassava,mais
UR	organized	oil palm, cassava, coffee, vegetables, rice, tobacco
	traditional	coffe, mais, beans, groundnuts, fruit,
GR	organized	coffee, cacao, oil palm, cotton, sisal, tobacco,
	traditional	cassava, vegetables, cashew, oilpalm, coffee, groundnuts, cotton, beans, sweet potatoes, mais, tobacco, rice
PR	organized	coffee, mais, citrus, fruit
	traditional	oilpalm, raphia, coffee, mais, beans, cassava
	plantations	coffee, sisal, cane, oil palms, cotton tobacco.

Table 3.4 Land use systems description for Angola

LR	Rainfall	: 300 mm
	Soil fertility	: moderate
LR-L.1	Fertilizer use	: 0.2
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 5 tonnes/hayr
	Crops	: maiz, mill, puls
UR	Rainfall	: 800 mm
	Soil fertility	: moderate
UR-L.1	Fertilizer use	: 0.6
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 7 tonnes/hayr
	Crops	: maiz, mill, puls, grou
UR-L.2	Fertilizer use	: 0.6
	Manure applic.	: none
	Residue removal	: 15%
	Erosion	: 5 tonnes/hayr
	Crops	: spot, cass, vege, frui, sunf
UR-L.3	Fertilizer use	: 0.8
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 7 tonnes/hayr
	Crops	: cott

Table 3.4 (Cont.)

GR	Rainfall	: 1200 mm
	Soil fertility	: low
GR-L.1	Fertilizer use	: 1.0
	Manure applic.	: during grazing
	Residue removal	: 30%
	Erosion	: 10 tonnes/hayr
	Crops	: whea, maiz, mill, puls, grou, sesa
GR-L.2	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 30%
	Erosion	: 10 tonnes/hayr
	Crops	: pota, spot, cass, vege, frui, oilc, sunf, toba (50%)
GR-L.3	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 10 tonnes/hayr
	Crops	: cott
GR-H.1	Fertilizer use	: 2.0
	Manure applic.	: none
	Residue removal	: 0%
	Erosion	: 10 tonnes/hayr
	Crops	: toba (50%)
GR-H.2	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 5%
	Erosion	: 5 tonnes/hayr
	Crops	: bana, citr, coff
PR	Rainfall	: 1600 mm
	Soil fertility	: low
PR-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 15 tonnes/hayr
	Crops	: whea, rice, maiz (50%), mill, puls, grou
PR-L.2	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 10 tonnes/hayr
	Crops	: pota, cass
PR-H.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 8 tonnes/hayr
	Crops	: palm, coff
PR-H.2	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 20 tonnes/hayr
	Crops	: maiz (50%), cane

Table 3.4 (Cont.)

NF	Rainfall	: 1200 mm
	Soil fertility	: high
NF-L.1	Fertilizer use	: 0.6
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: rice, mill
NF-L.2	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: cass, toba

BENIN

Table 3.5 Average annual rainfall for the Land/Water Classes in Benin (Instituto Geografico De Agostini, 1976) (in mm)

Land/Water Class	Annual rainfall
low rainfall	700
uncertain rainfall	1000
good rainfall	1200
problem area	1300
naturally flooded	1200
irrigated area	1200

(Instituto Geografico De Agostini, 1976):
Livestock is almost completely restricted to the uncertain rainfall area.

Table 3.6 Major soil types and average soil fertility class for the Land/Water classes in Benin (FAO, 1977b and FAO, 1978)

Land/Water class	Major soil types	Average soil fertility class
Low rainfall	Lf	1
Uncertain rainfall	Lf, Bv	2
Good rainfall	Lf, Lp, Nd	1
Problem area	Lg	2
Naturally flooded	Vp(?)	3
Irrigated area	Lf(?)	1

(Different authors cited by Lal et al, 1989):
Rate of erosion from croplands: 17.0 - 28.0 (t/ha/yr)

(Braun, 1974):
The following crops are grown in rotation under shifting cultivation:
South and centre: maize, groundnuts, beans, yams and cotton
North : maize, yams, beans, sorghum and cotton
On farmers level, soil conservation is done by planted fallow.

Table 3.7 Land use systems description for Benin

LR	Rainfall	: 700 mm
	Soil fertility	: low
LR-L.1	Fertilizer use	: 0.2
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 10 tonnes/hayr
	Crops	: mill, sesa

Table 3.7 (Cont.)

UR	Rainfall	: 1000 mm
	Soil fertility	: moderate
UR-L.1	Fertilizer use	: 0.6
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 15 tonnes/hayr
	Crops	: maiz, mill, sorg, othc, puls, grou
UR-L.2	Fertilizer use	: 0.6
	Manure applic.	: 500 kg/ha
	Residue removal	: 20%
	Erosion	: 10 tonnes/hayr
	Crops	: spot, cass, vege, frui, oilc
UR-H.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 15 tonnes/hayr
	Crops	: cott
GR	Rainfall	: 1200 mm
	Soil fertility	: low
GR-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 5%
	Erosion	: 25 tonnes/hayr
	Crops	: maiz, sorg, othc, puls, grou
GR-L.2	Fertilizer use	: 1.0
	Manure applic.	: 500 kg/ha
	Residue removal	: 30%
	Erosion	: 20 tonnes/hayr
	Crops	: spot, cass, othr, vege, frui, oilc, toba
GR-L.3	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 5%
	Erosion	: 10 tonnes/hayr
	Crops	: bana, citr
GR-H.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 25 tonnes/hayr
	Crops	: cott
PR	Rainfall	: 1300 mm
	Soil fertility	: moderate
PR-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 10 tonnes/hayr
	Crops	: maiz, mill, sorg, puls, grou

Table 3.7 (Cont.)

PR-L.2	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 5 tonnes/hayr
	Crops	: spot, cass
PR-H.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 5%
	Erosion	: 5 tonnes/hayr
	Crops	: palm, cocn, coff
NF	Rainfall	: 1200 mm
	Soil fertility	: high
NF-L.1	Fertilizer use	: 0.6
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: rice, sorg, spot
IR	Rainfall	: 1200 mm
	Soil fertility	: low
IR-L.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: rice, vege

BOTSWANA

Table 3.8 Average annual rainfall for the Land/Water Classes in Botswana (Instituto Geografico De Agostini, 1976) (in mm)

Land/Water Class	Annual rainfall
low rainfall	400
uncertain rainfall	600
irrigated area	400

(Instituto Geografico De Agostini, 1976):
No manure is applied on the fields. Stover is being grazed on the fields.

Table 3.9 Major soil types and average soil fertility class for the Land/Water classes in Botswana (FAO, 1977b and FAO, 1978)

Land/Water class	Major soil types	Average soil fertility class
Low rainfall	Qc, Lc, Je, Qa	2
Uncertain rainfall	Qc	1
Irrigated area	Lc, Qc	2

(Jeske, 1977):
Although the cattle yards are full of cattle manure, it is not applied to arable land.

Table 3.10 Land use systems description for Botswana

LR	Rainfall	: 400 mm
	Soil fertility	: moderate
LR-L.1	Fertilizer use	: 0.2
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 5 tonnes/hayr
	Crops	: maiz, mill, sorg, puls, grou
LR-L.2	Fertilizer use	: 0.2
	Manure applic.	: during grazing
	Residue removal	: 20%
	Erosion	: 5 tonnes/hayr
	Crops	: vege, frui
UR	Rainfall	: 600 mm
	Soil fertility	: low

Table 3.10 (Cont.)

UR-L.1	Fertilizer use	: 0.6
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 10 tonnes/hayr
	Crops	: othr, sunf
IR	Rainfall	: 400 mm
	Soil fertility	: moderate
IR-H.1	Fertilizer use	: 2.5
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 0 tonnes/hayr
	Crops	: vege, citr
IR-H.2	Fertilizer use	: 2.5
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 0 tonnes/hayr
	Crops	: cott

BURKINA FASO

Table 3.11 Average annual rainfall for the Land/Water Classes in Burkina Faso (Instituto Geografico De Agostini, 1976) (in mm)

Land/Water Class	Annual rainfall
low rainfall	550
uncertain rainfall	845
good rainfall	1550
problem area	900
naturally flooded	1100
irrigated area	1200

(Instituto Geografico De Agostini, 1976):
Cattle is grazing crop residues. No mixed farming takes place.

Table 3.12 Major soil types and average soil fertility class for the Land/Water classes in Burkina Faso (FAO, 1977b and FAO, 1978)

Land/Water class	Major soil types	Average soil fertility class
Low rainfall	Re, Bv, Ql	3
Uncertain rainfall	Re, Lp, Lg, Lf	2
Good rainfall	Lp, Lg, Lf, Be	2
Problem area	Ws(?)	1
Naturally flooded	Vc(?)	3
Irrigated area	Re	3

Table 3.13 Pressure on land by cattle breeding and agriculture in Burkina Faso (Breman, 1986 cited by Ministerie van Landbouw en Visserij, 1988)

Land/Water Class	cattle	agriculture
low rainfall	+++	-
uncertain rainfall	++	++
good rainfall	-	+

(Charreau, 1972):
Erosion in Ouagadougou (850 mm rainfall/yr, 0.5% slope):
under cultivation: 0.6-0.8 ton/ha,yr
bare soil : 10 -20 ton/ha,yr

(Different authors cited by Lal et al, 1989):
Rate of erosion from croplands: 10.0 - 20.0 (t/ha/yr)

(Fournier, 1967):

Niangoloko	2.5% slope	groundnut	516 mm	5.4 ton/ha/yr
		millet	1400 mm	7.5 ton/ha/yr

(World Bank, 1988):
82% of the cotton producers apply mineral fertilizers. Ultra low volume spraying techniques are used by 50% of the farmers. 35% of the area under cotton is cultivated with animal traction. Tractor cultivation made a good start.

(Didier, 1986):
Yatenga (uncertain rainfall)
- Almost all crop residues are removed or grazed on the field.

(FAO, 1986):
Cereal and legume residues are often used as animal feed, as a construction material and as cooking fuel. Surveys on the Mossi Plateau (uncertain rainfall) indicate that all groundnut and cowpea residues and 40 to 45% of the cereal straw are removed.

Table 3.14 Land use systems description for Burkina Faso

LR	Rainfall	: 550 mm
	Soil fertility	: high
LR-L.1	Fertilizer use	: 0.2
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 5 tonnes/hayr
	Crops	: maiz, mill, sorg, othc, puls, grou, sesa
LR-L.2	Fertilizer use	: 0.2
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 5 tonnes/hayr
	Crops	: vege, frui
UR	Rainfall	: 845 mm
	Soil fertility	: moderate
UR-L.1	Fertilizer use	: 0.6
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 5 tonnes/hayr
	Crops	: maiz, mill, sorg, othc, puls, grou, sesa
UR-L.2	Fertilizer use	: 0.6
	Manure applic.	: during grazing
	Residue removal	: 25%
	Erosion	: 5 tonnes/hayr
	Crops	: spot, cass, othr, vege, frui, oilc, toba

Table 3.14 (Cont.)

UR-L.3	Fertilizer use	: 0.6
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 5 tonnes/hayr
	Crops	: cott (50%)
UR-H.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 10 tonnes/hayr
	Crops	: cott (50%)
GR	Rainfall	: 1550 mm
	Soil fertility	: moderate
GR-L.1	Fertilizer use	: 1.0
	Manure applic.	: 500 kg/ha
	Residue removal	: 30%
	Erosion	: 20 tonnes/hayr
	Crops	: rice, maiz, mill, sorg, othc, spot, cass, puls, vege, frui, oilc, grou, sesa, toba
GR-L.2	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 20 tonnes/hayr
	Crops	: cott (50%)
GR-H.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 15 tonnes/hayr
	Crops	: cott (50%)
PR	Rainfall	: 900 mm
	Soil fertility	: low
PR-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 15 tonnes/hayr
	Crops	: maiz, mill, sorg, othc, puls, grou, sesa
NF	Rainfall	: 1100 mm
	Soil fertility	: high
NF-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: rice, mill, sorg

Table 3.14 (Cont.)

IR	Rainfall	: 1200 mm
	Soil fertility	: high
IR-H.1	Fertilizer use	: 2.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: rice, cane, vege, frui

BURUNDI

Table 3.15 Average annual rainfall for the Land/Water Classes in Burundi (Instituto Geografico De Agostini, 1976) (in mm)

Land/Water Class	Annual rainfall
good rainfall	1200
problem area	1500
naturally flooded	900

(Instituto Geografico De Agostini, 1976):
The subsistence farmers take great care in their cultivation and, although the application of manure is very slight, reasonable yields are obtained. Only manual methods are used.

Table 3.16 Major soil types and average soil fertility class for the Land/Water classes in Burundi (FAO, 1977b and FAO, 1978)

Land/Water class	Major soil types	Average soil fertility class
Good rainfall	Fo, Fh, Nh	2
Problem area	Nh, Fh, Bh	2
Naturally flooded	Vp	3

Table 3.17 Relative soil loss for the Land/Water Classes in Burundi (Hakkeling, 1989)

Land/Water class	Relative soil loss
Good rainfall	1,3
Problem area	2,3
Naturally flooded	2

(Scott, 1988):
Peasant farmers dominate potato production. They generally employ cow manure and/or compost instead of chemical fertilizers.

(Miracle, 1967):
Miracle mentions the use of manure for fertilizer purposes in Burundi and Rwanda.

Table 3.18 Land use systems description for Burundi

GR	Rainfall	: 1200 mm
	Soil fertility	: moderate
GR-L.1	Fertilizer use	: 1.0
	Manure applic.	: 500 kg/ha
	Residue removal	: 30%
	Erosion	: 25 tonnes/hayr
	Crops	: whea, maiz, mill, sorg, puls, grou
GR-L.2	Fertilizer use	: 1.0
	Manure applic.	: 1000 kg/ha
	Residue removal	: 30%
	Erosion	: 20 tonnes/hayr
	Crops	: pota, spot, cass, othr, vege, frui, toba
GR-L.3	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 25 tonnes/hayr
	Crops	: cott
GR-H.1	Fertilizer use	: 1.5
	Manure applic.	: 500 kg/ha
	Residue removal	: 30%
	Erosion	: 15 tonnes/hayr
	Crops	: bana, coff
PR	Rainfall	: 1500 mm
	Soil fertility	: moderate
PR-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 15 tonnes/hayr
	Crops	: rice, maiz, mill, sorg, puls, grou
PR-L.2	Fertilizer use	: 1.0
	Manure applic.	: 500 kg/ha
	Residue removal	: 20%
	Erosion	: 15 tonnes/hayr
	Crops	: spot, cass, othr, vege, frui
PR-L.3	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 10 tonnes/hayr
	Crops	: bana, palm, coff, teas
NF	Rainfall	: 900 mm
	Soil fertility	: high
NF-L.1	Fertilizer use	: 0.6
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: rice, maiz, mill, sorg, spot, cass, puls

Table 3.18 (Cont.)

IR	Rainfall	: 1300 mm
	Soil fertility	: moderate
IR-H.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: rice, vege

CAMEROON

Table 3.19 Average annual rainfall for the Land/Water Classes in Cameroon (Instituto Geografico De Agostini, 1976) (in mm)

Land/Water Class	Annual rainfall
low rainfall	700
uncertain rainfall	900
good rainfall	1450
problem area	1700
naturally flooded	1600
irrigated area	900

Table 3.20 Major soil types and average soil fertility class for the Land/Water classes in Cameroon (FAO, 1977b and FAO, 1978)

Land/Water class	Major soil types	Average soil fertility class
Low rainfall	Ws	1
Uncertain rainfall	Vp, Je, Re	3
Good rainfall	Lg, Nd, Lf, Re, Fr	2
Problem area	Fo, Nd	2
Naturally flooded	Vp	3
Irrigated area	Je	3

(Atayi and Knipscheer, 1980):
Zapi-Est, East Cameroon (Problem area)
Animals do not play an important role in the farming system.
4% of the farmers uses fertilizers.
Erosion, mainly in maize, groundnut, plantain, cassava and cocoyam .
Little crop residue removal is reported.

(Duckham and Masefield, 1970):
Large estates producing bananas, cocoa and other crops are present.

(Westphal, 1981):
La région forestière et postforestière du sud et du Littoral.(Problem area):
1. Production takes place without any fertilizer or organic input.
2. Erosion occurs in some places, with a moderate extension.

Le haut plateau de l'Ouest (problem area):
1. All kinds of crop residues, like banana leaves etc. are used as organic manure.
2. Erosion occurs over the whole area.

North Cameroon (Uncertain rainfall):

1. No mention is made of use on cattle manure, mulching seems to be a common practice.
2. Intensive practices against erosion are taken. Nevertheless some erosion takes place.

