MSc Dissertation Timothy Dowson

Biomass Production
in villages recovering from drought
in the Nigerien Sahel

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Abstract

Throughout the 1970s and 80s the semi-desert West African Sahel suffered devastating drought and famine. Since the early 1990s increasing rainfall has encouraged recovery, but neither on the ground nor on satellite imagery is this re-growth uniform, sometimes being greater than expected. At both local and larger scales considerable patchiness is evident. Uncertainties include how much variation is of human rather than physical causation, and whether appearances correspond to measurable differences in biomass.

This research compared biophysical data from two neighbouring agricultural communities with similar human and physical characteristics, one manifesting more recovery. It was performed in central southern Niger, early in the short rainy, growing, season. It assessed the quantity of vegetation present (both trees and crops), the soil quality, and use of water in the landscape. Data sampling points radiated from the centre across the territory, and community members were asked about water and land practices.

Major findings were that the more 're-greened' village had more trees, giving twice the ground cover in both wet and dry seasons. It practices more intercropping of its staple crop with nitrogen-fixing vegetables, and uses more manure. The soil contained more carbon, suggesting greater fertility, despite similar mineral particle size composition. In neither village was run-off constrained for irrigation, or to increase infiltration around crops.

In summary, the greener village apparently has better conserved trees, with greater biomass, helping protect soil; and encourages soil fertility further through its manure and cropping technique use.

Repeating this work elsewhere, after the rainy season, and comparing productivity over several seasons would be worthwhile. Confirmation that geology and local rainfall variation are not major factors is also important. While the greener village is nearer the influence and markets of local towns, greater understanding of differing agricultural practices is important for promoting food security across the Sahel.

Acknowledgements

My grateful thanks for the assistance I have received from various sources:

In Mayahi, in rural Niger, to my Nigerien fellow Masters student Amadou Abdou Bagna, for helping me find my feet and work in a strikingly different environment.

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Declaration

I hereby declare that the work undertaken in writing this dissertation is mine alone.

Timothy Dowson

25.9.09

Contents

Background and Literature Review

a) The Sahel and its climate

The Sahel comprises a large area of Africa, approximately 2 million square kilometres in extent, forming a belt from 200 to 400 kilometers wide, between the southern edge of the Sahara Desert proper and the established savannah zones further south. It stretches 6000 km from Senegal in the west (or even the Cape Verde Islands) to Eritrea in the east (Gritzner, 1988). See map, figure 1.

While a semi-arid climate is a defining aspect of the Sahel, a more detailed picture is important to understanding the region's nature. It can be very roughly delineated by the 100mm isohyet to the north, and the 500 mm isohyet to the south, roughly corresponding to the zone from 12^0 to 18^0 north. There is therefore a rapid increase in rainfall across the zone to the south throughout the region. However, there is a higher degree of seasonality to the climate, with rainfall distributed very unevenly through the year; the rainy season is from three to five months, during which time over 90% of precipitation falls (see figure 2) with much of this being in a few thunderstorms particularly in August. This is the result of the West African Monsoon moving north with each (northern hemisphere) summer (Brooks, 2004). The intensity of rain can be quite dramatic, and can lead to soil damage in exposed areas, with increased soil erosion, particularly of the finer

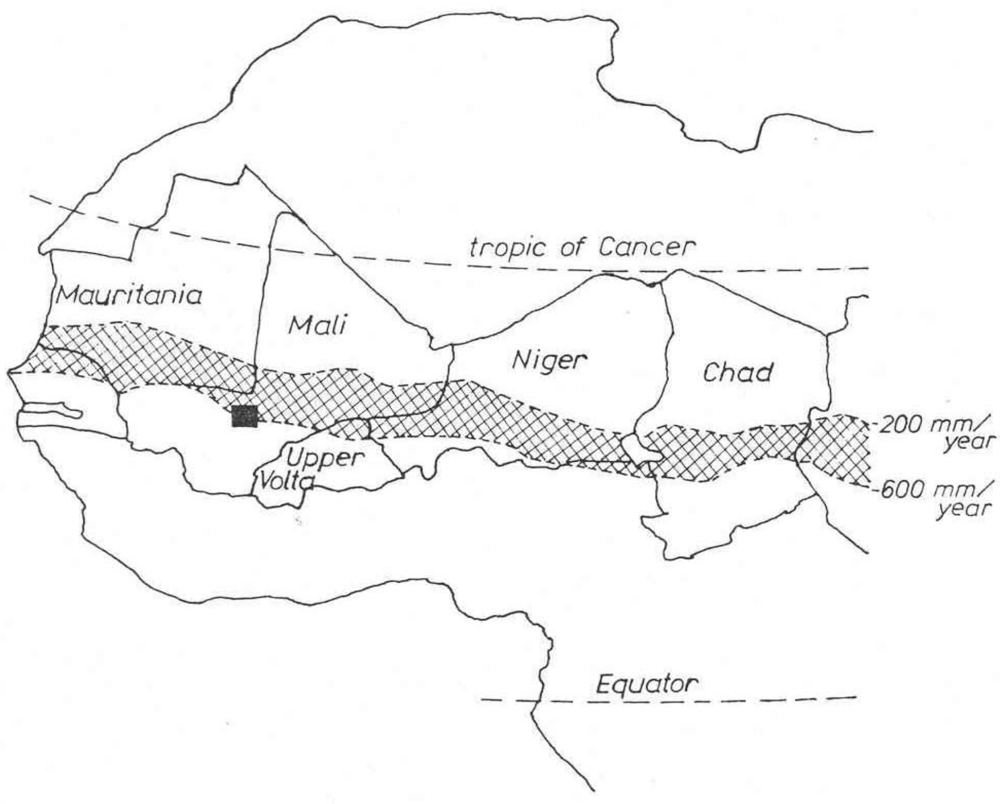


Figure 1; The Sahel, with isohyets (from Hoogmoed and Stroosnijder, 1984). Some sources would place the 100 mm and 500 mm isohyets in about the positions labelled as 200 mm and 600 mm, respectively.

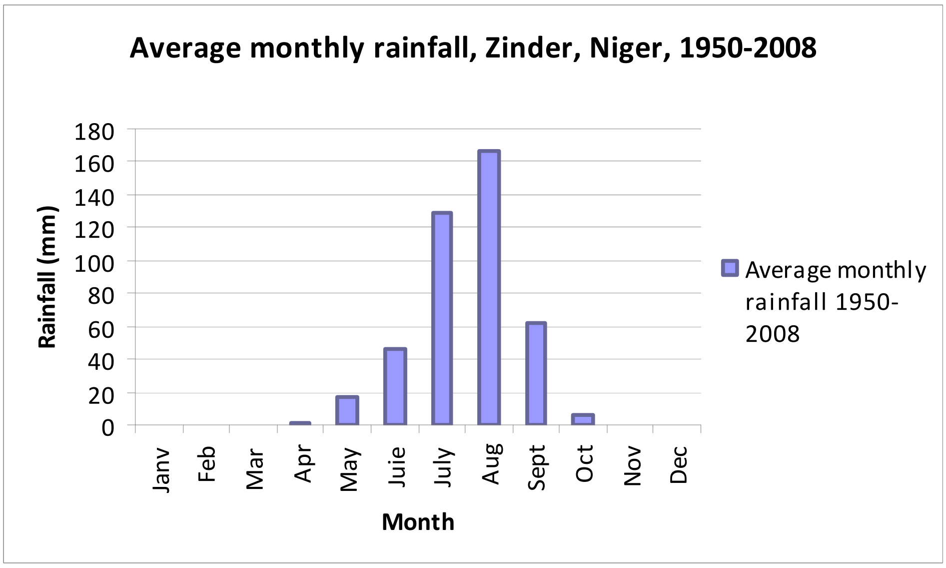


Figure 2: Monthly rainfall distribution in south-eastern Niger

particles. The remainder of the year is sunny and dry, becoming progressively hotter towards the start of the rainy period when it can often exceed 40^0 Celsius. In addition, during the dry months, the dry harmattan wind from the north-east, can cause dust storms and accentuate aeolian soil erosion.

b) Droughts and desertification

Despite variation about the precise meaning of the term "desertification", international concern about this became widespread in the early 1970s, when a disastrous drought and famine in the Sahel began, leading to the deaths of tens or hundreds of thousands of people and several million head of livestock (Grainger, 1990). This period of drought, which eventually continued on into the 1980s, prompted the organising of the United Nations Conference on Desertification, in Nairobi in 1977, to agree a plan of action to bring this process under control.

While this drought continued for over a decade, disagreement has continued about the role of human agency in the degradation of land in the arid zones. Grainger (1982) states that "Desertification is caused by overcultivation, overgrazing, deforestation and bad irrigation" but a contrary view is given in " More People, Erosion; Environmental Recovery in Kenya" (Tiffen, Mortimore et al, 1994) which discusses re-vegetation of the semi-arid Machakos district , and the stabilisation of rainwater runoff gullies there between the 1930s and the 1990s, despite the population increasing by over five times. There are numerous examples from around the world of human activity causing severe land degradation , both localised and more widespread (Thomas and Middleton, 1994), but it is clear that problems developing in an area are a response to local, regional and international factors, which include boundaries or land ownership changes impeding the movement of nomadic herdsmen, the effect of policies promoting cash cropping rather than subsistence farming, as well as the continuing growth in population.

Understanding of climatic cycles in the Sahel has increased considerably in recent decades (Hulme, 2001). Climatic variability in this region, both year-to-year and decade-to-decade is much greater than in the more temperate climatic regions of the world and may be the most variable of any zone in the world, He suggests that the idea of 'average' rainfall is therefore misleading in this area, as equilibrium there must be viewed over centuries or longer, rather than over a few years as in most other areas, and consequently ecological and human systems in the Sahel are primarily adapted to this variability, more than to any notional mean value of rainfall.   It is clear that the post war period in the years leading up to independence, for most of the countries of, had more rain than average period, but has been followed in the past few decades by the worst drought in a century (Anyamba and Tucker 2005). Figure 3 shows the variation in rainfall since 1950, from two sites in Niger, with the first few years having around double the rainfall of the 1970s and 80s. In fact, it appears that periodic droughts have been very common in the Sahel for thousands of years (Shanahan, Overpeck et al, 2009), although evidence has been pieced together from environmental and historical evidence rather than direct measurement of rainfall. Table 1 lists some famines linked to droughts in recent centuries.

