The long dry season:

Crop-livestock linkages in Southern Mali

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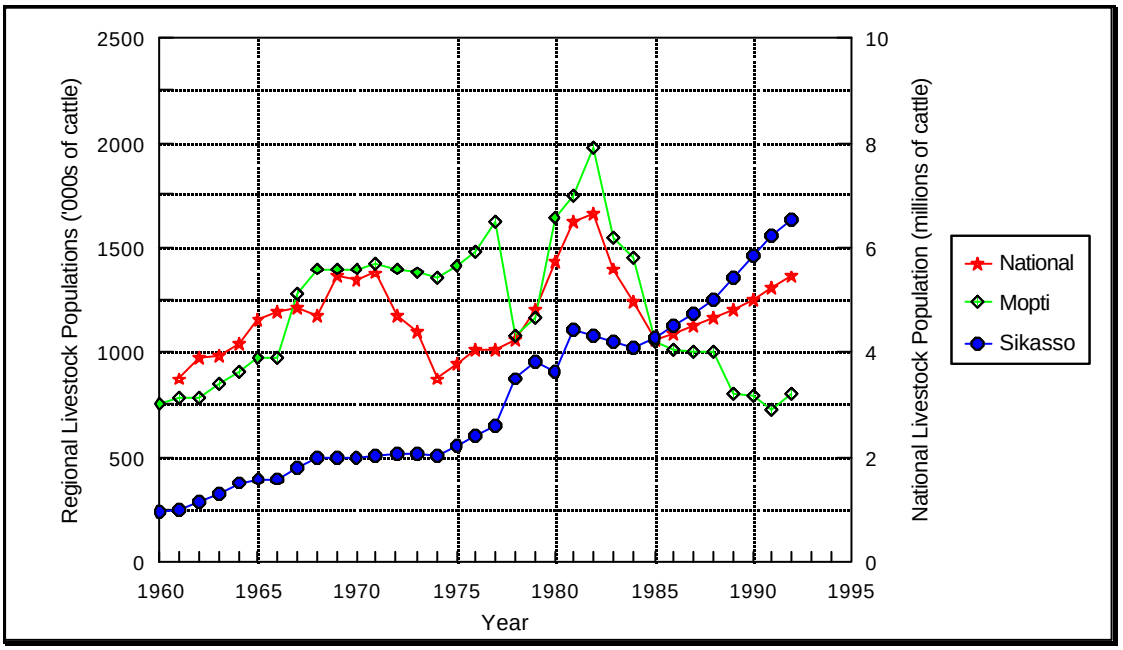
INTRODUCTION:

The expansion of herds in the "agricultural" sub-humid zone

The Sikasso region in the south of Mali has the country's highest rainfed agricultural potential. Since the 1960s, cotton has become the major cash crop for smallholders, who are intensifying their production by investing in ploughs and inorganic fertiliser.

The cattle population of the region has also been steadily growing, so that by 1985 more cattle were found in the south than in the formerly pre-eminent grazing area of the Niger Delta (Figure 1). National and regional livestock figures should be treated warily, as their collection is prone to significant errors. However, aerial studies of human and livestock populations in Nigeria and the southern boundaries of the Sahel in Mali, Niger, Chad, and the Sudan, show that in all of these regions livestock population density is now strongly correlated with land use intensity and human population density, suggesting the growing importance of crop-livestock interactions (Bourn and Wint, 1994).

Figure 1. Livestock in Mali, 1960-1992.



(Source: Kébé, 1994)

Two parallel processes are at work here. Following the Sahelian droughts of the 1970s and 1980s, pastoralists have moved southwards with their herds, into wetter, more productive environments (Bassett, 1994; Vabi, 1993; Boutrais, 1990; Landais, 1985; Bernus, 1974). At the same time, cultivators are increasingly investing in livestock as the plough replaces the hoe (Raynaut, 1997; Bosma *et al.*, 1996; Faye, 1989; le Roy, 1983).

This paper investigates the interactions brought about by the co-existence of herds and agriculture in a village setting. It draws on Ph.D. research that used soil nutrient balances to evaluate exchanges of animal manure and traction between owners and non-owners of livestock (Ramisch, 1998). The methodological complexities of using nutrient balances in such a study are presented elsewhere (Ramisch, 1999).

Agro-pastoralism and "mixed farming"

The "co-existence" of farming and large populations of livestock in the sub-humid zone could be evidence of beneficial trends (greater crop–livestock integration and increasing productivity) or negative ones (competition between animals and crops for land, labour, and capital). It is not just livestock and crop land that are sharing space, but different social actors: herders and farmers, owners and non-owners of livestock, mobile, sedentary and semi-sedentary populations (Turner, 1995; Landais and Lhoste, 1990). Each group of actors will be using crop-land and livestock — engaging in agro-pastoralism — to varying degrees, having come from different starting points and with different goals and assets. Within these agro-pastoral communities, some of the actor groups will clearly be better placed than others to capitalise on the opportunities that livestock can offer to crop production.