Table 3.21 Land use systems description for Cameroon

LR	Rainfall	: 700 mm
	Soil fertility	: low
LR-L.1	Fertilizer use	: 0.2
	Manure applic.	: during grazing
	Residue removal	: 30%
	Erosion	: 4 tonnes/hayr
	Crops	: mill, grou, sesa
LR-L.2	Fertilizer use	: 0.2
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 4 tonnes/hayr
	Crops	: vege, frui
UR	Rainfall	: 900 mm
	Soil fertility	: high
UR-L.1	Fertilizer use	: 0.6
	Manure applic.	: during grazing
	Residue removal	: 20%
	Erosion	: 8 tonnes/hayr
	Crops	: maiz, mill, puls, grou, sesa
UR-L.2	Fertilizer use	: 0.6
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 8 tonnes/hayr
	Crops	: spot, cass, othr, vege, frui, toba
UR-H.1	Fertilizer use	: 0.6
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 8 tonnes/hayr
	Crops	: cott
GR	Rainfall	: 1450 mm
	Soil fertility	: moderate
GR-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 30%
	Erosion	: 10 tonnes/hayr
	Crops	: whea, maiz, mill, puls, grou, sesa
GR-L.2	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 10 tonnes/hayr
	Crops	: spot, cass, othr, plan (50%), vege, frui, toba

Table 3.21 (Cont.)

GR-L.3	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 5 tonnes/hayr
	Crops	: plan (50%), bana
GR-H.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 10 tonnes/hayr
	Crops	: cott
PR	Rainfall	: 1700 mm
	Soil fertility	: moderate
PR-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 15 tonnes/hayr
	Crops	: whea, maiz, mill, puls, grou, sesa
PR-L.2	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 10 tonnes/hayr
	Crops	: pota, spot, cass, othr, plan (50%), vege, frui
PR-H.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 10 tonnes/hayr
	Crops	: plan (50%), cane, bana, palm, cocn, coco, coff, teas, rubb
NF	Rainfall	: 1600 mm
	Soil fertility	: high
NF-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: rice, mill, spot, othr, vege
IR	Rainfall	: 900 mm
	Soil fertility	: high
IR-H.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: rice

CENTRAL AFRICAN REPUBLIC

Table 3.22 Average annual rainfall for the Land/Water Classes in Central African Republic (Instituto Geografico De Agostini, 1976) (in mm)

Land/Water Class	Annual rainfall
uncertain rainfall	800
good rainfall	1400
problem area	1600
naturally flooded	1400

(Instituto Geografico De Agostini, 1976):
Cotton unpopular by small farmers.
Coffee grown on large estates.
Sesame is cultivated on a very low-technology basis.
No commercial market for oil palm.
Mixed farming does occur.

Table 3.23 Major soil types and average soil fertility class for the Land/Water classes in Central African Republic (FAO, 1977b and FAO, 1978)

Land/Water class	Major soil types	Average soil fertility class
Uncertain rainfall	Lg, Lf	2
Good rainfall	Fp, Af, Qf	1
Problem area	Fo, Qf, Fr	1
Naturally flooded	Fr, Ql	2

Table 3.24 Land use systems description for Central African Republic

UR	Rainfall	: 800 mm
	Soil fertility	: moderate
UR-L.1	Fertilizer use	: 0.6
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 10 tonnes/hayr
	Crops	: maiz, mill, puls, grou, sesa
UR-L.2	Fertilizer use	: 0.6
	Manure applic.	: 500 kg/ha
	Residue removal	: 25%
	Erosion	: 5 tonnes/hayr
	Crops	: spot, cass, othr, vege

Table 3.24 (Cont.)

GR	Rainfall	: 1400 mm
	Soil fertility	: low
GR-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 30%
	Erosion	: 15 tonnes/hayr
	Crops	: maiz, mill, puls, grou, sesa
GR-L.2	Fertilizer use	: 1.0
	Manure applic.	: 500 kg/ha
	Residue removal	: 20%
	Erosion	: 10 tonnes/hayr
	Crops	: spot, cass, othr, vege, frui, toba
GR-L.3	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 5 tonnes/hayr
	Crops	: plan, bana, citr
GR-L.4	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 10 tonnes/hayr
	Crops	: cott
PR	Rainfall	: 1600 mm
	Soil fertility	: low
PR-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 15 tonnes/hayr
	Crops	: rice, maiz, mill, puls, grou
PR-L.2	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 10 tonnes/hayr
	Crops	: spot, cass, othr, vege, frui
PR-L.3	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 5 tonnes/hayr
	Crops	: plan, bana (50%), palm
PR-H.1	Fertilizer use	: 2.0
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 10 tonnes/hayr
	Crops	: bana (50%), coff, rubb
PR-H.2	Fertilizer use	: 2.0
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 10 tonnes/hayr
	Crops	: cott

Table 3.24 (Cont.)

NF	Rainfall	: 1400 mm
	Soil fertility	: moderate
NF-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: rice, vege, bana

CHAD

Table 3.25 Average annual rainfall for the Land/Water Classes in Chad (Instituto Geografico De Agostini, 1976) (in mm)

Land/Water Class	Annual rainfall
low rainfall	400
uncertain rainfall	800
good rainfall	1200
problem area	800
naturally flooded	800
irrigated area	800

Table 3.26 Major soil types and average soil fertility class for the Land/Water classes in Chad (FAO, 1977b and FAO, 1978)

Land/Water class	Major soil types	Average soil fertility class
Low rainfall	Qc, Re, Rd	2
Uncertain rainfall	Lf, Je, Qf, Lg	2
Good rainfall	Lg, Nd, Je	2
Problem area	So, W	1
Naturally flooded	Vp	3
Irrigated area	Qc, Nd	2

Table 3.27 Land use systems description for Chad

LR	Rainfall	: 400 mm
	Soil fertility	: moderate
LR-L.1	Fertilizer use	: 0.2
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 10 tonnes/hayr
	Crops	: mill, othc, puls, grou, sesa
LR-L.2	Fertilizer use	: 0.2
	Manure applic.	: 500 kg/ha
	Residue removal	: 40%
	Erosion	: 10 tonnes/hayr
	Crops	: vege, frui
UR	Rainfall	: 800 mm
	Soil fertility	: moderate
UR-L.1	Fertilizer use	: 0.6
	Manure applic.	: none
	Residue removal	: 50%
	Erosion	: 10 tonnes/hayr
	Crops	: maiz, mill, othc, puls, grou, sesa

Table 3.27 (Cont.)

UR-L.2	Fertilizer use	: 0.6
	Manure applic.	: none
	Residue removal	: 25%
	Erosion	: 10 tonnes/hayr
	Crops	: pota, spot, cass, othr, vege, frui
UR-L.3	Fertilizer use	: 0.8
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 15 tonnes/hayr
	Crops	: cott
GR	Rainfall	: 1200 mm
	Soil fertility	: moderate
GR-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 30%
	Erosion	: 15 tonnes/hayr
	Crops	: rice, maiz, mill, othc, puls, grou, sesa
GR-L.2	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 10 tonnes/hayr
	Crops	: pota, spot, cass, othr, vege, frui
GR-L.3	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 15 tonnes/hayr
	Crops	: cott
PR	Rainfall	: 800 mm
	Soil fertility	: low
PR-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 15 tonnes/hayr
	Crops	: mill, othc, puls, grou, sesa
PR-L.2	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 20 tonnes/hayr
	Crops	: spot, cass, othr
NF	Rainfall	: 800 mm
	Soil fertility	: high
NF-L.1	Fertilizer use	: 0.6
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: rice, mill, othc

Table 3.27 (Cont.)

IR	Rainfall	: 800 mm
	Soil fertility	: moderate
IR-H.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: whea, rice, cane

CONGO

Table 3.28 Average annual rainfall for the Land/Water Classes in Congo (Instituto Geografico De Agostini, 1976) (in mm)

Land/Water Class	Annual rainfall
good rainfall	1200
problem area	1600
naturally flooded	1800
irrigated area	1400

(Instituto Geografico De Agostini, 1976):
Commercial agricultural production zones for cocoa, coffee, sugar cane and tobacco do occur.

Table 3.29 Major soil types and average soil fertility class for the Land/Water classes in Congo (FAO, 1977b and FAO, 1978)

Land/Water class	Major soil types	Average soil fertility class
Good rainfall	Fx, Qf, Bf	1
Problem area	Fx, Fo, Gh	1
Naturally flooded	Gh	3
Irrigated area	Qf(?)	1

(Duckham and Masefield, 1970):
Large estates produce oil-palms and coffee

(Braun, 1974):
The following crops are grown in rotation under shifting cultivation: maize, yam, groundnuts, cassava, pumpkin, tobacco.
Soil conservation on plantations takes place by ridging and rotation.
On farmers level soil conservation is done by ridging and mulching.

(Miracle, 1967):
The Congo Basin (Problem area):
Main crops that are cultivated under shifting cultivation are yams, bananas, beans, cassava, maize, groundnuts, plantains and sweet potatoes.
The use of animal manures are found in the Congo Basin only in the short fallow systems of the Lugbara.

Table 3.30 Land use systems description for Congo

GR	Rainfall	: 1200 mm
	Soil fertility	: low
GR-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 10 tonnes/hayr
	Crops	: maiz, puls, grou
GR-L.2	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 10 tonnes/hayr
	Crops	: cass, vege, frui, toba
GR-H.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 5 tonnes/hayr
	Crops	: plan, bana, citr
PR	Rainfall	: 1600 mm
	Soil fertility	: low
PR-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 20 tonnes/hayr
	Crops	: maiz, puls, grou
PR-L.2	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 10 tonnes/hayr
	Crops	: pota, spot, cass, othr, plan, vege, frui
PR-H.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 7 tonnes/hayr
	Crops	: cane, bana, palm, coco, coff
NF	Rainfall	: 1800 mm
	Soil fertility	: high
NF-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 0 tonnes/hayr
	Crops	: rice
NF-L.2	Fertilizer use	: 0.6
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 0 tonnes/hayr
	Crops	: cass, vege

Table 3.30 (Cont.)

IR	Rainfall	: 1400 mm
	Soil fertility	: low
IR-H.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: rice, cane

COTE D'IVOIRE

Table 3.31 Average annual rainfall for the Land/Water Classes in Côte d'Ivoire (Instituto Geografico De Agostini, 1976) (in mm)

Land/Water Class	Annual rainfall
good rainfall	1300
problem area	1600
naturally flooded	1400
irrigated area	1300

(Instituto Geografico De Agostini, 1976)
No cattle in problem area.

Table 3.32 Major soil types and average soil fertility class for the Land/Water classes in Côte d'Ivoire (FAO, 1977b and FAO, 1978)

Land/Water class	Major soil types	Average soil fertility class
Good rainfall	Ap, Ao, Af, Lp	1
Problem area	Af, Ao, Ap	1
Naturally flooded	Af(?)	1
Irrigated area	Ao(?)	2

(Iloeje, 1972):
Coffee, cocoa, bananas, groundnuts, pineapples and oil palm are grown on large modern estates and by modern scientific methods.

Table 3.33 Erosion rates under different types of tillage in Bouaké between 1971 and 1974 (in tonnes/ha) (Kalms, 1977)

Tillage	Year			
	1971	1972	1973	1974
ploughing up and down the hill	12	20	18	12
ploughing followed by rotovation	15	11	9	11
rotovation	13	25	49	44
no tillage	--	18	41	52

Table 3.22 Erosion rates on two locations in Côte d'Ivoire (Charreau, 1972) (in ton/ha,yr)

Location	slope	rain	Erosion	
			crop	bare soil
Bouaké	4.0%	1200 mm	0.1	18-30
Abidjan	7.0%	2100 mm	0.03	108-170

(Different authors cited by Lal et al, 1989):
Rate of erosion from croplands: 60.0 - 570 (t/ha/yr)

(Fournier, 1967):
Erosion in Adiopodoumé under cassava on a 7% slope:
93 ton/ha,yr (1939 mm rain/yr)
29 ton/ha,yr (2383 mm rain yr)

(World Bank, 1988):
100% of the cotton producers apply mineral fertilizers. Ultra low volume spraying techniques are used by all farmers. 25% of the area under cotton is cultivated with animal traction. Tractor cultivation is stable at 4% .

(Gigou, 1987):
Central Côte d'Ivoire (problem area + good rainfall area):
Yam, maize, cotton, cassava, groundnuts and soybeans are grown under a low level of management.

Table 3.34 Land use systems description for Côte d Ivoire

GR	Rainfall	: 1300 mm
	Soil fertility	: low
GR-L.1	Fertilizer use	: 1.0
	Manure applic.	: during grazing
	Residue removal	: 50%
	Erosion	: 10 tonnes/hayr
	Crops	: maiz, mill, sorg, othc, puls, soyb, grou (20%), sesa
GR-L.2	Fertilizer use	: 1.0
	Manure applic.	: 500 kg/ha
	Residue removal	: 20%
	Erosion	: 10 tonnes/hayr
	Crops	: spot, cass, othr, vege, frui, oilc, toba
GR-L.3	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 10 tonnes/hayr
	Crops	: cott (50%)

Table 3.34 (Cont.)

GR-L.4	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 15%
	Erosion	: 5 tonnes/hayr
	Crops	: plan, bana, citr
GR-H.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 30%
	Erosion	: 15 tonnes/hayr
	Crops	: grou (80%)
GR-H.2	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 15 tonnes/hayr
	Crops	: cott (50%)
PR	Rainfall	: 1600 mm
	Soil fertility	: low
PR-L.1	Fertilizer use	: 1.0
	Manure applic.	: during grazing
	Residue removal	: 20%
	Erosion	: 15 tonnes/hayr
	Crops	: rice, maiz, mill, sorg, puls, grou (20%), sesa
PR-L.2	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 10 tonnes/hayr
	Crops	: pota, spot, cass, othr, vege, frui, plan (50%)
PR-H.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 20 tonnes/hayr
	Crops	: plan (50%), bana, palm, grou (80%), cocn, coco, coff, rubb
NF	Rainfall	: 1400 mm
	Soil fertility	: low
NF-L.1	Fertilizer use	: 0.6
	Manure applic.	: none
	Residue removal	: 30%
	Erosion	: 0 tonnes/hayr
	Crops	: rice, sorg
NF-L.2	Fertilizer use	: 0.6
	Manure applic.	: none
	Residue removal	: 15%
	Erosion	: 0 tonnes/hayr
	Crops	: spot, cass, othr, vege

Table 3.34 (Cont.)

IR	Rainfall	: 1300 mm
	Soil fertility	: moderate
IR-H.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: rice, cane

ETHIOPIA

Table 3.35 Average annual rainfall for the Land/Water Classes in Ethiopia (Instituto Geografico De Agostini, 1976) (in mm)

Land/Water Class	Annual rainfall
low rainfall	400
uncertain rainfall	800
good rainfall	1500
problem area	2000
naturally flooded	1500
irrigated area	500

(Instituto Geografico De Agostini, 1976)
75% of the agricultural area is subdivided in small farms. Coffee, cotton, sugar cane, citrus and tobacco are generally plantation crops, often with irrigation.
Mixed farming is common practice.

Table 3.36 Major soil types and average soil fertility class for the Land/Water classes in Burkina Faso (FAO, 1977b and FAO, 1978)

Land/Water class	Major soil types	Average soil fertility class
Low rainfall	Rc, Xh, Re	3
Uncertain rainfall	Be, Rc, Ah, Bd, Ne	3
Good rainfall	Ne, Bh, Be	3
Problem area	Ne, Re	3
Naturally flooded	Vc(?)	3
Irrigated area	Xh, Re	3

(Biswas et al, 1987):
The peasant sector has adopted a very simple low management kind of farming system with only very few inputs. The use of fertilizers is reduced to 14% of the peasants and the use of improved seeds to 2% .

Table 3.37 Land use systems description for Ethiopia

LR	Rainfall	: 400 mm
	Soil fertility	: high
LR-L.1	Fertilizer use	: 0.2
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 10 tonnes/hayr
	Crops	: whea, maiz, barl, mill, sorg, othc, puls, oilc, sesa
UR	Rainfall	: 800 mm
	Soil fertility	: high
UR-L.1	Fertilizer use	: 0.6
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 15 tonnes/hayr
	Crops	: whea, maiz, barl, mill, sorg, othc, puls, soyb, grou, sesa
UR-L.2	Fertilizer use	: 0.6
	Manure applic.	: 500 kg/ha
	Residue removal	: 40%
	Erosion	: 10 tonnes/hayr
	Crops	: pota, spot, othr, vege, frui, oilc, sunf, fibr, fodd
UR-H.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 15 tonnes/hayr
	Crops	: cott
GR	Rainfall	: 1500 mm
	Soil fertility	: high
GR-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 30%
	Erosion	: 15 tonnes/hayr
	Crops	: whea, maiz, barl, mill, sorg, othc, puls, soyb, grou, sesa
GR-L.2	Fertilizer use	: 1.0
	Manure applic.	: 500 kg/ha
	Residue removal	: 10%
	Erosion	: 10 tonnes/hayr
	Crops	: pota, spot, othr, vege, frui, oilc, sunf, fibr, fodd
GR-H.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 10 tonnes/hayr
	Crops	: citr, coff, toba
GR-H.2	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 10 tonnes/hayr
	Crops	: cott

Table 3.37 (Cont.)

