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Nutrient budgets in relation to the sustainability of indigenous farming systems in northern Nigeria.

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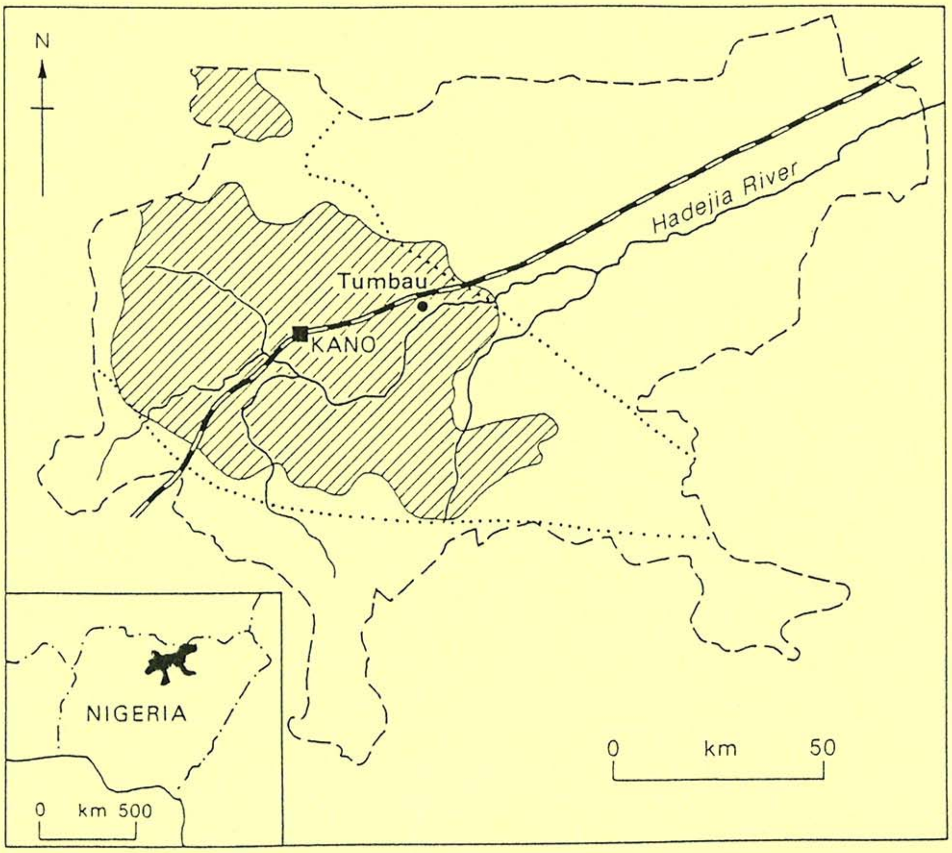

FINAL REPORT

Agronomy and Cropping Systems Programme
NATURAL RESOURCES INSTITUTE

DEPARTMENT OF
GEOGRAPHY

Final report to
Agronomy and Cropping Systems Programme
Natural Resources Institute
on
EMC contract X 0216

"Nutrient Budgets in relation to the sustainability of indigenous farming systems in northern Nigeria."

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Notes:

- To avoid breaking the continuity of the text, all the tables and figures are collected together at the end.
- This report is based on a Ph D dissertation by F M A Harris, entitled "Nutrient dynamics of the farming system of the Kano close settled zone, Nigeria", University fo Cambridge, December, 1995.

"Nutrient Budgets in relation to the sustainability of indigenous farming systems in northern Nigeria."

Summary

The Kano close-settled zone (CSZ) has been the site of an intensive farming system for many years, and for at least the last 30 years all available land has been under annual cultivation. This appears to be a sustainable farming system, but there have not previously been any detailed studies on soil fertility management of this system.

A two year case study has monitored in detail the soil fertility management practices of three farmers within the Kano CSZ. Inputs from organic manure and inorganic fertilizer, Harmattan dust deposition and biological nitrogen fixation by leguminous crops, and outputs in harvested products, have been quantified at the field level. Chemical analyses of these inputs and outputs has enabled a nutrient balance to be calculated for each landholding. The balance varied according to the farmers' management of individual fields, and the effect of rainfall on the size of the harvest, which is the main factor determining nutrient removal from the fields.

It transpires that the key to this farming system is the integration of crop and livestock production. Small ruminants consume crop residues and weeds, and their nutrients (together with those in household waste) are converted to manure, which is transported back to the fields. Legume grains are sold, allowing farmers to purchase inorganic fertilizers if they so wish. Cation nutrients and micronutrients are added to the system in Harmattan dust in the dry season.

The ability of the three farmers to control soil productivity was compared, and the constraints centred on the availability of labour and their relative abilities to invest in yield-enhancing technologies. However, our results demonstrate that the nutrients cycled are able to support this farming system in a sustainable manner.

The results contrast with reports elsewhere from semi-arid west Africa, that crop-livestock systems can only support farming at lower intensities. We have shown that the extra labour available from increasing populations can manage an intensive system of annual cropping in a sustainable manner, when integrated with livestock production.

of wasting money with the deluded notion of teaching modern methods to the northern Nigerian farmers we should be better employed in endeavoring to find an answer to the puzzling question of how it is that land which for centuries has been yielding enormous crops of grain, which in the spring is one carpet of green, and in November one huge cornfield white unto harvest, can continue to do so", quoted in Hill (1982).

The objective of the work reported here is to answer Morel's question from the vantage point of our current understanding of the needs of crops for nutrients and water. By detailed monitoring of farming practices (in particular the use of inputs such as livestock manure, inorganic fertilizers, compound wastes, the role of the Harmattan dust, biological nitrogen fixation, and the measurement of their outputs in harvest yields) and the chemical analysis of all of these components, a nutrient balance has been constructed that indicates whether indeed farmers are managing to restore to the soil the nutrients removed in annual harvests. An additional objective is to understand how the farmers maintain soil fertility. The results will allow us to assess whether it is likely that the farming systems of less densely populated areas could intensify production to meet the demands of increasing populations.

2. Methods of study

The perspective from which this work has developed is the concept of a sustainable farming system, i.e. one which will continue or endure, but this involves not just the physical environment and the biological components of the farm, but the whole household involved in the enterprise, including the social and economic factors that affect the farming system (Castillo, 1992). However, fundamental to this is the maintenance or improvement of the natural resource base as expressed in its chemical and physical properties, and in particular the nutrients required for the crops and stock. Thus nutrient cycling and nutrient budgets are the focus of this work.

A simple nutrient cycling diagram for a cropping situation is shown in Figure 2, but when livestock are involved they may be considered as *interacting* with the cropping system, consuming fodder and releasing nutrients in manure and urine as shown in Figure 3. However, it soon became obvious that in the Kano CSZ the livestock enterprise is an integral part of the farming system, and the more appropriate theoretical basis for the study is the diagram shown in Figure 4, where crop and livestock are closely *integrated.* To achieve the general objectives outlined above, we need to put numbers onto this diagram for the taken into consideration in calculating the nutrient balance because in any one year the crop would be benefitting from the previous year's manure as well as the current year's supply, and we considered only the total annual input.

Manure deposited by grazing animals during the dry season is another possible input. Estimates were made of this by sampling fields with quadrats, and the amounts were found to be very low. Most of the dry season manure is deposited in the compounds when the animals are tethered at night.

3.2 Inorganic fertilizers. A small amount of inorganic fertilizer was used by some of the farmers. The amounts of fertilizer used by the three farmers on their various fields were weighed, samples of the different types were analysed, and the inputs resulting from this for the two years are given in Tables 6 and 7.

3.3 Harmattan dust. It has always been considered by the local farmers that Harmattan dust makes a significant contribution to soil fertility. Detailed studies of the nature, amounts and chemical composition of harmattan dust have been made in the past. Dust collecting traps were erected both at Tumbau and at Kano (the latter to allow us to relate the Tumbau depostions to the extensive data sets obtained in the past for Kano), and the dust analyses in the literature were used to make an estimate of the inputs to the fields under study. These are given in Table 8.

3.4 Nitrogen fixation. The growth of the leguminous crops cowpea and groundnut, mostly intercropped with the cereals millet and sorghum, would be expected to make an important contribution to the nitrogen budget. It is difficult to measure nitrogen fixation accurately without sophisticated equipment. An experiment was performed in 1994 based on the N-difference method Hauser (1992). A small plot of land was borrowed from one of the farmers, and a trial involving the synchronous growth of maize, groundnut and cowpea was undertaken to estimate the increase in N uptake by the legumes over that taken up by the maize. Knowing the numbers and distribution of these leguminous crops in the fields being studied, it was then possible to make an estimate of N fixation for all the fields being monitored. This is shown for 1993 in Table 9, and for 1994 in Tables 10, 11 and 12.

3.5 Total nutrient inputs. Using the data already described, these are summarised in Table 13. The 1993 data indicated that the cation nutrients K, Ca and Mg were in unlikely to be limiting, and in view of both some difficulties that has to be considered in relation to the use made of the harvested material, shown in Figure 8. An important point coming out of this is that the amount of fodder from one year determines the amount of manure for the next year. Higher rainfall gives higher yields all round, which permits farmers to earn a profit, some of which may be invested in fertilizers; it also produces more fodder which permits formers to keep more livestock through the dry season and hence have more taki in the following season.

The detailed data for the nitrogen and phosphorus cycling between the various components of the biomass for the two seasons are given in Figures 9 and 10. Most of the phosphorus input has come from the manure, but a considerable proportion of the nitrogen input has come from fixation by the leguminous crops. The leguminous fodder is a nutritious animal feed, but the nuts and beans are mostly sold in the markets. The latter is a nutrient leakage from the system, but it may allow the farmers to replace the leakage by having sufficient money to buy some fertilizer.

Livestock convert crop residues and weeds into manure, which when applied to the land gradually decomposes and releases nutrients to crops and soil. The added organic matter can also be assumed to make a small increase in the cation-exchange capacity, the water-holding capacity and the structural stability of these poor sandy soils, although these components were not measured in this study.

The Harmattan dust provides mainly K, Mg and Ca, small amounts of micronutrients and a little organic matter.

The data produced here may be taken as an indication of the balance rather than a definitive quantitative balance, both because the actual balance clearly varies strongly between seasons, and because the estimate of nitrogen fixation was relatively crude. However, identifying and quantifying the various components of the nutrient flow through the system has helped us to understand how this sustainable farming system works. The negative nitrogen balance in 1994 may be partly due to under-estimation of N fixation, but is clearly also due to the high yields obtained by the higher rainfall that year. Because this is likely to produce more manure the next year, these seasonal fluctuations would be expected to even out the nutrient balance over a number of years, and the soil will provide sufficient reserve to feed crops in a particularly demanding year.