Interactions and exchanges between such groups either have long traditions (Ezeomah, 1987; Frantz, 1980) or have emerged in the wake of recent migrations bringing the groups into contact (Jabbar *et al.*, 1995; Zuppan, 1994). The exchanges are not just of manure, stock, milk, and grazing land, but also of knowledge and information. Herders take up farming, and farmers herding (or at least the ownership of livestock) for a number of different reasons, but the degree of variation within an "agro-pastoral" identity and practice is far greater than a simple presentation of "mixed farming" might imply (Bonfiglioli, 1993; Toulmin, 1983).

The "mixed farming" model is the framework upon which "sustainable" crop–livestock integrations are most often hung. This model depicts systems where

independent peasant farmers, with secure ties to their land, own and manage livestock whose role is to cycle nutrients through fodder crops and bush grazing back to the land as manure and draught power (cf. Sumberg, 1998; Turner, 1995). Such a model, with its pleasingly symmetrical crop–livestock relationships, has gained much currency with the increasing interest in soil fertility processes. However, this study indicated that agricultural intensification could take place under situations where access to animal manure and traction was obtained, not simply through ownership, but also through a variety of other exchanges.

Agricultural intensification and agro-pastoral exchanges

Agricultural intensification can be defined as the process by which yields are increased whether per unit area or per animal, and is associated with an increasingly efficient use of internal and external inputs (Temé, *et al.*, 1996). Greater integration of crop and livestock systems increases the efficient use of internal inputs and helps improve crop yields, though longer term increases in yields may require access to external nutrient inputs (Smaling and Braun, 1996; McIntire and Powell, 1995). However, a household with no livestock of its own can gain access to organic nutrients from beyond that household's farm boundaries, by entering a series of exchange relations. Such nutrients are effectively "external" to that household, although they are "internal" to some larger frame of reference such as the village or region.

Given the recent interest in ensuring agricultural intensification is based on sustainable nutrient management and viable livelihoods (i.e. Deugd *et al.*, 1998), this study examined the agro-ecological consequences of agro-pastoral exchanges and the social institutions through which they take place. The methods used included estimating balances at household level of the primary soil nutrients essential for plant growth, N, P and K, while tracking the sources and destinations of nutrient transfers that had crossed farm boundaries (cf. Ramisch, 1999). The overall balance of soil nutrients for the study area in 1996 was only a moderate deficit for nitrogen (–8.2 kg/ha) and was positive for both phosphorus and potassium (+19.5 and +8.9 kg/ha respectively). However, individual households displayed a vast range of balances (especially for nitrogen, the most limiting nutrient), from +65.1 kg N/ha to deficits of 56.5 kgN/ha. These variations reflect systematic differences in cropping systems, based on ethnicity, geography, and access to livestock as sources of traction and manure.

CONTEXT

Map 1. Location of the study village, Lanfiéla.

Study setting

Lanfiéla was selected as a "typical" agro-pastoral community of southern Mali (see Map 1). It is home to three main ethnic groups. The "village" was founded in the late 19th century by Bambara/Senoufo farmers who today grow cotton with maize, millet and sorghum as the principal food crops. Minianka have settled in a nearby "hamlet" since the 1980s and also cultivate cotton with maize. Finally, Fulani have settled in two hamlets since the late 1970s, referred to collectively as "Fulawere". Most but not all of the Fulani cultivate maize and millet; all have at least a modest herd of 30 cattle, but some maintain a purely pastoral livelihood. Resident pastoralists rotate their herds between two

or three local grazing regions over the year. In the dry season they are camped on the harvested village plain, and are joined by other Fulani from villages further south[1].

Land rights are based on use and backed by customary law vested in the founding lineage of the village. Most of the arable land near the village has been cleared for at least four decades, but households are free to clear more land in the relatively uncultivated bush regions if they ask the village chief. The founding households of the hamlets and Fulawere were "allowed" to settle in the area only when they agreed to clear and farm land of their own. The Fulani households that did not farm were therefore often considered transient, even though some of them had been in Lanfiéla for nearly ten years.

The proximity of Lanfiéla to Côte d'Ivoire means that up to half the total population may be absent at any time, involved in migrant labour south of the border. The decision to leave the village (either seasonally or more permanently) was phrased most often as reducing the number of mouths to feed at home, while increasing household income through remittances. Ploughs in particular have been seen as a way to improve labour efficiency for those household members who have remained behind in the village.

The parastatal Compagnie Malienne pour le Développement des Textiles (CMDT) provides the seed, fertilisers, herbicides, and marketing that support cotton growers in Mali. Cotton sales represented the single largest source of cash income in Lanfiéla, ahead of remittance income from migrants working in Côte d'Ivoire. The CMDT established an Association Villageoise (AV) for Lanfiéla in 1984. A half dozen large Senoufo/Bambara households owned ploughs prior to this point, but credit programmes in the mid-1980s allowed plough ownership to more than double. Most of the carts and ploughs purchased in the last decade, however, have been paid for directly using cotton revenue and not credit.