PR	Rainfall	: 2000 mm
	Soil fertility	: high
PR-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 15 tonnes/hayr
	Crops	: whea, maiz, barl, mill, sorg, othc, puls
PR-L.2	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 10 tonnes/hayr
	Crops	: pota, spot, othr, vege, oilc, fodd
PR-H.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 10 tonnes/hayr
	Crops	: bana, frui, coff
NF	Rainfall	: 1500 mm
	Soil fertility	: high
NF-L.1	Fertilizer use	: 0.6
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 0 tonnes/hayr
	Crops	: mill, othc, puls
IR	Rainfall	: 500 mm
	Soil fertility	: high
IR-L.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 0 tonnes/hayr
	Crops	: puls, vege, fodd
IR-H.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 0 tonnes/hayr
	Crops	: cane, bana, citr, toba
IR-H.2	Fertilizer use	: 2.5
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 0 tonnes/hayr
	Crops	: cott

GABON

Table 3.38 Average annual rainfall for the Land/Water Classes in Gabon (Instituto Geografico De Agostini, 1976) (in mm)

Land/Water Class	Annual rainfall
problem area	1900
naturally flooded	2000

(Instituto Geografico De Agostini, 1976)
Oil palm is grown on plantations (on a relatively small scale)
Almost no cattle is present.

Table 3.39 Major soil types and average soil fertility class for the Land/Water classes in Gabon (FAO, 1977b and FAO, 1978)

Land/Water class	Major soil types	Average soil fertility class
Problem area	Fo, Bf, Qf, Jd	1
Naturally flooded	Bf, Qf	1

Table 3.40 Land use systems description for Gabon

PR	Rainfall	: 1900 mm
	Soil fertility	: low
PR-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 10 tonnes/hayr
	Crops	: rice, maiz, grou
PR-L.2	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 5 tonnes/hayr
	Crops	: spot, cass, othr, vege, frui
PR-L.3	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 5 tonnes/hayr
	Crops	: plan, bana, palm, coco, coff
PR-H.1	Fertilizer use	: 2.0
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 5 tonnes/hayr
	Crops	: cane

Table 3.40 (Cont.)

NF	Rainfall	: 2000 mm
	Soil fertility	: low
NF-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: rice

GAMBIA

Table 3.41 Average annual rainfall for the Land/Water Classes in Gambia (Instituto Geografico De Agostini, 1976) (in mm)

Land/Water Class	Annual rainfall
uncertain rainfall	1050
problem area	1150
naturally flooded	1050
irrigated area	1050

(Instituto Geografico De Agostini, 1976)
No plantations of importance.

Table 3.42 Major soil types and average soil fertility class for the Land/Water classes in Gambia (FAO, 1977b and FAO, 1978)

Land/Water class	Major soil types	Average soil fertility class
Uncertain rainfall	Nd, Jt	2
Problem area	?	1
Naturally flooded	Jt	2
Irrigated area	Jt	2

Table 3.43 Land use systems description for Gambia

UR	Rainfall	: 1050 mm
	Soil fertility	: moderate
UR-L.1	Fertilizer use	: 0.6
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 5 tonnes/hayr
	Crops	: maiz, mill, othc, puls, grou
UR-L.2	Fertilizer use	: 0.6
	Manure applic.	: 500 kg/ha
	Residue removal	: 40%
	Erosion	: 5 tonnes/hayr
	Crops	: cass, vege, frui
UR-L.3	Fertilizer use	: 0.6
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 5 tonnes/hayr
	Crops	: cott

Table 3.43 (Cont.)

PR	Rainfall	: 1150 mm
	Soil fertility	: low
PR-L.1	Fertilizer use	: 0.5
	Manure applic.	: during grazing
	Residue removal	: 50%
	Erosion	: 5 tonnes/hayr
	Crops	: maiz, mill, othc, grou
PR-L.2	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 5 tonnes/hayr
	Crops	: cass
PR-L.3	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 5%
	Erosion	: 0 tonnes/hayr
	Crops	: palm
NF	Rainfall	: 1050 mm
	Soil fertility	: moderate
NF-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: rice
IR	Rainfall	: 1050 mm
	Soil fertility	: moderate
IR-H.1	Fertilizer use	: 2.5
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: rice, maiz

GHANA

Table 3.44 Average annual rainfall for the Land/Water Classes in Ghana (Instituto Geografico De Agostini, 1976) (in mm)

Land/Water Class	Annual rainfall
uncertain rainfall	800
good rainfall	1100
problem area	1400
naturally flooded	1000
irrigated area	800

(Instituto Geografico De Agostini, 1976):
Millet and groundnuts are grown in the cattle area (good rainfall). On small scale, manure is collected and crop residues are fed to the cattle.

Table 3.45 Major soil types and average soil fertility class for the Land/Water classes in Ghana (FAO, 1977b and FAO, 1978)

Land/Water class	Major soil types	Average soil fertility class
Uncertain rainfall	Ao	2
Good rainfall	Lf, Lp	1
Problem area	Ao, Lf	2
Naturally flooded	G, V	3
Irrigated area	Lf, Ao	2

(Balasubramanian et al, 1982):
Atebubu district (Problem area)
- Livestock is almost entirely absent
- No fertilization takes place
- Groundnut residues are sometimes harvested with the pods and not returned to the field. In other crops no residue removal is mentioned.

(Iloeje, 1972):
Nangodi (Hot savanne region in the far north)
- Fertilization with cow dung takes place. Manure is collected in enclosures.

(Sipkens, 1989):
Northern Ghana (good rainfall)
- Cattle is daily herded into the bush and kraaled at night around the houses. Systems of "compound farming" have evolved where the kraal manure is incorporated in fields directly around the house or compound. Maize or early millet are grown on compound fields, which is illustrated in the higher yields for these two cereals in the villages Binduri, Nakpanduri and Wantugu. In other villages where no compound farming occurs this difference in yield does not occur.

Table 3.46 Land use systems description for Ghana

UR	Rainfall	: 800 mm
	Soil fertility	: moderate
UR-L.1	Fertilizer use	: 0.6
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 15 tonnes/hayr
	Crops	: maiz, sorg, grou
UR-L.2	Fertilizer use	: 0.6
	Manure applic.	: 500 kg/ha
	Residue removal	: 50%
	Erosion	: 15 tonnes/hayr
	Crops	: spot, cass, othr, vege, frui, toba
UR-L.3	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 15 tonnes/hayr
	Crops	: cott
GR	Rainfall	: 1100 mm
	Soil fertility	: low
GR-L.1	Fertilizer use	: 1.0
	Manure applic.	: during grazing
	Residue removal	: 50%
	Erosion	: 15 tonnes/hayr
	Crops	: rice, maiz, mill, sorg, puls, grou
GR-L.2	Fertilizer use	: 1.0
	Manure applic.	: 1000 kg/ha
	Residue removal	: 30%
	Erosion	: 10 tonnes/hayr
	Crops	: spot, cass, othr, vege, frui, toba
GR-L.3	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 15 tonnes/hayr
	Crops	: cott

Table 3.46 (Cont.)

GR-L.4	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 5 tonnes/hayr
	Crops	: plan, bana, citr, cocn
PR	Rainfall	: 1400 mm
	Soil fertility	: moderate
PR-L.1	Fertilizer use	: 1.2
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 15 tonnes/hayr
	Crops	: rice, maiz, mill, sorg, puls
PR-L.2	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 10 tonnes/hayr
	Crops	: spot, cass, othr, vege, oilc
PR-H.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 10 tonnes/hayr
	Crops	: plan, bana, palm, cocn, coco, coff, rubb
NF	Rainfall	: 1000 mm
	Soil fertility	: high
NF-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: rice, maiz, mill, sorg
IR	Rainfall	: 800 mm
	Soil fertility	: moderate
IR-H.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 0 tonnes/hayr
	Crops	: rice, cane, vege

GUINEA

Table 3.47 Average annual rainfall for the Land/Water Classes in Guinea (Instituto Geografico De Agostini, 1976) (in mm)

Land/Water Class	Annual rainfall
uncertain rainfall	1150
good rainfall	1700
problem area	2000
naturally flooded	1600
irrigated area	1200

Table 3.48 Major soil types and average soil fertility class for the Land/Water classes in Guinea (FAO, 1977b and FAO, 1978)

Land/Water class	Major soil types	Average soil fertility class
Uncertain rainfall	Lf, Ne	2
Good rainfall	Af, Bf, Fo, Ag	1
Problem area	Fo, Af	1
Naturally flooded	Af(?)	1
Irrigated area	Af(?), Lf(?)	1

(Different authors cited by Lal et al, 1989):
rate of erosion from croplands: 17.9 - 24.5 (t/ha/yr)

(Fournier, 1967):

Seredou	(Cinchona)	25% slope	24.5 ton/ha/yr
Kindia	(Citrus on bare soil)	6%	17.9

Table 3.49 Land use systems description for Guinea

UR	Rainfall	: 1150 mm
	Soil fertility	: moderate
UR-L.1	Fertilizer use	: 0.6
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 20 tonnes/hayr
	Crops	: maiz, othc, puls, grou
UR-L.2	Fertilizer use	: 0.6
	Manure applic.	: 500 kg/ha
	Residue removal	: 50%
	Erosion	: 15 tonnes/hayr
	Crops	: cass, vege, frui

Table 3.49(Cont.)

GR	Rainfall	: 1700 mm
	Soil fertility	: low
GR-L.1	Fertilizer use	: 1.0
	Manure applic.	: during grazing
	Residue removal	: 30%
	Erosion	: 25 tonnes/hayr
	Crops	: maiz, sorg, othc, puls, grou, sesa
GR-L.2	Fertilizer use	: 1.0
	Manure applic.	: 500 kg/ha
	Residue removal	: 20%
	Erosion	: 20 tonnes/hayr
	Crops	: spot, cass, othr, plan (50%), vege, frui, toba
GR-H.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 15 tonnes/hayr
	Crops	: plan (50%), bana, citr
PR	Rainfall	: 2000 mm
	Soil fertility	: low
PR-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 25 tonnes/hayr
	Crops	: rice, maiz, sorg, othc, puls, grou
PR-L.2	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 20 tonnes/hayr
	Crops	: spot, cass, othr, vege, frui
PR-H.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 10 tonnes/hayr
	Crops	: plan, cane, bana, palm, cocn, coco, coff
NF	Rainfall	: 1600 mm
	Soil fertility	: low
NF-L.1	Fertilizer use	: 0.6
	Manure applic.	: none
	Residue removal	: 15%
	Erosion	: 0 tonnes/hayr
	Crops	: rice, spot, othr, vege
IR	Rainfall	: 1200 mm
	Soil fertility	: low
IR-H.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 15%
	Erosion	: 0 tonnes/hayr
	Crops	: rice, vege

KENYA

Table 3.50 Average annual rainfall for the Land/Water Classes in Kenya (Instituto Geografico De Agostini, 1976) (in mm)

Land/Water Class	Annual rainfall
low rainfall	400
uncertain rainfall	850
good rainfall	1200
problem area	1700
naturally flooded	1000
irrigated area	600

Table 3.51 Major soil types and average soil fertility class for the Land/Water classes in Kenya (FAO, 1977b and FAO, 1978)

Land/Water class	Major soil types	Average soil fertility class
Low rainfall	Lf, Re, Rc, Yh	2
Uncertain rainfall	Qf, Tm, Bh	2
Good rainfall	Nh, Bh, Fo	2
Problem area	Nh	2
Naturally flooded	Vp	3
Irrigated area	Vp, R,	3

(Instituto Geografico De Agostini, 1976)
Coffee (50%), tea (75%), sisal (75%), sugar (25%) are the plantation crops.
On large farms the following crops are grown:
- Wheat, Maize (35%), Barley, Other Cereals (15%)
On small farms are grown:
- Maize (65%), Rice, Other Cereals (85%)

Table 3.52 Relative soil loss for the Land/Water Classes in Kenya (Hakkeling, 1989)

Land/Water class	Relative soil loss
Low rainfall	2,3
Uncertain rainfall	3
Good rainfall	2
Problem area	3

(Llano et al, 1983):
Machakos district, (Low rainfall area)
- 75% of the farmers uses manure
  44% of the farmers: grazing of the crop residues
   9% of the farmers: slash the stover and burn it
  18% of the farmers: leave the stover on the field and let it rot
- Manure application takes place after the harvest.
- Main crops are maize, beans, sorghum, cassava and sweet potato.

(Hussain et al, 1982):
Machakos district, (Low rainfall)
- Crop residues are generally used as animal feed and taken away from the system. Some manure is returned to the field.

(Abella et al, 1984):
Tharaka (Low rainfall)
- 20% of the farmers uses manure.
- Crop residues (stalks of millet and sorghum) are used for erosion control
- 3/4 of livestock owners feed stover to their livestock, mainly by leaving them graze directly from the field.
- 92% of the households owns livestock.

(Abdullahi et al, 1986)
Embu district (Uncertain rainfall)
- Coffee receives fertilizer and manure (±200 kg/ha)

(Ahn, 1977)
In the highlands, much steep land is cultivated intensively but erosion is not as severe as might be expected.
Erosion losses can amount up to 140 ton/ha (young Tea on bare soil).

(Duckham and Masefield, 1970)
Wheat is grown under high management.
Western Kenya: Increasing use of manure.

(Bakema et al, 1988)
Manure is generally used, especially in maize and sorghum.

(Different authors cited by Lal et al, 1989)
rate of erosion from croplands: 5.0 - 47.1 (t/ha/yr).

Table 3.53 Land use systems description for Kenya

LR	Rainfall	: 400 mm
	Soil fertility	: moderate
LR-L.1	Fertilizer use	: 0.2
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 15 tonnes/hayr
	Crops	: maiz (50%), mill (50%), sorg (50%), puls (50%), grou (50%), sesa (50%)

Table 3.53(Cont.)

LR-L.2	Fertilizer use	: 0.2
	Manure applic.	: 1000 kg/ha
	Residue removal	: 75%
	Erosion	: 10 tonnes/hayr
	Crops	: maiz (50%), mill (50%), sorg (50%), puls (50%), grou (50%), sesa (50%)
LR-H.1	Fertilizer use	: 0.4
	Manure applic.	: during grazing
	Residue removal	: 50%
	Erosion	: 10 tonnes/hayr
	Crops	: whea, barl, oilc, fibr
UR	Rainfall	: 850 mm
	Soil fertility	: moderate
UR-L.1	Fertilizer use	: 0.6
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 20 tonnes/hayr
	Crops	: whea (25%), maiz, mill, sorg, othc, puls, grou
UR-L.2	Fertilizer use	: 0.6
	Manure applic.	: 500 kg/ha
	Residue removal	: 50%
	Erosion	: 15 tonnes/hayr
	Crops	: pota, spot, cass, vege, frui, sunf, fodd
UR-H.1	Fertilizer use	: 1.0
	Manure applic.	: during grazing
	Residue removal	: 50%
	Erosion	: 20 tonnes/hayr
	Crops	: whea (75%), barl
UR-H.2	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 20 tonnes/hayr
	Crops	: cott
GR	Rainfall	: 1200 mm
	Soil fertility	: moderate
GR-L.1	Fertilizer use	: 1.0
	Manure applic.	: 500 kg/ha
	Residue removal	: 50%
	Erosion	: 25 tonnes/hayr
	Crops	: whea, maiz, mill, sorg, othc, puls, grou
GR-L.2	Fertilizer use	: 1.0
	Manure applic.	: 500 kg/ha
	Residue removal	: 25%
	Erosion	: 20 tonnes/hayr
	Crops	: pota, spot, cass, vege, frui, sunf, toba, fodd

Table 3.53(Cont.)

GR-L.3	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 25 tonnes/hayr
	Crops	: cott
GR-L.4	Fertilizer use	: 1.0
	Manure applic.	: 500 kg/ha
	Residue removal	: 20%
	Erosion	: 15 tonnes/hayr
	Crops	: plan, bana, citr, coff (50%), teas (25%)
GR-H.1	Fertilizer use	: 2.0
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 15 tonnes/hayr
	Crops	: coff (50%), teas (75%)
GR-H.2	Fertilizer use	: 2.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 20 tonnes/hayr
	Crops	: barl
PR	Rainfall	: 1700 mm
	Soil fertility	: moderate
PR-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 30 tonnes/hayr
	Crops	: maiz, mill, sorg, puls, grou
PR-L.2	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 25 tonnes/hayr
	Crops	: spot, cass, frui
PR-L.3	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 20 tonnes/hayr
	Crops	: plan, bana, cocn, coff (50%), teas (25%)
PR-L.4	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 50%
	Erosion	: 35 tonnes/hayr
	Crops	: whea
PR-H.1	Fertilizer use	: 2.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 20 tonnes/hayr
	Crops	: barl, cane, coff (50%), teas (75%)
NF	Rainfall	: 1000 mm
	Soil fertility	: high

Table 3.53(Cont.)