These conclusions are presented diagramatically in Figure 12, and indicate that the transition from separate livestock and crop enterprises at a low level of production to an integrated crop-livestock system at a higher level of production requires more labour and so can only take place when population increases. This carries with it the important conclusion (following Boserup, 1965) that an increased population density, far from leading to land degradation and unsustainable agriculture, is in fact a necessary component of a higher production system, which we have shown here can have a balanced nutrient budget and be sustainable in the long term.

6. Key References

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Table 1

The three farmers selected for the study

	Farmer I	Farmer Y	Farmer S
size of landholding	1.4 ha	3.0 ha	0.66 ha
no. of fields	3	4	5
location of fields	close to compound	3 adjacent to compound, 4th distant	widely dispersed
range of field sizes (ha)	0.2871 - 0.7505	0.5948 - 1.0275	0.07 - 0.2054
predominant soil type	red	white	mixture
<u>taki</u> production in 1992 (t/ha)	3.9	3.1	3.3
use of inorganic fertilizer in 1992 (kg/ha)	28	11	0
livestock owned in 1992 - 1993	5 goats 2 sheep 1 donkey	7 goats 1 ox 1 donkey	7 goats 6 sheep
estimated grain yield in 1992 (t/ha)	1	0.65	2.3
family size	4	9	2

Surface soil properties (0-15 cm) prior to study

field	pH	organic carbon %	nitrogen %	phosphorus * ppm	potassium %	magnesium %	calcium %
Farmer I 1	6.3	0.24	0.06	33.63	0.17		3.19
Farmer I 2	6.4	0.23	0.04	30.66	0.16	0.49	2.06
Farmer I 3	6	0.29	0.07	25.09	0.11	0.38	1.78
Farmer Y 1	6	0.28	0.07	25.54	0.18	0.46	2.10
Farmer Y 2	6.4	0.21	0.06	26.48	0.27	0.51	2.30
Farmer Y 3	6	0.30	0.06	29.76	0.14	0.53	2.60
Farmer Y 4	6	0.21	0.04	20.57	0.24	0.64	2.28
Farmer S 1	6.2	0.23	0.06	26.83	0.19	0.69	2.62
Farmer S 2	6.6	0.26	0.07	40.19	0.13	0.48	2.30
Farmer S 3	6.5	0.17	0.03	26.73	0.11	0.53	2.20
Farmer S 4	5.3	0.18	0.06	24.50	0.08	0.72	2.20
Farmer S 5	5.6	0.22	0.04	24.05	0.19	0.62	2.30
Average	6.1	0.24	0.05	27.83	0.17	0.55	2.32

*Bray 1

Texture of red, white and yellow soils

soil type	red			white			yellow		
depth cm	sand %	silt %	clay %	sand %	silt %	clay %	sand %	silt %	clay %
0-15	78.2	8.4	13.4	82.2	0	17.8	80.2	7.4	12.4
15-30	80.2	7.4	12.4	82.2	4.4	13.4	82.2	4.4	13.4
30-45	80.2	5.4	14.4	83.2	4.4	12.4	81.2	4.4	14.4
45-60	81.2	3.4	15.4	81.2	7.4	11.4	82.2	3.4	14.4
60-75	77.2	4.4	18.4	82.2	6.4	11.4	79.2	6.4	14.4
75-90	77.2	4.4	18.4	85.2	4.4	10.4	80.2	5.4	14.4

red: Farmer I field 2
white: Farmer Y field 3
yellow: Farmer S field 4

Table 2

Table 3

. Nutrient content of taki

category	n		organic C (%)	total N (%)	total P (%)	potassium (%)	magnesium (%)	calcium (%)
all taki samples	37	mean	6.58	0.30	0.19	0.80	0.24	0.84
		cv (%)	45	43	47	73	58	65
small ruminant manure and straw	15	mean	7.79	0.34	0.14	0.82	0.25	0.83
		cv (%)	33	47	44	72	51	57
small ruminant manure	5	mean	3.94	0.25	0.20	0.83	0.20	0.76
		cv (%)	34	29	35	74	89	62
ash and grass	4	mean	3.40	0.17	0.18	0.97	0.25	0.91
		cv (%)	31	19	49	58	62	50
composted small ruminant manure	8	mean	6.76	0.32	0.20	0.70	0.21	0.72
		cv (%)	27	33	37	68	59	51
small ruminant manure and cow manure	2	mean	8.45	0.37	0.36	0.69	0.32	0.88
		cv (%)	8	55	16	11	38	3
cow and donkey manure	1	mean	11.90	0.38	0.14	0.44	0.18	0.45
donkey manure	1	mean	8.90	0.34	0.28	0.40	0.22	0.48
ash	1	mean	1.40	0.21	0.28	1.66	0.56	2.86

Table 4

Application of taki to fields in 1993

farmer and field	no. mangalas	description	average wt mangala (kg)	total applied (kg)	field area (ha)	application (t / ha)	obsv'ns
Farmer I 1	0				0.7505		
Farmer I 2	39	small ruminant manure	94	3668	0.3449	10.6	
Farmer I 3	22	small ruminant manure	94	2068	0.2871	7.2	a
Farmer I	61			5436	1.3825	4.1	b
Farmer Y 1	22	small ruminant manure	90	1980	1.0275	1.9	a
Farmer Y 2	5	SR and cow manure	81	403	0.5984	0.7	
	2	ash	102	205	0.5948	0.3	
Farmer Y 3:grain	3	donkey manure	90	269	0.6249	0.4	
	5	small ruminant manure	98	492	0.6249	0.8	
	4	donkey and cow mannure	42	168	0.6249	0.3	
	52	composted SR manure	82	4285	0.6249	6.9	
Farmer Y 3:cassava	18	ash and grass	92	1661	0.1219	13.6	
Farmer Y 4:grain	0				0.5314		
Farmer Y 4:cassava	0				0.1225		
Farmer Y	111			9461	3.023	3.1	b
Farmer S 1	21	SR manure and straw	69	1439	0.1617	8.9	
Farmer S 2	12	SR manure and straw	32	383	0.07	5.5	
Farmer S 3	5	SR manure and straw	32	160	0.0925	1.7	a,c
Farmer S 4	7	SR manure and straw	46	321	0.132	2.4	
Farmer S 5	0				0.2054		
Farmer S	45			2302	0.6616	3.5	b

a: placed in field after rains began, assumed to be the same as those applied during the dry season.
b: average application over whole landholding, including manured and non-manured plots.
c: scrub vegetation burned and ash left on field surface.

Table 5

.. Application of taki to fields in 1994

farmer and field	no. mangalas	description	average wt mangala (kg)	total applied (kg)	field area (ha)	application (t / ha)	obsv'ns
Farmer I 1	40	composted SR manure	110	4400	0.4911	9	
	6	ash	121	726	0.4911	1.5	
	6	donkey	121	726	0.4911	1.5	
Farmer I 2	0				0.3449		
Farmer I 3	0				0.2871		a
Farmer I	52			5852	1.1231	5.2	b
Farmer Y 1	42	small ruminant manure	98	4129	1.0275	4	
	29	composted SR manure	82	2399	1.0275	2.3	
	13	ash and grass	92	1200	1.0275	1.2	
Farmer Y 2	15	small ruminant manure	98	1475	0.5984	2.5	
	10	composted SR manure	82	824	0.5948	1.4	
	5	ash and grass	92	462	0.5948	0.8	
Farmer Y 3	17	composted SR manure	82	1401	0.7468	1.9	
	17	small ruminant manure	98	1671	0.7468	2.2	
Farmer Y 4	12	small ruminant manure	94	1129	0.6539	1.7	
	6	ash	94	564	0.6539	0.9	
Farmer Y	166			15252	3.023	5	b
Farmer S 1	26	composted SR manure	56	1443	0.1617	8.9	
Farmer S 2	5	SR manure and straw	45	223	0.07	3.2	
	18	composted SR manure	56	999	0.07	14.3	
Farmer S 3	0				0.0925		
Farmer S 4	0				0.132		
Farmer S 5	0				0.2054		c
Farmer S	49			2665	0.6616	4	b

a: placed in field after rains began, assumed to be the same as those applied during the dry season.
b: average application over whole landholding, including manured and non-manured plots.
c: scrub vegetation burned and ash left on field surface.

Table 6

Inorganic fertilizer use during 1993

field	no. mudus	type	amount applied (kg)	nutrient addition by inorganic fertilizer (kg) N	P	K
Farmer I 1	14	20 : 10 : 5	56	11.20	2.52	2.35
Farmer I 2	2.5	20 : 10 : 5	10	2.00	0.45	0.42
	4	27 : 13 : 13	16	4.32	0.72	1.68
Farmer I 3	1.5	20 : 10 : 5	6	1.20	0.27	0.25
Farmer I : total			88	7.16	3.96	4.70
Farmer Y 1	12	20 : 10 : 10	48	10.66	2.11	5.76
Farmer Y 2	0		0			
Farmer Y 3:grain	0		0			
Farmer Y 3:cassava	0		0			
Farmer Y 4:grain	4	20 : 10 : 5	16	3.20	0.72	0.67
Farmer Y 4:cassava	0		0			
Farmer Y : total			80	13.86	2.83	6.43
Farmer S 1	0		0			
Farmer S 2	0		0			
Farmer S 3	0		0			
Farmer S 4	0		0			
Farmer S 5	0		0			
Farmer S : total	0		0	0	0	0

20 : 10 : 5 = 20 % N, 4.5 % P, 4.2 % K

20 : 10 : 10 = 22.2 % N, 4.4 % P, 12 % K

27 : 13 : 13 = 27 % N, 4.5 % P, 10.5 % K

Table 7

Inorganic fertilizer use during 1994

Field	no. mudus	type	amount applied (kg)	nutrient addition by inorganic fertilizer (kg) N	P	K
Farmer I 1	7	20 : 10 : 5	28	5.60	1.26	1.18
Farmer I 2	5	20 : 10 : 5	20	4.00	0.90	0.84
Farmer I 3	5	20 : 10 : 5	20	4.00	0.90	0.84
Farmer I : total	17		68	13.60	3.06	2.86
Farmer Y 1	10	20 : 10 : 10	40	8.88	1.76	4.80
Farmer Y 2	3	20 : 10 : 10	12	2.66	0.53	1.44
Farmer Y 3	5	20 : 10 : 10	20	4.44	0.88	2.40
Farmer Y 4	6	20 : 10 : 10	24	5.33	1.06	2.88
Farmer Y : total	24		96	21.31	4.22	11.52
Farmer S 1	0		0			
Farmer S 2	0		0			
Farmer S 3	0		0			
Farmers S 4	3	20 : 10 : 5	12	2.40	0.54	0.50
Farmer S 5	3	20 : 10 : 5	12	2.40	0.54	0.50
Farmer S : total	6		24	4.80	1.08	1.00

