5. Results

The first section describes the farming system; knowledge, attitude and practice of AAT management; animal health services for AAT control, and understanding and management of trypanocide resistance. Then the epidemiological findings on AAT and other relevant diseases and their interactions are given. Together these comprise the situational analysis. Next, the results of the evaluation of three strategies for AAT control (vector control, keeping trypanotolerant cattle, and rational use of trypanocides) are presented. The third section describes a mathematical model for trypanocide resistance.

5.1 Situational analysis

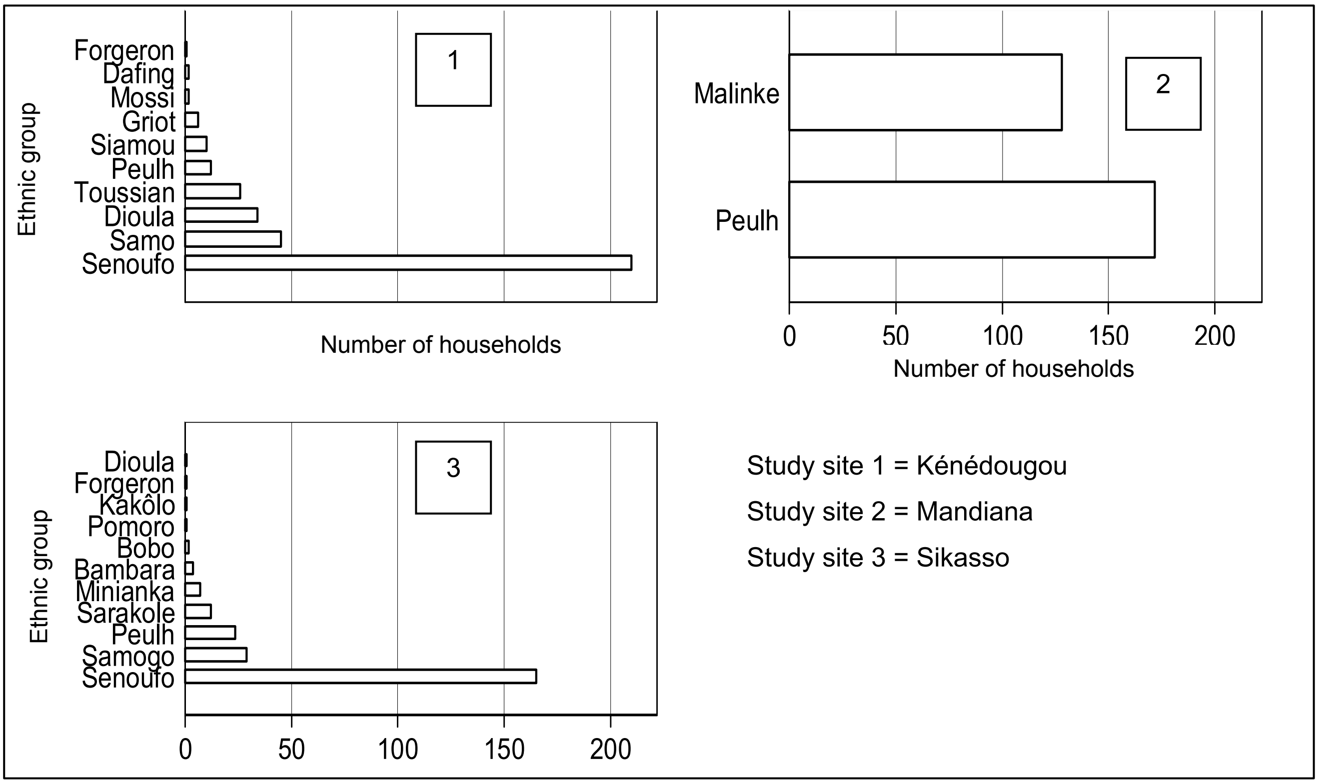
5.1.1 Demography

The study population consisted of rural, cattle-keeping, sedentary households in south-west Burkina Faso, south-east Mali and north-east Guinea.