Beyond cotton and local cereal varieties, most households have smaller plots of groundnuts, yams, sweet potatoes and upland rice. Cowpeas were frequently inter-planted with cereals. The residues of crops like cowpeas and sweet potatoes are very often collected in bundles as feed for household animals. Cotton-seed cake is also extremely popular as a feed supplement, to the point

[1] These transhumant Fulani spend the wet season near an artificial lake close to the border with Côte d'Ivoire. In the dry season, this lake region does not support enough vegetation to feed their herds. They prefer to make the 70 km trek to Lanfiéla, where grazing is abundant. Several of these Fulani are also relatives of Lanfiélan households.

that local demand always outstrips the amounts that the CMDT is able to supply.

Soils are sandy loams with a tendency to form laterite hardpans (PIRL, 1988). The village and hamlet are both located on plains of finer soils, considered more productive than those of the surrounding hills and slopes. Many village households have both home fields on the plain and bush fields in the hills; hamlet and Fulawere households typically maintain only home fields near their compounds.

Rain falls in a single rainy season from mid-May until September. Farmers (and regional rainfall data series) indicated that this region has become drier and rainfall more erratic over the last generation. The average annual rainfall in the ten years 1962-1971 was 1219 ± 101 mm, significantly higher than the average for 1987-1996 of 1078 ± 168 mm (Loulouni arrondissement, unpub.).

Agro-pastoral exchanges in Lanfiéla

A consequence of the single short rainy season is that agricultural activity is concentrated into a relatively brief flurry of activity. This intense period is bracketed at either end by a long dry season, during which the fruits of one year's harvest must sustain the household and plans for the following year are implemented.

In both seasons households negotiate with each other to secure access to a range of resources. In the dry season, these exchanges are made to obtain either manure or the means to transport it to household fields. A common arrangement is for households borrowing a donkey cart to "pay" half of the transported manure to the cart owner's fields. Many cart owners actively seek out households that have manure or household wastes to transport, to profit from such a deal. Similarly, households with full manure or compost pits often view this arrangement as a way to empty these pits, using part of this manure supply as payment in lieu of cash, which may be less plentiful.

Another type of arrangement is made between transhumant Fulani, who need a place to camp in the dry season, and households that seek to manure their fields. Only the most senior and socially influential village households appeared to enter into such exchanges. Their fields all had wells where the Fulani would water their calves and draw household water. The Fulani also gained some grain, salt, and occasional symbolic gifts like cloth, while providing milk and manure to their "landlords".

The wet season exchanges are made for ploughing equipment. Very few households only cultivated with hoes, although over a third of households own no ploughs of their own. The hiring of a plough is usually paid for in cash and labour. Although considered expensive, the typical rate was not unaffordable[2]. Exchanges also took place between plough owners, where a group of households would come together to plough each other's fields in a reciprocal arrangement.

The exchanges that were documented in Lanfiéla were most commonly made between members of the same community (village, hamlet, or Fulawere), although a few took place between communities. The exchanges made for manure tended to be negotiated afresh each season, based on circumstances such as who needed manure and who had an abundance of it, or who had no means to transport it. Exchanges made for cultivation labour were more habitual: certain plough owners have been loaning their services to other households for at least a generation. These types of loans build on a cultural tradition of collective self-help, as exemplified by collective labour groups known as "*ton*", which bring together women, young men, or the entire village for various collective endeavours.

Social characteristics of the households

A study sample of 44 households was chosen from the 89 present in the area. This sample was stratified by group, and level of equipment ownership and use. Their characteristics are shown in Table 1.

Table 1. Average demographic, livestock, and equipment holdings of the sample households, taken by group and as a whole, 1996.

	Village (n = 24)		**Hamlets** (n = 8)		**Fulawere** (n = 12)†		**FULL SAMPLE** (n = 44)	
Household size	16.6	± 10.8	13.2	± 9.3	12.7	± 3.7	**14.9**	**± 8.6**
Number of labourers ‡	5.3	± 4.4	3.4	± 2.1	4.0	± 2.5	**4.7**	**± 3.8**
Cultivated field	7.2	± 4.3 **a**	7.0	± 3.2 **a**	3.2	± 1.6 **b**	**6.6**	**± 4.0 a**

[2] The standard rate was a day's labour and 6000 CFA francs, equivalent to half a bag of inorganic fertiliser or the cost of a sheep. The day's labour was typically devoted to weeding the plough owner's field later in the season. This often meant that plough borrowers were not able to weed their own fields as often or as effectively as they would have wanted.