20 : 10 : 5 = 20 % N, 4.5 % P, 4.2 % K

20 : 10 : 10 = 22.2 % N, 4.4 % P, 12 % K

27 : 13 : 13 = 27 % N, 4.5 % P, 10.5 % K

Table 8

Nutrient contribution to fields by Harmattan dust during one dry season

element	%	kg nutrient / ha	input to fields (kg):	I 1 *	I 2	I 3	Y 1	Y 2	Y 3 **	Y 4 **	S 1	S 2	S 3	S 4	S 5
			field area (ha):	0.7505	0.3449	0.2871	1.0275	0.5948	0.7468	0.6539	0.1617	0.07	0.0925	0.132	0.2054
Si	32.23	297		223	102	85	305	177	222	194	48	21	27	39	61
Al	6.11	56		42	19	16	58	34	42	37	9	4	5	7	12
Ca	1.13	10		8	4	3	11	6	8	7	2	1	1	1	2
Fe	3.1	29		21	10	8	29	17	21	19	5	2	3	4	6
Mg	0.39	4		3	1	1	4	2	3	2	1	0	0	0	1
K	2.03	19		14	6	5	19	11	14	12	3	1	2	2	4
Na	0.91	8		6	3	2	9	5	6	5	1	1	1	1	2
Ti	0.47	4		3	1	1	4	3	3	3	1	0	0	1	1
P	0.09	1		1	0	0	1	0	1	1	0	0	0	0	0
Mn	0.22	2		2	1	1	2	1	2	1	0	0	0	0	0
organic matter	8.01	74		56	26	21	76	44	55	48	12	5	7	10	15

* during 1994 season part of field size was temporarily reduced to 0.4911 ha
** during 1993 season these fields were divided, the large part growing grain crops, a smaller part growing cassava

Table 9

Symbiotic nitrogen fixation on farmers' fields, 1993

	g'nut harvest*	fixed N**	cowpea harvest*	fixed N***	total fixed N per field	
	(kg)	(kg)	(kg)	(kg)	(kg)	(kg/ha)
Farmer I						
field 1	0	0.00	439	6.50	6.50	8.66
field 2	452	5.33	91	1.35	6.68	19.37
field 3	0	0.00	95	1.41	1.41	4.91
total					14.58	10.55
Farmer Y						
field 1	200	2.36	591	8.75	11.11	10.81
field 2	638	7.53	103	1.52	9.05	15.22
field 3	383	4.52	480	7.10	11.62	15.56
field 4	0	0.00	120	1.78	1.78	2.27
total					33.56	11.10
Farmer S						
field 1	0	0.00	87	1.29	1.29	7.98
field 2	0	0.00	12	0.18	0.18	2.57
field 3	60	0.71	0	0.00	0.71	7.68
field 4	0	0.00	4	0.06	0.06	0.45
field 5	101	1.19	32	0.47	1.67	8.08
total					3.90	5.89

* weight of unthreshed grain and residues

** N fixed by groundnut = 1.18 % harvested biomass

*** N fixed by cowpea = 1.48 % harvested biomass

Table 1f

Symbiotic nitrogen fixation on Farmer I's fields, 1994.

field	section	legume	stands/ha	pls/stand	no. plants	fixed N/plant (g)	fixed N / ha land (kg)	field area (ha)	N fix'n / field (kg)
Farmer I 1		groundnut	14300	2	28600	0.611	17.47	0.4911	8.58
		cowpea	3900	3	11700	1.706	19.96	0.4911	9.80
					40300			total	18.38
Farmer I 2	total	cowpea	1200	3	3600	1.706	6.14	0.3449	2.12
Farmer I 3	total	cowpea	1500	3	4500	1.706	7.68	0.2871	2.20
Farmer I :	complete landholding							1.3825	22.71

Table 11

. Symbiotic nitrogen fixation on Farmer Y's fields, 1994.

field	section	legume	stands/ha	pls/stand	no. plants	fixed N/plant (g)	fixed N / ha land (kg)	field area (ha)	N fix'n / field (kg)
Farmer Y 1	A	cowpea	3500	3	10500	1.706	17.91	0.4913	8.80
	B	cowpea	4100	3	12300	1.706	20.98	0.5028	10.55
	C	groundnut	14300	2	28600	0.611	17.47	0.2948	5.15
		cowpea	3700	3	11100	1.706	18.94	0.2948	5.58
								total	30.09
Farmer Y 2	A	cowpea	1900	3	5700	1.706	9.72	0.1219	1.19
	B	groundnut	12700	2	25400	0.611	15.52	0.3127	4.85
		cowpea	3200	3	9600	1.706	16.38	0.3127	5.12
	total							total	11.16
Farmer Y 3	A	cowpea	1900	3	5700	1.706	9.72	0.6249	6.08
		groundnut	14500	2	29000	0.611	17.72	0.6249	11.07
								total	17.15
Farmer Y 4	A	cowpea	3500	3	10500	1.706	17.91	0.6139	11.00
		groundnut	9800	2	19600	0.611	11.98	0.6139	7.35
	total							total	18.35
Farmer Y:	complete landholding								76.74

Table

Symbiotic nitrogen fixation on Farmer S's fields, 1994.

field	section	legume	stands/ha	pls/stand	no. plants	fixed N/plant (g)	fixed N / ha land (kg)	field area (ha)	N fix'n / field (kg)
Farmer S 1		cowpea	3321	3	9963	1.706	17.00	0.1617	2.75
Farmer S 2		groundnut	7567	2	15134	0.611	9.25	0.07	0.65
		cowpea	7612	3	22836	1.706	38.96	0.07	2.73
								total	3.37
Farmer S 3		groundnut	11465	2	22930	0.611	14.01	0.0925	1.30
		cowpea	1135	3	3405	1.706	5.81	0.0925	0.54
								total	1.83
Farmer S 4		groundnut	19386	2	38772	0.611	23.69	0.132	3.13
		cowpea	2255	3	6765	1.706	11.54	0.132	1.52
								total	4.65
Farmer S 5		cowpea	743	3	2229	1.706	3.80	0.2054	0.78
Farmer S:	complete landholding							0.6616	13.39

Table 13

Summary of nutrient inputs to fields, 1993 and 1994.

field			I 1	I 2	I 3	Y 1	Y 2	Y 3 **	Y 4 **	S 1	S 2	S 3	S 4	S 5
inputs to fields (kg):	1993	N	17.73	22.18	7.79	15.65	10.99	30.95	5.01	6.19	1.48	1.26	2.77	3.91
		P	3.17	8.96	4.74	7.05	2.56	14.21	1.36	2.12	0.59	0.30	0.56	0.18
		K	16.51	39.00	22.86	41.58	17.36	66.00	14.75	14.79	4.45	3.04	5.11	3.87
		Mg	2.72	8.44	5.10	7.61	4.58	17.47	2.71	4.17	1.21	0.74	1.28	0.75
		Ca	7.92	31.44	18.71	25.84	15.66	59.57	7.87	13.66	3.92	2.16	4.06	2.17
	1994	N	42.04	6.13	6.21	59.05	20.96	30.28	27.71	7.37	7.33	1.83	7.06	3.19
		P	14.59	1.20	1.15	18.04	6.53	7.74	5.52	3.03	2.37	0.08	0.65	0.72
field area (ha):			.7505 *	0.3449	0.2871	1.0275	0.5948	0.7468	0.6539	0.1617	0.07	0.0925	0.132	0.2054
inputs to fields (kg/ha):	1993	N	23.62	64.30	27.13	15.23	18.48	41.44	7.66	38.28	21.14	13.62	20.98	19.04
		P	4.22	26.00	16.51	6.86	4.30	19.03	2.08	13.11	8.43	3.24	4.24	0.88
		K	22.00	113.08	79.62	40.47	29.19	88.38	22.56	91.47	63.57	32.86	38.71	18.84
		Mg	3.62	24.47	17.76	7.41	7.70	23.39	4.14	25.79	17.29	7.89	9.70	3.65
		Ca	10.55	91.16	65.17	25.15	26.33	79.77	12.04	84.48	56.00	23.35	30.76	10.56
	1994	N	85.60	17.77	21.63	57.48	35.23	40.55	42.38	47.80	104.71	19.78	53.48	15.53
		P	29.71	3.48	4.01	17.56	10.98	10.36	8.44	18.74	33.86	0.86	4.92	3.51

* during 1994 season part of field size was temporarily reduced to 0.4911 ha

** during 1993 season these fields were divided, the large part growing grain crops, a smaller part growing cassava

Table 14

1993 Harvest (kg dm/ha)

field	early millet		late millet		sorghum		groundnut		cowpea		maize		pepper	cassava	pigeon pea		sesame	gamba	henna	weeds
	grain	res	grain	res	grain	res	grain	res	grain	res	grain	res	fruit	tuber	bean	res	seed			
Farmer I 1	1206	2426	40	133					220	365										131
Farmer I 2			452	1392	1108	1870	458	81	255	217								87	58	876
Farmer I 3	766	1696	122		139				70	261	28	63	21				84		139	536
Farmer Y 1	170	389	15	117	214	569	193	442	30	71			11							172
Farmer Y 2	350	1160	466	1696	372	1316	69	210												71
Farmer Y 3**	1184	1216	128	352	272	592	542	109	318	462	333		3							179
Farmer Y 4**	92		84		731	1606			84	104				428	15	14		107		222
Farmer S 1	959	1014			649	322			74	464										414
Farmer S 2	1671	2929	143	714			29	143										429		129
Farmer S 3					270	2162	108	541												486
Farmer S 4	1000	758							23									909		76
Farmer S 5	234	662			73	146	161	1689	58	97										200

** durlng 1993 season thse fields were divided, the large part growing grain crops, a smaller part growing cassava

Table 15

5.15. 1994 Harvest (kg dm/ha)

field	early millet		late millet		sorghum		groundnut		early cowpea		late cowpea		maize		pepper	henna		weeds
	grain	res	grain	res	grain	res	grain	res	grain	res *	grain	res	grain	res	fruit	leaves	branches	
Farmer I 1			159	774	106	3928	485	1332	35		118	269						364
Farmer I 2	2479	2389	339	797	371	876			72									188
Farmer I 3	1411	5528	272	1115	366	2003			80		157	383				279	564	174
Farmer Y 1	462	3109	80	482	471	1279	87	234	31		33	74			15			58
Farmer Y 2	1027	2387	192	572	37	474	82	387	8		30	25						26
Farmer Y 3	1426	2524	190	643	295	512	315	502	55		64	129	607	837				35
Farmer Y 4			185	520	688	2046	162	471			110	231			32			130
Farmer S 1					5628	4799			62		31	186						62
Farmer S 2	1643	3500					1886	1900	200		71	429						143
Farmer S 3	595	2216			216		1330		141		141	195						108
Farmer S 4	644	1818			167		848		136		91	136						76
Farmer S 5	292	2191			365				127		97	117						141

* due to late rains, all the residues of early cowpea rotted in the fields

Nutrient content of harvest, 1993.