NF-L.1	Fertilizer use	: 0.6
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: mill, sorg, othc, puls
NF-H.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: cane
IR	Rainfall	: 600 mm
	Soil fertility	: high
IR-H.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: rice, vege
IR-H.2	Fertilizer use	: 2.5
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 0 tonnes/hayr
	Crops	: cane, citr, coff, teas

LESOTHO

Table 3.54 Average annual rainfall for the Land/Water Classes in Lesotho (Instituto Geografico De Agostini, 1976) (in mm)

Land/Water Class	Annual rainfall
low rainfall	600
uncertain rainfall	800
good rainfall	1000
problem area	800

Table 3.55 Major soil types and average soil fertility class for the Land/Water classes in Chad (FAO, 1977b and FAO, 1978)

Land/Water class	Major soil types	Average soil fertility class
Low rainfall	Bc, L	2
Uncertain rainfall	Bc, L	2
Good rainfall	Bc, L	2
Problem area	We	1

(Different authors cited by Lal et al, 1989):
rate of erosion from croplands: 40.0 (t/ha/yr)

Table 3.56 Land use systems description for Lesotho

LR	Rainfall	: 600 mm
	Soil fertility	: moderate
LR-L.1	Fertilizer use	: 0.2
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 20 tonnes/hayr
	Crops	: whea, maiz, sorg, puls
LR-L.2	Fertilizer use	: 0.2
	Manure applic.	: none
	Residue removal	: 0%
	Erosion	: 15 tonnes/hayr
	Crops	: frui
UR	Rainfall	: 800 mm
	Soil fertility	: moderate
UR-L.1	Fertilizer use	: 0.6
	Manure applic.	: during grazing
	Residue removal	: 50%
	Erosion	: 25 tonnes/hayr
	Crops	: whea, maiz, sorg, puls

Table 3.56(Cont.)

UR-L.2	Fertilizer use	: 0.6
	Manure applic.	: 500 kg/ha
	Residue removal	: 20%
	Erosion	: 10 tonnes/hayr
	Crops	: othr, vege, frui
GR	Rainfall	: 1000 mm
	Soil fertility	: moderate
GR-L.1	Fertilizer use	: 1.0
	Manure applic.	: 500 kg/ha
	Residue removal	: 30%
	Erosion	: 30 tonnes/hayr
	Crops	: whea, maiz, sorg, puls
GR-L.2	Fertilizer use	: 1.0
	Manure applic.	: 500 kg/ha
	Residue removal	: 25%
	Erosion	: 20 tonnes/hayr
	Crops	: vege
PR	Rainfall	: 800 mm
	Soil fertility	: low
PR-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 25%
	Erosion	: 25 tonnes/hayr
	Crops	: maiz, sorg, othc, puls

LIBERIA

Table 3.57 Average annual rainfall for the Land/Water Classes in Liberia (Instituto Geografico De Agostini, 1976) (in mm)

Land/Water Class	Annual rainfall
problem area	2200
naturally flooded	2200
irrigated area	2200

(Instituto Geografico De Agostini, 1976)
- Rubber: 100% on plantations
- Palm oil: spread all over the country
- No cattle

Table 3.58 Major soil types and average soil fertility class for the Land/Water classes in Liberia (FAO, 1977b and FAO, 1978)

Land/Water class	Major soil types	Average soil fertility class
Problem area	Fo, Fx	1
Naturally flooded	Fx(?)	1
Irrigated area	Af(?)	1

(Braun, 1974)
The following crops are grown in rotation under shifting cultivation:
Coastal region : cassava, maize, rice, yams and sweet potatoes.
Central region : rice, maize, cassava, groundnuts, okra and sweet potatoes.
Northern region: rice, maize, cassava and okra.

Table 3.59 Land use systems description for Liberia

PR	Rainfall	: 1200 mm
	Soil fertility	: low
PR-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 40%
	Erosion	: 15 tonnes/hayr
	Crops	: rice, puls, soyb, grou

Table 3.59(Cont.)

PR-L.2	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 25%
	Erosion	: 10 tonnes/hayr
	Crops	: spot, cass, othr, cane, vege, frui
PR-L.3	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 5 tonnes/hayr
	Crops	: plan, bana, citr, palm, cocn, coco, coff, rubb
NF	Rainfall	: 2200 mm
	Soil fertility	: low
NF-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: rice
NF-L.2	Fertilizer use	: 0.6
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 0 tonnes/hayr
	Crops	: vege, bana
IR	Rainfall	: 2200 mm
	Soil fertility	: low
IR-H.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: rice

MADAGASCAR

Table 3.60 Average annual rainfall for the Land/Water Classes in Madagascar (Instituto Geografico De Agostini, 1976) (in mm)

Land/Water Class	Annual rainfall
low rainfall	600
uncertain rainfall	900
good rainfall	1500
problem area	2400
naturally flooded	3000
irrigated area	2000

(Instituto Geografico De Agostini, 1976)
- Sisal: 100% planation
- Cotton: 80% plantation
- Tobacco: 80% plantation
- The application of animal manure or ash as fertilizer is only practiced in the densely populated parts of the highlands.

Table 3.61 Major soil types and average soil fertility class for the Land/Water classes in Madagascar (FAO, 1977b and FAO, 1978)

Land/Water class	Major soil types	Average soil fertility class
Low rainfall	Qc, Bc, Bk,	2
Uncertain rainfall	Qc, Bc, Bd, Bf	2
Good rainfall	Fo, Lf, Lc, Bf	1
Problem area	Fo, Lf	1
Naturally flooded	Fo	1
Irrigated area	Fo	1

Table 3.62 Relative soil loss for the Land/Water Classes in Madagascar (Hakkeling, 1989)

Land/Water class	Relative soil loss
Low rainfall	1,4
Uncertain rainfall	1,4
Good rainfall	2-4
Problem area	2-4

(Different authors cited by Lal et al, 1989)
Rate of erosion from croplands: 25.0 - 250 (t/ha/yr)

(Fournier, 1967)
Lake Aloatra, 978 mm rain/yr, cropland with 7% slope:
- erosion of 59 ton/ha,yr

(Braun, 1974)
The following crops are grown in rotation under shifting cultivation: rice, cassava, bananas, coffee
On farmers level, soil conservation is done by contour cropping with alternating strips.

(FAO, 1986)
The cattle population of Madagascar is considerable and for several decades has enabled FYM, containing animal droppings and straw, to be used on some scale in crop production. FYM has been used mostly for rice production and little has been applied to the hilly terrain fields growing root or tuber crops.

Table 3.63 Land use systems description for Madagascar

LR	Rainfall	: 600 mm
	Soil fertility	: moderate
LR-L.1	Fertilizer use	: 0.2
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 10 tonnes/hayr
	Crops	: maiz, sorg, puls, grou
UR	Rainfall	: 900 mm
	Soil fertility	: moderate
UR-L.1	Fertilizer use	: 0.6
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 15 tonnes/hayr
	Crops	: maiz, puls, grou
UR-L.2	Fertilizer use	: 0.6
	Manure applic.	: 500 kg/ha
	Residue removal	: 25%
	Erosion	: 15 tonnes/hayr
	Crops	: pota, spot, cass, othr, vege, frui, oilc, toba, fibr
UR-L.3	Fertilizer use	: 0.6
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 15 tonnes/hayr
	Crops	: cott

Table 3.63(Cont.)

GR	Rainfall	: 1500 mm
	Soil fertility	: low
GR-L.1	Fertilizer use	: 1.0
	Manure applic.	: during grazing
	Residue removal	: 50%
	Erosion	: 25 tonnes/hayr
	Crops	: maiz, puls, grou
GR-L.2	Fertilizer use	: 1.0
	Manure applic.	: 500 kg/ha
	Residue removal	: 30%
	Erosion	: 20 tonnes/hayr
	Crops	: pota, spot, cass, othr, vege, frui, oilc, toba, fibr
GR-H.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 25 tonnes/hayr
	Crops	: cott
GR-H.2	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 15 tonnes/hayr
	Crops	: bana, citr, coff
PR	Rainfall	: 2400 mm
	Soil fertility	: low
PR-L.1	Fertilizer use	: 1.0
	Manure applic.	: 500 kg/ha
	Residue removal	: 40%
	Erosion	: 25 tonnes/hayr
	Crops	: rice, puls, grou
PR-L.2	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 35 tonnes/hayr
	Crops	: pota, spot, cass, othr, vege, frui, fibr
PR-H.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 20 tonnes/hayr
	Crops	: cane, bana, palm, cocn, coco, coff
NF	Rainfall	: 3000 mm
	Soil fertility	: low
NF-L.1	Fertilizer use	: 0.6
	Manure applic.	: 500 kg/ha
	Residue removal	: 40%
	Erosion	: 0 tonnes/hayr
	Crops	: rice

Table 3.63(Cont.)

IR	Rainfall	: 2000 mm
	Soil fertility	: low
IR-L.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: rice, cane
IR-H.1	Fertilizer use	: 3.0
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 0 tonnes/hayr
	Crops	: cott

MALAWI

Table 3.64 Average annual rainfall for the Land/Water Classes in Malawi (Instituto Geografico De Agostini, 1976) (in mm)

Land/Water Class	Annual rainfall
uncertain rainfall	900
good rainfall	1000
problem area	1500
naturally flooded	1200
irrigated area	1400

Table 3.65 Major soil types and average soil fertility class for the Land/Water classes in Malawi (FAO, 1977b and FAO, 1978)

Land/Water class	Major soil types	Average soil fertility class
Uncertain rainfall	Fo	1
Good rainfall	Lf, Bc, Je	2
Problem area	Ne, Bc, Nd	2
Naturally flooded	Bc(?), Fr(?)	2
Irrigated area	Bc, Fr	2

Table 3.66 Relative soil loss for the Land/Water Classes in Madagascar (Hakkeling, 1989)

Land/Water class	Relative soil loss
Uncertain rainfall	3
Good rainfall	2
Problem area	2,3

(Ambühl et al, 1985):
Mulanje area (Problem area)
- Mainly smallholders growing tea, maize, cassava, beans, groundnuts and fruit.
- No mention of cattle, only some goats. No mention of manure.

(Hekstra et al, 1988):
Nkhata bay RDP (Problem area)
Smallholders grow mainly maize, cassava, rice, groundnut and bananas. Estates grow rubber, tea, coffee and macadamia nuts.
Of the smallholders, only 17% uses fertilizers and even then on a small part of the area. Almost no manure is used (some poultry manure). Bananas residues are left on the field.
Almost no cattle rearing in the area.

(Chandele et al, 1987):
West Mulanje (Good rainfall area)
- Ridging takes place, resulting in erosion control.
- Maize residues are incorporated and therefore returned.
- 10% of the farmers uses FYM.
- 14% of the farmers uses fertilizers.

(Brown and Young, 1967):
Central Malawi:

Uncertain rainfall	- Extensive farming (Maize, groundnuts and tobacco)
	- Livestock ranching
Good rainfall	- Intensive farming (maize, groundnuts and tobacco)
	- Livestock ranching
	- Intensive farming (maize, cotton and rice)

(Braun, 1974):
- Maize, millet and cassava are grown in rotation under shifting cultivation.
- In plantations a wide range of techniques for soil conservation is used. On farmers level soil conservation needs improvement.

(Payr, 1977):
Maize: monoculture without fertilizer application
Groundnuts: export product
Cotton: cashcrop for small farmers
Tobacco: plantation crop
Tea: 20% small farmers, 80% plantations
Sugar cane: plantations.

Table 3.67 Land use systems description for Malawi

UR	Rainfall	: 900 mm
	Soil fertility	: low
UR-L.1	Fertilizer use	: 0.6
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 25 tonnes/hayr
	Crops	: maiz, sorg, puls, grou
UR-L.2	Fertilizer use	: 0.6
	Manure applic.	: none
	Residue removal	: 50%
	Erosion	: 15 tonnes/hayr
	Crops	: pota, cass, vege, frui, toba
UR-H.1	Fertilizer use	: 1.5
	Manure applic.	: during grazing
	Residue removal	: 80%
	Erosion	: 20 tonnes/hayr
	Crops	: fodd

Table 3.67(Cont.)

UR-H.2	Fertilizer use	: 0.6
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 15 tonnes/hayr
	Crops	: cott
GR	Rainfall	: 1000 mm
	Soil fertility	: moderate
GR-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 30%
	Erosion	: 30 tonnes/hayr
	Crops	: whea, maiz, sorg, puls, grou
GR-L.2	Fertilizer use	: 1.0
	Manure applic.	: 500 kg/ha
	Residue removal	: 30%
	Erosion	: 20 tonnes/hayr
	Crops	: pota, cass, vege, frui, oilc
GR-H.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 15 tonnes/hayr
	Crops	: plan, bana, citr
GR-H.2	Fertilizer use	: 2.0
	Manure applic.	: none
	Residue removal	: 30%
	Erosion	: 20 tonnes/hayr
	Crops	: sunf, toba, fodd
GR-H.3	Fertilizer use	: 2.0
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 20 tonnes/hayr
	Crops	: cott
PR	Rainfall	: 1500 mm
	Soil fertility	: moderate
PR-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 30 tonnes/hayr
	Crops	: maiz, sorg, puls, grou
PR-L.2	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 20 tonnes/hayr
	Crops	: pota, vege, frui
PR-H.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 25 tonnes/hayr
	Crops	: plan, bana, coff, teas

Table 3.67(Cont.)

NF	Rainfall	: 1200 mm
	Soil fertility	: moderate
NF-L.1	Fertilizer use	: 0.6
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: rice, maiz, vege
IR	Rainfall	: 1400 mm
	Soil fertility	: moderate
IR-H.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: whea, rice, cane, vege

MALI

Table 3.68 Average annual rainfall for the Land/Water Classes in Mali (Instituto Geografico De Agostini, 1976) (in mm)

Land/Water Class	Annual rainfall
low rainfall	300
uncertain rainfall	900
good rainfall	1300
problem area	500
naturally flooded	1300
irrigated area	400

Table 3.69 Major soil types and average soil fertility class for the Land/Water classes in Mali (FAO, 1977b and FAO, 1978)

Land/Water class	Major soil types	Average soil fertility class
Low rainfall	Ql, Re, Lf	2
Uncertain rainfall	Lf, Re	2
Good rainfall	Lf, Ne	2
Problem area	G	3
Naturally flooded	G, Vc	3
Irrigated area	G, Vc	3

Table 3.70 Pressure on land by cattle breeding and agriculture in Mali (Breman, 1986 cited by Ministerie van Landbouw en Visserij, 1988)

Land/Water Class	cattle	agriculture
low rainfall	+/++	-/+
uncertain rainfall	+	+
good rainfall	-	-

(van der Klauw, 1989)
The crop residues are grazed all over the country.

Table 3.71 Land use systems description for Mali

LR	Rainfall	: 300 mm
	Soil fertility	: moderate
LR-L.1	Fertilizer use	: 0.2
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 5 tonnes/hayr
	Crops	: maiz, mill, puls, grou
LR-L.2	Fertilizer use	: 0.2
	Manure applic.	: 500 kg/ha
	Residue removal	: 75%
	Erosion	: 3 tonnes/hayr
	Crops	: vege, frui
UR	Rainfall	: 900 mm
	Soil fertility	: moderate
UR-L.1	Fertilizer use	: 0.6
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 10 tonnes/hayr
	Crops	: maiz, mill, puls, grou
UR-L.2	Fertilizer use	: 0.6
	Manure applic.	: 500 kg/ha
	Residue removal	: 50%
	Erosion	: 5 tonnes/hayr
	Crops	: spot, cass, vege, frui, oilc
UR-H.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 10 tonnes/hayr
	Crops	: cott
GR	Rainfall	: 1300 mm
	Soil fertility	: moderate
GR-L.1	Fertilizer use	: 1.0
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 10 tonnes/hayr
	Crops	: maiz, mill, puls, grou
GR-L.2	Fertilizer use	: 1.0
	Manure applic.	: 500 kg/ha
	Residue removal	: 30%
	Erosion	: 5 tonnes/hayr
	Crops	: spot, cass, vege, frui, oilc, toba
GR-H.1	Fertilizer use	: 2.0
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 10 tonnes/hayr
	Crops	: cott

Table 3.71(Cont.)