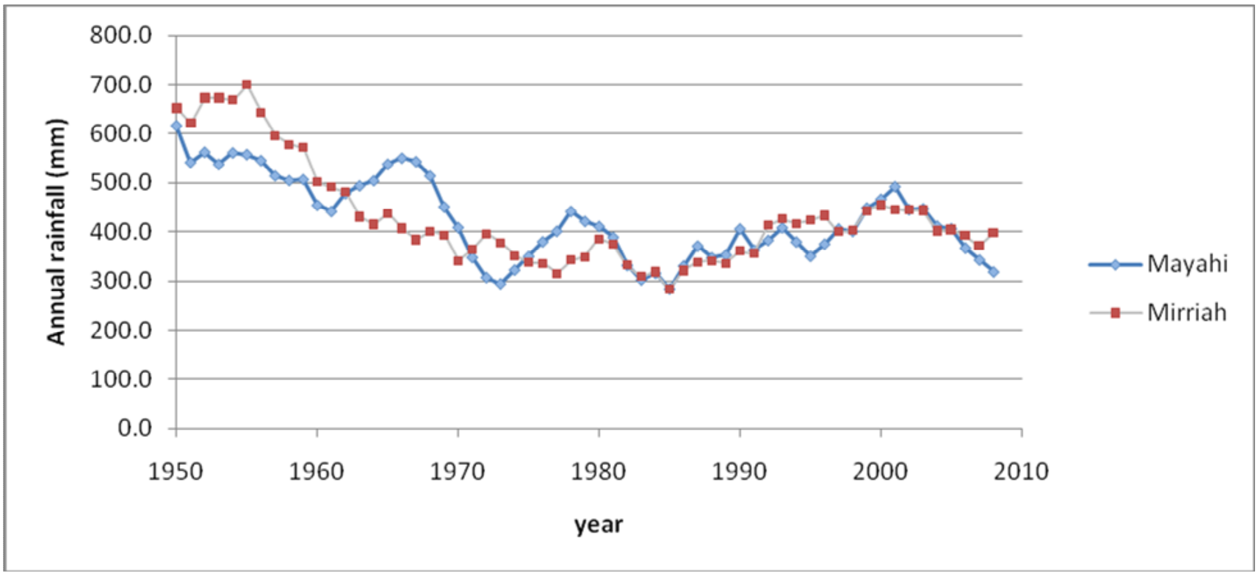


Figure 3: Rainfall variation since 1950 at two sites in central south Niger

Table 1; Some historical famines in the West African Sahel (Alpha Gado, 1994)

Year	The regions affected	Name; other features
1535 - 43	Sahel	"Horror"; drought and epidemics
1752-44	Sahel	People reduced to cannibalism
1830-33	Sahel	
1870-73	Sahel	Drought, epidemics, and armed conflict
1890-93	Sahel	90% of livestock died
1901-03	West Niger	" The sale of the children"

c) Recovery from the major drought of the 1970s and '80s.

As well as increase in rainfall in the Sahel over the past 20 years, as is evident in Figure 5, there has been an increase in the greenness noted on rainy season satellite images This has been seen as evidence of recovery of the zone from the devastating droughts of the 1970s and 80s, and suggests that permanent desertification had not in fact been taking place. The Normalised Difference Vegetation Index (NDVI) has been used by a number of researchers to investigate vegetation recovery. This index is a measurement of radiation absorption by plants, corresponding to the wavelength used by the chlorophyll responsible for photosynthesis in actively growing plants, and is therefore sensitive to the amount of vegetation, and to its current biological activity. Using an NDVI time series for the period 1982 to 2003, Herrmann, Anyamba et al (2005), found good correlation of increased greenery with rainfall, as measured by gridded satellite precipitation estimates (which combine a number of different satellite data series with direct ground-based precipitation measurements) at the 8 km scale. In addition, satellite precipitation estimates are particularly valuable in an area such as the Sahel, which has a very sparse network of rain gauges on the ground. In addition, however, they found a number of areas where the increase of vegetation seems to be greater than expected. These included areas such as plateaus, where there had been great concern about desertification, and the scope for irrigation (as an explanation for greater than expected re-greening) is minimal, but also areas where various projects have attempted to address water conservation and food productivity. They hypothesise that these areas of increased greenness related to improved land management, but also comment that the manifestation of this on the ground has not yet been clearly established.

d) Factors affecting crop yield and plant production in the Sahel

Although the low availability of water is a critical limiting factor for plant growth, there are other environmental circumstances which are also very demanding in the Sahel. The soils in the Sahel are extremely sandy so any water which does penetrate will often rapidly percolate to a deep level potentially beyond the reach of most roots, particularly of crops. This limits the growing period to the rainy season, and even then a prolonged gap between rainstorms can kill plants which have recently been sown. Organic matter within the soil is also easily removed, and sometimes remedying the organic deficit is as important to crop productivity has increasing water supply (Fofana, Wopereis et al, 2004). Therefore, while increasing water supply for crops is an essential part of increasing production, when combined with some form of fertiliser, including straw from previous crops or manure, the yield can increase many fold (Fatondji, Martius et at, 2007).

e) The situation in Niger

Niger is a large country, in central West Africa, the majority of which is part of the Sahara desert. In the southern and western zones, the majority of of the population practice intensive subsistence farming, very largely rain fed, is practised. Fields for arable crops have spread to cover most of the available area where crops can be grown. Much of the ground surface is bare of vegetation, and this is often coated with a crust, of microorganisms, which resist rainfall penetration and promote surface run-off on even shallow slopes (Hoogmoed and Stroosnijder, 1984).

Niger ranks second to last on the UNDP Human Poverty Index Scale, with over 60% of the population living on less than one dollar per day (WHO 2005), a low life expectancy and literacy rate, a high proportion of young children being malnourished, and frequently having areas suffer from famine requiring aid. Population growth is one of the highest in the world at over 3% per year, with an infant mortality rate of 156 per thousand births (UN 2009).

In view of the national importance of farming and the problems there have been in the past, a number of government initiatives and aid projects have attempted to improve farming techniques and food security, often through promoting small-scale rainwater retention and the promotion of tree growth (Tougiani, Guero et al, 2008).

f) This work and the wider research partnership

There is a considerable body of evidence now available confirming the partial recovery of the West African Sahel from the devastating droughts of the 1970s and 80s. There is also evidence pointing to active human agency in this process, in part through the small-scale patchiness of the re-greening that is seen. There has, however been little work quantifying the degree of the differential between areas that have shown better recovery and areas with less, on a local level. It is important to understand what changes in vegetation are taking place at local level, as well as why, in order to guide future policy. The research undertaken here is an attempt to quantify those changes.

Aims

To answer the following questions:

1. Is there evidence of different productivity of biomass in these two types of area?
2. Are there different bio-physical circumstances supporting vegetation growth in the two areas?
3. Are the water resources in the two areas different, or differently managed?

Objectives

These aims give rise to several subsidiary questions:

1. Is there a measurable difference in the number and size of plants, per unit area, different in the two areas?
2. Is there evidence of qualitative differences between the soils in the two areas?
3. What evidence is there from the villagers, and in the landscape, of active management of water, whether to capture it, or to use it more effectively?

This research was undertaken as part of a wider international project, extending across several growing seasons, and looking not just at physical outcomes but also at social processes and understandings, and economic consequences. This international cooperative research work has been established between a number of units, both in Europe and in the Sahel. This comprises the Centre for Ecology, Law and Policy (CELP) in the Environment Department at York University, the Stockholm Environment Institute (SEI) in both Stockholm and York, the Centre Regional d'Enseignement Specialise en Agriculture (CRESA) at Universite Abdou Moumouni in Niamey, Niger, the Institut de l'Environment et de Recherches Agricoles (INERA) in Ouagadougou, Burkina Faso, and the Stockholm Resilience Centre (SRC) in Sweden, over several years.

Methods

This research, into variations in biological productivity within an apparently fairly homogeneous area, took the form of a comparison within the land of 2 villages, chosen for their apparently contrasting levels of vegetation, while otherwise having many similarties. These villages were close to each other in the West African Sahel, in central Niger; one site, Maissakoni, being a representative of more degraded and barren areas in its crop and tree growth since the major droughts discussed above, the other, Wazou, representing a 're-greened' village which has shown good recovery.

The field work carried out for this research fell into two parts. The major part of the work was an assessment of a number of biophysical parameters at points within the land of each village, on a pre-determined pattern. Secondly, in each village, a group of local farmers were interviewed about their land management systems to increase the understanding of the local context, and thereby directly inform the other aspects of the research.

Timing of the research

This work was carried out during July 2009, before the peak of the brief rainy season, but while plant growth was actively underway. This meant that it comprises a 'snapshop' comparison of existing biophysical parameters between the two sites.

Fieldwork

i) Selection of villages

A number of possible villages were selected in the intensively farmed region north of Maradi, in central southern Niger, on the basis of local knowledge, satellite imagery and field visits, by a local partner to the research project from INRAN, Maradi, and the Universite Abdou Moumouni in Niamey. The final decision on research sites was made on the basis of the proximity of the villages to each other, their geographical similarity, and the language spoken in both villages. Proximity was important in order to minimise differences in soil, rainfall, geology, and drainage, whether current or historical, from wetter epochs in the history of the Sahel, which can influence vegetation It was preferable that the language used in both villages should be the same, in order to minimise any differences in quality of communication with the villagers, and, as language and culture are often closely connected in Niger, to minimise cultural and historical differences and attitudes to land management.

In each village, representatives of the local office of the Nigerien Department of the Environment arranged introduction to the community, and at an initial meeting with the village chief agreement was reached for the research to be undertaken, and also to hold a discussion with a small group of villagers to discuss land management.

ii) Distribution of data collection points within each village territory

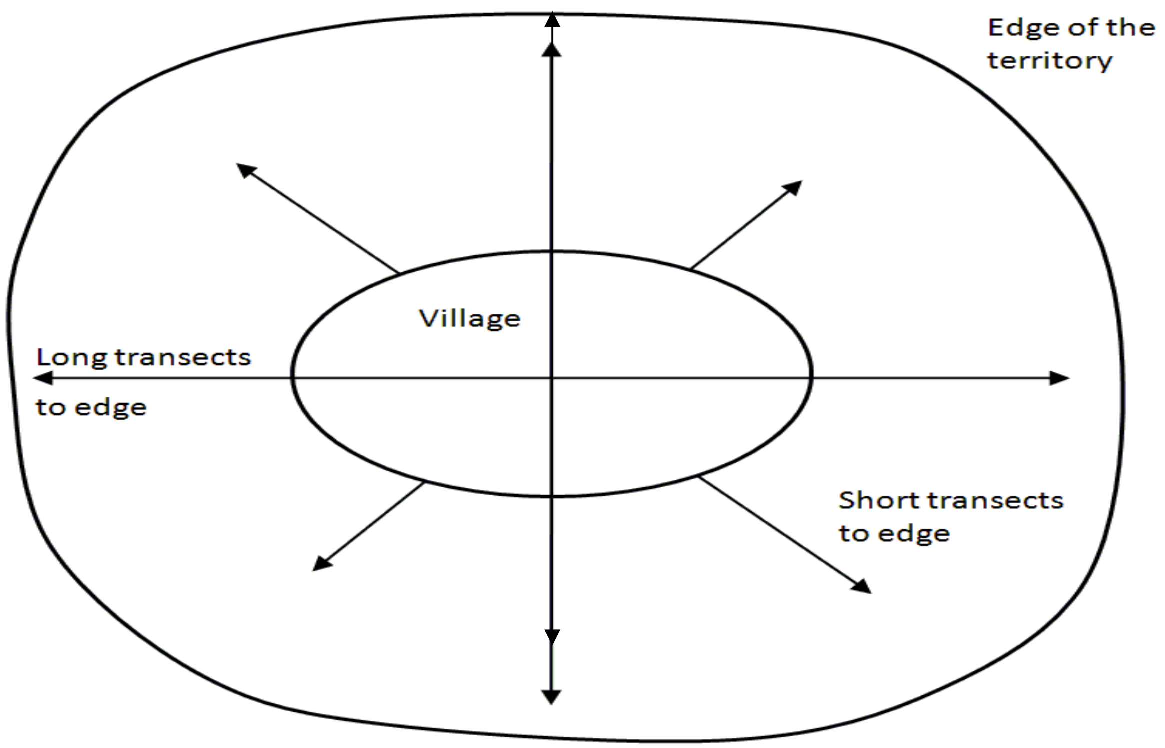
Data collection was carried out along 4 straight transect lines ('long' transects) radiating out from the centre of each village, across the village boundary into the agricultural areas, continuing to the edge of the village lands. These lines were to the north, east, west and south. This pattern was chosen in order to:

- cover the full extent of each village's lands;
- ensure that areas with different characteristics, whether close to the village or towards the boundary with other villages, were sampled; and
- avoid observer bias in choice of sampling sites, by having pre-determined points for this.