Crop	Part	Nitrogen %	Phosphorus** %	Potassium %	Magnesium %	Calcium %
Early millet	grain	1.03	0.15	1.667	0.19	0.201
	chaff	0.9	0.09	1.756	0.135	0.384
	sticks	0.33	0.05	1.22	0.186	0.53
	stalks	0.34	0.12	1.507	0.24	0.42
Cowpea	beans	2.8	0.43	1.62	0.52	0.41
	pods	1.386	0.15	1.43	0.21	0.36
	straw	1.23	0.23	1.38	0.33	0.89
Sorghum	grain	0.83	0.29	0.998	0.227	0.214
	chaff	0.5	0.36	0.57	0.145	0.12
	sticks	0.32	0.18	0.855	0.206	0.21
	stalks	0.22	0.19	0.787	0.147	0.291
Groundnut	nuts	3.53	0.65	1.06	0.54	0.48
	pods	0.96	0.09	0.88	0.07	0.11
	haulms	1.45	0.11	1.76	0.32	0.84
Late millet	grain	1.37	0.27	0.84	0.171	0.535
	chaff	0.69	0.37	0.527	0.149	0.136
	sticks	0.47	0.23	1.72	0.13	0.216
	stalks *	0.35	0.33			
Gamba grass		0.27	0.18	0.383	0.115	0.363
Weeds **		1.32	0.18	1.65	0.297	0.578
Henna		0.443	0.56	1.28	0.194	0.272
Maize	corn	0.75	0.14	0.146	0.16	0.27
	husks	0.48	0.02	0.138	0.15	0.21
	cobs	0.372	0.03	0.5	0.04	0.1
	stalks ***					
Pepper	fruit	2.38	0.26	2.64	0.22	0.3
Cassava	tuber	0.336	0.11	2.04	0.102	0.2

* average of values determined in 1994
** average of analysis of samples from 1993 and 1994
*** data not available

Phosphorus content of harvested crops

crop		no. samples	mean P content (%)	range
early millet	grain	15	0.15	.12 - .19
	chaff	16	0.09	.07 - .15
	sticks	17	0.05	.02 - .08
	stalks	16	0.12	.06 - .19
late millet	grain	9	0.28	.10 - .44
	chaff	8	0.37	.07 - .69
	sticks	9	0.23	.06 - .34
	stalks	6	0.33	.31 - .35
sorghum	grain	19	0.29	.10 - .69
	chaff	13	0.36	.19 - .67
	sticks	16	0.13	.02 - .32
	stalks	16	0.19	.01 - .39
groundnut	nuts	12	0.65	.40 - 1.13
	shells	13	0.09	.03 - .23
	haulms	17	0.11	.04 - .26
early cowpea	beans	18	0.37	.05 - .73
	pods	18	0.15	.03 - .39
late cowpea	beans	15	0.49	.01 - 1.19
	pods	15	0.15	.02 - .35
cowpea	straw	30	0.23	.04 - .73
cowpea average *	beans	33	0.43	.01 - 1.19
	pods		0.15	.03 - .73
weeds		8	0.18	.11 - 2.06
gamba		3	0.18	.05 - .39

* in 1993 no distinction was made between early and late cowpea

Table 19

Nitrogen content of harvest, 1994 (%)

crop	field	I1	I2	I3	Y1	Y2	Y3	Y4	S1	S2	S3	S4	S5
early	grain		1.09	1.35	1.48	1.38**	1.48			1.61	1.38**	1.13	1.38**
millet	chaff		0.60	0.90	0.87	0.85**	0.99			0.92	0.85**	0.79	.850**
	sticks		0.42	0.45	0.46	0.50**	0.48			0.57	0.50**	0.62	.500**
	stalks		0.57	0.57	0.82	0.71**	0.57			0.92	0.71**	0.71	.710**
groundnut	nuts	2.61*			3.46**	3.46**	3.53*	3.79*		4.08	3.93	3.81	
	shells	0.70*			0.82**	.82**	0.97*	0.80*		0.73	0.97	0.68	
	haulms	1.43*			1.48**	1.48**	1.63*	0.34*		1.49	1.62	1.46	
early	beans	3.96	3.01	3.23	3.19*	3.37	3.66	3.01	3.52	3.39	3.34**	3.34**	3.34**
cowpea	pods	1.50	0.92	1.25	1.01*	1.60	1.37	1.20	1.09	1.20	1.20**	1.20**	1.20**
	straw	1.13	1.09	1.23	1.08*	0.84	1.29	1.62	1.27	0.79	1.14**	1.14**	1.14**
sorghum	grain	1.29*	1.13	1.34	1.39*	1.32**	1.38*	1.13*	1.31		1.32**	1.72	1.48
	chaff	0.61*	0.67	0.49	0.72*	0.62**	0.59*	0.57*	0.62		0.62**	0.62	0.75
	stocks	0.43*	0.44	0.34	0.53*	0.45**	0.43*	0.41*	0.41		0.45**	0.49	0.45**
	stalks	0.24	0.26	0.54	0.37	0.85	0.27	0.31	0.34		0.38	0.29	0.39
late	beans	3.18		3.67	3.55	3.44	3.35	3.72	3.50**	3.50**	3.50**	3.50**	3.57
cowpea	pods	0.94		1.29	1.58	1.46	1.41	2.00	1.44**	1.44**	1.44**	1.44**	1.39
	straw	1.46		2.04	1.74	1.53	1.41	1.87	1.55**	1.55**	1.55**	1.55**	1.65
late	grain	1.70	1.63**	1.41	1.88	1.37	1.53	1.87					
millet	chaff	0.95	0.82	1.06	0.91	0.94*	0.97	0.93					
	sticks	0.48	0.52*	0.60	0.55	0.41	0.53	0.58					
	stalks	0.37	0.25	0.33	0.41	0.32	0.44	0.35*					
weeds***		1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32
henna	leaves	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71
	branches	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
gamba		0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
sesame	seeds	3.07	3.07	3.07									
	branches	0.77	0.77	0.77									
baobab	leaves	1.52	1.52	1.52									

* average of 5 samples taken from 1 field   ** average of samples from all fields   *** analysis of samples from 1993 and 1994

Table 19

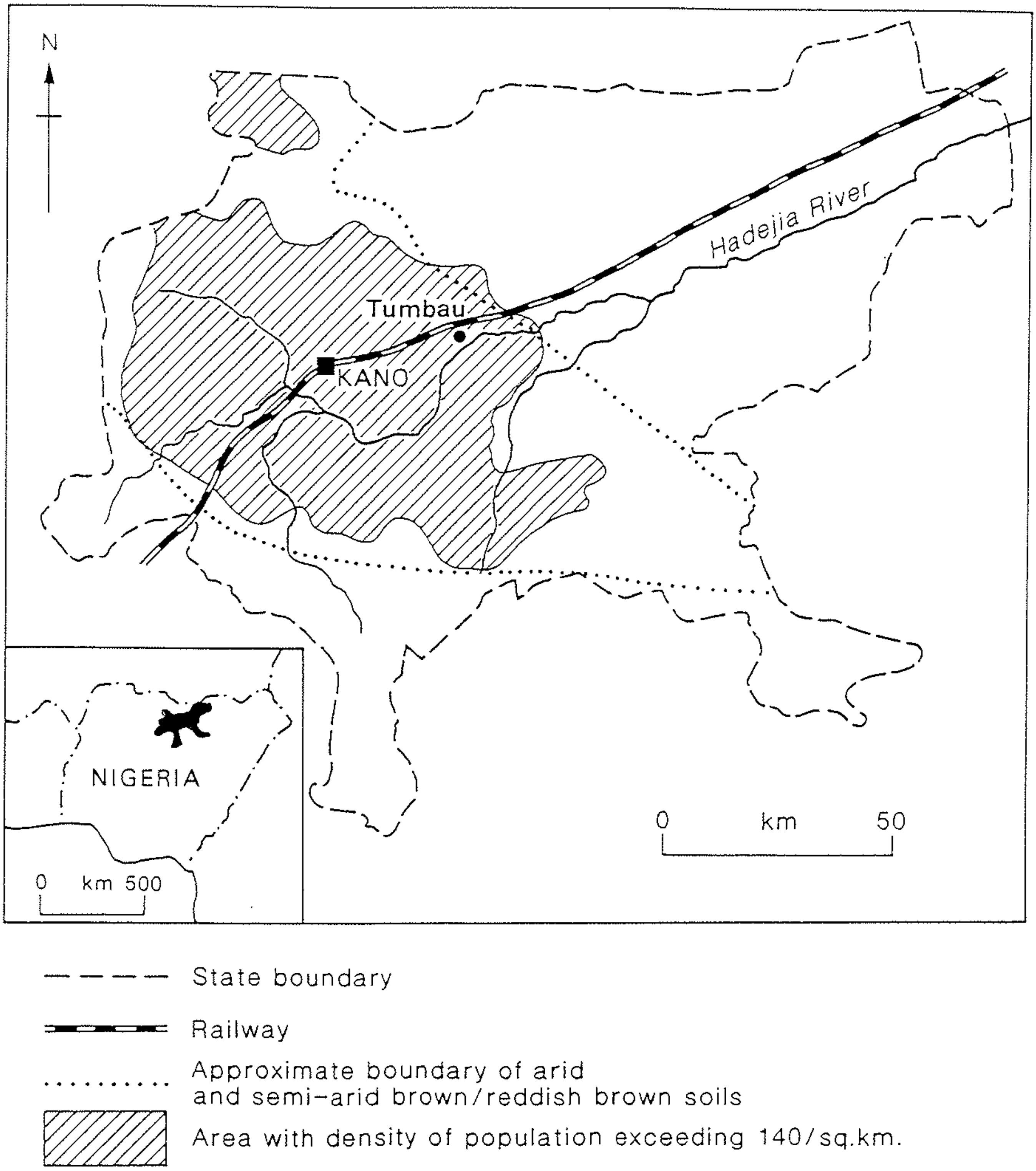
': Summary of nutrient removal from fields, 1993 and 1994.