Ethnicity and household members

All household (HH) heads, (except for one in Mandiana) were men. Only 9.3% (survey mean) of respondents were in-migrants. There were eighteen ethnic groups in the survey, but 79.4% of the sample belonged to one of the three majority groups (Senoufo, Peul and Malinké). The considerable variation in ethnicity between study sites is shown in Figure 5.1.1.

Figure 5.1.1 Ethnicity of respondents by country



The average age of the head of family was 51.9 years (survey mean, 95% CI: 49.8 to 53.9, range 19-116), with a significant difference between Kénédougou (BF) and the other areas. (Table 5.1.1

summarises socio-economic differences among countries.) There were on average 18.4 household members (95% CI: 16.0 to 20.9 survey mean, range 1-214). Households in pastoral ethnic groups tended to be smaller than in non-pastoral (16.4 members versus 19.4 members, p=0.052). There was a ratio 1.2 active household members to each inactive household member; the ratio was highest in Kénédougou. There were most children in Sikasso, reflecting the larger family size. Data on household structure were available for Kénédougou and Sikasso; households contained several adult males (average 3.3 and 5.9 respectively) and higher numbers of adult females (4.3 and 7.3), the result of polygyny and gender-differentiated out-migration.

Education, wealth and transport

Farmers were poorly educated; overall, just 10.4% had participated in formal education. Participation in education among school-age children was much higher than their fathers; 61.8% of children attending school. Education levels were significantly higher in Kénédougou.

Wealth was measured by two proxies: means of transport and cattle ownership (discussed later). The majority of households (79.2%) owned a scooter in Sikasso, compared to 52.8% in Kénédougou and just 14.7% in Mandiana. There was on average 2.9 bicycles per household with a moderately high correlation between bicycles and number of household members, scooters and household members and scooters and cattle. Calculating Somers D (a measure of association usually used for ordinal data, but suitable when data is clustered), the statistics were respectively: 0.36 (CI: 0.266 to 0.458, p=0.000); 0.28 (CI: 0.183 to 0 .383), p=0.000; 0.34 (CI: 0.213 to 0.459).

Table 5.1.1 Socio-economic and demographic differences among countries

	Countries			**Significance of differences**		
	Guinea	Mali	Burkina	G/M*	G/B**	B/M***
Percentage in-migrants	19.1	9.3	0.0	**p=0.021**	**p=0.000**	**p=0.008**
Age household head (years)	53.0	57.0	46.7	0.115	**0.021**	**0.000**
No. household members	16.6	26.7	13.8	**0.002**	0.165	**0.000**
No. children per household	4.3	7.4	3.9	**0.001**	0.534	**0.000**
Ratio active: inactive	1.2	1.0	1.6	0.106	0.147	**0.031**
% farmers educated	6.7	3.6	19.1	0.223	**0.000**	**0.000**
% children at school	48.8	46.7	85.9	0.672	**0.000**	**0.000**
No. scooters per HH	0.2	1.6	0.7	**0.000**	**0.000**	**0.000**
No. bikes per HH	2.1	2.5	2.9	0.263	**0.006**	0.074

* significance of difference between Mandiana, Guinea and Sikasso, Mali; ** significance of difference between Mandiana, Guinea and Kénédougou, Burkina Faso; *** significance of difference between Kénédougou, Burkina Faso and Sikasso, Mali

5.1.2 Farming system

The farming system was mixed, agro-pastoral, commercial-subsistence farming. All farmers cultivated crops and a significant proportion kept cattle. In Kénédougou, the PRA estimated that 42.4% of households kept cattle, in Mandiana, 97.2% kept livestock and around 50% kept cattle. In Mali around 75% of households kept cattle.

Farm household production and consumption

Information about the farming system was obtained from the PRAs and/or Focus Group Discussions and refers mainly to Kénédougou and Sikasso. All farmers in the study were agro-pastoralists and 21 different crops were cultivated (nine of these are cultivated with draft cattle). The staples of cotton, maize, beans, peas, sweet potatoes, yam, ground-nut, sesame and fruit were grown in most villages. Ginger, rice, hibiscus, pearl millet and fonio (the smallest millet species) were grown in some villages. The main cash crops were cotton, hibiscus, ginger and avocado (except for cotton, these are also consumed at home). Farmers cultivated on average seven hectares, yielding a harvest of around seven tonnes of products worth around $5000 USD; cotton was the single most important cash crop, generating 30% of total revenue. Farmers consumed products worth $2,000 and sold products worth $3,000. All bought food crops, most commonly maize, rice and sorghum. Livestock-poor farmers bought much less than livestock-rich farmers. (Farmers' own definition for livestock-rich and poor were used; the number of cattle corresponding varied from village to village.) Livestock-rich farmers sold more agricultural product than they consumed and livestock-poor farmers consumed more than they sold (Table 5.1.2).