A GPS and compass were used for position finding, as well as direction and distance selection when moving between sampling points, and obtaining the latitude, longitude and elevation of sampling sites.

Data collection points were the centre of each village; at 100m intervals along the transects until 400m was reached; then every 200 m to the edge of the village territory. Some further data were later collected from the omitted hundred metre points. The greater frequency of data collection in the central area was chosen because of uncertainty about the position of the village edge, where the land use would change significantly, as well as the possibility that there would be a number of zones close to the village with different characteristics. A second set of 4 transects ('short' transects) was also used, spaced midway between the initial four lines, radiating to the north-east, south-east, south west, and
northwest; these additional lines omitted the village itself, but started at its edge, covering five points each, 200m apart, rather than continuing up to the edge of the territory. See figure 4.

Figure 4: Idealised plan of village and transect lines



Within the villages themselves, sampling was only possible in the roadways and clearings between housing compounds. This limits the representativeness of the village sampling points to a degree. These roadways are bounded by mud walls and for traditional religious reasons are orientated in a grid in a north/south or east/west direction. The roads did not continue in this grid pattern outward across the fields however, and therefore the sections of the transects beyond the edge of the villages went across not only cultivated areas, but also pathways, boundary hedges, and grazing land. Outside the actual villages it was only occasionally necessary to move a data collection point sideways by 1 or 2 metres, because of the presence of a tree or a grain store.

The work was carried out along the transects together with a representative of the Department of the Environment, who assisted with interpreting as well as plant identification and measurement, and a student from the national University of Abdou Moumouni in Niamey, also undertaking research, assisting with orientation and position finding.

iii) Parameters measured at data collection points

At each sampling point, a number of data were collected, from within a circular area of 10 m radius (314 m^2). This unit was chosen to maximise the quantity of data available while minimizing need for measurement (as would happen with a square for example). When there was uncertainty about whether a tree or shrub was within 10m of the sampling position a tape measure was used to check.

The following information was collected at each point:

Routine data; Day, date, time; village, transect direction, site number and distance from start; latitude, longitude and elevation

Description of the sampling point; Whether field, grazing area, pathway, etc; slope of ground, and any particular features such as granaries, paths or buildings.

Soil; Type (subjective description) and surface quality (presence of a crust) were visually assessed, as well as quantity of plant debris (straw)

Crops; Types growing within the 10m circle.

Tree species, Numbers, and sizes; height, and DBH (diameter at breast height). Heights of trees were estimated visually in conjunction with an experienced, trained, local forester, who also identified the species within the sample area. DBH - diameter at breast height - is an approximate practical measurement used to assess tree size, especially in plantations. This was measured at upper arm height, either directly, as the width of the trunk, or as a circumference using a tape measure and the diameter calculated assuming a circular cross-section

Tree canopy size; The long transects were also re-walked, outside the village boundary, to assess tree canopy size, as a measure of ground cover by the branches and leaves. This was estimated after the height was estimated; the width, on a ruler held at arm's length, being compared with the height on the ruler. The depth was also measured, being a second 'width' at right angles to the first, and these two dimensions used to calculate a canopy area, assuming a symmetrical shape to the crown.

Other perennial plants (shrubs) were counted and identified, by the forester, as another manifestation of biological productivity, with type (species) and height. The change from 'tree' to 'shrub' was taken as being 1m.

Animal droppings; the volume of droppings from domesticated animals was measured in a representative part of each 10m into collection point. A $4m^2$ area (1.12m radius circle) was marked out, and the droppings on the ground gathered and placed, with gentle shaking but without pressure, in a calibrated container. The measurements obtained therefore include the air spaces between the droppings. No distinction was made between different types of animal droppings, although these were overwhelmingly from goats and of fairly uniform size. As an initial trial, a measurement was also made for a $1m^2$ area (56 cm circle) but the values obtained varied much more dramatically than the larger one, which was felt to give a better balance of accuracy and practicality.

Soil samples were taken at each sampling point. On all transects samples were taken for measurement of soil carbon content, as an proxy measure of soil organic content and an indicator of fertility. Three scoops of surface soil were taken from spots 1 m apart that were clear of crops, droppings and plant debris such as stalks or leaves. These samples were mixed and dried before transporting for analysis.

Soil was also taken for texture analysis (particle size distribution,or granulometry) along the short transects; both surface (0-5cm) and deeper samples (25-30 cm) were taken. This was done for pooled samples, one mixed sample for the five surface sites on each short transect and another for the five deeper samples.

. The soil samples taken were dried, mixed, and transported for laboratory analysis in the soil laboratory of the Universite Abdou Moumouni in Niamey. Two sets of tests were carried out. For all sites the soil was analysed for its carbon content, as a measure of organic content. This was done by assessing loss of weight on
of the dried sample, after passing through a 2mm sieve to remove any stones or gross organic material such as crumbled leaves or droppings. In addition, for the short transects, particle size composition was assessed, by shaking a dried sample through a graded series of sieves.

iv) Villager consultations

A meeting was held in each village, with the help of a local interpreter, to ask about various aspects of land management, developments in recent years, and water supply within the village and its lands. The questions were initially discussed with the interpreter in French, the national language, to ensure a good understanding of their purpose, before they were put to the villagers in the local language, Hausa. Five or six men of varying ages, including the village chief, took part in an informal discussion in a shaded area of the street, over 45 minutes. The questions are listed in Appendix 2.

Results

Description of villages
The two villages chosen were in Mayahi District, Maradi Region in central southern Niger. They are of a roughly similar physical size, layout and housing make-up, although Wazou has a rather larger and more modern mosque. The houses are adobe, made of earth, and single-storey, and situated in their own small compounds; vegetation within the villages consists of mature trees, and some weeds after the rains. The more degraded village, Maissakoni, is slightly more remote from the major town, market and road. They are on the same level plain, their centres being 10km apart. The more re-greened village, Wazou, is close to the edge of a partial forest reserve which marks a very shallow valley. In both sites, the ground is slightly undulating, with shallow or sometimes steep slopes extending for 100 m or so. Other details are given in Table 2.

Data	**Maissakoni**	**Wazou**
'Designation' of village	'degraded'	're-greened'
District (main town)	Mayahi	Mayahi
Distance to central town	22 km	12 km
Distance to major road	5 km	0
Distance to weekly market	5 km	14 km
Latitude of centre	13*48'58" North	13*53'10" North
Longitude of centre	7*32'14" East	7*35'53" East
Elevation of centre	402 m	382 m
Distance between villages	10 km	10 km
Village spread	250 x 500m	300 x 400 m
Approx. agricultural area	3 x 3.5 km	3 x 2.5 km
Language spoken	Hausa	Hausa
Majority livelihood	subsistence farming; arable and pastoral	subsistence farming; arable and pastoral

Table 2: Basic data about villages researched

Data from sampling points
The data from sampling sites have been presented in relation to distance from the edge of the village, rather than from the central point of the village where the long transects began. This is because the villages are asymmetrical, with a wide variation in distance from the centre point to the edge. The edge is a more useful baseline as the agricultural areas can then be considered separately from those inside the village boundary. .

a) Routine data from sampling points

Table 3 shows the principle data relating to the transects

b) Soil and surface assessment

Initial assessment of soil crusts on the four Maissakoni long transects showed 13 of 30 potential field areas (those outside the village) having a crust in Maissakoni, prior to the first heavy rain of the year, but in Wazou only 2 of 28 equivalent areas had a crust three days later, this being after heavy rain. During further work in the first village, Maissakoni, a few days later, no further crusts were noted.

Table3: Details of Transects at Maissakoni and Wazou villages

Date	Line	name	Approx. direction	start point Lat. (N)	Long. (E)	Height (m)	finished point Lat. (N)	Long. (E)	height (m)	point	length (m)
Maissakoni											
12.7.09	1	Long transect 1	South(w)	*13* 48'58"*	*7*32'40.5"*	403	13*48'12.6	7*32'17.3"	410	9	1400
12.7.09	2	Long transect 2	North (w)	*(village*	*Centre)*		13* 49'44.5"	7*32'14.4"	410	10	1600
13.7.09	3	Long transect 3	West (s)	"	"		13*48'53.6"	7*31'23.2"	399	10	1600
13.7.09	4	Long transect 4	East (s)	"	"		13*48'47.4*	7*33.04.9"	418	10	1600
18.7.09	11	Short transect 11	SW	*13* 48'50.6"*	*7*32'8.2"*	408	13* 48'39.2"	7*31'48.7"	408	5	800
18.7.09	12	Short transect 12	East	*13* 48'42.9"*	*7*32'16.8"*	409	13* 48'42.5"	7*32'39.0"	414	"	"
18.7.09	13	Short transect 13	NE	*13* 49'7.7"*	*7*32'17.7"*	389	13* 49'9.5"	7*32.40.5"	417	"	"
18.7.09	14	Short transect 14	East	*13* 49'3.0"*	*7*32'11.3"*	408	13* 49'3.8"	7*33.45.7"	400	"	"
Wazou											
15.7.09	5	Long transect 5	West	*13*53'10.2"*	*7*35'53.1"*	*382*	13*53'05.1"	7*34'48.8"	405	9	1400
15.7.09	6	Long transect 6	East	*(village*	*Centre)*	*382*	13*53'10.2"	7*35'53.1"	382	10	1600
16.7.09	7	Long transect 7	South	"	"	*382*	13*52'29.9"	7*36'0.7"	382	10	1600
16.7.09	8	Long transect 8	North	"	"	*382*	13*53'34.3"	7*35'48.2"	388	10	1600
18.7.09	15	Short transect 15	South (w)	*13° 53' 0 9.5 "*	7° 35'59.2"	*376*	13° 52'49.1"	*7° 36'13.7"*	387	5	800
18.7.09	16	Short transect 16	South(e)	*13° 53'16.6"*	*7° 35'56.6"*	*376*	*13° 53'35 .0*	*7° 36'5.7"*	378	"	"
18.7.09	17	Short transect 17	North(e)	*13° 53'14.8"*	*7° 35'46.4"*	*388*	*13° 53'36.2"*	*7° 35'40.9"*	388	"	"
18.7.09	18	Short transect 18	North (w)	*13° 53'4.6"*	*7° 3546.3"*	*386*	*13° 53'14.1"*	*7° 35'31.5"*	388	"	"

c) Crops

There were considerable differences in the distribution of crops in the agricultural areas in two villages, as measured within the sampling sites; see tables 4 and 5. While in both, millet predominated as the staple crop, Maissakoni had a much smaller number of sites where other crops are used alongside it, intercropping being fairly unusual there; 10 of 45 sampled sites (28%) in contrast to being the norm on the majority of sites as in Wazou (65%). The choice of crop combinations also varied. In Maissakoni, 6 of the 10 (60%) intercropping sites were a combination of a staple (millet and/or sorghum) and a leguminous, nitrogen-enriching plant (beans or groundnuts); in contrast, in Wazou 27 of the 30 (90%) inter-cropped sites had such combinations, therefore the majority of sites with crops - 27 of 46 - had nitrogen-enriching plants sown in them.