field			I 1*	I 2	I 3	Y 1	Y 2	Y 3 **	Y 4 **	S 1	S 2	S 3	S 4	S 5
nutrient removal from fields (kg):	1993	N	23.92	22.53	8.86	28.12	20.22	33.04	12.24	4.85	2.27	2.20	2.03	3.84
		P	5.09	6.42	1.99	5.37	4.61	7.93	4.23	1.10	0.61	0.64	0.52	0.73
		K	49.46	23.35	15.86	36.09	27.36	41.64	24.07	8.37	5.69	3.52	4.09	5.94
		Mg	7.83	4.91	2.55	6.48	5.25	7.98	3.99	1.43	0.87	0.68	0.63	1.05
		Ca	13.62	8.51	4.57	10.88	9.77	12.89	6.86	2.49	1.55	1.35	1.23	2.07
	1994	N	34.36	17.55	26.70	33.41	27.46	50.44	19.04	13.57	10.74	7.02	7.19	6.90
		P	9.73	4.33	6.67	8.12	5.07	9.44	6.45	4.16	1.34	1.08	1.13	1.09
field area (ha):			0.7505	0.3449	0.2871	1.0275	0.5948	0.7468	0.6539	0.1617	0.07	0.0925	0.132	0.2054
nutrient removal from fields (kg/ha):	1993	N	31.87	65.32	30.86	27.37	33.99	44.24	18.72	29.99	32.43	23.78	15.38	18.70
		P	6.78	18.61	6.93	5.23	7.75	10.62	6.47	6.80	8.71	6.92	3.94	3.55
		K	65.90	67.70	55.24	35.12	46.00	55.76	36.81	51.76	81.29	38.05	30.98	28.92
		Mg	10.43	14.24	8.88	6.31	8.83	10.69	6.10	8.84	12.43	7.35	4.77	5.11
		Ca	18.15	24.67	15.92	10.59	16.43	17.26	10.49	15.40	22.14	14.59	9.32	10.08
	1994	N	69.97	50.88	93.00	32.52	46.17	67.54	29.12	83.92	153.43	75.89	54.47	33.59
		P	19.81	12.55	23.23	7.90	8.52	12.64	9.86	25.73	19.14	11.68	8.56	5.31

* during 1994 season part of field size was temporarily reduced to 0.4911 ha

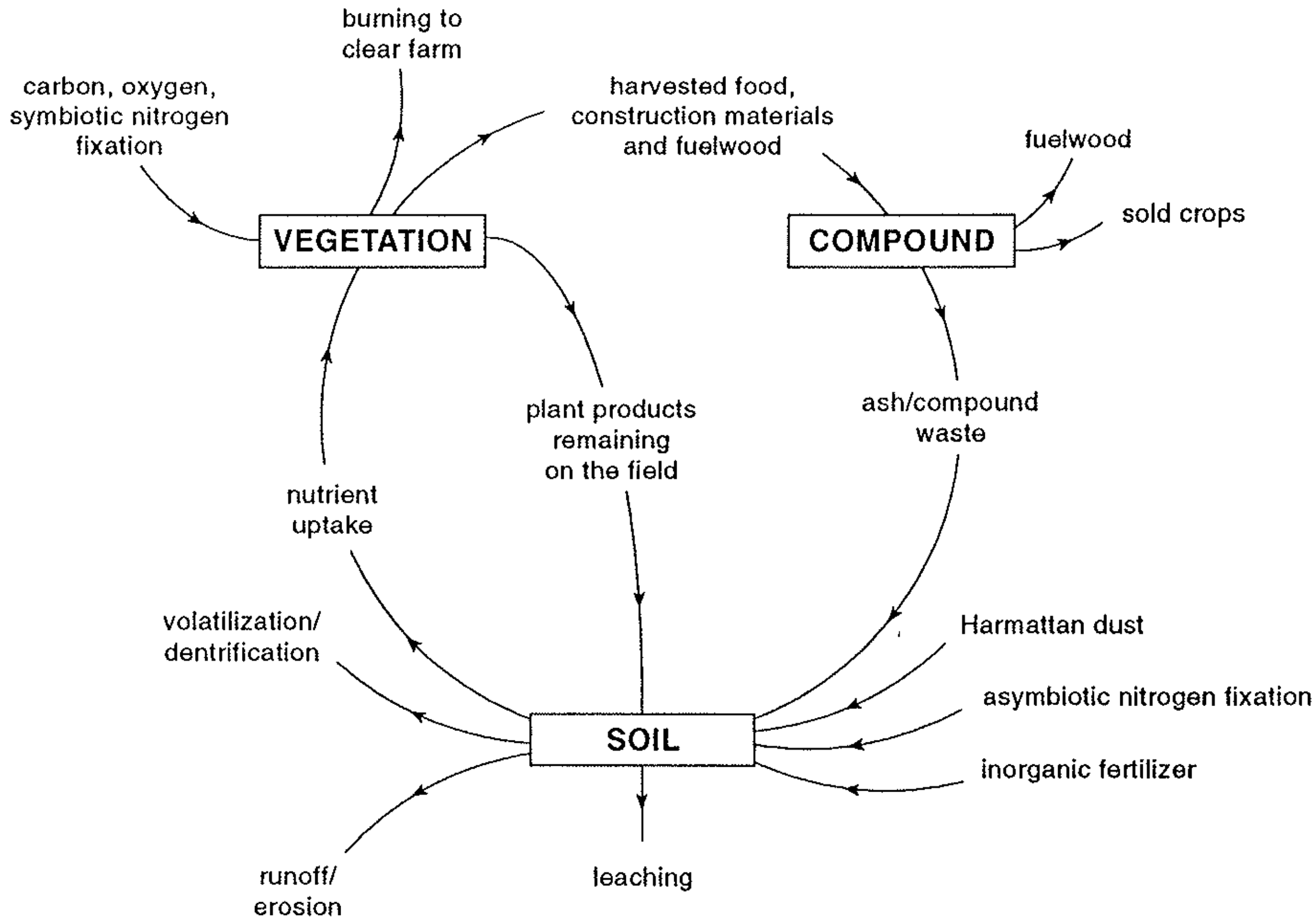
** during 1993 season these fields were divided, the large part growing grain crops, a smaller part growing cassava

Figure 1



THE KANO CLOSE-SETTLED ZONE
(Source: Mortimore 1970 p.138)

Figure ?