size (ha)								
Number of cattle	4.4	± 9.4 **a**	8.8	± 11.6 **a**	73.9	± 89.7 **b**	**1063**	Total
Number of draft oxen	2.2	± 2.2	2.3	± 1.2	2.4	± 1.7	**90**	Total
Number of small ruminants	2.8	± 6.4 **a**	7.3	± 8.9 **ab**	10.1	± 12.1 **b**	**245**	Total
Number of donkeys	0.3	± 0.5	0.4	± 0.5	0		**10**	Total
· **Households owning:**								
– ploughs	15 (63 %)		6 (75 %)		6 (50%)		27 (61 %)	
– cultivators	10 (42 %)		6 (75 %)		3 (25%)		19 (43 %)	
– donkey carts	8 (33 %)		3 (38 %)		0		11 (25 %)	
· **Households using:**								
– ploughs	21 (88%)		7 (88%)		6 (50%)		34 (77%)	
– cultivators	15 (63%)		7 (88%)		5 (42%)		27 (61%)	
– donkey carts	17 (71%)		4 (50%)		2 (17%)		23 (52%)	

† 6 of the 12 Fulani cultivate land, the other 6 are purely pastoral

‡ Self-defined for "those who work all season long in the fields" (usually "resident males aged 15-50")

Suffixed letters indicate significantly different means ($\alpha = 0.05$, one-way ANOVA)

The village and hamlet households are quite similar, except that hamlet residents are slightly better equipped and keep more small ruminants. The Fulani, however, are clearly distinct from the other communities by having much larger cattle herds and significantly smaller cultivated areas. Household size is roughly comparable across the region, with approximately 15 residents. Of these, typically five members are working in the fields full-time.

The discrepancy between ownership and use of equipment is quite striking, particularly for the use of donkey carts which have only been acquired by households in Lanfiéla over the last ten years. Households can be classified by their access to a particular resource, as shown in Table 2. The resources examined are ploughs and carts, with each having four possible types of access. The first category comprises households who are not involved in cultivation or have nothing to transport (0). The second group does not use draft power for preparing the land or for transport (1). They must rely on hoes for cultivation, and headloads to transport manure. The third group (2) gains access to equipment by borrowing it from others, while the final group (3) are those households who own all the necessary equipment.

Table 2. The classification system for plough and cart use.

	Level of Access			
Resource	**0: no use**	**1: non-animal**	**2: borrowed**	**3: owned**
Plough	P0: No cultivation	P1: Hoe only	P2: Plough borrower	P3: Plough owner
Cart	C0: Nothing transported	C1: Head-loads only	C2: Cart borrower	C3: Cart owner

CASE STUDIES

The long dry season: the dynamics of manure exchanges

The following four case studies present different situations where households either collected nutrients from others, or had to give some of their nutrients to others in order to gain access to transport. They also reveal a disparity between the materially well-off households (such as case study A), who stated that their manure problem was an "inadequate supply" and the smaller, lower income households who lacked transport and often viewed the waste piles accumulating in their compounds as "burdensome".

Households that collected manure from others

A) One of the largest and wealthiest households used both a donkey cart and a pickup truck for collecting manure from other households. This collection helps support above average yields of cotton, cereal, and rice on its 17.8 ha fields. The founder of this lineage was a pioneer farmer in many senses: the first to plant cotton, the first to use a plough, and the first to see the benefits of actively applying manure and household waste to his fields. All of the household's own wastes are dedicated to the fields and are supplemented by abundant inorganic fertiliser resources. However, "to keep the yields from declining", additional wastes are collected from households that do not use them. As a result, their land has been producing good harvests for over thirty years.

B) At the opposite end of the social spectrum, another household collected manure from Fulani wet season corral sites because it lacked any organic matter sources of its own. This household owns no animals, and cultivates a 2.55 ha field inherited from the previous generation. This land is more than three km from the village and too far to transport any household wastes. The household head (the only labourer) said they were "too poor to clear a closer field". The only organic matter the land received was a

few head-loads of manure collected from a Fulani corral near the field and what manure was dropped every day by Fulani herds heading to their morning watering point. The only other input was a modest dose of the CMDT's inorganic fertiliser. The cropland produced relatively low yields of cotton and cereals.

Households that gave manure to others

C) The founding family of the Fulawere camp has the largest cattle herd in the area (343 head in early 1997). Its crops also had well above average yields. Although corralling the herd on the cropland was the preferred means of fertilising their 5.88 ha field, the relocation of the massive branch enclosures was awkward enough that the corrals were moved only every three or four weeks. This technique could not completely occupy the entire cropping surface over the length of the dry season. To "fill the gaps" left by the corrals the household borrows a cart every year to empty the wet season corrals of manure. There is always more manure in the wet season corrals (14.63 tonnes in 1997) than is needed on the fields: giving half of the transported manure to the cart owner as "payment" therefore actually helps the household rid itself of manure that would be burdensome if left in the corrals.