PR	Rainfall	: 500 mm
	Soil fertility	: high
PR-L.1	Fertilizer use	: 1.0
	Manure applic.	: during grazing
	Residue removal	: 50%
	Erosion	: 10 tonnes/hayr
	Crops	: mill, othc, puls, grou
PR-H.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 8 tonnes/hayr
	Crops	: fibr
NF	Rainfall	: 1300 mm
	Soil fertility	: high
NF-L.1	Fertilizer use	: 0.6
	Manure applic.	: none
	Residue removal	: 50%
	Erosion	: 0 tonnes/hayr
	Crops	: rice, mill, othc, puls
IR	Rainfall	: 400 mm
	Soil fertility	: high
IR-H.1	Fertilizer use	: 2.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: whea, rice, mill, cane, puls, vege, grou
IR-H.2	Fertilizer use	: 2.0
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 0 tonnes/hayr
	Crops	: cott

MAURITANIA

Table 3.72 Average annual rainfall for the Land/Water Classes in Mauritania (Instituto Geografico De Agostini, 1976) (in mm)

Land/Water Class	Annual rainfall
low rainfall	200
uncertain rainfall	500
irrigated area	300

Table 3.73 Major soil types and average soil fertility class for the Land/Water classes in Mauritania (FAO, 1977b and FAO, 1978)

Land/Water class	Major soil types	Average soil fertility class
Low rainfall	Qc, Bk, Re	2
Uncertain rainfall	Re	3
Irrigated area	Qc, Bk	2

Table 3.74 Pressure on land by cattle breeding and agriculture in Mauritania (Breman, 1986 cited by Ministerie van landbouw en visserij, 1988)

Land/Water Class	cattle	agriculture
Low rainfall	++	++
Uncertain rainfall	+++	+++

Table 3.75 Land use systems description for Mauritania

LR	Rainfall	: 200 mm
	Soil fertility	: moderate
LR-L.1	Fertilizer use	: 0.2
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 5 tonnes/hayr
	Crops	: mill, puls
LR-L.2	Fertilizer use	: 0.2
	Manure applic.	: 500 kg/ha
	Residue removal	: 50%
	Erosion	: 3 tonnes/hayr
	Crops	: vege

Table 3.75(Cont.)

UR	Rainfall	: 500 mm
	Soil fertility	: high
UR-L.1	Fertilizer use	: 0.6
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 15 tonnes/hayr
	Crops	: maiz, mill, puls, grou
UR-L.2	Fertilizer use	: 0.6
	Manure applic.	: 500 kg/ha
	Residue removal	: 75%
	Erosion	: 10 tonnes/hayr
	Crops	: spot, vege
UR-H.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 25%
	Erosion	: 10 tonnes/hayr
	Crops	: frui
IR	Rainfall	: 300 mm
	Soil fertility	: moderate
IR-H.1	Fertilizer use	: 2.5
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: whea, rice, frui

MAURITIUS

Table 3.76 Average annual rainfall for the Land/Water Classes in Mauritius (Instituto Geografico De Agostini, 1976) (in mm)

Land/Water Class	Annual rainfall
problem area	2000
irrigated area	2000

Table 3.77 Major soil types and average soil fertility class for the Land/Water classes in Mauritius (FAO, 1977b and FAO, 1978)

Land/Water class	Major soil types	Average soil fertility class
Problem area	Ne, Bh	3
Irrigated area	Ne, Bh	3

Table 3.78 Land use systems description for Mauritius

PR	Rainfall	: 2000 mm
	Soil fertility	: high
PR-L.1	Fertilizer use	: 1.0
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 15 tonnes/hayr
	Crops	: puls
PR-L.2	Fertilizer use	: 1.0
	Manure applic.	: 500 kg/ha
	Residue removal	: 50%
	Erosion	: 10 tonnes/hayr
	Crops	: frui, toba
PR-L.3	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 5 tonnes/hayr
	Crops	: bana, cocn
PR-H.1	Fertilizer use	: 1.5
	Manure applic.	: during grazing
	Residue removal	: 60%
	Erosion	: 10 tonnes/hayr
	Crops	: grou

Table 3.78(Cont.)

PR-H.2	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: cane
PR-H.3	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 5 tonnes/hayr
	Crops	: pota, vege, mill (0%)
NF	Rainfall	: 2000 mm
	Soil fertility	: high
NF-H.1	Fertilizer use	: 2.5
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: cane

MOZAMBIQUE

Table 3.79 Average annual rainfall for the Land/Water Classes in Mozambique (Instituto Geografico De Agostini, 1976) (in mm)

Land/Water Class	Annual rainfall
low rainfall	450
uncertain rainfall	800
good rainfall	1100
problem area	1500
naturally flooded	1100
irrigated area	1000

Table 3.80 Major soil types and average soil fertility class for the Land/Water classes in Mozambique (FAO, 1977b and FAO, 1978)

Land/Water class	Major soil types	Average soil fertility class
Low rainfall	Qc, Bc, Lc	2
Uncertain rainfall	Lf, Fo, Qc, Ql	1
Good rainfall	Lf, Fo, Fr, Bc, Qf	2
Problem area	Lf, Qf, Je	2
Naturally flooded	G, Je	3
Irrigated area	Fr	2

(Instituto Geografico De Agostini, 1976)
60% of the herd is kept in kraals at night on small family farms
Three types of farming occur:
- small family farms
- medium sized mixed farms (cash crops)
- large industrial estates (sugar cane, sisal, tea or coconuts)

Table 3.81 Relative soil loss for the Land/Water Classes in Mozambique (Hakkeling, 1989)

Land/Water class	Relative soil loss
Low rainfall	1
Uncertain rainfall	2,3
Good rainfall	1,3
Problem area	1,2

Table 3.82 Major crops under two forms of management in the Land/Water Classes for Mozambique (Pössinger, 1968)

LWC	Management	Major crops
LR	organized	cane, cotton, vegetables
	traditional	cotton, vegetables, rice
UR	organized	cane, rice, cotton, vegetables, coffee, cashew groundnuts, sisal, coconut, tobacco,
	traditional	rice, cotton, vegetables, cofee, cashew, coconut, maize, sorghum, sesam, groundnuts, beans, cassava
GR	organized	cane, sisal, coconut, oil crops, kenaf, cotton, vegetables, cashew, tea, kapok, coffee
	traditional	maize, cassava, beans, rice, sweet potatoes, vegetables, cotton, yams, taro, sorghum, groundnuts
PR	organized	--
	traditional	cotton, mais, cassava

Table 3.83 Land use systems description for Mozambique

LR	Rainfall	: 450 mm
	Soil fertility	: moderate
LR-L.1	Fertilizer use	: 0.2
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 5 tonnes/hayr
	Crops	: maiz, mill, sorg, puls, grou, sesa
LR-H.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 0%
	Erosion	: 2 tonnes/hayr
	Crops	: oilc, fibr
UR	Rainfall	: 800 mm
	Soil fertility	: low
UR-L.1	Fertilizer use	: 0.6
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 20 tonnes/hayr
	Crops	: whea, maiz, mill, sorg, puls, grou, sesa
UR-L.2	Fertilizer use	: 0.6
	Manure applic.	: 1000 kg/ha
	Residue removal	: 75%
	Erosion	: 15 tonnes/hayr
	Crops	: spot, cass, othr, vege, frui, sunf, toba

Table 3.83(Cont.)

UR-H.1	Fertilizer use	: 0.6
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 15 tonnes/hayr
	Crops	: pota, fibr
UR-H.2	Fertilizer use	: 0.6
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 15 tonnes/hayr
	Crops	: cott
GR	Rainfall	: 1100 mm
	Soil fertility	: moderate
GR-L.1	Fertilizer use	: 1.0
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 15 tonnes/hayr
	Crops	: maiz, mill, sorg, puls, grou, sesa
GR-L.2	Fertilizer use	: 1.0
	Manure applic.	: 1000 kg/ha
	Residue removal	: 50%
	Erosion	: 10 tonnes/hayr
	Crops	: spot, cass, othr, vege, frui, sunf, toba, fibr
GR-H.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 30%
	Erosion	: 5 tonnes/hayr
	Crops	: pota, bana, citr, coff, teas
GR-H.2	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 30%
	Erosion	: 10 tonnes/hayr
	Crops	: cane
GR-H.3	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 10 tonnes/hayr
	Crops	: cott
PR	Rainfall	: 1500 mm
	Soil fertility	: moderate
PR-L.1	Fertilizer use	: 1.0
	Manure applic.	: during grazing
	Residue removal	: 50%
	Erosion	: 25 tonnes/hayr
	Crops	: rice, maiz, sorg, puls
PR-L.2	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 15 tonnes/hayr
	Crops	: cass

Table 3.83(Cont.)

PR-H.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 50%
	Erosion	: 20 tonnes/hayr
	Crops	: cane, cocn, teas
NF	Rainfall	: 1100 mm
	Soil fertility	: high
NF-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: rice, sorg, cass
IR	Rainfall	: 1000 mm
	Soil fertility	: moderate
IR-H.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: rice, vege
IR-H.2	Fertilizer use	: 2.5
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: cane

NIGER

Table 3.84 Average annual rainfall for the Land/Water Classes in Niger (Instituto Geografico De Agostini, 1976) (in mm)

Land/Water Class	Annual rainfall
low rainfall	450
uncertain rainfall	800
naturally flooded	750
irrigated area	500

(Instituto Geografico De Agostini, 1976)
Fallow is used as grazing land.
More than 70% of the area is cultivated with intercropping.
The only time that animal manure is normally applied to the fields is after the harvest, when the nomadic pastoralists, moving their herds south before the onset of the dry season, are allowed to pasture their livestock on the stubble. However during the dry season a proportion of the manure becomes dried out and is carried away by the wind. Few of the sedentary farmers use the manure of their farm stock.

Table 3.85 Major soil types and average soil fertility class for the Land/Water classes in Niger (FAO, 1977b and FAO, 1978)

Land/Water class	Major soil types	Average soil fertility class
Low rainfall	Q1, Re, Be	2
Uncertain rainfall	Q1	1
Naturally flooded	Q1	1
Irrigated area	Q1	1

Table 3.86 Pressure on land by cattle breeding and agriculture in Niger (Breman, 1986 cited by Ministerie van Landbouw en Visserij, 1988)

Land/Water Class	cattle	agriculture
low rainfall	++	++
uncertain rainfall	++	++

(Different authors cited by Lal et al, 1989):
rate of erosion from croplands: 35.0 - 70.0 (ton/ha,yr)

(Braun, 1974)
Groundnuts, millet and pulses are grown in rotation under shifting cultivation.
Soil conservation is done by maintenance of tree belts, contour cropping on slopes and contour protection by stone walls.
There are no plantations.

Table 3.87 Land use systems description for Niger

LR	Rainfall	: 450 mm
	Soil fertility	: moderate
LR-L.1	Fertilizer use	: 0.2
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 10 tonnes/hayr
	Crops	: mill, sorg, othc, puls, grou
LR-L.2	Fertilizer use	: 0.2
	Manure applic.	: 500 kg/ha
	Residue removal	: 50%
	Erosion	: 10 tonnes/hayr
	Crops	: vege, frui
UR	Rainfall	: 800 mm
	Soil fertility	: low
UR-L.1	Fertilizer use	: 0.6
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 25 tonnes/hayr
	Crops	: maiz, mill, sorg, puls, grou
UR-L.2	Fertilizer use	: 0.6
	Manure applic.	: none
	Residue removal	: 75%
	Erosion	: 20 tonnes/hayr
	Crops	: spot, cass, vege, frui, toba
UR-L.3	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 25 tonnes/hayr
	Crops	: cott
NF	Rainfall	: 750 mm
	Soil fertility	: low
NF-L.1	Fertilizer use	: 0.6
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: rice

Table 3.87(Cont.)

IR	Rainfall	: 500 mm
	Soil fertility	: low
IR-H.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: whea, rice, cane, vege

NIGERIA

Table 3.88 Average annual rainfall for the Land/Water Classes in Nigeria (Instituto Geografico De Agostini, 1976) (in mm)

Land/Water Class	Annual rainfall
low rainfall	600
uncertain rainfall	800
good rainfall	1200
problem area	2000
naturally flooded	1500
irrigated area	1000

(Instituto Geografico De Agostini, 1976)
Due to tsetse fly infestation the occurrence of cattle is restricted to low and uncertain rainfall areas.

Table 3.89 Major soil types and average soil fertility class for the Land/Water classes in Nigeria (FAO, 1977b and FAO, 1978)

Land/Water class	Major soil types	Average soil fertility class
Low rainfall	Qc, Ql, Je	1
Uncertain rainfall	Lf, Ql, Re, Nd	2
Good rainfall	Lf, Nd, Af	2
Problem area	Nd, Af, Fx	2
Naturally flooded	G	3
Irrigated area	Lf, Nd, Lp	2

(Iloeje, 1972):
No important mixed farming takes place in the southern belt and in the savanna areas. In the northern part of Nigeria mixed farming takes place where the cattle feeds on the grain stalks and manure reaches the field when cattle grazes outside.
Plantation agriculture takes place with rubber, palm, cocoa and cashew.

(Different authors cited by Lal et al, 1989):
rate of erosion from croplands: 14.4 (ton/ha,yr).

Table 3.90 Erosion rates in Nigeria under different crops and on different slopes (814 mm rain/yr) (Lal, 1976)

Crop (Rotation)	Slope			
	1%	5%	10%	15%
fallow	5.0	43	58.9	116
maize (mulched)	0.0	0.1	0.1	0.2
maize	1.1	3.1	6.4	14.7
maize-cowpeas	0.4	1.5	5.1	8.8
cowpeas-maize	0.5	1.1	3.0	6.2

(Mortimore 1989):
The northernmost states of Nigeria: 55-100% of farmers applies FYM. Under small farm conditions in south-western Kano State 34% of the plots received FYM, 20% FYM and inorganic fertilizers, 24% only inorganic fertilizers and 22% was not fertilized at all. On plots receiving FYM 55% received 14 ton/ha,yr or less and 27% received 15-30 ton/ha,yr.
The use of inorganic fertilizers:
In Buachi 38% of the plots receive 35 kg/ha,yr on average
In Kano 22% of the plots receive 94 kg/ha,yr on average
In Sokoto 31% of the plots receive 30 kg/ha,yr on average

(Powell, 1985):
During an 8 week grazing period following grain harvest, animals consumed 49% of the total sorghum stover and 57% of the total millet stover.

(Powell and Bayer, 1985):
In central Nigeria (Good rainfall) Bunaji cattle spent 50% of their dry season grazing time on sorghum, millet, soybean and rice residues, representing 20% of their total annual grazing time. In terms of grazing time, millet stover and rice residues were the most important feed sources, followed by sorghum and soybeans.

(Datiri, 1974):
Main crops under shifting cultivation in the savanna zone are sorghum, rice, wheat, beans, soybeans and maize. In the forest zone the main crops grown under shifting cultivation are yams, cassava, oil palm, citrus, banana, plantain and cocoa. Almost no fertilizers are applied to crops under shifting cultivation.

Table 3.91 Land use systems description for Nigeria

LR	Rainfall	: 600 mm
	Soil fertility	: low
LR-L.1	Fertilizer use	: 0.2
	Manure applic.	: during grazing
	Residue removal	: 55%
	Erosion	: 5 tonnes/hayr
	Crops	: mill, sorg, othc, puls, grou, sesa
LR-L.2	Fertilizer use	: 0.2
	Manure applic.	: 500 kg/ha
	Residue removal	: 75%
	Erosion	: 5 tonnes/hayr
	Crops	: vege, frui
UR	Rainfall	: 800 mm
	Soil fertility	: moderate
UR-L.1	Fertilizer use	: 0.6
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 15 tonnes/hayr
	Crops	: maiz, mill, sorg, othc, puls, soyb, grou, sesa
UR-L.2	Fertilizer use	: 0.6
	Manure applic.	: 500 kg/ha
	Residue removal	: 50%
	Erosion	: 10 tonnes/hayr
	Crops	: pota, spot, cass, othr, vege, frui, oilc, toba
UR-L.3	Fertilizer use	: 0.6
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 15 tonnes/hayr
	Crops	: cott
GR	Rainfall	: 1200 mm
	Soil fertility	: moderate
GR-L.1	Fertilizer use	: 1.0
	Manure applic.	: during grazing
	Residue removal	: 50%
	Erosion	: 15 tonnes/hayr
	Crops	: maiz, mill, sorg, othc, puls, soyb, grou, sesa
GR-L.2	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 30%
	Erosion	: 10 tonnes/hayr
	Crops	: cass, othr, plan, vege, frui, oilc, toba
GR-L.3	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 15 tonnes/hayr
	Crops	: cott

Table 3.91(Cont.)