While there were six sites planted with 3 crops in Wazou, there were none in Maissakoni, although there was one with 4 crops. This is shown in figure 3. In both villages the number of inter-cropped sites was greater nearer to the villages than further out; see figure 6. The timing of data collection is also noted in table 7; data collected 'before' was immediately prior to the first major rainstorm of the year, although in fact this was two weeks after two rather minor episodes of (discussed in results of questionnaire). The other timings relate to days after this first major rainstorm. While in Maissakoni, where the long transects were surveyed before the storm and the short ones afterwards, the portion off intercropped sites increased dramatically, in Wazou where all the transects were studied afterwards, the proportions did not change significantly. Despite this, in Maissakoni the amount of intercropping remains far below the level in Wazou.

Table 4: Frequency of different multi-cropping at sites in the two villages

	1 crop	2 crops	3 crops	4 crops	Non-cropped sites	Total cropped sites	Total inter-cropped sites	Sites with Nitrogen-fixing crops
Maissakoni	36	9	0	1	5	45	10	6
Wazou	16	24	6	0	2	46	30	27

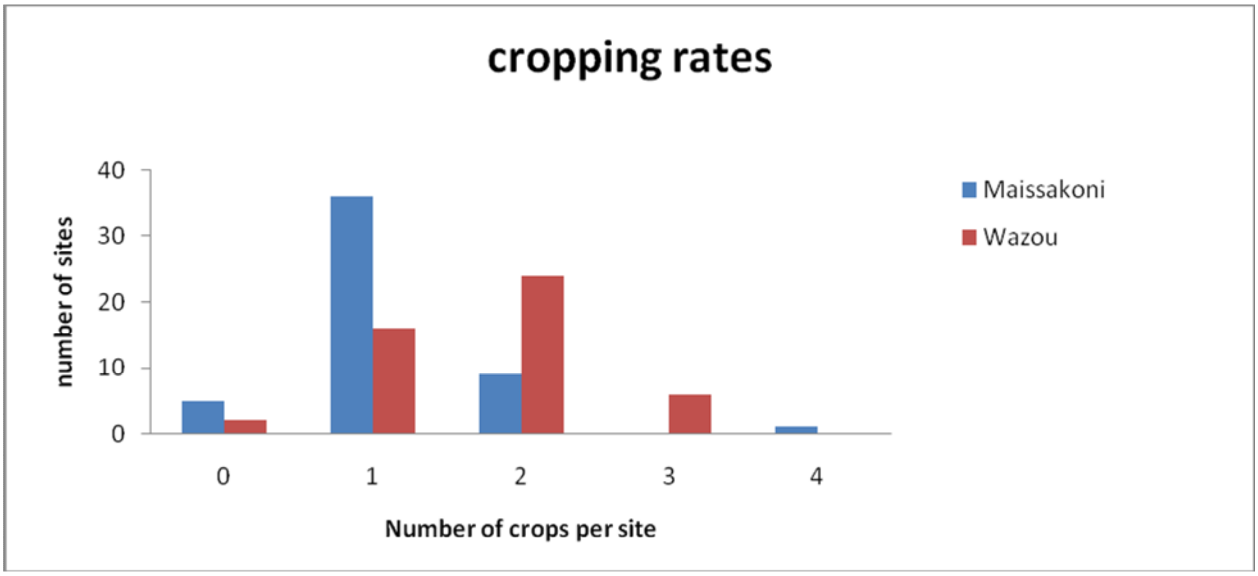


Figure 5: Frequency of cropping rates

Table 6: Specific cropping regimes (key to crops is in first line of table 2)

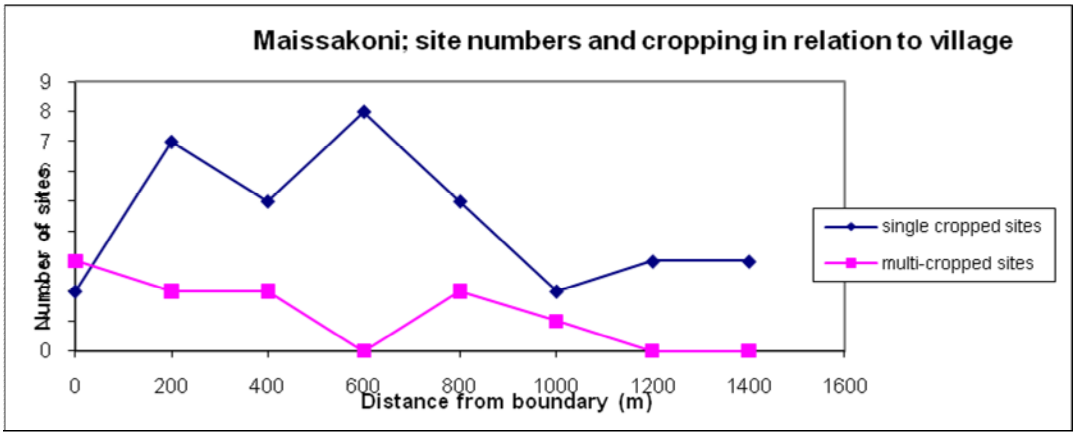
	1-crop sites				2-crop sites				multi-crop sites				Total sites
	M	**S**	**B**	**Gn**	**M-B**	**M-S**	**M-Gn**	**mZ**	**M-S-Gn**	**M-S-B**	**M-Z-Gn**	**M-S-Gn-Z**	
Maissakoni long	22	1	0	0	0	2	0	0	0	0	0	0	25
Maissakoni short	12	0	0	0	4	1	1	1	0	0	0	1	20
Maissakoni	**34**	**1**	**0**	**0**	**4**	**3**	**1**	**1**	**0**	**0**	**0**	**1**	**45**
Wazou long	8	0	1	1	6	1	5	0	0	4	0	0	26
Wazou short	8	0	0	0	7	1	1	1	1	0	1	0	20
Wazou	**16**	**0**	**1**	**1**	**13**	**2**	**6**	**1**	**1**	**4**	**1**	**0**	**46**

Key; M=millet, s= sorghum, B= beans, Gn=groundnuts, Z = sesame

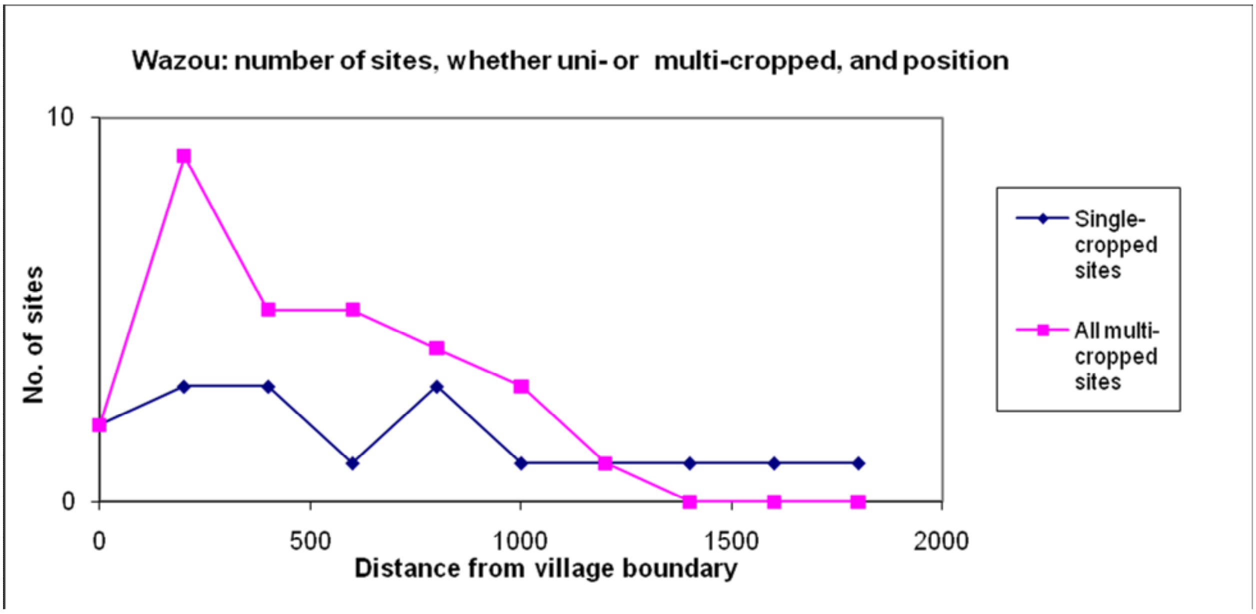
Table 7: Cropping variations between long- and short transects (for discussion of timing column see text).

	cropped sites	**variations in crops used**	Multi-cropped sites		Timing of data sampling
			No's	**%**	
Maissakoni 4 long transects	25	3	2 of 25	8	(Before)
Maissakoni 4 short transects	20	6	8 of 20	40	5 days after
Maissakoni total	**45**	**7**	**10 of 45**	22	-
Wazou 4 long transects	26	7	16 of 26	62	2-3 days after
Wazou 4 short transects	20	7	12 of 20	60	5 days after
Wazou total	**46**	**11**	**28 of 46**	61	

Figure 6: Number of single- and inter-cropped sites with distance from village edge:
a) Maissakoni



b) Wazou



In both villages there is a noticeable decline, with distance, in the numbers of crops per site, particularly from about one kilometre from the village. This is most dramatic in relation to multi-cropping, especially in Wazou, although this is from a higher level closer to the village. The proportionate decline in multi-cropping in Wazou is clearly shown in figure 6b.

c) **Tree, and perennial plant numbers**:

In both villages most sampling points had no trees, and at most of the rest there was only one tree. These data have therefore been grouped together as totals, and averages, in order to demonstrate any differences in distribution that there may be between the two villages.

Figure 7 compares the absolute numbers of trees at successive sites away from the centre of the villages. This takes no account of size, but does suggest a greater number of trees in Wazou, except in the outer part of the territory. Figure 8 compares this absolute number for each village with the average number of trees per four sampling points.

Figure 7: total trees in both villages, at all sampling points at a given distance.