D) Most of the households that trade manure for use of a cart do not have such impressive herds. A typical example is a village household that made payments both in cash and in manure. This household cultivates both a home and a bush field, totalling 8.06ha. Their crop yields were close to the sample averages. Although this household called its growing compost and household waste pile "troublesome", their actions also demonstrated that it was also not something that they wanted to surrender to somebody else lightly. A new plough team had swelled their manure pile to overflowing. The deal struck with a cart owner meant that of the 8.16 tonnes available for transport, 3.52 tonnes went to the cart owner's field. However, the household had enough cash in hand (from a family member working in Côte d'Ivoire) to pay for 10 of the 44 journeys in cash, so that more than the customary 50% of the manure remained with the household. These extra ten cartloads of manure helped to improve their cotton yield by 380kg (+17%) on the 1996 harvest. Their remittance income, we were told, was now being saved up to buy a cart of their own, so that all of the manure would reach their household land.

Discussion of the manure exchanges

Table 3 summarises the characteristics of the case study households. In the larger study sample, field size was a function of labour and that pattern is visible here. Having access to a cart is clearly essential if more organic nutrients are going to be applied, but this presupposes that the household has some manure or other organic waste to apply. Households such as case B described above, have no access to organic matter of their own nor draft power for transport. Consequently, B was not in a position to negotiate access to both at the same time and clearly suffered low yields as a consequence.

Table 3. Characteristics of organic matter case study households [Land and Labour, 1997; Nutrient balance, 1996]

	Exchanges increased organic matter				**Exchanges decreased organic matter**			
Case study:	**A**		**B**		**C**		**D**	
Means of transport**	**C3**		**C1**		**C2**		**C2**	
Total field size (ha)	17.8		2.55		5.88		8.06	
# Labourers	20		1		5		7	
Total N applied (kg)	972		89		749		239	
- own organic N (kg)	77		0 (9)*		749		33	
- inorganic N	730		80		0		206	
- kg N in exchanges	165	IN	8	IN	190	OUT	25	OUT
Total N balance (kg)	–238		–14		+ 329		–72	
N balance (kg/ha)	–13.4		–5.5		+ 56.0		–8.9	
Biomass production (T/ha)	4.89		3.11		4.95		3.62	

*This is manure dropped in passing by grazing Fulani herds
** see table 2 for description of these categories

Table 3 demonstrates a trend observed throughout the sample of higher rates of fertilisation leading to higher biomass production, but no subsequent relationship with the ultimate nutrient balance. The rich household in case A applied one of the heaviest rates of both organic and inorganic nutrients, and has obtained high crop yields for decades, but appeared to run one of the worst nutrient deficits in the area. However, the Fulani household in case C, with another high dose of nutrients, obtained a high nutrient balance in part because it grew no cotton. Cotton extracts considerable nutrients from the soil, both from the average yield of 1300 kg/ha of seeds and fibre, and from the burning of residues (another 1300 kg/ha) to minimise disease problems.

What is “surplus” manure?

The decision to hire a cart is based on the farmer's estimation of a "surplus" of manure that could be spared to "pay" the cart owner, and alternatives for transporting household manure to fields before the planting season. This in turn depends on the household's access to means of transport, available labour, herd size, total field size, and the area that they intend to fertilise. The significance of each of these five variables was identified by conducting stepwise linear regressions for the "total amount of manure" that each household actually transported (see Ramisch, 1998).

The regression line predicts the total amount of manure that a household should be able to transport, given the five variables noted above. If this amount was greater than the manure actually available from its own supplies, and the household owned a cart, it might very well try to lend its cart to another household in exchange for more manure. Conversely, a 'manure surplus' exists for those households where the amount which could be transported by the household itself was less than the organic matter available on-farm. This "surplus" could be partly used to pay another household with spare transport capacity. For all four case study households, the actual amount transported (after accounting for exchanges) corresponded closely with the amount predicted by the regression analysis.

Therefore, a major problem for ensuring effective manure use is access to labour and transport, rather than the overall number of animals available for producing it. The households who produced a lot of manure (ie, most Fulani) did not have the labour to transport it, nor fields large enough to put it to maximum use. Such a picture of "manure surplus" was recognised by the village farmers. The Fulani are certainly the first households visited by cart owners seeking to collect all the manure that their labour and land area can exploit. But the regression equation also explains why many poor, small households (with little labour, small plots of land, and few animals) are also left with "surplus" manure that they could not and did not transport, even while their low crops yields suggested that their land would benefit from an input of organic nutrients.

It is tempting to conclude that the borrowers' out-payments to the cart owners are indeed "surpluses" that they can spare, not only from the labour view-point explained above, but also from a nutrient and field size perspective. However, on average the C1 and C2 households cultivated fields of 3.9 and 5.8ha, manuring 2.3 and 2.0ha plots within those fields respectively. Cart owners had much larger (10.8ha) fields of which 4.3ha were manured. Households that traded manure to others also had lower overall nutrient balances (–29.5 kgN/ha) than those who were not involved in trade (–9.0 kgN/ha) or those whose supply was increased by exchanges (–3.8 kg N/ha). The lack of a cart means that households must cultivate less well fertilised plots, leading to greater soil nutrient depletion.