GR-H.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 15%
	Erosion	: 15 tonnes/hayr
	Crops	: rice, pota, spot, cane
PR	Rainfall	: 2000 mm
	Soil fertility	: moderate
PR-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 15%
	Erosion	: 20 tonnes/hayr
	Crops	: maiz, mill, sorg, othc, puls, grou, sesa
PR-L.2	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 10 tonnes/hayr
	Crops	: spot, cass, othr, vege, frui
PR-L.3	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 5 tonnes/hayr
	Crops	: plan, palm, cocn, coco, coff, rubb
PR-H.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 10 tonnes/hayr
	Crops	: rice, pota
NF	Rainfall	: 1500 mm
	Soil fertility	: high
NF-L.1	Fertilizer use	: 0.6
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: mill, sorg, puls
NF-L.2	Fertilizer use	: 0.6
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: spot, othr, plan, vege, frui
NF-H.1	Fertilizer use	: 2.0
	Manure applic.	: none
	Residue removal	: 5%
	Erosion	: 0 tonnes/hayr
	Crops	: rice

Table 3.91(Cont.)

IR	Rainfall	: 1000 mm
	Soil fertility	: moderate
IR-H.1	Fertilizer use	: 2.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: whea, rice, cane, vege
IR-H.2	Fertilizer use	: 2.0
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 0 tonnes/hayr
	Crops	: cott

RWANDA

Table 3.92 Average annual rainfall for the Land/Water Classes in Rwanda (Instituto Geografico De Agostini, 1976) (in mm)

Land/Water Class	Annual rainfall
good rainfall	1000
problem area	1500
naturally flooded	1200
irrigated area	1100

(Instituto Geografico De Agostini, 1976)
The high rural population density explains why the Rwandese farmers use more intensive techniques than their neighbours. They apply a certain amount of animal manure to their fields which are permanently cultivated.

Table 3.93 Major soil types and average soil fertility class for the Land/Water classes in Rwanda (FAO, 1977b and FAO, 1978)

Land/Water class	Major soil types	Average soil fertility class
Good rainfall	Fo	1
Problem area	Nh, Tm	2
Naturally flooded	Fo	1
Irrigated area	Fh(?)	2

Table 3.94 Relative soil loss for the Land/Water Classes in Rwanda (Hakkeling, 1989)

Land/Water class	Relative soil loss
Good rainfall	2
Problem area	4

(Scott, 1988)
potato growers can be sub-divided in:
- Small family farmers (majority)
- Settlement growers
- Large commercial growers

The small farmers have a mixed cropping system with no chemical fertilizers. The settlers grow tea, coffee, pyrethum and potatoes.

(Miracle, 1967)
Miracle mentions the use of manure in Burundi and Rwanda.

(FAO, 1986)
No organic manure is used on 65% of the fields, FYM is used on 24%, straw on 7% and a combination of straw and FYM on 4% . Straw is often used for mulching coffee, bananas and other crops and is sometimes incorporated in the soil by cultivation.

Table 3.95 Land use systems description for Rwanda

GR	Rainfall	: 1000 mm
	Soil fertility	: low
GR-L.1	Fertilizer use	: 1.0
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 15 tonnes/hayr
	Crops	: whea, maiz, sorg, puls, soyb, grou
GR-L.2	Fertilizer use	: 1.0
	Manure applic.	: 1000 kg/ha
	Residue removal	: 50%
	Erosion	: 10 tonnes/hayr
	Crops	: pota (30%), spot (30%), cass (30%), othr (30%), vege (30%), frui (30%), toba (30%)
GR-L.3	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 30%
	Erosion	: 15 tonnes/hayr
	Crops	: pota (70%), spot (70%), cass (70%), othr (70%), vege (70%), frui (70%), toba (70%)
GR-H.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 5 tonnes/hayr
	Crops	: plan, coff
PR	Rainfall	: 1500 mm
	Soil fertility	: moderate
PR-L.1	Fertilizer use	: 1.0
	Manure applic.	: during grazing
	Residue removal	: 25%
	Erosion	: 25 tonnes/hayr
	Crops	: maiz, sorg, puls, soyb, grou
PR-L.2	Fertilizer use	: 1.0
	Manure applic.	: 500 kg/ha
	Residue removal	: 30%
	Erosion	: 15 tonnes/hayr
	Crops	: pota (30%), spot (30%), cass (30%), vege (30%), frui (30%)

Table 3.95(Cont.)

PR-L.3	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 20 tonnes/hayr
	Crops	: pota (70%), spot (70%), cass (70%), vege (70%), frui (70%)
PR-H.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 15 tonnes/hayr
	Crops	: plan, coff, teas
NF	Rainfall	: 1200 mm
	Soil fertility	: low
NF-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: rice, maiz, mill, sorg, spot, cass, puls
IR	Rainfall	: 1100 mm
	Soil fertility	: moderate
IR-L.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: rice

SENEGAL

Table 3.96 Average annual rainfall for the Land/Water Classes in Senegal (Instituto Geografico De Agostini, 1976) (in mm)

Land/Water Class	Annual rainfall
low rainfall	400
uncertain rainfall	900
good rainfall	1200
problem area	900
naturally flooded	1000
irrigated area	600

(Instituto Geografico De Agostini, 1976)
- farming methods are generally traditional.
- animal husbandry and crop cultivation are not generally integrated.
- Serer people (1/6th of the population) keep cattle and can therefore manure their fields .
- In upper and middle Casamance the Manding and Fouladou possess cattle. Only the Fouladou use manure (uncertain rainfall area)

Table 3.97 Major soil types and average soil fertility class for the Land/Water classes in Senegal (FAO, 1977b and FAO, 1978)

Land/Water class	Major soil types	Average soil fertility class
Low rainfall	Qc, Ql, Je	1
Uncertain rainfall	Ql, Lf, Lg, Re Nd	2
Good rainfall	Lg, Re	2
Problem area		1
Naturally flooded	Lg	2
Irrigated area	Je, Nd	3

(Boughton et al, 1986)
Serer area (Central Uncertain rainfall area).
During the day grazing on the field.
At night livestock is tethered in a particular field.
The manure from draught animals is stocked from December to April and then spread out during soil preparation.
First the millet fields are manured, followed by manuring of the groundnut fields (at a lower intensity 30-50%).
All manure is used.
1/3 of the area is manured.

(Albrecht et al, 1983)
Lower Casamance area (Uncertain rainfall)
Three types of fields:
- Upland fields with groundnut, millet, sorghum and maize.
  15% received manure,
  most crop residues are burned.
- Compound field with maize and sometimes cassava.
  40% of the fiels receive dung, grazing takes place
- Lowland rice fields.
  stubble is grazed.

Large herds which graze outside the agricultural area are kept on the arable fields at night.
In the whole area almost no mineral fertilizers are used.

Table 3.98 Crop residue removal in Senegal (Allard et al, 1983) (in %)

	Casamance	Bassin arachidier South	Bassin arachidier North
Millet	5	13	75
Maize	5		
Sorghum	5		
Rice	5		
Groundnuts	100	100	100

(Charreau, 1972)
Erosion in Séfa (1300 mm rain/yr) at a slope of 1.5% :
7.3 ton/ha,yr under crop and 21.3 ton/ha,yr under bare soil

(Different authors cited by Lal et al, 1989)
rate of erosion from croplands: 14.9 - 55.0 (t/ha/yr).

(Charreau cited by Lal, 1977)
Erosion in Sefa:

groundnuts	6.9 ton/ha/yr
Sorghum	8.4 ton/ha/yr
Maize	10.3 ton/ha/yr

Table 3.99 Erosion in Sefa (Senegal) (Fournier, 1967)

Crop	Slope (%)	Rainfall (mm/yr)	Erosion (ton/ha,yr)
groundnuts	1		17
groundnuts	2		15
sorghum	1	1340	7
sorghum	1.5	1340	14
groundnuts	1	1148	3
groundnuts	1.5	1148	10

Table 3.100 Land use systems description for Senegal

LR	Rainfall	: 400 mm
	Soil fertility	: low
LR-L.1	Fertilizer use	: 0.2
	Manure applic.	: during grazing
	Residue removal	: 80%
	Erosion	: 10 tonnes/hayr
	Crops	: mill, sorg, grou
UR	Rainfall	: 900 mm
	Soil fertility	: moderate
UR-L.1	Fertilizer use	: 0.3
	Manure applic.	: during grazing
	Residue removal	: 50%
	Erosion	: 10 tonnes/hayr
	Crops	: maiz, mill, sorg, othc
UR-L.2	Fertilizer use	: 0.3
	Manure applic.	: during grazing
	Residue removal	: 80%
	Erosion	: 10 tonnes/hayr
	Crops	: puls, grou
UR-L.3	Fertilizer use	: 0.3
	Manure applic.	: none
	Residue removal	: 50%
	Erosion	: 15 tonnes/hayr
	Crops	: spot, cass, vege, frui
UR-L.4	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 15 tonnes/hayr
	Crops	: cott

Table 3.100(Cont.)

GR	Rainfall	: 1200 mm
	Soil fertility	: moderate
GR-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 30%
	Erosion	: 15 tonnes/hayr
	Crops	: maiz, mill, sorg
GR-L.2	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 95%
	Erosion	: 15 tonnes/hayr
	Crops	: grou
GR-L.3	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 30%
	Erosion	: 10 tonnes/hayr
	Crops	: pota, spot, vege
GR-L.4	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 5 tonnes/hayr
	Crops	: cocn
GR-H.1	Fertilizer use	: 2.0
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 10 tonnes/hayr
	Crops	: frui
GR-H.2	Fertilizer use	: 2.0
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 15 tonnes/hayr
	Crops	: cott
PR	Rainfall	: 900 mm
	Soil fertility	: low
PR-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 10 tonnes/hayr
	Crops	: rice, mill, sorg, puls, grou
PR-L.2	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 5 tonnes/hayr
	Crops	: palm
NF	Rainfall	: 1000 mm
	Soil fertility	: moderate
NF-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 0 tonnes/hayr
	Crops	: rice, mill, sorg, othc

Table 3.100(Cont.)

IR	Rainfall	: 600 mm
	Soil fertility	: high
IR-H.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 5%
	Erosion	: 0 tonnes/hayr
	Crops	: rice, pota, cane, vege, bana, citr, frui
IR-H.2	Fertilizer use	: 2.5
	Manure applic.	: none
	Residue removal	: 75%
	Erosion	: 0 tonnes/hayr
	Crops	: puls
IR-H.3	Fertilizer use	: 2.0
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 0 tonnes/hayr
	Crops	: cott

SIERRA LEONE

Table 3.101 Average annual rainfall for the Land/Water Classes in Sierra Leone (Instituto Geografico De Agostini, 1976) (in mm)

Land/Water Class	Annual rainfall
good rainfall	2000
problem area	2500
naturally flooded	2500
irrigated area	2700

(Instituto Geografico De Agostini, 1976)
Small amount of cattle in non-agricultural area.

Table 3.102 Major soil types and average soil fertility class for the Land/Water classes in Sierra Leone (FAO, 1977b and FAO, 1978)

Land/Water class	Major soil types	Average soil fertility class
Good rainfall	Fo	1
Problem area	Fo, Fp	1
Naturally flooded	Fo	1
Irrigated area	Fo	1

(Knickel, 1988):
In 63% of the developed swamps no fertilizer application takes place. No mention of crop residue removal.

(Gwynne-Jones et al, 1978):
Cattle rearing only occurs in north-east of Sierra Leone. In the wet season cattle is kept in enclosures. During the dry season cattle is left wandering around. No information on manure or grazing of crop residues.

Table 3.103 Land use systems description for Sierra Leone

GR	Rainfall	: 2000 mm
	Soil fertility	: low
GR-L.1	Fertilizer use	: 1.0
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 20 tonnes/hayr
	Crops	: rice, maiz, mill, sorg, puls, grou
GR-L.2	Fertilizer use	: 1.0
	Manure applic.	: 500 kg/ha
	Residue removal	: 50%
	Erosion	: 15 tonnes/hayr
	Crops	: spot, cass, vege, frui
GR-H.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 20 tonnes/hayr
	Crops	: plan, citr
PR	Rainfall	: 2500 mm
	Soil fertility	: low
PR-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 20 tonnes/hayr
	Crops	: rice, maiz, mill, sorg, othc, spot, cass, othr, puls, vege, frui, grou, sesa, fibr
PR-H.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 10 tonnes/hayr
	Crops	: plan, palm, cocn, coco, coff
NF	Rainfall	: 2500 mm
	Soil fertility	: low
NF-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: rice
NF-L.2	Fertilizer use	: 0.6
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: cass, othr, vege
IR	Rainfall	: 2700 mm
	Soil fertility	: low
IR-H.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 0 tonnes/hayr
	Crops	: rice

SOMALIA

Table 3.104 Average annual rainfall for the Land/Water Classes in Somalia (Instituto Geografico De Agostini, 1976) (in mm)

Land/Water Class	Annual rainfall
low rainfall	400
uncertain rainfall	650
problem area	600
naturally flooded	700
irrigated area	600

(Instituto Geografico De Agostini, 1976)
Commercial plantations with sugar cane and bananas.

Table 3.105 Major soil types and average soil fertility class for the Land/Water classes in Somalia (FAO, 1977b and FAO, 1978)

Land/Water class	Major soil types	Average soil fertility class
Low rainfall	Rc, Yk, Xk, Ne	3
Uncertain rainfall	Bk	3
Problem area	So, Zo	1
Naturally flooded	Vc	3
Irrigated area	Xk, Vc, Jc	3

Table 3.106 Relative soil loss for the Land/Water Classes in Somalia (Hakkeling, 1989)

Land/Water class	Relative soil loss
Low rainfall	2
Uncertain rainfall	3
Problem area	2

Table 3.107 Land use systems description for Somalia

LR	Rainfall	: 400 mm
	Soil fertility	: high
LR-L.1	Fertilizer use	: 0.2
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 10 tonnes/hayr
	Crops	: maiz, sorg, puls, grou, sesa
LR-L.2	Fertilizer use	: 0.4
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 10 tonnes/hayr
	Crops	: frui
UR	Rainfall	: 650 mm
	Soil fertility	: high
UR-L.1	Fertilizer use	: 0.6
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 15 tonnes/hayr
	Crops	: maiz
UR-L.2	Fertilizer use	: 0.6
	Manure applic.	: 500 kg/ha
	Residue removal	: 50%
	Erosion	: 15 tonnes/hayr
	Crops	: cass
UR-L.3	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 15 tonnes/hayr
	Crops	: cott
PR	Rainfall	: 600 mm
	Soil fertility	: low
PR-L.1	Fertilizer use	: 1.0
	Manure applic.	: during grazing
	Residue removal	: 80%
	Erosion	: 10 tonnes/hayr
	Crops	: sorg
NF	Rainfall	: 700 mm
	Soil fertility	: high
NF-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: maiz, sorg, puls, vege

Table 3.107(Cont.)

IR	Rainfall	: 600 mm
	Soil fertility	: high
IR-H.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 40%
	Erosion	: 0 tonnes/hayr
	Crops	: whea, rice, maiz, sorg, vege, grou
IR-H.2	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 5%
	Erosion	: 0 tonnes/hayr
	Crops	: bana, citr, cocn
IR-H.3	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: cane

SUDAN

Table 3.108 Average annual rainfall for the Land/Water Classes in Sudan (Instituto Geografico De Agostini, 1976) (in mm)

Land/Water Class	Annual rainfall
low rainfall	300
uncertain rainfall	800
good rainfall	1100
problem area	1400
naturally flooded	700
irrigated area	300

Table 3.109 Major soil types and average soil fertility class for the Land/Water classes in Sudan (FAO, 1977b and FAO, 1978)

Land/Water class	Major soil types	Average soil fertility class
Low rainfall	Xh, Qc, Lc, V	2
Uncertain rainfall	Rd, V	2
Good rainfall	Fp, Lf	1
Problem area	Fo	1
Naturally flooded	V	3
Irrigated area	Y	1

(Abu Sin, 1982)
Butana (Low rainfall)
- Due to the expansion of agricultural schemes in Butana pastoral nomadism in Butana is undergoing a rapid change. Even though such schemes caused a reduction in natural pastures, they provided the nomads with supplementary fodders (crop remains).

(FAO, 1986)
Farmyard manure is of some importance in mixed farming systems. In the irrigated Gezira there is little or no use of FYM and the small amounts that are available are sometimes wasted. In the irrigated riverine areas of the north appreciable amounts of FYM are used, mainly on vegetables, citrus and mangos. The practice of herding animals on the cultivated land is also common in some regions. In the south the Dinka tribe, who are large cattle owners, practice a system of manure application in which cattle are penned on the same site for three nights, providing a liberal dressing of dung and urine.