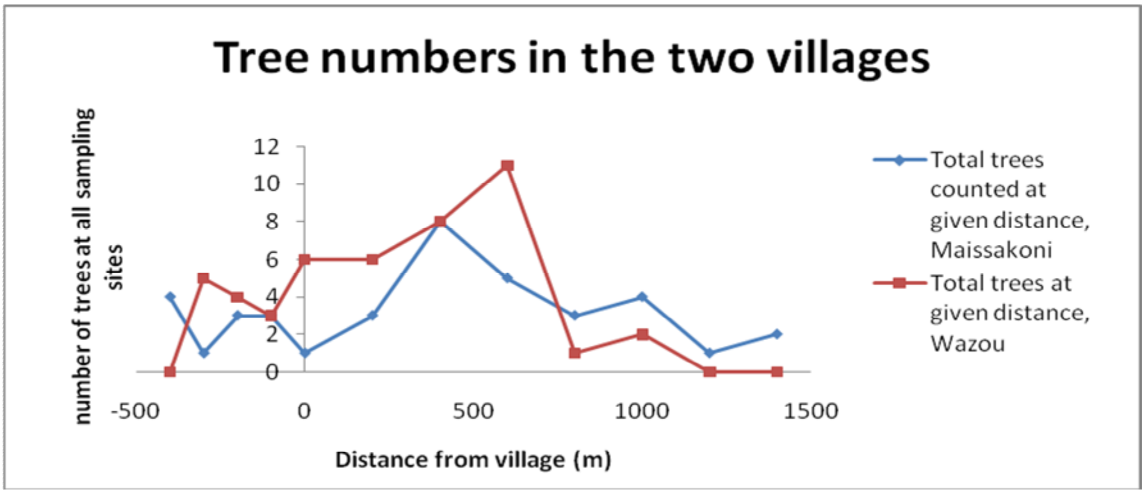
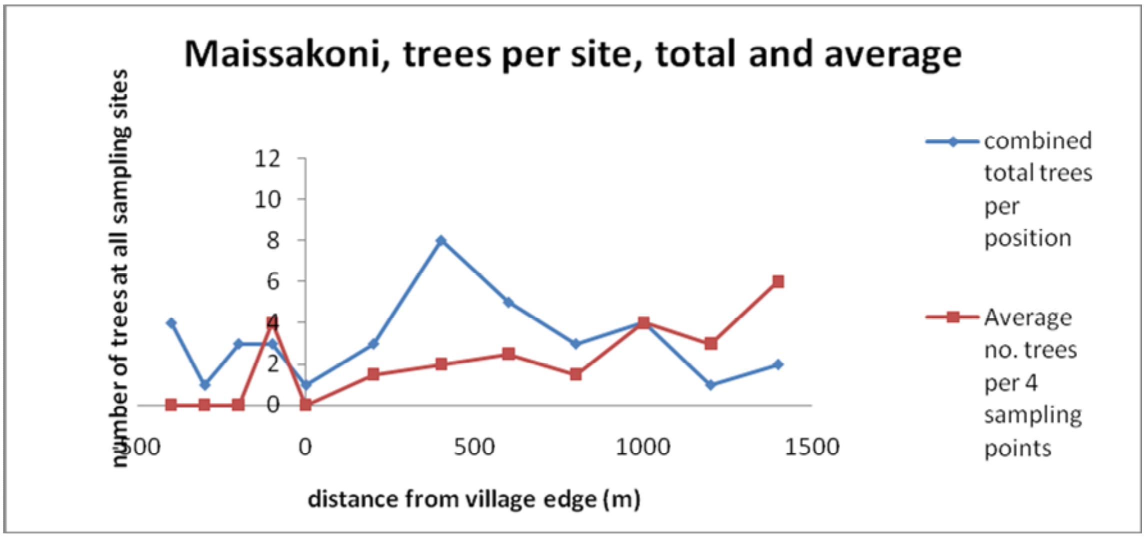
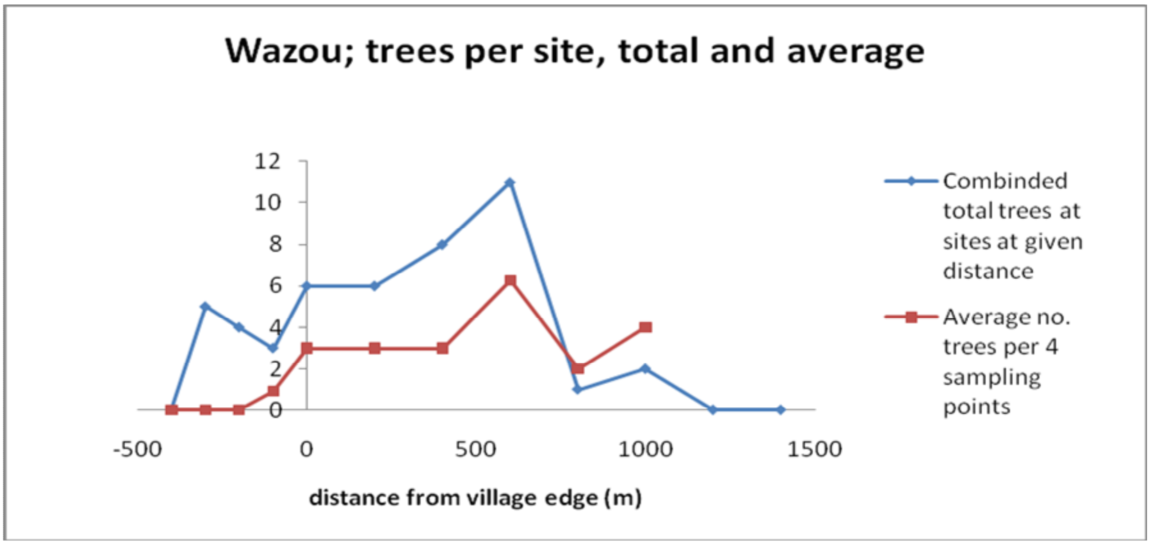


Figure 8: total and average numbers of trees for each village.

a) Maissakoni



b) Wazou



The number of trees, and perennial plants, is shown in table 8. Maissakoni had 76 trees on 103 sites (0 .74 trees per site), in contrast to Wazou's 97 trees on 97 sites (1.0 per site).

The number of perennial plants counted was very different on the long transects (17 for Maissakoni and 38 for Wazou), but identical on the short transects (25 in each village).

Table 8: total trees and perennial plants counted at sampling points

Maissakoni	trees	perennial plants		**Wazou**	trees	perennial plants
Long transects	25	17		Long transects	31	38
short transects	13	25		short transects	12	25
Canopy transects	38	N/A		canopy transects	54	N/A
total/points	**76/103**	**42/62**		**total/points**	**97/97**	**63/55**
Average	**0.74**	**1.25**		**Average**	**1.0**	**1.25**

c) Tree canopy cover

There was a considerable difference in tree canopy cover between the two villages. Tree canopies cover approximately 3.3% of the sampled areas in Maissakoni, but 7.3% in Wazou, representing 2.2 times the coverage. However, in each village, a large proportion of this cover is accounted for by a small number of very large trees; in Maissakoni, 3 trees account for over half the area (298/535 m^2 = 56%) and in Wazou, the single largest tree accounts for most of the coverage (625/1221 m² = 51%); this area is more than the total canopy coverage at all the sampling points in Maissakoni.

There is a close link between the estimate made height and the calculation of breadth and depth of the trees, using the technique discussed above. Any error in these estimates is likely to be broadly similar for trees of similar size. However, in view of the second largest tree measured in Wazou being 22m high and the third only 12m , the very largest tree in Wazou, at 25 m, is an outlier to a degree suggesting a) the possibility of over-estimation and b) a consequent disproportionate degree of error to total canopy size (given the contribution height gives to width estimates and multiplication for the canopy size). If this single tree is taken as 20 rather than 25m high, and the same reduction made to both width and depth, this gives a canopy of 400 m^2 rather than 625; Wazou's canopy coverage therefore being reduced to 5.9%, which is 1.8 times Maissakoni's canopy cover.

To try to reduce wider error from over-estimation of the largest trees in both villages, if all those of 10m height or more have their width and depth reduced by 10%, but the largest tree discussed above by 20% (to 20m), canopy coverage reduces to 5.8 and 3.0% for Maissakoni and Wazou respectively, giving Wazou 1.93 times the canopy cover.

These three estimates for difference in canopy cover (2.2, 1.8, and 1.93) at the sampling points give a practical estimate that Wazou has twice as much tree cover as Maissakoni.

A cumulative frequency diagram for the canopy areas for the 2 villages is shown in figure 9.

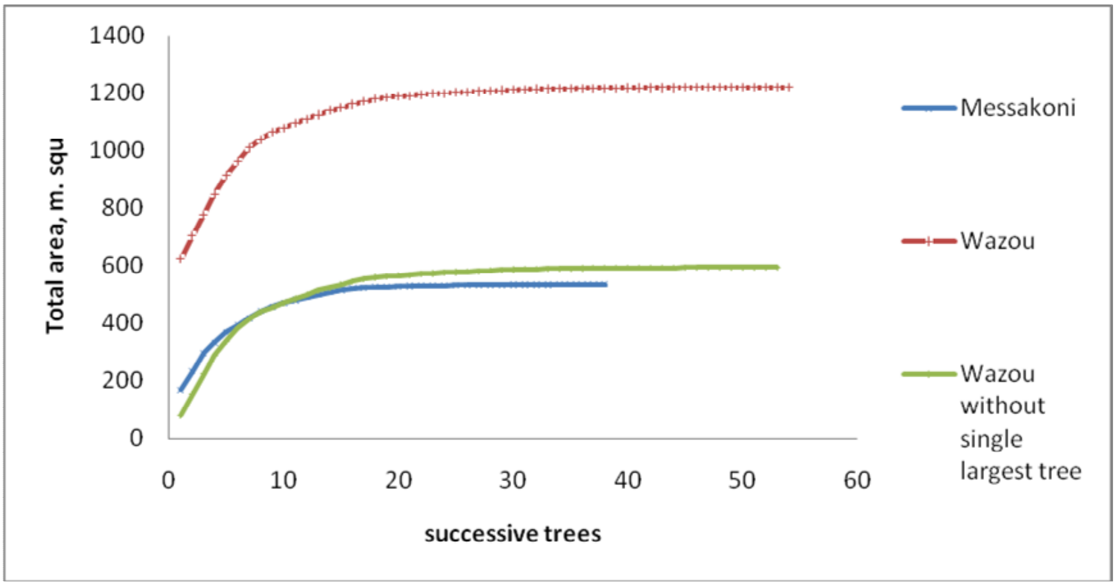
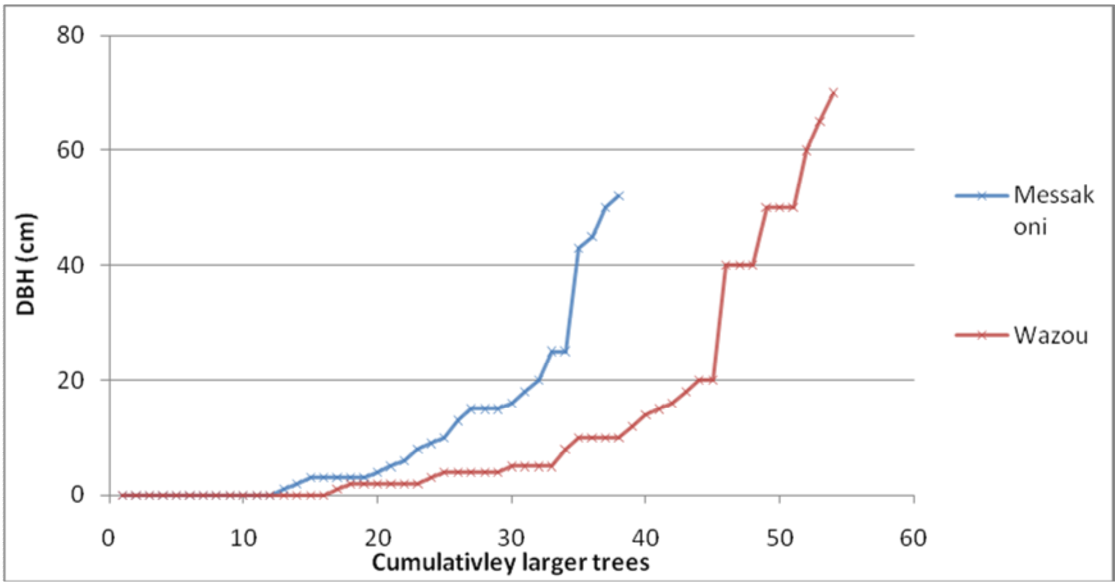


Figure 9: Cumulative Frequency diagram for tree canopies in Maissakoni and Wazou. The third line is Wazou without the largest tree included.