Manure from Fulani herds

The household in case C demonstrates a common practice amongst the Fulani households. Each of them cultivates a small plot of land and accumulates more manure than they need to fertilise it. Several borrow a cart to help clear out their wet season parks which keeps their fields in positive nutrient balance. The remainder are left with a large accumulation of manure, part of which might be transported by head-load in basins to the nearby fields, although this does not always happen annually. The remainder tends to be left in the wet season corral sites, and there is rarely an objection if another household gathers some of this supply (as in case B).

Many authors suggest that the manure of Fulani herds is a key resource, both for facilitating the integration of crop and livestock systems in sub-humid West Africa (de Leeuw *et al.*, 1995; Kébé, 1994) and for smoothing relations between Fulani and sedentary farmers (Guillard, 1993; de Haan *et al.*, 1990; Seur, 1983). This had been my expectation as well, but villagers and Fulani alike explained that now that villagers had animals and manure piles of their own they no longer had the time or inclination to collect Fulani herd manure.

The manure from the Fulani herds that camp on village lands in the dry season is spread on fields relatively haphazardly, at least from the field owner's perspective, and most households treat such manure as a "bonus". All fields that had been manured by transhumant Fulani herds also received at least some inorganic fertiliser or even some of the landowner's household wastes. This behaviour is akin to that shown by case B, which used carted manure to "fill in" gaps missed by corralling.

Chasing the rain: the dynamics of cultivation exchanges

The main incentive for using ploughs was the ability to cultivate larger areas than hoe cultivation allows. Both hoe and plough cultivators, however, seek to plant in a timely fashion, racing to work after each rain storm. The best yields of cotton (which is photoperiod sensitive) are also obtained only if the seed is planted during a narrow "window" of about a week in early June.

The various cultivation strategies found in Lanfiéla are presented in five case studies, taken from the 1997 rainy season. They demonstrate some of the relationships between cultivation strategy, labour, area planted and yields. A discussion of the characteristics of these households, and the implications of their strategies follows.

Hoe cultivation (P1)

E) One of the households that relied purely on hoe cultivation has five labourers who worked a 5.4 ha field. The head of the household used to hire a plough from a neighbour when his sons were younger, but "now we have enough labour to manage on our own". He laughed at the idea of hiring an "expensive" plough to cultivate this area when he already had four strong boys to help him. Neither did the household intend to buy a plough in the near future: their cotton incomes, and the remittances from the eldest son's migrant work, were saved for weddings in 1998.

This household appears to be moderately successful in its attempts to intensify its production using hoe cultivation. It was able to hoe and plant its fields over the space of 12 days, which amounted to 85 person-days of work[3]. Cotton constituted 27% of the field area, and was planted relatively early (compared with the sample mean) between 22 and 27 May. Maize was planted on 2 June and millet on 7 July, which were neither unusually early nor late. The yields of cotton and maize were both above the village average (1573 and 1335 kg/ha respectively). Millet yields suffered throughout the region when rain "failed" for several weeks following thinning of young seedlings: this household's millet yield was close to the village average at 935 kg / ha.

[3] Person-days of work are calculated as the sum of the number of labourers active in the field on each day of labour.

Plough borrowing (P2)

F) A smaller hoe-cultivating household (only two labourers) had been hiring ploughs to cultivate ever since it began planting cotton in 1989. In 1997 it hired a plough team for two days, to cultivate a cotton field (0.7 ha) and a plot of maize (1.7 ha) in which millet was later inter-planted. Considering that the total area of the household's fields was 3.9 ha, the borrowing of a plough to clear such a large proportion (62%) was considered a wise and necessary investment. The two days of ploughing cost the standard 12,000CFA francs, paid in cash. This is equivalent to the cost of one 50-kg bag of fertiliser which, the household head complained (all too aware of the opportunity cost), could at least have been bought on credit and paid for after the cotton harvest.

However, without the ploughing, there was no way that the household could support itself. The cotton yield was quite high by local standards - 1900 kg/ha - but this crop only occupies 17% of the field area and the total harvest was very small compared to the average village households' production. Maize and millet crops both had low yields (840 and 950kg/ha respectively).

The planting of crops was largely dependent on the borrowing schedule: cotton was planted on 7 and 8 June, as was the maize on the ploughed plot. Another plot of maize was worked by hand, and planted earlier, between 25 and 28 May. Millet was sown on 4 July. All of the household's land preparation and sowing activities took only eight days, and represented 30 person-days of work. This was the lowest labour input found in any of the case study households.

Plough ownership (P3)

To contrast the Fulani farmers (all of those who cultivate own ploughs) with their non-Fulani neighbours, the next two cases compare a hamlet household with one of the three cotton-growing Fulani households. The final case presents a village household that engages in reciprocal ploughing arrangements.

G) The Minianka household was one of the more successful plough-owners. This household had five labourers (as in the intensive, hoe-cultivating household described above) but in 1997 cultivated much more land: 16.5ha.