Nutrient Cycling in Farming

Figure 3

Nutrient Cycling under Crop-Livestock Interaction

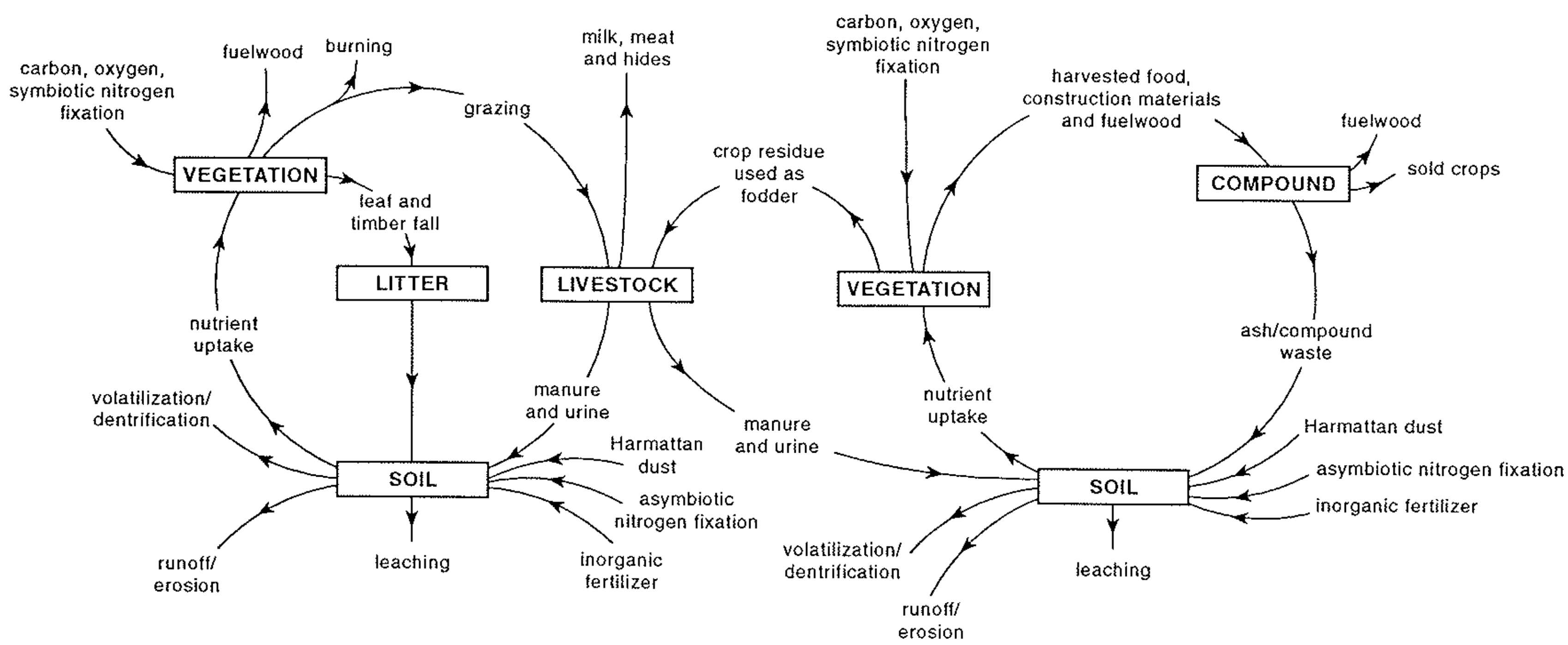
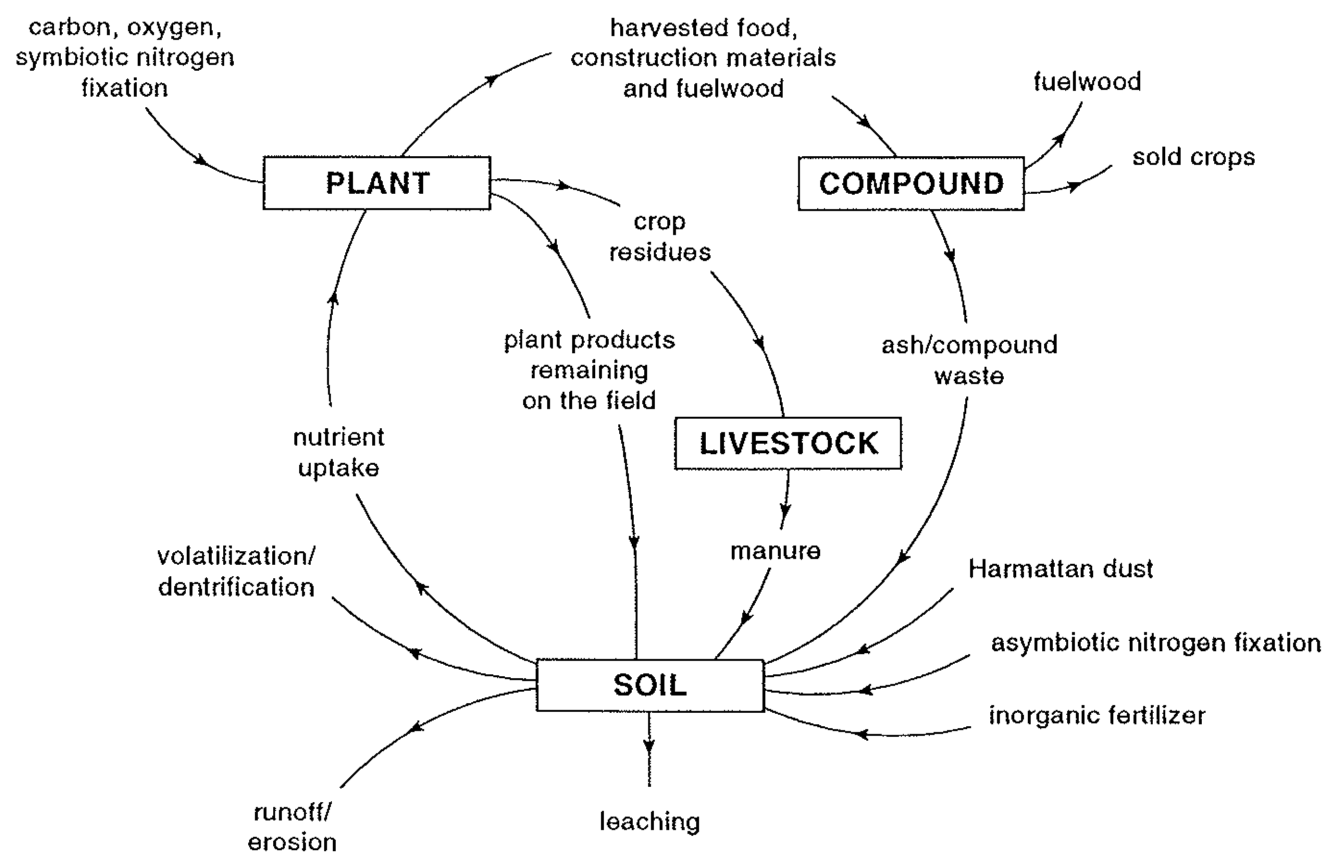


Figure 4



Nutrient Cycling within Crop - Livestock Integration

Figure 5

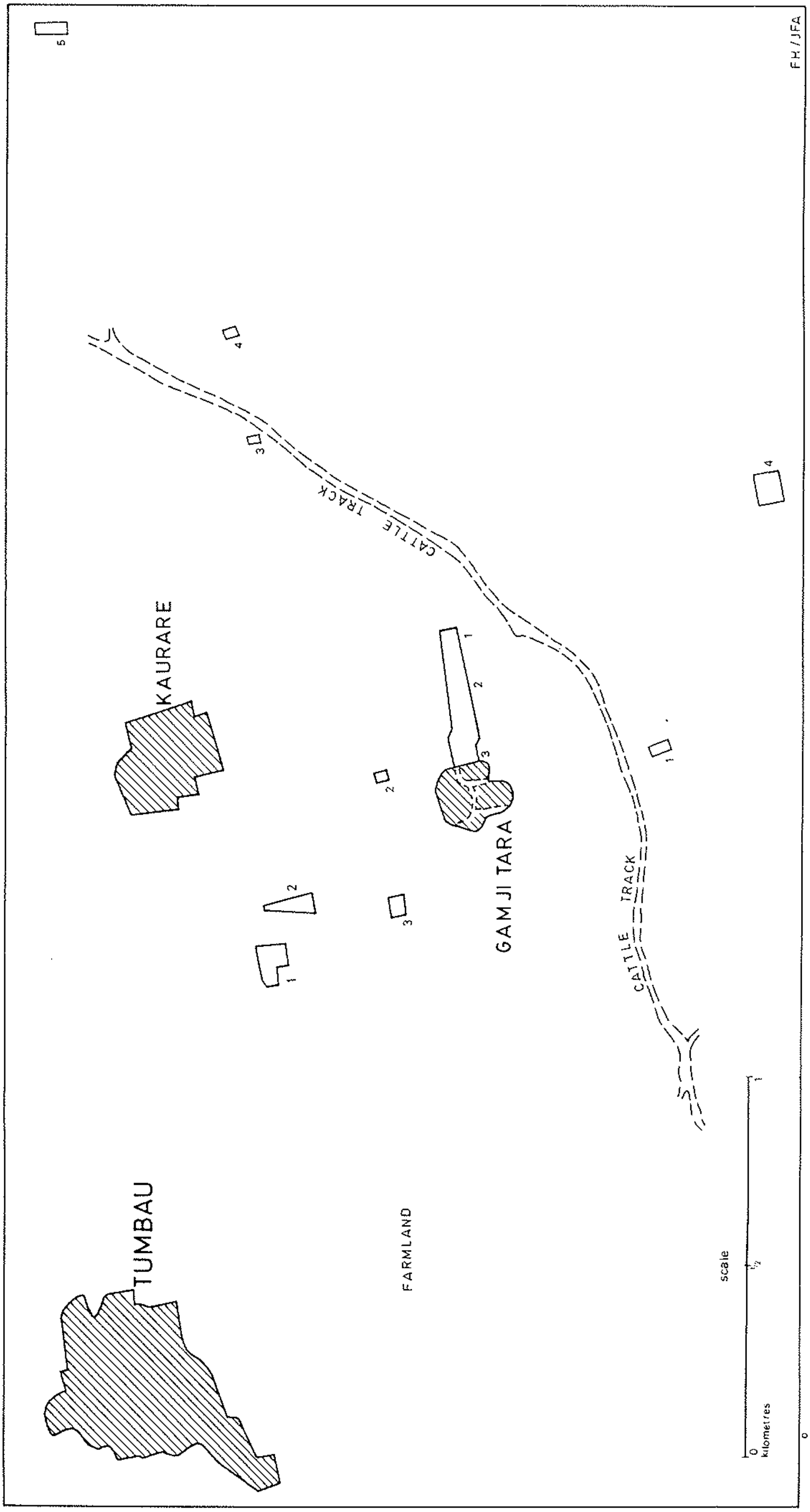
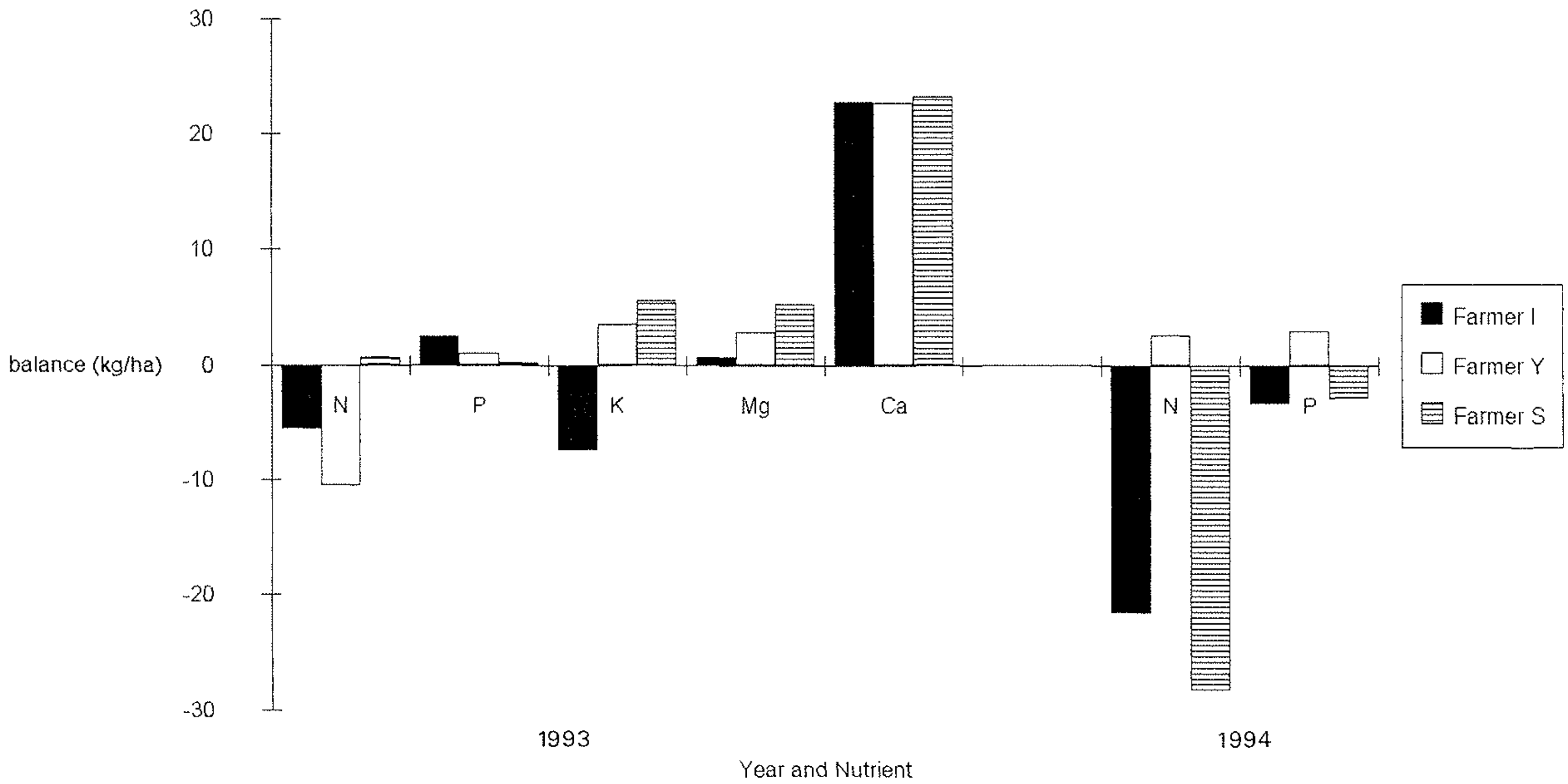