Diameter at Breast Height (DBH)

The crude average figures found were 15.7cm for Maissakoni, and 16.5cm for Wazou, but for trees (i.e. all the perennial plants more than 1 m high) with a DBH above 1 cm the averages were 16.4 cm (25 trees) for Maissakoni and 18.5 (37 trees) for Wazou. Figure 10 demonstrates the considerable difference in spread for the 2 villages.

Figure 10: Combined cumulative frequency diagram for both villages of diameter at breast height



d) Types of tree

There were seven species of tree in the Maissakoni sampling points, five with a number of specimens; and 11 in Wazou, six with multiple representation. Details of types and dimentions are given in table 9. The canopy cover provided by 'Gao' trees (***Faidherbia albida*** (syn. *Acacia albida)* Delile), which keep their foliage during the long dry season, is of importance. This was 66% in Maissakoni and 67% in Wazou, or 58% in both villages if the very largest tree dimensions are modified as discussed above was greater significance. However, this amounts to twice as much actual ground cover in Wazou during the dry season, as tree canopy cover there is twice as high (see above).

Table 9: Trees and their dimensions, in both villages.

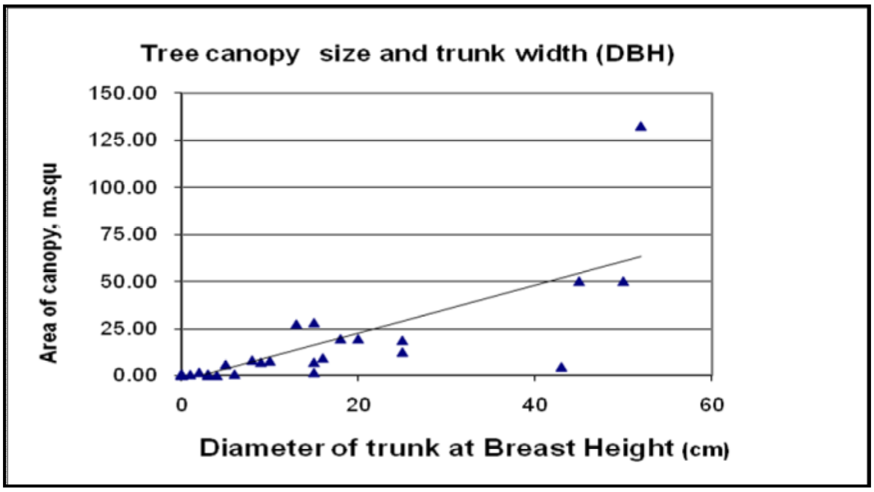
trees with above 1 represetative	Maiss-akoni	average height	canopy area	Wazou	average height	canopy area
Acacia albida	5.0	8.1	322.7	12.0	7.4	833.3
Balanites Aegyptiaca	2.0	5.3	32.5	5.0	2.9	120.4
Bohenia rufecus	0.0	0.0	0.0	6.0	2.4	32.2
Combretum glutinosum	8.0	4.4	41.6	0.0	0.0	0.0
Guiera senegalensis	16.0	1.7	10.1	8.0	1.5	1.4
Piliostigma reticulatum	4.0	3.0	49.2	14.0	3.3	149.5
Ziziphus mauritiana	0.0	0.0	0.0	3.0	1.3	1.9
other trees	2.0	3.7	34.3	5.0	3.7	109.0

e) Correlation of DBH and canopy spread

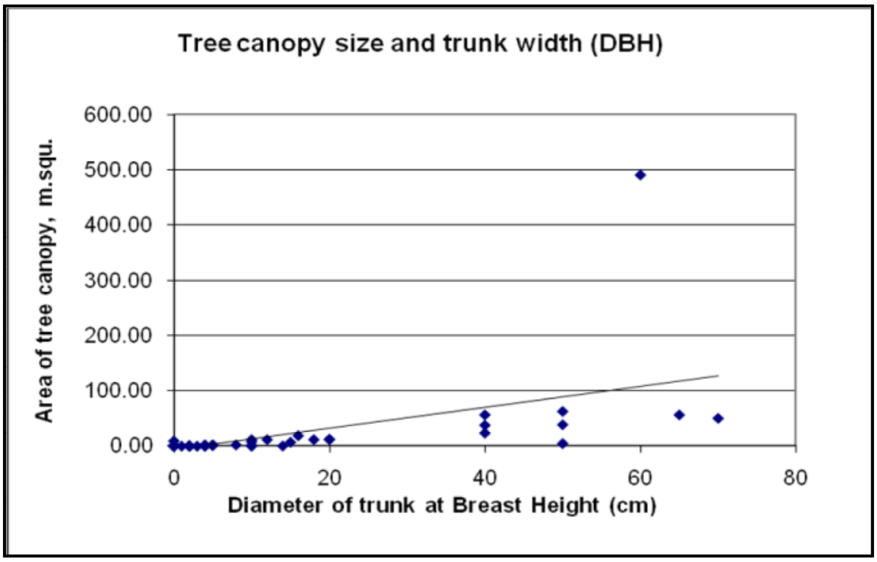
This provides a useful check on the height estimations of trees.

If the biggest tree in each village is excluded, because of uncertainty about the accuracy of the stated dimensions (as discussed above) there is a fairly good correlation between trunk size and foliage spread, of 0.81 in Maissakoni and 0.88 in Wazou. This would be expected of trees growing in comparable circumstances, and the poorer correlation in Maissakoni implies greater variability, whether of tree type of environmental conditions, or of pollarding. There is therefore a suggestion in this result of greater removal of branches from trees in Maissakoni, which would reduce the canopy without affecting the trunk diameter.
However, If the 2 largest trees are included, the correlation drops slightly to 0.77 in Maissakoni, but much more dramatically to 0.53 in Wazou, now showing a much weaker relationship between canopy size and width rather than a stronger one. This provides support to the stated height, and spread, of this largest tree actually being incorrect. The scatter diagram and trend lines in figure 9 show these two largest trees are outliers, as the highest marked points within each figure, in their respective villages.

Figure 10: Scatter diagram of tree size plotted against trunk size, with trend lines. Note different scales.
a) Maissakoni



b) Wazou



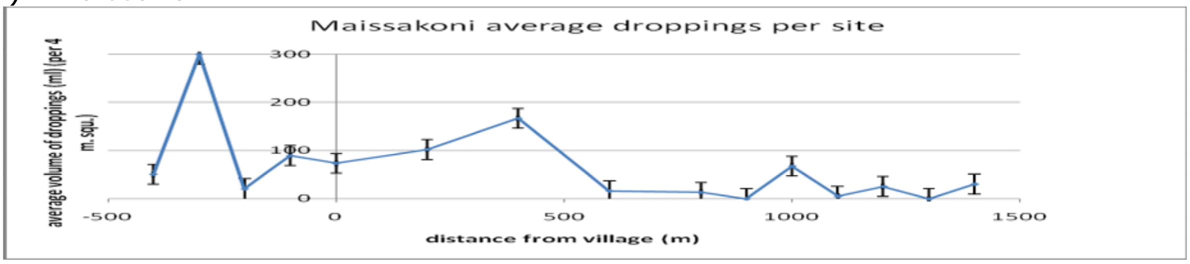
f) Animal droppings

This shows a large variation both between the two villages (see figure 12), and also within each village grounds. There were quite a few sites with no droppings all, and also many sites with the numbers. Within the villages, and towards the edge of the territory, there are similar levels of droppings. Outside both villages there is an increase, but this is especially marked in Wazou the volume is a lot higher, and although variable, remains (with few exceptions) above the Maissakoni levels throughout the territory.

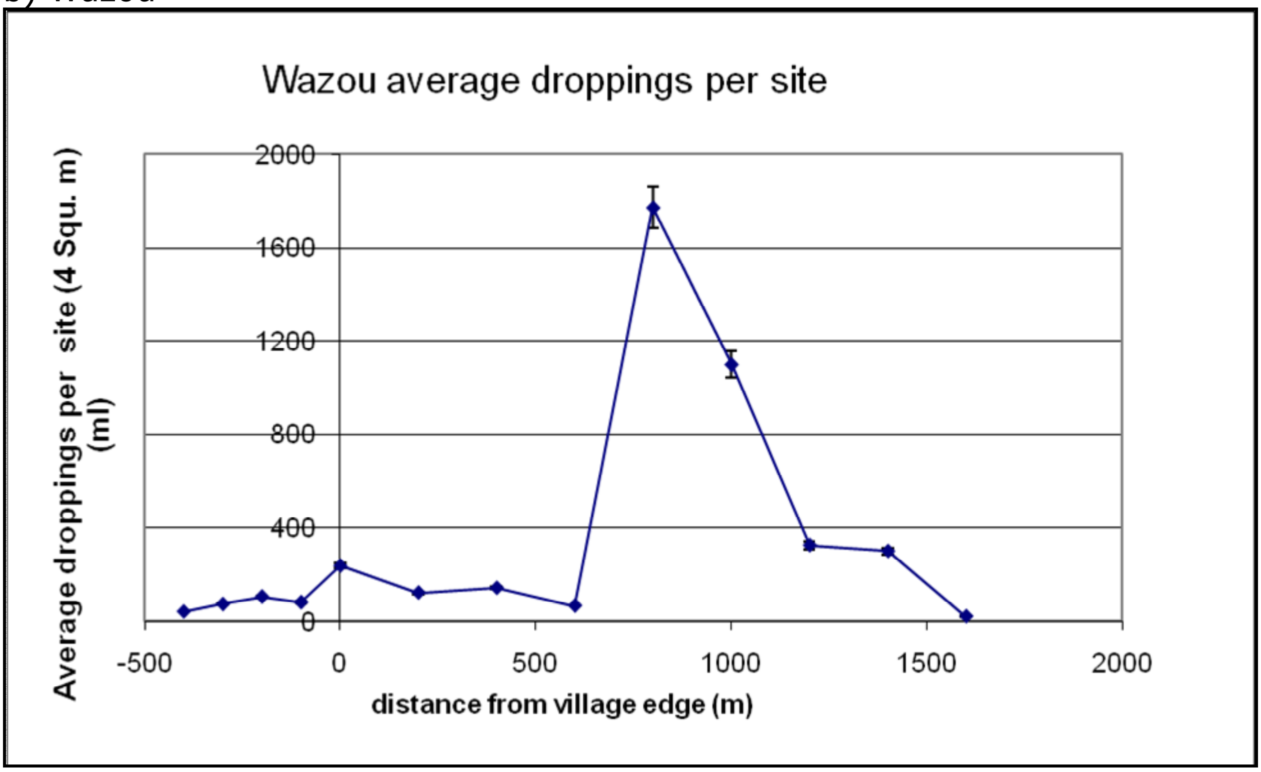
In Wazou there are a few very large single measurements, which account for the dramatic increase. In both villages there is a decline towards the edge of the village territories. In the number of cases the areas with higher levels were well delineated, supporting the information given that these additional droppings brought in from elsewhere by the farmer, as fertiliser.