Table 3.110 Land use systems description for Sudan

LR	Rainfall	: 300 mm
	Soil fertility	: moderate
LR-L.1	Fertilizer use	: 0.2
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 5 tonnes/hayr
	Crops	: mill, sorg, puls, vege, oilc, grou, sesa
UR	Rainfall	: 800 mm
	Soil fertility	: moderate
UR-L.1	Fertilizer use	: 0.6
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 10 tonnes/hayr
	Crops	: maiz, mill, sorg, grou, sesa
UR-L.2	Fertilizer use	: 0.6
	Manure applic.	: 500 kg/ha
	Residue removal	: 50%
	Erosion	: 10 tonnes/hayr
	Crops	: spot, cass, frui, fodd
UR-L.3	Fertilizer use	: 0.6
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 10 tonnes/hayr
	Crops	: cott
GR	Rainfall	: 1100 mm
	Soil fertility	: low
GR-L.1	Fertilizer use	: 1.0
	Manure applic.	: during grazing
	Residue removal	: 50%
	Erosion	: 15 tonnes/hayr
	Crops	: maiz, mill, sorg, grou, sesa
GR-L.2	Fertilizer use	: 1.0
	Manure applic.	: 500 kg/ha
	Residue removal	: 30%
	Erosion	: 10 tonnes/hayr
	Crops	: spot, cass, frui, fodd
GR-L.3	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 15 tonnes/hayr
	Crops	: cott
PR	Rainfall	: 1400 mm
	Soil fertility	: low
PR-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 50%
	Erosion	: 20 tonnes/hayr
	Crops	: maiz, sorg

Table 3.110(Cont.)

PR-L.2	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 25%
	Erosion	: 10 tonnes/hayr
	Crops	: spot, cass
PR-H.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 5%
	Erosion	: 5 tonnes/hayr
	Crops	: teas
NF	Rainfall	: 700 mm
	Soil fertility	: high
NF-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: rice, mill, sorg
IR	Rainfall	: 300 mm
	Soil fertility	: low
IR-L.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: pota, spot, vege, frui, oilc, fodd
IR-H.1	Fertilizer use	: 3.0
	Manure applic.	: none
	Residue removal	: 40%
	Erosion	: 0 tonnes/hayr
	Crops	: whea, rice, maiz, sorg, puls, grou
IR-H.2	Fertilizer use	: 3.0
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 0 tonnes/hayr
	Crops	: cott
IR-H.3	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 5%
	Erosion	: 0 tonnes/hayr
	Crops	: cane, bana, citr

SWAZILAND

Table 3.111 Average annual rainfall for the Land/Water Classes in Swaziland (Instituto Geografico De Agostini, 1976) (in mm)

Land/Water Class	Annual rainfall
low rainfall	600
uncertain rainfall	850
good rainfall	1250
problem area	1100
irrigated area	800

Table 3.112 Major soil types and average soil fertility class for the Land/Water classes in Swaziland (FAO, 1977b and FAO, 1978)

Land/Water class	Major soil types	Average soil fertility class
Low rainfall	Bc	2
Uncertain rainfall	Lc	2
Good rainfall	Fr, Ne	2
Problem area	We	2
Irrigated area	(?)	2

Table 3.113 Relative soil loss for the Land/Water Classes in Swaziland (Hakkeling, 1989)

Land/Water class	Relative soil loss
Low rainfall	4
Uncertain rainfall	4
Good rainfall	3

Table 3.114 Land use systems description for Swaziland

LR	Rainfall	: 600 mm
	Soil fertility	: moderate
LR-L.1	Fertilizer use	: 0.2
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 15 tonnes/hayr
	Crops	: maiz, sorg

Table 3.114(Cont.)

LR-L.2	Fertilizer use	: 0.2
	Manure applic.	: 500 kg/ha
	Residue removal	: 75%
	Erosion	: 10 tonnes/hayr
	Crops	: vege, frui
LR-L.3	Fertilizer use	: 0.2
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 15 tonnes/hayr
	Crops	: cott
UR	Rainfall	: 850 mm
	Soil fertility	: moderate
UR-L.1	Fertilizer use	: 0.6
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 15 tonnes/hayr
	Crops	: maiz, grou
UR-L.2	Fertilizer use	: 0.6
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 15 tonnes/hayr
	Crops	: pota, spot, vege, frui
UR-L.3	Fertilizer use	: 0.6
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 15 tonnes/hayr
	Crops	: cott
GR	Rainfall	: 1250 mm
	Soil fertility	: moderate
GR-L.1	Fertilizer use	: 1.0
	Manure applic.	: during grazing
	Residue removal	: 35%
	Erosion	: 15 tonnes/hayr
	Crops	: whea, maiz, puls, grou
GR-L.2	Fertilizer use	: 1.0
	Manure applic.	: 500 kg/ha
	Residue removal	: 25%
	Erosion	: 10 tonnes/hayr
	Crops	: pota, spot, vege
GR-L.3	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 15 tonnes/hayr
	Crops	: cott
GR-H.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 5%
	Erosion	: 5 tonnes/hayr
	Crops	: citr, frui

Table 3.114(Cont.)

PR	Rainfall	: 1100 mm
	Soil fertility	: moderate
PR-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 25%
	Erosion	: 20 tonnes/hayr
	Crops	: maiz
IR	Rainfall	: 800 mm
	Soil fertility	: moderate
IR-H.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: rice, cane
IR-H.2	Fertilizer use	: 2.0
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 0 tonnes/hayr
	Crops	: cott

TANZANIA

Table 3.115 Average annual rainfall for the Land/Water Classes in Tanzania (Instituto Geografico De Agostini, 1976) (in mm)

Land/Water Class	Annual rainfall
low rainfall	550
uncertain rainfall	750
good rainfall	900
problem area	800
naturally flooded	900
irrigated area	1000

Table 3.116 Major soil types and average soil fertility class for the Land/Water classes in Tanzania (FAO, 1977b and FAO, 1978)

Land/Water class	Major soil types	Average soil fertility class
Low rainfall	Af, Lf, Bc, Ne	1
Uncertain rainfall	Af, Bk, Bc	2
Good rainfall	Af, Lf, Qf, Fo	1
Problem area	We, Vp, Gp	2
Naturally flooded	Gp, Gh, Vp	2
Irrigated area	Qc, Ne	2

Table 3.117 Relative soil loss for the Land/Water Classes in Tanzania (Hakkeling, 1989)

Land/Water class	Relative soil loss
Low rainfall	4
Uncertain rainfall	2-3
Good rainfall	1-2

(Schultz, 1971):
Feeding livestock in yards has been introduced but takes only place with milking cows. Therefore almost no manure is collected and used. Coffee is grown on plantations, maize by the smallholders.
To prevent erosion, no grazing of the crop residues is allowed. To 'get rid' of the residues, they are frequently burned.

(Ahn, 1977):
At Mpwapwa, measurements on erosion were done under sorghum and losses of 6 - 50 m^3 / ha were recorded.
At Tenguru (near Arusha) erosion plots on deep volcanic soils were established. Great differences in soil loss between bananas and maize are recorded.

(Duckham and Masefield, 1970):
Wheat is grown under high management.

(Baum, 1968):
Kilombero Valley: good rainfall
Sugar is grown by a large estate and many smallholders.
Cotton is only grown by smallholders.
The garden plot around the farms receives poultry manure; crop residues are carried to these plots, where vegetables and peppers are the main products.
On the outlying fields shifting cultivation and semi-permanent hoe cultivation of rice, maize and occasionally cotton is practised.

(Ludwig, 1968):
Ukara: uncertain rainfall
Manuring is generally practised, up to amounts of 4 - 5 ton per acre per year. Every field is manured once in three years.
Erosion control is practised by ridging and terracing fields. Almost all crops are grown with little inputs on smallholdings.

(Friedrich, 1968):
Bukoba: good rainfall
37% of the farmers keep cattle (3-4 head per farm) and can therefore manure their fields.

(Ruthenberg, 1968):
Mt Kilimanjaro: low rainfall
Cattle is fed with crop residues of the bananas. Animal husbandry is practised to obtain manure, to be used for coffee and bananas.

(Different authors cited by Lal et al, 1989):
Rate of erosion from croplands: 10.1 - 92.8 (t/ha/yr).

Table 3.118 Erosion rates in Mlingano (793 mm rain/yr) (Ngatunga et al, 1984) (in ton/ha,yr)

Slope (%)	**Coverage**	
	Grass cover	Bare soil
10	0.08	37.8
19	0.14	92.8
22	0.10	88.2

(FAO, 1986):
The use of FYM is very limited. Only to the limited extent that cattle are zero grazed and stall fed, or where cattle are fenced in at night for safety, are significant amounts of FYM available.

Table 3.119 Land use systems description for Tanzania

LR	Rainfall	: 550 mm
	Soil fertility	: low
LR-L.1	Fertilizer use	: 0.2
	Manure applic.	: during grazing
	Residue removal	: 50%
	Erosion	: 20 tonnes/hayr
	Crops	: maiz, mill, sorg, puls, grou, sesa
LR-L.2	Fertilizer use	: 0.2
	Manure applic.	: 500 kg/ha
	Residue removal	: 75%
	Erosion	: 15 tonnes/hayr
	Crops	: vege, frui, fibr
LR-H.1	Fertilizer use	: 0.8
	Manure applic.	: none
	Residue removal	: 40%
	Erosion	: 15 tonnes/hayr
	Crops	: oilc
UR	Rainfall	: 750 mm
	Soil fertility	: moderate
UR-L.1	Fertilizer use	: 0.6
	Manure applic.	: during grazing
	Residue removal	: 25%
	Erosion	: 15 tonnes/hayr
	Crops	: whea, maiz, mill, sorg, puls, soyb, grou, sesa
UR-L.2	Fertilizer use	: 0.6
	Manure applic.	: 500 kg/ha
	Residue removal	: 50%
	Erosion	: 20 tonnes/hayr
	Crops	: pota, spot, cass, vege, frui, sunf, toba, fibr
UR-L.3	Fertilizer use	: 0.6
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 15 tonnes/hayr
	Crops	: cott

Table 3.119(Cont.)

GR	Rainfall	: 900 mm
	Soil fertility	: low
GR-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 30%
	Erosion	: 20 tonnes/hayr
	Crops	: whea, maiz, barl, mill, sorg, puls, soyb, grou, sesa
GR-L.2	Fertilizer use	: 1.0
	Manure applic.	: 500 kg/ha
	Residue removal	: 30%
	Erosion	: 15 tonnes/hayr
	Crops	: pota, spot, cass, plan (50%), vege, bana (50%), frui, sunf, toba, fibr
GR-L.3	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 20 tonnes/hayr
	Crops	: cott (75%)
GR-H.1	Fertilizer use	: 1.5
	Manure applic.	: 500 kg/ha
	Residue removal	: 30%
	Erosion	: 10 tonnes/hayr
	Crops	: plan (50%), bana (50%), cocn, coff, teas
GR-H.2	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 20 tonnes/hayr
	Crops	: cott (25%)
PR	Rainfall	: 800 mm
	Soil fertility	: low
PR-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 20 tonnes/hayr
	Crops	: whea, rice, maiz, mill, sorg, puls, grou
PR-L.2	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 20 tonnes/hayr
	Crops	: pota, spot, cass, plan (75%), vege, bana (25%), frui
PR-H.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 30%
	Erosion	: 10 tonnes/hayr
	Crops	: plan (25%), bana (75%), palm, cocn, coff, teas

Table 3.119(Cont.)

PR-H.2	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 10 tonnes/hayr
	Crops	: cane
NF	Rainfall	: 900 mm
	Soil fertility	: moderate
NF-L.1	Fertilizer use	: 0.6
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: rice, teas
IR	Rainfall	: 1000 mm
	Soil fertility	: moderate
IR-H.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 50%
	Erosion	: 0 tonnes/hayr
	Crops	: rice, maiz
IR-H.2	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 0 tonnes/hayr
	Crops	: cane, citr, frui, coff

TOGO

Table 3.120 Average annual rainfall for the Land/Water Classes in Togo (Instituto Geografico De Agostini, 1976) (in mm)

Land/Water Class	Annual rainfall
uncertain rainfall	700
good rainfall	1200
problem area	1500
naturally flooded	1600
irrigated area	900

(Instituto Geografico De Agostini, 1976):
- Farm land on slopes is terraced.
- They build dry-stone walled manure heaps to contain animal manure, straw and kitchen compost and ashes, and as well applying this manure to the crops they plant green crops for ploughing in.

Table 3.121 Major soil types and average soil fertility class for the Land/Water classes in Togo (FAO, 1977b and FAO, 1978)

Land/Water class	Major soil types	Average soil fertility class
Uncertain rainfall	Nd	2
Good rainfall	Lf, Lp	1
Problem area	Lf	1
Naturally flooded	Je	3
Irrigated area	Je	3

(World Bank, 1988):
100% of the cotton producers apply mineral fertilizers. Ultra low volume spraying techniques are used by 67% of the farmers. 5% of the area under cotton is cultivated with animal traction. Tractor cultivation is not mentioned.

Table 3.122 Land use systems description for Togo

UR	Rainfall	: 700 mm
	Soil fertility	: moderate
UR-L.1	Fertilizer use	: 0.6
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 10 tonnes/hayr
	Crops	: maiz, othc, puls

Table 3.122(Cont.)

UR-L.2	Fertilizer use	: 0.6
	Manure applic.	: 500 kg/ha
	Residue removal	: 50%
	Erosion	: 5 tonnes/hayr
	Crops	: spot, cass, vege, oilc
UR-L.3	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 10 tonnes/hayr
	Crops	: cott
GR	Rainfall	: 1200 mm
	Soil fertility	: low
GR-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 40%
	Erosion	: 25 tonnes/hayr
	Crops	: rice, maiz, mill, sorg, othc, puls, grou, sesa
GR-L.2	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 20 tonnes/hayr
	Crops	: spot, cass, othr, vege, frui, oilc, toba
GR-L.3	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 20 tonnes/hayr
	Crops	: cott
GR-L.4	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 10 tonnes/hayr
	Crops	: bana, citr
PR	Rainfall	: 1500 mm
	Soil fertility	: low
PR-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 30%
	Erosion	: 10 tonnes/hayr
	Crops	: rice, maiz, mill, sorg, puls, grou
PR-L.2	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 5 tonnes/hayr
	Crops	: spot, cass
PR-L.3	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: palm, cocn, coco, coff

Table 3.122(Cont.)

NF	Rainfall	: 1600 mm
	Soil fertility	: high
NF-L.1	Fertilizer use	: 0.6
	Manure applic.	: none
	Residue removal	: 40%
	Erosion	: 0 tonnes/hayr
	Crops	: rice
NF-L.2	Fertilizer use	: 0.6
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: spot, othr, vege, bana
IR	Rainfall	: 900 mm
	Soil fertility	: high
IR-H.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: rice, spot, vege

UGANDA

Table 3.123 Average annual rainfall for the Land/Water Classes in Uganda (Instituto Geografico De Agostini, 1976) (in mm)

Land/Water Class	Annual rainfall
low rainfall	300
uncertain rainfall	800
good rainfall	1100
problem area	1400
naturally flooded	700
irrigated area	300

Table 3.124 Major soil types and average soil fertility class for the Land/Water classes in Uganda (FAO, 1977b and FAO, 1978)

Land/Water class	Major soil types	Average soil fertility class
Low rainfall	Af	1
Uncertain rainfall	Fo	1
Good rainfall	Af	1
Problem area	Fo	1
Naturally flooded	G	2
Irrigated area	(?)	2

Table 3.125 Relative soil loss for the Land/Water Classes in Uganda (Hakkeling, 1989)

Land/Water class	Relative soil loss
Low rainfall	2-3
Uncertain rainfall	1-3
Good rainfall	1-2
Problem area	2

(Hougham and Sturrock, 1973):
Just a small part of the coffee is still grown on small farms. Most coffee is nowadays grown at big enterprises. Sugarcane and Tea are also grown on large estates.

(Ahn, 1977):
Perennial crops such as bananas and coffee are mulched in most districts.
Serious erosion occurs on the steep cultivated slopes of the Ruwenzori and in the hilly, densely populated West Nile district. The coarse sandy loams in central and northern Uganda are very liable to erosion. In Southern Uganda more clayey soils occur with moderate sheet erosion. In the Karamoja district, severe erosion is confined to the pastures.

(Duckham and Masefield, 1970)
Wheat is grown under high management.
No important input of manure.
Western Uganda: Sugar is grown under high management.
Cotton is the most important cash crop.
Central Uganda: Coffee is the most important cash crop followed by cotton.

Table 3.126 Erosion rates under different crops in Uganda (Sperow and Keefer cited by Lal, 1977) (in ton/season)

Crop	**Soil loss**
bare, cultivated plot	81.5
Maize, annually	34.0
Cowpeas, annually	26.6

(Braun, 1974):
Groundnuts, millet, guinea corn and cotton are grown in rotation under shifting cultivation.
On farmers level soil conservation takes place by contour strip cropping.