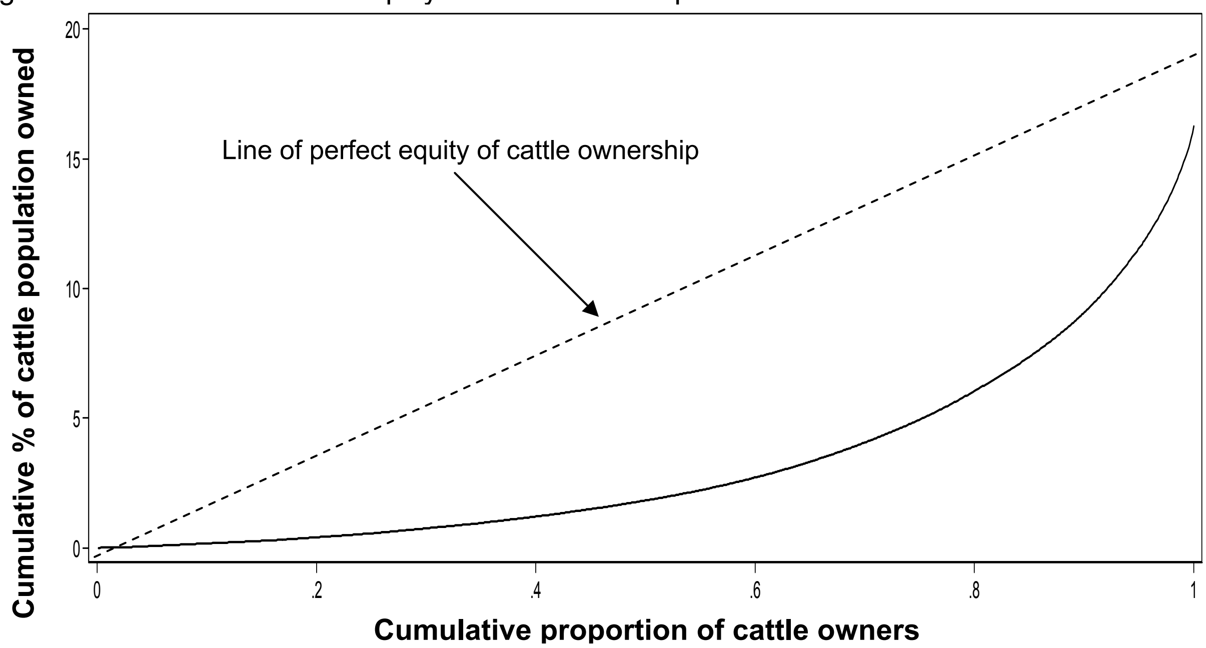
Table 5.1.2 Sale and consumption of agricultural products according to herd size

	Livestock rich farmers	**Livestock poor farmers**
Price of products sold	$3528	$1925
Value of products consumed	$1565	$3219
Price of products bought	$306	$22