Figure 12: Average volume of animal droppings per site, with error bars (1 standard error) Note different vertical scales in a) and b)

a) Maissakoni



b) Wazou



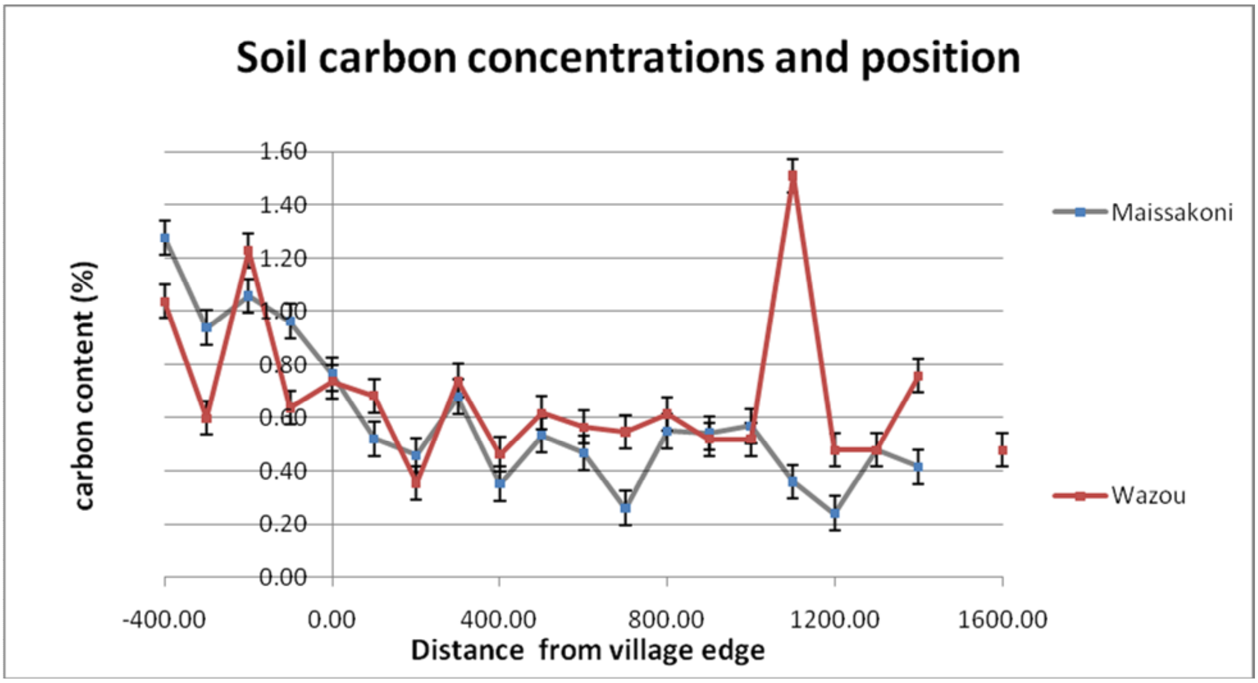
Laboratory Analysis of Soil

i) Carbon content of soil

Both villages show a pattern of a higher carbon concentration within the village, and lower outside (see figure 13). The level outside is generally slightly higher in Wazou than in Maissakoni, although this becomes more marked at the peak at 1100m, which corresponds to a large deposition of animal droppings. This applies to a degree to the other peaks in the agricultural areas, particularly in Wazou. This is in contrast to the high levels in the village, where the quantities of droppings are not high.

It is not clear why this is, nor why there is such a large drop in carbon content at 1200m in Maissakoni, to 0.24%, virtually the lowest level of any sample.

Figure 13: Comparison of carbon content of soil in the two villages (with error bars at 1 standard error)



Of interest is the close fit between the levels found at both village sites for much of the range outside the village edge.

ii) Soil Texture

This analysis was done for the short transects, with one pooled sample for the five sites' surface samples, and one pooled sample for the five sites' deep samples. There is a very high degree of similarity throughout with these results, between the values within each village, between the surface samples and the deep samples, and between the samples for Maissakoni and those for Wazou; see figure 12. The main difference is that both the surface and the deep samples for Maissakoni give a higher proportion of grains in the fine sand category, and a lower in the coarse silt category which is the adjacent category. This suggests a proportion of particles are marginally smaller by enough to put them on the other side of this size boundary than they are in Wazou. It is also possible that this is a laboratory artefact. See table 10 for particle size categories.

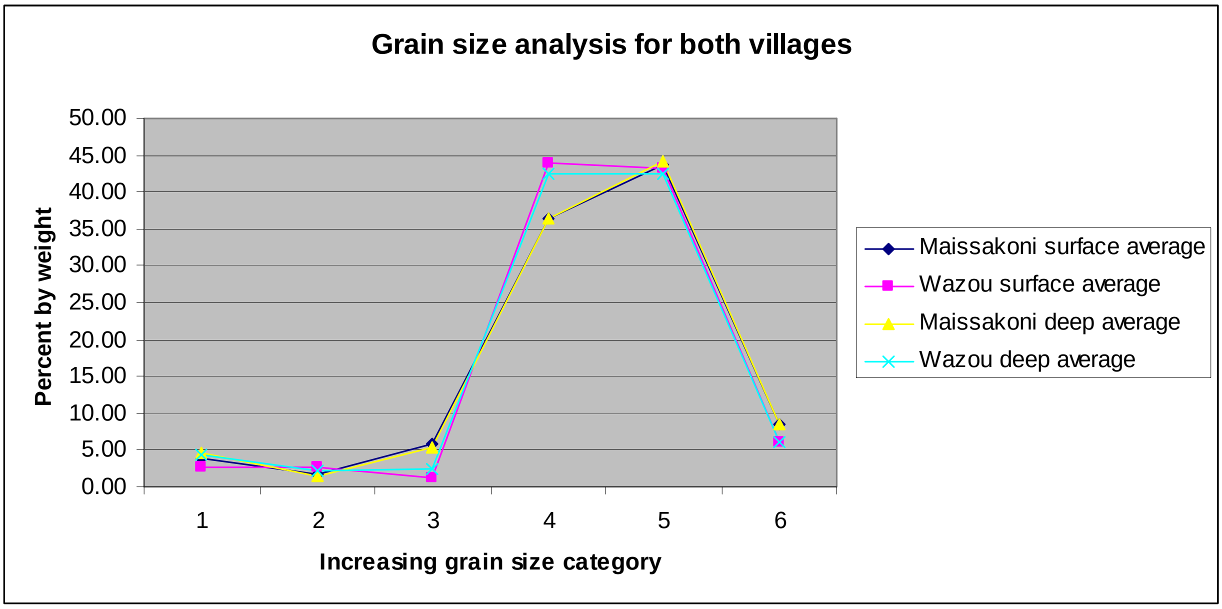


Figure 12: Combined soil particle size analysis (size categories are given in table 9)

Table 10: Category sizes used for soil particle distribution analysis

Minimum size, mm	Maximum size, mm	Category
0.5	2	Coarse sand
0.2	0.5	Medium
0.02	0.2	Fine sand
0.005	0.02	Coarse silt
.002	0.005	Fine silt
0	.002	Clay

Villager Questionnaire

The answers obtained from this are set out in Box 2. These are not statements by individual respondents but 'group' responses to questions, following discussion, and translation into French and then into English. The major points of note in the responses from the two villages are: a) (question 7) both groups of respondents suggested that in the more productive village they use a greater quantity of manure or animal fertiliser on the fields; that (question 8) in Maissakoni they cut their trees back for wood or for feeding animals more than is done in Wazou, and that there may be differences in soil; also (question 8) an implication that in Wazou they believe that a wider variety of vegetables helps with overall agricultural production. Finally, there has been some help given with water supplies, but that the village with recent offers for help with improving cultivation, Wazou, has some doubts about taking up the advice offered. In neither village, is there is active management of rainwater for agricultural use later.

Box 2: Responses to the questionnaire

Maissakoni Responses	Wazou Responses
1) There have been 3 big rainstorms so far this year; last night's was the biggest; the others were 2 weeks ago, and 2 days before that, both being quite small but together were enough for us to start planting crops. There's an overall a lack of water; it comes from wells and a borehole.	1) There have been 3 major rainfall events so far this year. There's not enough water for the houses even. There are 2 wells.
2) There are 2 wells, 1 manual pump borehole, and a small lake that lasts 2 months after the rains. The water from this lake is poor quality, OK for animals or for making bricks, but not for people to drink. It's not used for crops.	2) There is a man-made lake, from digging out material for the roads; this lasts 3 months after the rains and is drunk by the animals; the water is red, from the ground.
3) The big well was dug in 1977; the borehole in 2001 was not dug by hand. These are 74 and 70 metres deep. The water lasts all year but the level drops. The water is good, although it's cloudy. The borehole is best. The water's not used for the fields, but for everything else; people, animals, and building/making bricks. The water is lifted out using cattle to pull a large container up, with a rope.	3) The wells were built 31 and 15 years ago, by a Belgian aid project, and are 48 metres deep. The newer one lasts all year, the older is sandy because of the animals, and needs improving. There's no pump so the water is raised by hand, or by animals.
4) No, there are no streams here.	4) 4) There are no streams in this area.
5) There are no channels or tanks for run-off rainwater.	5) There are no water containers or channels for run-off collection.
6) The government helped us dig the first well, a German charity the second. They provided materials and expertise, we provided the labour.	6) There has been no outside help with these things.
7) No, there haven't been any new strains of crops introduced. Each year we choose the best heads of millet, while in the fields, to keep for the next year's planting. These we store in our houses for safety. The general harvest goes in the granaries (outside the village itself). A few people buy	7) We use animal manure all over, but fertiliser less so, as it's expensive; only the richer farmers can do

fertiliser, a few more buy manure, but it's a question of money. 8) We don't have so many types of tree here, only 'Guiera'. Our soil isn't as good as in other villages. It's worse since the big drought (in the 80's) – we used to have more trees, and larger ones. Some types have gone altogether. It's getting more degraded. (another man said later that all the villages cut branches off trees, but 'we cut them more' 9) No, there are no plans to manage water differently here in the future. 10) We have less livestock (sheep/goats) than previously, as there's no space left for pasture for them. 11) (as 8, about trees) 12) Trees are good – they help the land- with water, leaves (humus) and they cut down the wind. 13) There are no fallow periods for the soil now – not for 30 years – there's no land spare to have a rotation.	so. We use the traditional strains of crops. 8) We're doing better than other villages near here as we have more trees as we don't cut them. We have sandy but not hard soil, and more types of crop. Our soil is better, but in dry years we can't grow beans. 9) For the past 3 years someone from Maradi (the local town 12km away) has come and shown us how to make pits around some plants to help conserve water – but it's a lot of work. 10) There's less livestock here now as there's no pasture for animals to graze on. 11) There used to be more trees – they had to be cut down to make more fields. 12) Trees are helpful- they decrease the wind, and help to fertilise the soil with humus 13) There's not enough land to leave any fallow nowadays – not for the last 20 years – so there's no pasture for the animals.

Discussion

a) Limitations of this study

This study formed a static estimation of the situation in the two villages at one point in time rather than an assessment of bio-productivity over a period of time. The timing of research, beginning in one area, before the first major storm of the rainy season, means that the validity of some comparisons, in particular the rates of intercropping of beans or groundnuts with millet, are poorer than they might have been even one week later. Similarly, the numbers of shrubs may be less reliable, as they were counted at different points in the growth cycle in the two villages. The timing also meant that the 'deep' soil texture samples could not be taken from as deep as was wanted, because of concern not to disturb the early crops.