Table 3.127 Land use systems description for Uganda

LR	Rainfall	: 800 mm
	Soil fertility	: low
LR-L.1	Fertilizer use	: 0.2
	Manure applic.	: during grazing
	Residue removal	: 50%
	Erosion	: 20 tonnes/hayr
	Crops	: mill, sorg, puls, grou, sesa, oilc

Table 3.127(Cont.)

UR	Rainfall	: 1000 mm
	Soil fertility	: low
UR-L.1	Fertilizer use	: 0.6
	Manure applic.	: during grazing
	Residue removal	: 50%
	Erosion	: 15 tonnes/hayr
	Crops	: whea, maiz, mill, sorg, puls, soyb, grou, sesa
UR-L.2	Fertilizer use	: 0.6
	Manure applic.	: none
	Residue removal	: 30%
	Erosion	: 10 tonnes/hayr
	Crops	: pota, spot, cass, vege, frui, oilc, sunf, toba
UR-L.3	Fertilizer use	: 0.6
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 15 tonnes/hayr
	Crops	: cott
GR	Rainfall	: 1200 mm
	Soil fertility	: low
GR-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 25%
	Erosion	: 20 tonnes/hayr
	Crops	: whea, maiz, mill, sorg, puls, soyb, grou, sesa
GR-L.2	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 30%
	Erosion	: 10 tonnes/hayr
	Crops	: pota, spot, cass, plan, vege, bana, frui, sunf, coff, toba
GR-L.3	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 20 tonnes/hayr
	Crops	: cott
PR	Rainfall	: 1200 mm
	Soil fertility	: low
PR-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 15 tonnes/hayr
	Crops	: rice, maiz, mill, sorg, puls, grou, sesa
PR-L.2	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 10 tonnes/hayr
	Crops	: pota, spot, cass, plan (50%), frui

Table 3.127(Cont.)

PR-L.3	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 5 tonnes/hayr
	Crops	: plan (50%), bana (75%)
PR-H.1	Fertilizer use	: 2.0
	Manure applic.	: none
	Residue removal	: 5%
	Erosion	: 15 tonnes/hayr
	Crops	: cane, bana (25%), coff, teas
NF	Rainfall	: 1200 mm
	Soil fertility	: moderate
NF-L.1	Fertilizer use	: 0.6
	Manure applic.	: none
	Residue removal	: 15%
	Erosion	: 0 tonnes/hayr
	Crops	: rice, mill, sorg, spot, puls, vege
IR	Rainfall	: 1200 mm
	Soil fertility	: moderate
IR-L.1	Fertilizer use	: 2.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: rice
IR-H.1	Fertilizer use	: 2.5
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 0 tonnes/hayr
	Crops	: cane

ZAIRE

Table 3.128 Average annual rainfall for the Land/Water Classes in Zaire (Instituto Geografico De Agostini, 1976) (in mm)

Land/Water Class	Annual rainfall
low rainfall	300
uncertain rainfall	800
good rainfall	1100
problem area	1400
naturally flooded	700
irrigated area	300

Table 3.129 Major soil types and average soil fertility class for the Land/Water classes in Zaire (FAO, 1977b and FAO, 1978)

Land/Water class	Major soil types	Average soil fertility class
Good rainfall	Fo, Fx, Nd, Qf	1
Problem area	Fr, Fo, Fx	2
Naturally flooded	Gd, Gh	2
Irrigated area	Nh, Nd	2

(Scott, 1988):
Small producers located in the higher regions grow potatoes.

(FAO, 1986):
Various methods of organic manuring are known in Zaire but none is widely practised and their importance in Zairean agriculture is minimal. Animal dropppings are sometimes used by small farmers in the savannah and highland regions for vegetable production. They are rarely used for the main food crops.

Table 3.130 Land use systems description for Zaire

GR	Rainfall	: 1200 mm
	Soil fertility	: low
GR-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 40%
	Erosion	: 10 tonnes/hayr
	Crops	: whea, rice, maiz, mill, sorg, puls, soyb, grou, sesa

Table 3.130(Cont.)

GR-L.2	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 5 tonnes/hayr
	Crops	: pota, spot (50%), cass, othr (50%), frui, toba
GR-L.3	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 10 tonnes/hayr
	Crops	: cott
GR-L.4	Fertilizer use	: 0.5
	Manure applic.	: 500 kg/ha
	Residue removal	: 10%
	Erosion	: 3 tonnes/hayr
	Crops	: spot (50%), othr (50%), vege
GR-L.5	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 0%
	Erosion	: 0 tonnes/hayr
	Crops	: plan, bana, citr
PR	Rainfall	: 1200 mm
	Soil fertility	: moderate
PR-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 10 tonnes/hayr
	Crops	: rice, maiz, mill, sorg, puls, grou, sesa
PR-L.2	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 5 tonnes/hayr
	Crops	: pota, spot (50%), cass, othr (50%), cane, frui, toba
PR-L.3	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 10 tonnes/hayr
	Crops	: cott
PR-L.4	Fertilizer use	: 0.5
	Manure applic.	: 500 kg/ha
	Residue removal	: 10%
	Erosion	: 3 tonnes/hayr
	Crops	: spot (50%), othr (50%), vege
PR-L.5	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 5%
	Erosion	: 5 tonnes/hayr
	Crops	: plan, bana (75%), citr, palm (50%), coco, coff (25%), teas (50%)

Table 3.130(Cont.)

PR-H.1	Fertilizer use	: 2.0
	Manure applic.	: none
	Residue removal	: 0%
	Erosion	: 8 tonnes/hayr
	Crops	: bana (25%), palm (50%), coff (75%), teas (50%), rubb
NF	Rainfall	: 1200 mm
	Soil fertility	: moderate
NF-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 0 tonnes/hayr
	Crops	: rice, vege, puls
NF-L.2	Fertilizer use	: 0.6
	Manure applic.	: none
	Residue removal	: 5%
	Erosion	: 0 tonnes/hayr
	Crops	: coff (75%), teas (75%)
NF-H.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 5%
	Erosion	: 0 tonnes/hayr
	Crops	: coff (25%), teas (25%)
IR	Rainfall	: 1200 mm
	Soil fertility	: moderate
IR-H.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: rice
IR-H.2	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 0 tonnes/hayr
	Crops	: cane

ZAMBIA

Table 3.131 Average annual rainfall for the Land/Water Classes in Zambia (Instituto Geografico De Agostini, 1976) (in mm)

Land/Water Class	Annual rainfall
low rainfall	300
uncertain rainfall	800
good rainfall	1100
problem area	1400
naturally flooded	700
irrigated area	300

Table 3.132 Major soil types and average soil fertility class for the Land/Water classes in Zambia (FAO, 1977b and FAO, 1978)

Land/Water class	Major soil types	Average soil fertility class
Low rainfall	Lc	2
Uncertain rainfall	Lc, Fo	2
Good rainfall	Fo, Fr, Qc	1
Problem area	Vp, G	2
Naturally flooded	Gc, Ge, Vp	3
Irrigated area	Lc, Fr, Fo	2

Table 3.133 Relative soil loss for the Land/Water Classes in Zambia (Hakkeling, 1989)

Land/Water class	Relative soil loss
Low rainfall	2-3
Uncertain rainfall	1-3
Good rainfall	1-2

(Braun, 1974):
The following crops are grown in rotation under shifting cultivation:
grass fallow : cassava, sweet potatoes and maize,
bush fallow : millet beans and groundnuts,
stumped fields: maize.

Table 3.134 Acreage under different crops in different management sectors (FAO, 1987 b)

Crop	Sector	Acreage
Maize	commercial	50.000
	emergent	100.000
	small scale	187.500
Wheat	commercial	10.000
Rice	emergent	10.000
Sunflower	emergent	30.000
Sugarcane	emergent	10.000
Cotton	emergent	30.000
Tobacco	emergent	2.500
Other crops		5.000

(FAO, 1987 b):
"kraaling" of cattle is commonly practiced.

(FAO, 1986):
The use of animal wastes is limited. Only in the Southern, Western and Central provinces some use takes place. Especially among small scale farmers in rural areas who keep cattle and grow maize, sorghum and millet, dung is collected from kraals and carted to the fields where it is spread.
In many parts of the country, it is common practice for farmers to plough residues of the previous crop back into the soil. Thus maize and sorghum stalks, wheat and rice straw, groundnut, bean and soybean haulms are frequently returned. In mixed farming areas where cattle rearing is predominant crop residues are usually eaten by cattle in the fields soon after harvest. In the process dung is left on the field.

Table 3.135 Land use systems description for Zambia

UR	Rainfall	: 1000 mm
	Soil fertility	: moderate
UR-L.1	Fertilizer use	: 0.6
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 15 tonnes/hayr
	Crops	: mill, sorg, puls, grou
UR-L.2	Fertilizer use	: 0.6
	Manure applic.	: 500 kg/ha
	Residue removal	: 50%
	Erosion	: 10 tonnes/hayr
	Crops	: cass, frui, toba
UR-L.3	Fertilizer use	: 0.6
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 15 tonnes/hayr
	Crops	: cott

Table 3.135(Cont.)

UR-H.1	Fertilizer use	: 1.0
	Manure applic.	: during grazing
	Residue removal	: 50%
	Erosion	: 15 tonnes/hayr
	Crops	: maiz
UR-H.2	Fertilizer use	: 1.2
	Manure applic.	: none
	Residue removal	: 25%
	Erosion	: 10 tonnes/hayr
	Crops	: spot, vege, sunf
GR	Rainfall	: 1200 mm
	Soil fertility	: low
GR-L.1	Fertilizer use	: 1.0
	Manure applic.	: during grazing
	Residue removal	: 50%
	Erosion	: 10 tonnes/hayr
	Crops	: mill (50%), sorg (50%), puls (50%), soyb (50%), grou (50%)
GR-L.2	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 0%
	Erosion	: 5 tonnes/hayr
	Crops	: mill (50%), sorg (50%), puls (50%), soyb (50%), grou (50%)
GR-L.3	Fertilizer use	: 1.0
	Manure applic.	: 500 kg/ha
	Residue removal	: 30%
	Erosion	: 5 tonnes/hayr
	Crops	: spot, cass, vege, frui, sunf, toba
GR-L.4	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 5%
	Erosion	: 0 tonnes/hayr
	Crops	: citr
GR-H.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 5%
	Erosion	: 5 tonnes/hayr
	Crops	: maiz
GR-H.2	Fertilizer use	: 2.0
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 10 tonnes/hayr
	Crops	: cott
PR	Rainfall	: 1200 mm
	Soil fertility	: moderate
PR-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 10 tonnes/hayr
	Crops	: mill, sorg, grou

Table 3.135(Cont.)

PR-L.2	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 5 tonnes/hayr
	Crops	: cass, vege
PR-H.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 5%
	Erosion	: 10 tonnes/hayr
	Crops	: maiz
PR-H.2	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 5%
	Erosion	: 5 tonnes/hayr
	Crops	: frui
NF	Rainfall	: 1200 mm
	Soil fertility	: high
NF-L.1	Fertilizer use	: 0.6
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 0 tonnes/hayr
	Crops	: rice, mill, sorg
IR	Rainfall	: 1200 mm
	Soil fertility	: moderate
IR-L.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 0 tonnes/hayr
	Crops	: rice, vege, frui
IR-L.2	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 0 tonnes/hayr
	Crops	: cane (50%)
IR-L.3	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 0 tonnes/hayr
	Crops	: cott (50%)
IR-H.1	Fertilizer use	: 3.0
	Manure applic.	: none
	Residue removal	: 5%
	Erosion	: 0 tonnes/hayr
	Crops	: whea
IR-H.2	Fertilizer use	: 3.0
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 0 tonnes/hayr
	Crops	: cott (50%)

Table 3.135(Cont.)

IR-H.3	Fertilizer use	: 2.5
	Manure applic.	: none
	Residue removal	: 15%
	Erosion	: 0 tonnes/hayr
	Crops	: cane (50%)

ZIMBABWE

Table 3.136 Average annual rainfall for the Land/Water Classes in Zimbabwe (Instituto Geografico De Agostini, 1976) (in mm)

Land/Water Class	Annual rainfall
low rainfall	300
uncertain rainfall	800
good rainfall	1100
problem area	1400
naturally flooded	700
irrigated area	300

Table 3.137 Major soil types and average soil fertility class for the Land/Water classes in Zimbabawe (FAO, 1977b and FAO, 1978)

Land/Water class	Major soil types	Average soil fertility class
Low rainfall	Qc, Lf, Lc	1
Uncertain rainfall	Lf, Bc	2
Good rainfall	Lf, Bc	2
Problem area	Vp	3
Naturally flooded	Vp	3
Irrigated area	Lf, Lc	2

Table 3.138 Relative soil loss for the Land/Water Classes in Zambia (Hakkeling, 1989)

Land/Water class	Relative soil loss
Low rainfall	1-4
Uncertain rainfall	2-4
Good rainfall	1-4

(Stocking, 1986)
Commercial arable lands: predicted rate of erosion: 15 ton/ha,yr
Communal arable lands : predicted rate of erosion: 50 ton/ha,yr

(Different authors cited by Lal et al, 1989)
Rate of erosion from croplands: 50.0 t/hayr

Table 3.139 Land use systems description for Zimbabwe

LR	Rainfall	: 800 mm
	Soil fertility	: low
LR-L.1	Fertilizer use	: 0.2
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 10 tonnes/hayr
	Crops	: mill, sorg, puls, grou
UR	Rainfall	: 1000 mm
	Soil fertility	: moderate
UR-L.1	Fertilizer use	: 0.6
	Manure applic.	: during grazing
	Residue removal	: 75%
	Erosion	: 15 tonnes/hayr
	Crops	: maiz, mill, sorg, puls, grou
UR-L.2	Fertilizer use	: 0.6
	Manure applic.	: 500 kg/ha
	Residue removal	: 50%
	Erosion	: 10 tonnes/hayr
	Crops	: cass, vege, frui, sunf
UR-H.1	Fertilizer use	: 1.2
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 10 tonnes/hayr
	Crops	: pota, toba, fodd
UR-H.2	Fertilizer use	: 0.6
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 15 tonnes/hayr
	Crops	: cott
GR	Rainfall	: 1200 mm
	Soil fertility	: moderate
GR-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 25 tonnes/hayr
	Crops	: maiz, mill, sorg, puls, soyb, grou
GR-L.2	Fertilizer use	: 1.0
	Manure applic.	: 500 kg/ha
	Residue removal	: 40%
	Erosion	: 20 tonnes/hayr
	Crops	: cass, vege, frui, sunf
GR-H.1	Fertilizer use	: 2.0
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 25 tonnes/hayr
	Crops	: whea, pota, toba, fodd
GR-H.2	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 25 tonnes/hayr
	Crops	: cott

Table 3.139(Cont.)

GR-H.3	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 50%
	Erosion	: 10 tonnes/hayr
	Crops	: bana, citr
PR	Rainfall	: 1200 mm
	Soil fertility	: moderate
PR-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 25 tonnes/hayr
	Crops	: maiz, mill, sorg, puls, grou
PR-L.2	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 20 tonnes/hayr
	Crops	: vege
PR-L.3	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 10 tonnes/hayr
	Crops	: bana, coff (50%), teas (50%)
PR-H.1	Fertilizer use	: 2.0
	Manure applic.	: none
	Residue removal	: 5%
	Erosion	: 10 tonnes/hayr
	Crops	: coff (50%), teas (50%)
NF	Rainfall	: 1200 mm
	Soil fertility	: high
NF-L.1	Fertilizer use	: 1.0
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 0 tonnes/hayr
	Crops	: rice
IR	Rainfall	: 1200 mm
	Soil fertility	: moderate
IR-H.1	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 20%
	Erosion	: 0 tonnes/hayr
	Crops	: whea, rice, maiz, barl, vege
IR-H.2	Fertilizer use	: 1.5
	Manure applic.	: none
	Residue removal	: 50%
	Erosion	: 0 tonnes/hayr
	Crops	: citr

Table 3.139(Cont.)

IR-H.3	Fertilizer use	: 2.5
	Manure applic.	: none
	Residue removal	: 10%
	Erosion	: 0 tonnes/hayr
	Crops	: cane
IR-H.4	Fertilizer use	: 2.5
	Manure applic.	: none
	Residue removal	: burning
	Erosion	: 0 tonnes/hayr
	Crops	: cott

West Africa, general

(Duckham and Masefield, 1970):
West Africa is dominated by small peasant farms. Plantations are relatively rare.

(Ajibola Taylor et al, 1980):
Grain crops are mainly grown on small scale as food crops. Major industrial crops such as cocoa, coffee, rubber, oil palm and coconut palm are grown on a large scale and contribute substantially to the economy in the southern sector while groundnuts, cotton and soybeans represent the major industrial cops of the northern sector.