Ploughing began almost immediately after the first rains fell in May, with planting first of a large plot of groundnuts, and then ploughing newly-cleared fields in the bush for cotton and maize. A total of 7.6ha of cotton was planted (46% of the total field), between 30 May and 5 June. Several plots of maize were planted over the period 5 to 10 June, and again 1 to 7 July. Millet was planted up until 4 July. In all, 26 days were spent cultivating (the most of any household), equivalent to 145 person-days of labour.

Such intensive work was repaid with very good cotton yields (1679 kg/ha) and over nine tonnes of maize (1265 kg/ha). The millet yields were disappointingly low (420 kg/ha) and the groundnuts, planted before 7 May never fruited very well and yielded only 472 kg/ha. Nevertheless, there was more than enough produce to support the household through until the following year. The household cotton income was in the top 10% of the sample, and was used to purchase (among other things) a cart, two more oxen, a large bed, and a Yamaha-100 motorcycle.

H) This Fulani household had five labourers (as in households E and F above), one of which was a herder hired to tend 36 cattle. In contrast with the plough-owning Minianka described above, the household's field in 1997 was only 3.1 ha. This was smaller even than the total area cultivated by either of the hoe-farmers described at the outset.

However, from this small field came rather impressive cotton and maize yields. The cotton plot was just over half a hectare (19% of the total land), but yielded 1690 kg/ha in 1996 and 2374 kg/ha in 1997. The household also harvested just under three tonnes of maize (2195 kg/ha) and one and half tonnes of millet (1245 kg/ha) in 1997.

This household settled here in 1990, began to plant cotton in 1995 and also acquired a plough that year. Initially their settlement had been motivated by joining relatives already resident in the area, and herding was the mainstay of both families' livelihoods, supplemented only by small cereal plots. However, contact with the Minianka households of the hamlet encouraged three of the Fulani households to begin planting cotton and to equip themselves with ploughs in 1995. In 1997, this number had grown to five, and the well-manured corral-lands have proven to be excellent for cotton production. At the same time, the Fulani say because of the manure and the inorganic fertilisers that they now can obtain from the CMDT, they do not need to expand their cropland at all. Thus, for these Fulani

ploughs have been a means of intensifying agricultural production without having to withdraw any labour from herding.

I) In both the village and the hamlet, some plough owners have reciprocal arrangements with each other to lighten the burdens of cultivation and weeding. The final case study household joins forces with two or three other households during the cropping season. The heads of these households are all sons of the same father, but have lived and farmed independently for over thirty years.

There were six labourers during the ploughing and weeding season, and the total field area was 9.5 ha. Of this area, 3.8 ha (40%) was ploughed in concert with two other pairs of oxen-teams over a stretch of five days. In total, 13 days were spent working the fields, or 124 person-days. For each day that his brothers' plough teams joined in the work on his land, this household head had to reciprocate a day of ploughing and a day of weeding by his family on each of the brothers' fields. Such exchanges demonstrate the fluidity of boundaries between "households" as defined by the villagers, since although these brothers have collaborated for many years, they consider their households distinct, and they each eat from separate granaries, reside apart, etc.

The yields of cotton and maize (1868 kg/ha and 1328 kg/ha) were above the sample average, but millet failed miserably and only yielded 110 kg/ha.

Discussion of the cultivation exchanges

The most salient attributes of the cases are summarised in Table 4. Household labour is relatively similar throughout the cases, but the total field size increased with better access to animal draft power. Similarly, the number of person-days of labour also increased greatly moving from the hoe cultivators to the plough owners, as more and more labour was invested in land preparation and sowing. The households with the largest fields had the greatest proportion of land under cotton, suggesting that the expansion of cultivation especially favoured cash crops. Finally, nitrogen balance was positive for the households with the greatest use of animal traction, and most negative for those still largely reliant on hoe cultivation. This was largely due to the greater use of manure and mineral fertilisers by the wealthier, plough-owning households.

Table 4. Basic attributes of cultivation case study households [Land and Labour, 1997; Nutrient balance, 1996]

Form of cultivation:	P1. Hoe only	P2. Hoe + borrowed plough	P3. Own Plough…		(Reciprocal ploughing)
			(non-Fulani)	(Fulani)	
Case Study	**E**	**F**	**G**	**H**	**I**
Total Field Size (ha)	5.4	3.9	16.5	3.1	9.5
# Labourers	5	2	5	5	6
# Dependents	4	6	4	2	19
Person-days labour	85	30	145	40	124
Person-days / ha	15.7	7.7	8.8	12.9	13.0
# days labour	12	8	26	10	13
Cotton as % of field	27%	18%	46%	19%	40%
Cotton Income Class (1-10)	6	2	10	2	7
Nitrogen Balance from 1996 (kg N/ha)	–19.4	–24.5	+ 12.6	+ 7.6	+ 9.8

Notes: Person-days labour**:** sum of number of labourers active on each day of land preparation and sowing
days labour**:** total number of days spent on land preparation and sowing
Cotton Income Class**:** the rank of household's cotton sales in the sample, in increments of 10% (0 = none, 1 = bottom 10%, though 10 = top 10%)

If we consider the number of "person-days per hectare" as a measure of labour-use intensity, we can see that relative to hoeing (Class P1), the use of animal traction (Class P2 and P3) was distinctly labour-saving. Ploughing requires roughly half the number of person-days per hectare in comparison to hoeing.