The estimation of tree size was not very precise. This probably that mattered less for the majority of trees, but as discussed above, there was doubt about the accuracy of estimates of the largest trees. Measurement of diameter at breast height provided a useful check on this. More precise methods, for example assessing the angle subtended at a given distance by the extremes of a tree, could be used but might be much more time-consuming, potentially leading to a reduction in data volume. In addition, there is some evidence that this is not very much more precise (Lovett, 2009). Ideally, it would have been useful to estimate the biomass of the trees at the sampling sites. However, although equations are available for estimating the biomass of certain species of trees, these require the trees to be growing in similar circumstances, but also unpollarded specimens. With two weeks, branches, and major types being cut from trees in an irregular fashion anything beyond the overall dimensions of trees found would have been extremely time-consuming but nonetheless still a rough estimate.
The assessment of volume of animal droppings could also be refined, maybe using several different sized containers for different size droppings (e.g. from goats and from cattle) although again this measurement would probably benefit more from being performed at all sites than from being performed very accurately at fewer.

More extensive discussion with the villagers would have been very useful. In particular, discussion with women farmers, who were not available at the time of interview because of the urgent need to continue with cultivation, might have revealed a different viewpoint about past and current practices. Greater understanding of the use of manure and fertiliser, ideas about promotion of soil fertility, and knowledge of landholding patterns within families and villages, which have implications for individual farmers' duration of interest in a given plot of land would be useful.

Localised rain data in the individual villages, both long-term and short-term, would help to highlight differences in water availability as a possible source of difference in bio-productivity. Local geology, and drainage patterns, including levels of groundwater, form an important background even if only to exclude underlying physical reasons for differences in productivity.

A second pair of villages, or ideally a larger group would have provided confirmation that the two villages chosen were not in some way unrepresentative.

b) The study's findings and implications

This study aimed to answer the following questions, in relation to a 're-greened' village and one that remains more degraded, in the central Nigerien Sahel:

Is there evidence of different productivity of biomass in these two types of area?

Are there different bio-physical circumstances supporting vegetation growth in the two areas?

Are the water resources in the two areas different, or differently managed?

Is there a measurable difference in the number and size of plants, per unit area, different in the two areas?

Is there evidence of qualitative differences between the soils in the two areas?

What evidence is there from the villagers, and in the landscape, of active management of water, whether to capture it, or to use it more effectively?

The findings from the sampling points in the two villages were that, in the 're-greened' village, Wazou:

1. There were considerably more trees per sampling point (1.0, against 0.74 for Maissakoni);
2. There were a greater variety of species of tree (11, against 7);
3. They had a greater canopy spread (>5.9%, against 3.3%), giving better ground protection from the force of the sun, the wind and the rain;
4. The trunks had a slightly greater diameter at breast height (18.5cm for those above 1 cm, against 16.4 cm) also implying greater age;
5. If the single largest tree (with its uncertain height) is excluded, they showed a better correlation between diameter at breast height and canopy size, (0.88 against 0.81) implying that they had been pollarded less;
6. There were more shrubs per site (1.15 against 0.65);
7. There was a much higher rate of multi-cropping (65% against 28%) with implications for productivity of crops, through increased fertility of the soil;
8. There were more animal droppings per sampling point with potential implications for soil fertility;
9. The carbon content of the soil was higher, as a proxy for organic content, and a rough measure of potential soil fertility.

The soil texture analysis for both villages was very similar, implying that this is not a likely cause of the degree of re-greening in the two villages. There were no measurements of biomass, or associated parameters, which appeared to be better for Maissakoni.

In summary, there is not only greater 'standing' biomass, in the total quantity of tree bulk, in particular, but there is roughly twice the potential for biomass production by trees per year (as there is roughly twice the canopy cover). Similarly, greater shrub numbers suggest greater annual productivity. The higher soil carbon content, availability of animal droppings, and intercropping (particularly with nitrogen fixing plants) suggests that greater crop productivity is likely; it is impossible to estimate how much greater this might be in Wazou itself, but de Rouw and Rajot (2004), working in Niger, found that the use of animal dung at similar levels to those found in this study, gave an increase in grain yield and a decline in deterioration in yield with continuous cropping over a period of years.

The biophysical circumstances in the two villages can be viewed in two parts. Climatically, although weather (especially precipitation) data for the specific villages is not available, in terms of precipitation, temperature, insolation, and wind, the conditions are effectively identical. The altitude, topography and physical soil conditions are extremely similar. The similarity in soil particles size distribution is important as well have similar total surface area to release nutrients for plant growth. However, the biological circumstances supporting vegetation growth are different in a number of important ways. Not only is the carbon content of the soil greater, but the protection afforded to the soil, by the increased tree (and shrub) and size helps to prevent some rainwater run-off, to reduce soil erosion by the wind (especially of the important fine particles -see de Rouw and Rajot (2004)), and to lessen soil particle breakup by heavy rain. It seems likely, however that the difference in carbon content and tree numbers is relatively recent and probably a result of differing land husbandry in recent years or decades in the two villages.

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This research has demonstrated that, in the two villages concerned, the appearance of greater recovery and re-greening in Wazou is the result of a considerable additional amount of tree biomass, and a likely increase in crop productivity. The productivity could not be assessed within the timeframe of this study, but is suggested by the increased carbon content of soil and intercropping of plants. This lends weight to the significance of studies such as by Herrmann, Anyamba et al 2005) as discussed above, confirming that an increasing greenness reflects an increase in vegetation growth. The resolution of their research images, down to 8 km areas, is at approximately the scale of the village territories in the area of Niger investigated here, and therefore can give a useful analysis of productivity.

c) Suggestions for future research

The implication of this research is that, in the re-greened village, more effective promotion of tree growth, multi-cropping and possibly the active use of animal droppings, has had a positive result on arboreal and agricultural production. Confirmation of this by similar research in other villages and areas would be useful. The research could also be strengthened by looking at the geology and drainage patterns, local rainfall patterns, as well as repeating on the same sites at different times of year and over several agricultural seasons.

This piece of research was the first stage of a longer research project covering multiple growing seasons, which in addition to quantifying the re-greening at the local level will attempt to look at local understanding of and decisions about land management, as well as the role of external interventions in promoting developments around soil water, and tree management.

With the arable area having expanded to cover almost all the territory of the villages, increasing food supply for the growing population can only be done by intensification. Differences in the active management of water in different areas, in cropping techniques, and the management of livestock, all require better understanding. The probability of a further temperature rise in the Sahel as a result of global climate change, as well as future prolonged drought caused by longstanding climate patterns, makes the need for increased food security even more urgent. Therefore, research concerning the successful dissemination of improved agricultural approaches amongst communities that are largely self-sufficient is an important area for development.

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Appendix 1

Box 1; **Data collected at each site (10m radius) on village transects**

- Day, Date, Time
- Village name, line no. and direction from centre
- Site no., metres from centre, latitude longitude and elevation, GPS point
- Surface slope (and its direction); type of area (field, path, pasture, etc)
- Per cent of site that is non-productive (e.g. track) and why
- Buildings, gullies and other features on site
- Soil surface (presence of crust) and appearance
- Crop types
- Tree types (species), heights, and DBH (diameter at breast height)

Other species of plants
Volume of animal droppings
Ground cover with straw or plant stalks

Appendix 2

Water Management questionnaire, in English and French

1) i) How many rains have there been this year? Approximately when were they?
ii) Is there a shortage of water (in the respondent's view)?
iii) Where do most people get their domestic water from? (ponds,or wells)

a) Il y-a eu combien de pluies cette année? Et quand?
b) Est-ce qu'il y a insuffisance de l'eau dans ce terroir?
c) Quelles sont les places où la population prend l'eau (des lacs, des puits..) ?

2) If there are ponds/reservoirs

i) Are ponds natural or manmade (hand dug or machine)?
ii) How many PONDS are there?
iii) How many months do they last through the year,
iv) Is the water from them used for crops, animals or people?
v) How good quality is the water?

S'il y a des mares (lacs) ou réservoirs,

a) Combien de mares y-a-t'il?
b) Est-ce qu'elles sont naturelles, ou artificielles
c) L'eau dure combien de mois chaque année?
d) L'eau est-elle utilisée pour les champs, les animaux ou pour les maisons?
e) Est-ce que l'eau est de bonne qualité?

3) If there are WELLS:

i) How many wells are there?
ii) Where they made recently or a long time ago?
iii) Are they hand dug?
iv) How deep are they?
v) How many months of the year do they last
vi) Is the water good, or is it saline
vii) Is the water from them used for crops, animals or people?
viii) Are the wells open (e.g. needing buckets) or closed (pumps)?
ix) How deep is the water in them?

S'il y a des puits,

a) Il y a combien de puits dans le village?
b) Ils sont faits depuis combien d'années?
c) Sont-ils faits à la main?
d) Quelles sont leurs profondeurs?
e) Pendant combien de mois on a l'eau dans les puits par an?
f) Est-ce que l'eau est de bonne qualité?
g) L'eau est-elle utilisée pour les champs, les animaux, ou pour les maisons?
h) Quels sont les moyens d'exhaure (pompage)? A la main (corde et calebasse) ou avec les motos pompes ?
i) L'eau est à combien de mètres de profondeur?

4) Are there many streams in the area? If so,
i) How much of the year do they continue flowing?
ii) Is the water in them actively used in any way?

Est-ce qu'il y a des ruisseaux dans le terroir ? Si 'Oui',

a) Ils continuent de couler pendant combien de temps dans l'année ?
b) Est-ce que on utilise cette eau ?

5) i) Are there any dams or channels to stop rainwater run-off during storms?
ii) Do these hold the water so it can soak into the ground, or take it to a pond or reservoir?
iii) Has the number of these structures changed in recent years?

Est-ce qu'il y a des barrages ou autres ouvrages choses pour arrêtter le ruissellement pendant les pluies ?

A) Est-ce qu'ils retiennent l'eau pour laisser infiltrer dans la terre ; ou pour conduire vers un lac ou un réservoir ?
B) Est-ce qu'il y a plus, ou moins, de ces ouvrages 'il y a quelques années ?

6) i) Has there been help from outside agencies with developing water systems?
ii) What sort of help? (Advice, meetings, demonstrations, money, goods?

a) Est-ce que vous avez reçu l'assistance extérieur avec ces systèmes de gestion de l'eau ?
b) Quel type de aide?

7) i) Have there been any changes in soil cultivation methods or other farming techniques in recent years, including in the varieties of crops used, or manure or fertiliser use
ii) or are there differences within the village in these aspects?

a) Est –ce qu'il y a des techniques de cultures, application d'engrais ou fumier, ou les variétés des plantes sont différentes de ceux d'avant plusieurs ans ?
b) Est–ce qu'il y a quelques grandes différences entre les habitudes des villageoises?

8) Is this village faring better (or worse) than the nearby ones, and why?

Est-ce que ce village va mieux, ou pire, que les autres près d'ici, et pour quoi ?

9) Are there any plans to change water management approaches in the near future?)

Est-ce que vous avez des projets pour le gestion de l'eau dans le future?

10) Have there been any changes to the numbers of livestock in recent years?

Est-ce que la quantité de cheptel est plus qu'autrefois, ou moins?

11) Have there been any changes in the number of trees in the village recently?

Est-ce que la quantité d'arbres est plus qu'autrefois, ou moins?

12) Are trees seen as being good, or bad, for the land – and why?

Est-ce que les gens pensent que les arbres sont bénéfiques pour les champs, ou non? Et pourquoi?

12) Are there fallow periods used in this area?

Est-ce qu'il y a des jachères dans votre terroir?

13) How long do the fallow periods last?
Combien de temps dure la jachère dans votre terroir?

14) Are there any pasture areas for animal grazing in the area?
Est qu'il y a des aires de pâturage dans votre terroir?

15) What is their status?
Quel est leur statut?