TUMBAU
KAURARE
GAM JI TARA
FARMLAND
CATTLE TRACK
CATTLE TRACK
scale
0
½
1
kilometres
FH/JFA

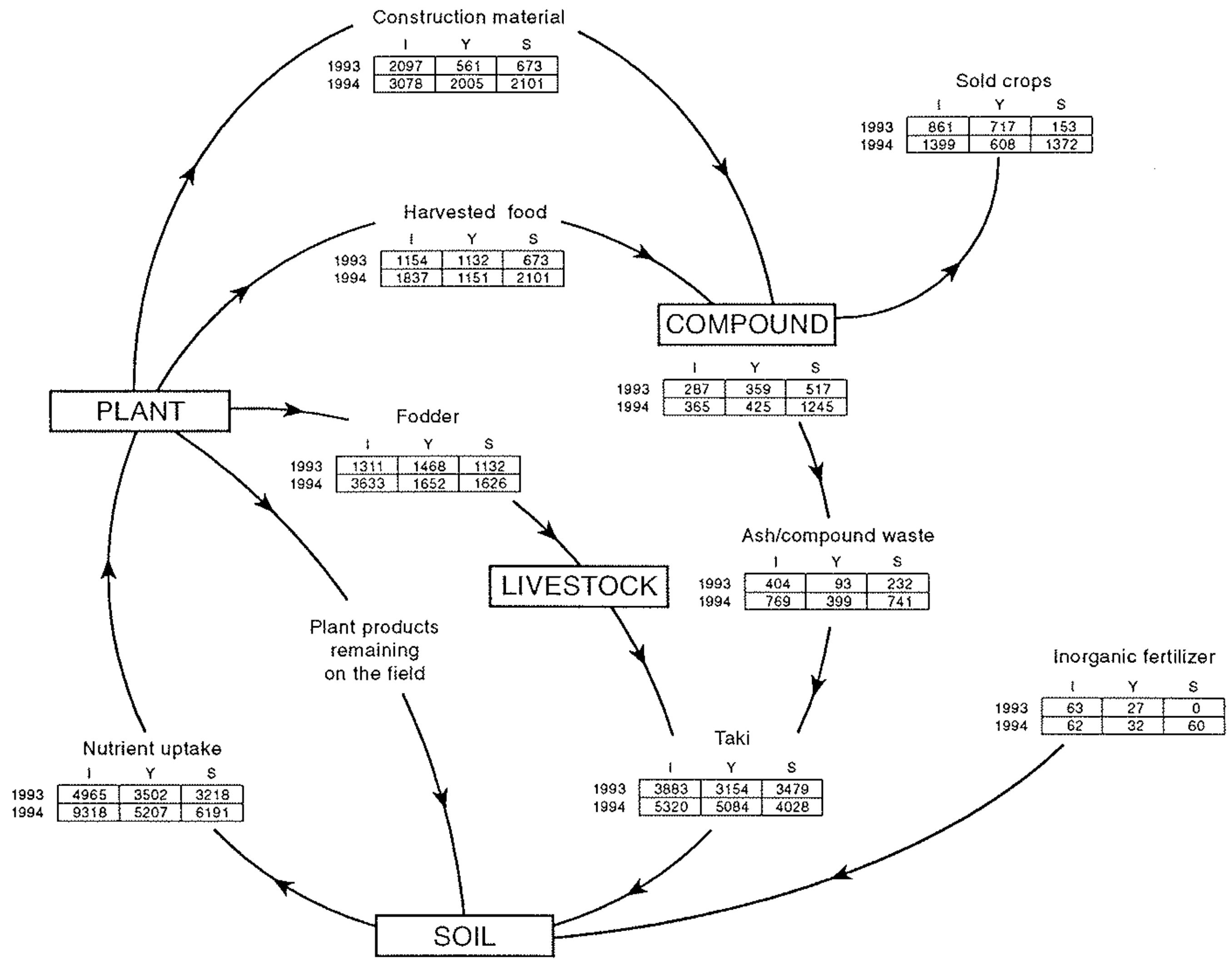
Figure 6 : Nutrient balance of landholdings (kg/ha)



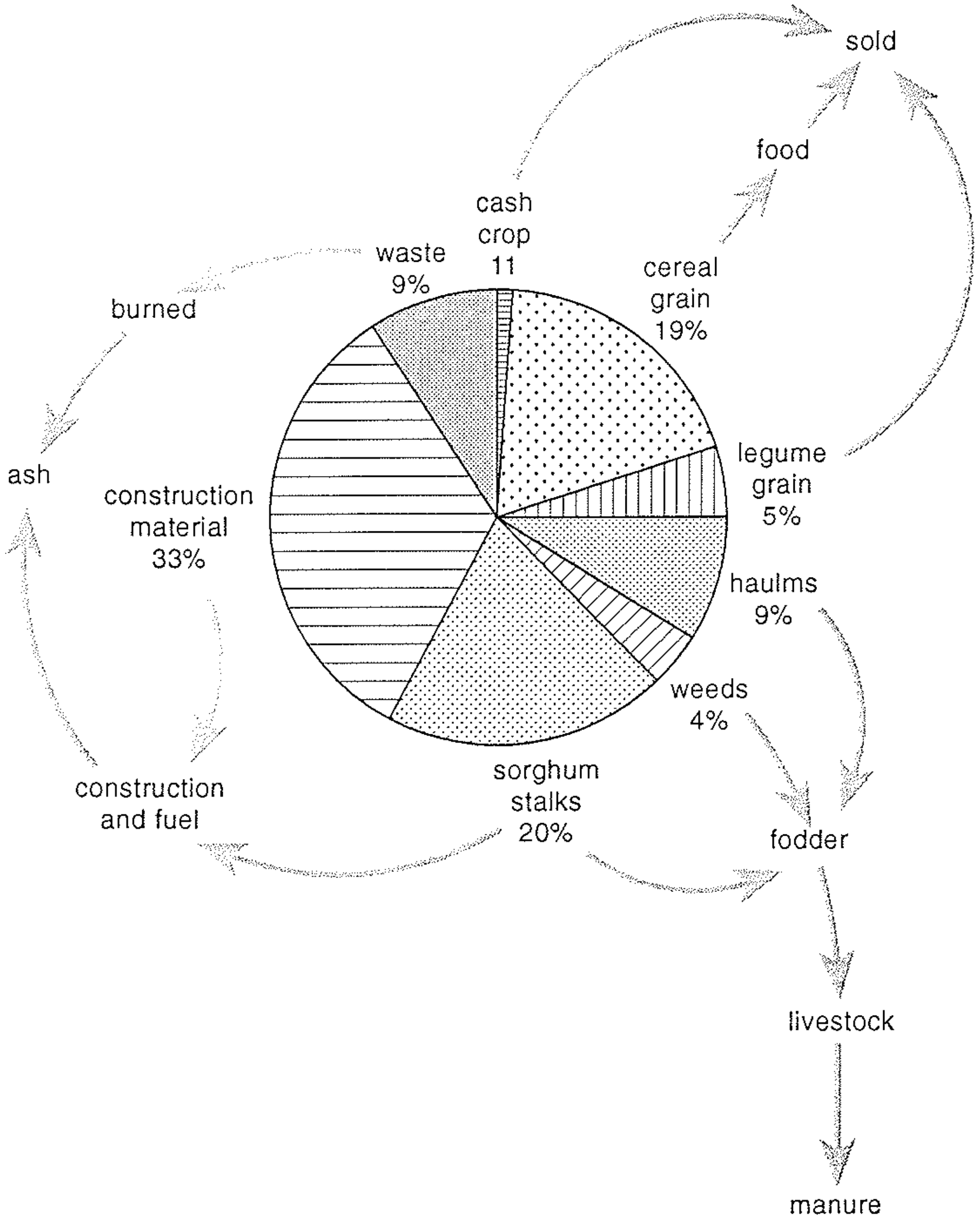
Figure

Figure 7

: Biomass cycling in the Kano close-settled zone (kg/ha dm)



Use of harvested material



Nitrogen cycling in the Kano close-settled zone (kg/ha dm)