Herd size and composition

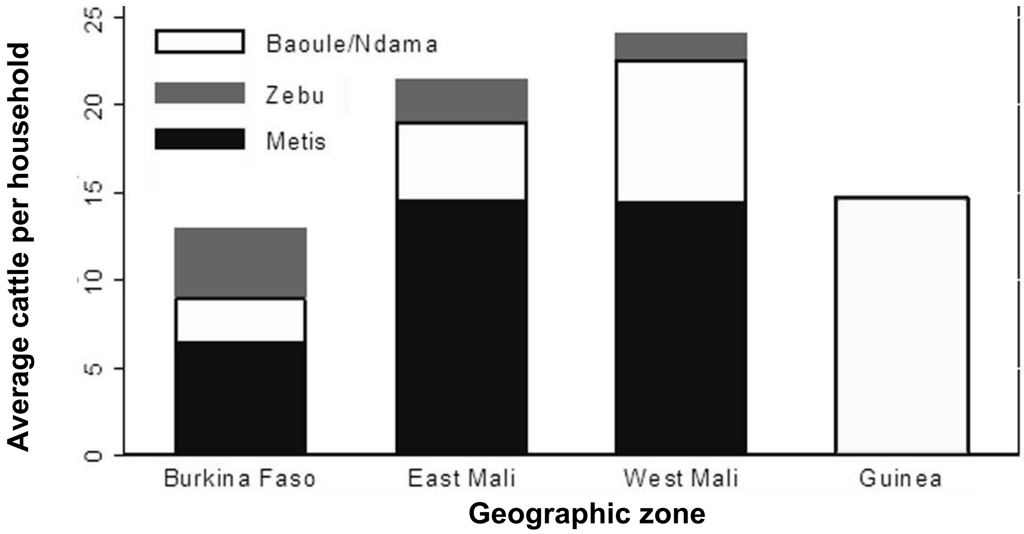
There was an average of 14.4 cattle per household (range: 1 to 235; 95% CI: 10.6 to 18.2 survey mean); as shown in Figure 5.1.2, cattle ownership was inequitable (Gini coefficient 0.592). Half the farmers (51.2%) had seven or fewer cattle and 10.1% had more than 70 cattle.

Figure 5.1.2 Lorenz curve for equity of cattle ownership



Data on cattle breeds existed for 1252 herds; the proportion of Zebus increased towards the east and that of trypanotolerant cattle towards the west (see Figure 5.1.3). Métis now predominate in Mali and Kénédougou but in Mandiana the population is still almost entirely trypanotolerant.

Figure 5.1.3 Average number of cattle of each breed per household in different regions



Data on herd structure was available for 867 herds. In Kénédougou there was greater draft orientation; most farmers had only male animals and the ratio of oxen to bulls was 3.2. The ratio of cows to calves were greater than one, indicating a low calving index, high calf mortality or both. The highest ratio of calves to cows was in Sikasso indicating best reproductive performance.

Role of cattle in the farm household

The role of cattle was assessed on the subset of 867 herds. Cattle occupied from one to seven roles, most in Mandiana and fewest in Kénédougou. Disregarding the small number of eccentric responses ("*we have cattle to keep the children occupied*", or "*to make the herder happy*"), the reasons for cattle-keeping were grouped firstly around arable production (traction and manure); secondly, social and cultural functions; thirdly, financial services (savings, credit access, insurance and sale) and lastly, milk production (Table 5.1.3). Most farmers (82.4%, survey mean) considered traction the most important role. Only in Mandiana were social reasons important (bride-price, sacrifice and status). Although production of meat and skins were mentioned by some farmers, these outputs were only of minor importance; just 20.5% of farmers considering they had a role and no farmer placing them in greater than third place.

Table 5.1.3 Percentage of farmers assigning first role to different production objectives

	Arable first	**Financial first**	**Ritual first**	**Milk first**
Kénédougou	89.7	10.0	0.9	0.3
Mandiana	72.7	5.0	18.7	4.3
Sikasso	81.8	15.4	0.0	1.6
Overall	81.5	9.8	6.6	2.1

Exploded logistic regression revealed the predominance of traction. Cultural motives came in second place, followed by savings, manure, sale and milk (see Table 5.1.4).