However, while the Class P2 (case F) household may have economised on use of labour, it appeared to do so at the cost of nutrient balance and income, since hiring a plough and cart costs money that could have been invested in fertiliser. The other hoe cultivating household (case E), by contrast, may not have many more nutrients at its disposal than P2, but engaged in fewer transactions that would surrender them to other households. It also had more labour available to tend its crops through the growing season. Although both households were considered "poor" by villagers, case E's greater labour force appeared decisive in allowing it to avoid the costly plough-borrowing arrangements faced by case F.

Finally, one of the patterns raised in passing by the case studies was that, while hoe cultivators tended to prepare and sow their crops in discrete instalments, the plough cultivators tended to add more land to a plot, or clear a new one, and keep sowing these plots long after the recommended planting dates. This

strategy (extending into the time when hoe-cultivators are already busy weeding) was mentioned as a means for spreading risk now that the mid-July rains in particular have become more unpredictable. In the sample as a whole, plough ownership appeared to allow labourers to work 1.5 to 3 times the area that hoe-cultivators could.

CONCLUSIONS

Lanfiéla's agro-pastoral exchanges facilitate agricultural intensification even by households that did not own or manage all of the equipment or livestock that they used. Households themselves often expressed the view that these exchanges were evidence of healthy, community solidarity, and served to maintain social cohesion. Does this mean that such exchanges are worth encouraging or preserving?

Such exchanges are certainly valuable where they permit households to become familiar with technologies and farming systems that have been mastered only by better off farmers. They have also allowed non-owners of livestock to benefit from the nutrients mobilised by animals in the area, with some visible improvements in crop yields as a result.

While the borrowing arrangements allowed many of the poorer households to meet their immediate needs, it was often at the expense of trading away nutrients or cash that would have been of great value in the longer term. The high crop yields of the cart-lenders, and the plough-owners (who are often one and the same), rely in part on the extraction of nutrients and labour from the cart-less and plough-less. Households with less secure access to livestock and equipment had low yields and thus suffered problems of recurrent poverty. However, the land cultivated by the wealthier households often suffered the worst nutrient deficits of all. This seemingly unsustainable "soil mining" has nevertheless greatly benefited these households, which have often maintained above average yields on the same land for many decades with no visible decline in productivity. It is tempting to conclude that nutrient balance calculations on their own are inadequate for characterising "sustainability", but are valuable for demonstrating the extraction of nutrients from poorer households for the benefit of the wealthier. It is also possible that unchecked soil fertility decline represented by negative nutrient balances may ultimately undermine some of the prosperity of even these well-off households.

What might improve the chances of agricultural intensification? It is clear that the use of ploughs, as well as carts and animal manure, is much more prevalent than simple ownership statistics would indicate. Credit programmes

that help poorly-equipped households acquire carts or ploughs of their own have had moderate success in the region, but could more explicitly address households that have experience from borrowing equipment from neighbours. Encouraging reciprocal ploughing arrangements could also offer plough owners higher yields from more timely planting and weeding, and better nutrient balances, without necessarily "exploiting" plough-less households. Increasing cart ownership could also lift many households into a position of being able to transport more of their manure to what their labour could carry by head-loads alone, eliminating the need to sacrifice future productivity against present needs.

Just as important would be a broader recognition of the viability of the cereal-based Fulani farming system. This was the only system in the study area that regularly maintained positive nutrient balances; it was also the only one to benefit in a regular and substantial manner from the abundant manure of extensively grazed animals. In this system, the use of ploughs and the hiring of carts not only intensified agricultural production, but also helped free labour from farming to herding. Recognition of the successful attributes of Fulani farming activities by the CMDT should improve their eligibility for credit to purchase equipment, fertilisers, cereal seed, or other crop inputs. A longer term objective would be to encourage a greater social inclusion of the Fulani in village networks of solidarity, recognising their competence not only as herders but as farmers and partners in the region's future.

The view that livestock are "poorly integrated" into West African farming systems has been repeated many times since the earliest colonial times (Meniaud, 1912, 1931; Faulkner and Mackie, 1933; Lugard, 1965). However, the examples from Lanfiéla show an agricultural sector undergoing an increasing level of intensification which co-exists with a growing number of animals, such co-existence being based on a number of exchanges between crops and livestock. The challenge is now to find ways of building on practices to intensify agricultural production further, while keeping at bay the risks of soil mining or widening inequality between different groups.

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