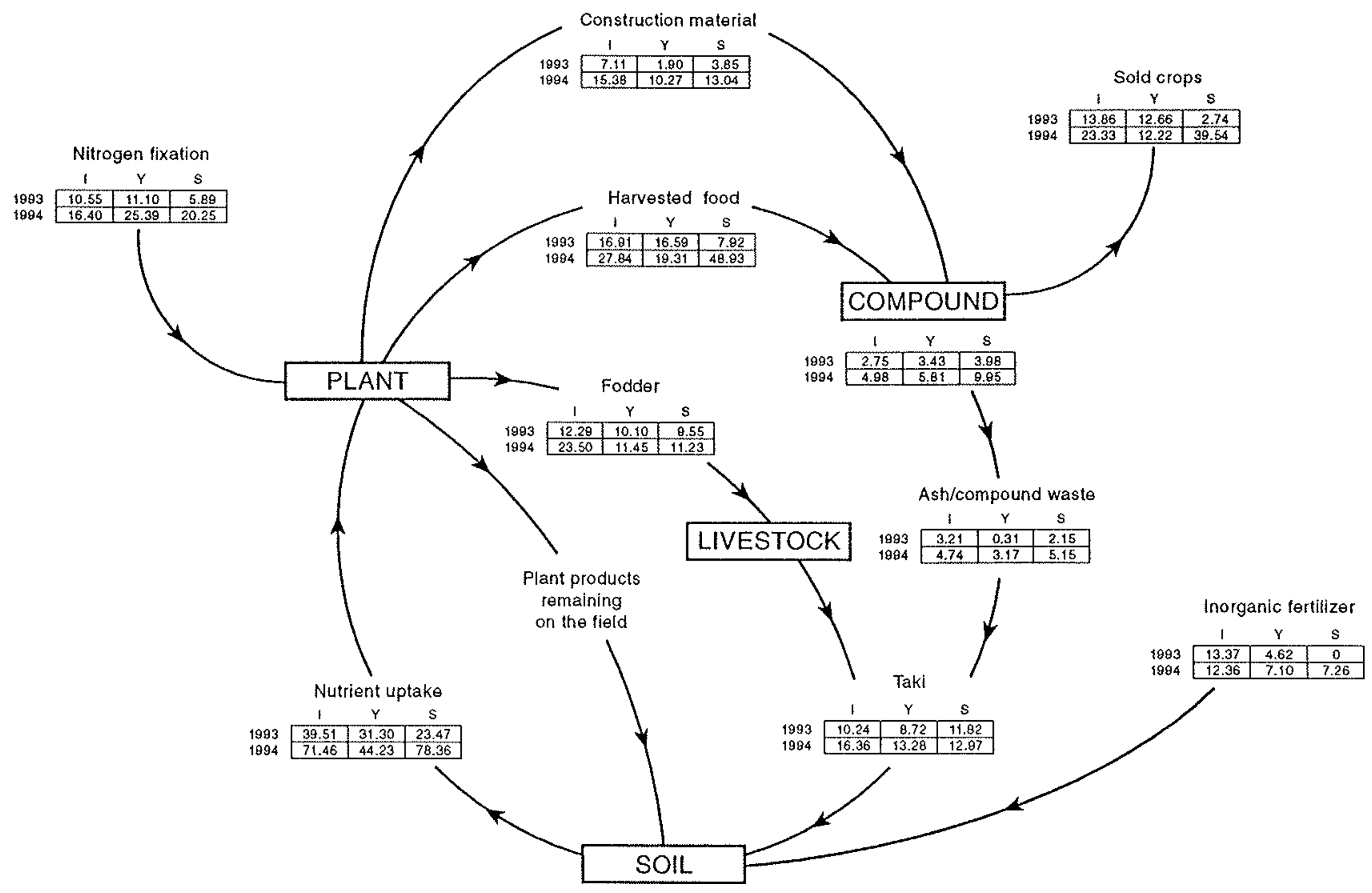


Figure 9

Figure 1

Phosphorus cycling in the Kano close-settled zone (kg/ha dm)

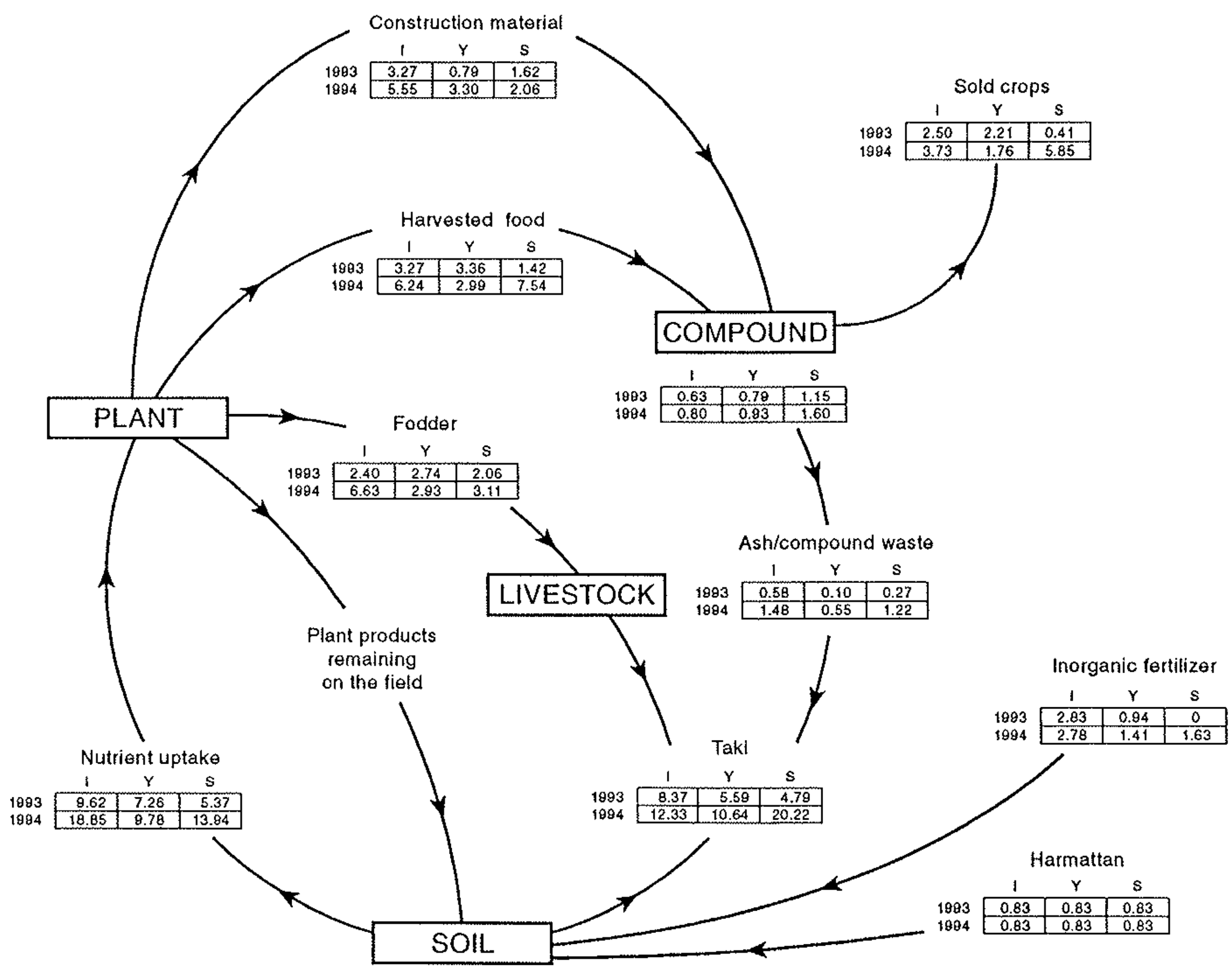
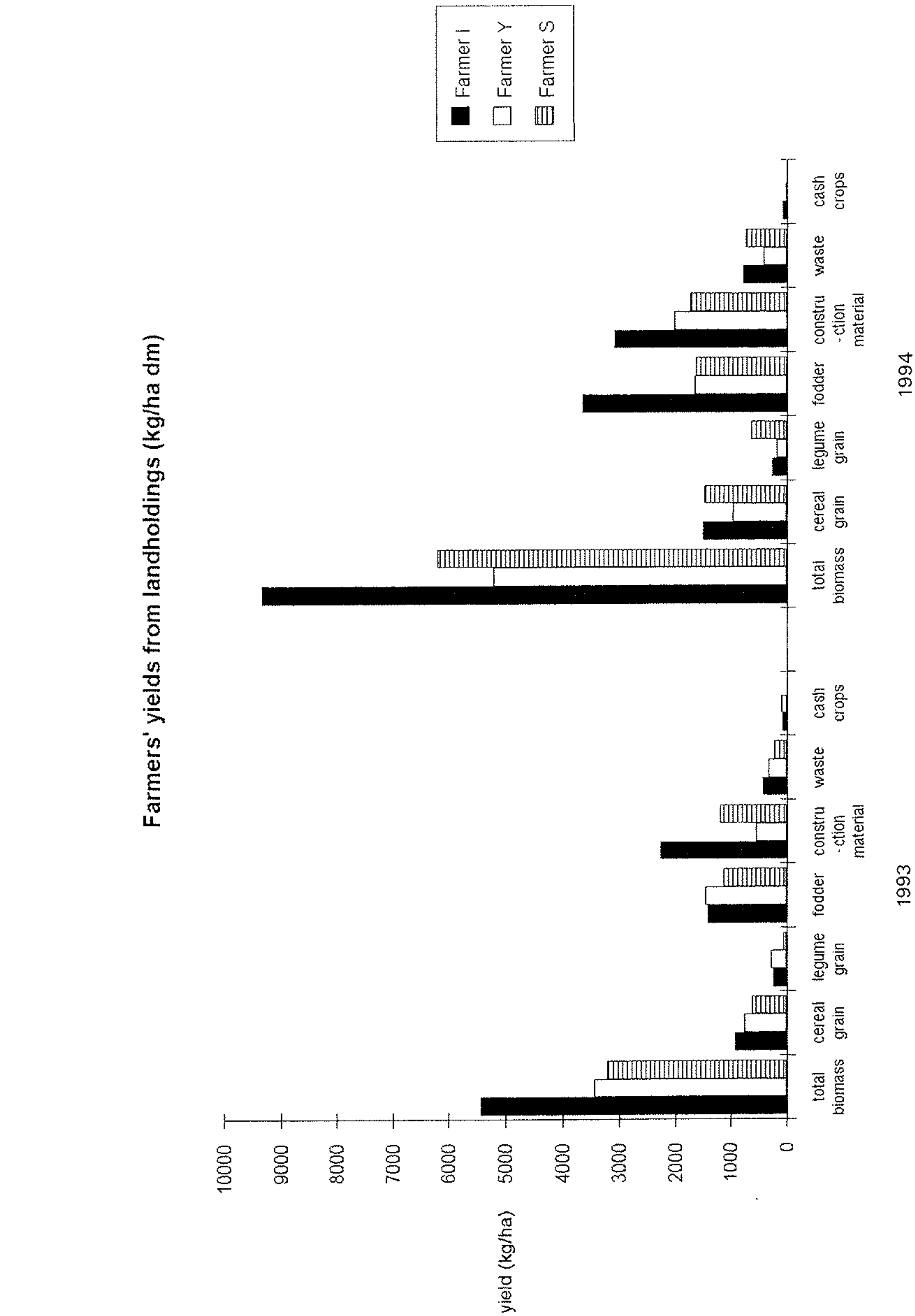


Figure 11


Farmers' yields from landholdings (kg/ha dm)
yield (kg/ha)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
total biomass
cereal grain
legume grain
fodder
constru -ction material
waste
cash crops
1993
1994
Farmer I
Farmer Y
Farmer S

Figure

Population Density and Agricultural Intensification