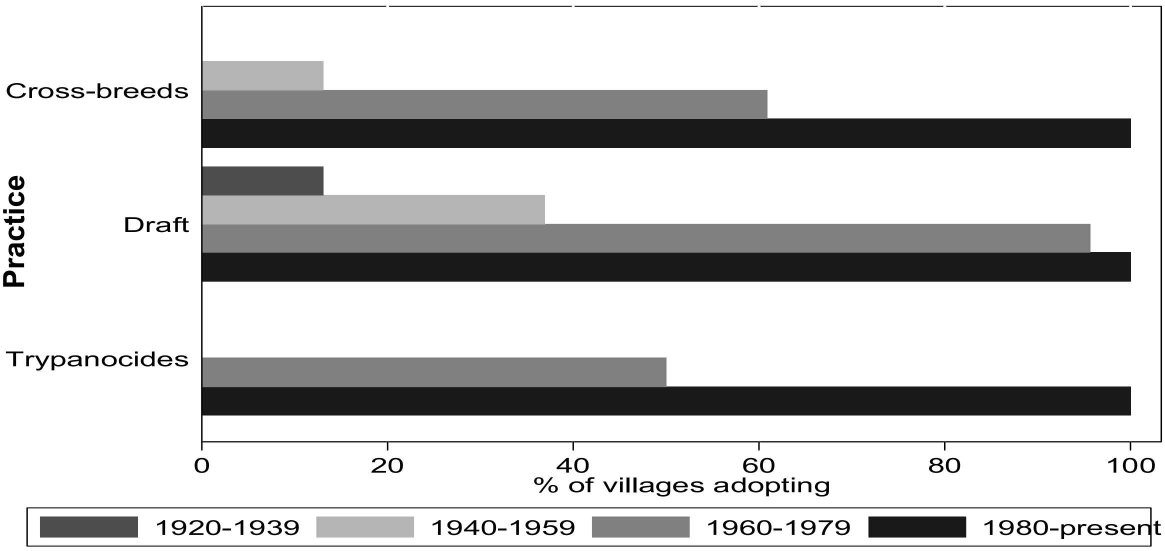
Table 5.1.4 Exploded logistic regression showing importance of different roles occupied by cattle

Cattle role	**OR**	**SE**	**z**	**p>z**	**95% Conf.**	
Traction	190.7	51.53	19.43	**0.000**	112.29	323.86
Ritual	50.1	13.68	14.33	**0.000**	29.32	85.56
Savings	27.7	7.35	12.49	**0.000**	16.43	46.57
Manure	27.6	7.29	12.54	**0.000**	16.41	46.28
Sale	19.6	5.24	11.08	**0.000**	11.55	33.08
Milk	15.1	4.02	10.16	**0.000**	8.92	25.41
Observations	n=10 434				Pseudo R^2=0.2420	

History of draft cattle introduction and breed change

In a minority of villages, arable farming using draft cattle was introduced to the village as early as the 20s-30s; in most it was not introduced until after the second half of the last century (Figure 5.1.4). Draft farming was followed by the introduction of cross-breeds and later Zebus. Keeping of trypanosusceptible cattle in large numbers was only possible after the widespread use of modern trypanocides. Not until the 80s, did the majority of farmers in villages in Kénédougou and Mali engage in draft farming, keep Métis, and use trypanocide drugs. In three villages in Mali, and in all villages in Mandiana cross-breeds are still kept by a minority of farmers.

Figure 5.1.4 Date at which villages adopted draft cattle, cross-breeds and trypanocides



Cattle as a limiting factor to agricultural production

A sub-sample of farmers (n=103) ranked the main limiting factors for agricultural production. Lack of cattle was cited as a limiting factor by 93.2% of farmers; but was not the first or second limiting factor; lack of capital for investment in the farm enterprise and lack of land being more important as priority constraints. Labour shortage (human) was the least important constraint (Table 5.1.5).

Table 5.1.5 Percentage of farmers ranking factors of agricultural production as limiting constraints

	Most limiting	Second	Third	Fourth	Overall
Capital	45.6	39.8	10.5	8.0	100
Land	26.2	14.6	15.8	37.3	82.5
Draft-cattle	20.4	27.2	37.9	14.7	93.2
Labour-human	7.8	18.5	35.8	40.0	88.3

Husbandry practices - transhumance

Feeding and grazing practices were evaluated in Kénédougou and Sikasso. Only a minority of farmers practised transhumance and, among these, short distance transhumance (up to 25km) predominated (87.5%). Table 5.1.6 summarises features of transhumance. Farmers with large herds (defined as more than the average number of cattle) were significantly more likely to practice transhumance than farmers with small herds (26.6% vs 8.4% respectively, p=0.000, chi 2). The place visited during transhumance was usually decided by the household head (54.7%) followed by the person responsible for cattle (22.6%) or by the herder (22.6%).

Table 5.1.6 Characteristics of transhumance (adoption, distance and duration)

	Practicing	Distance		Duration	
	Farmer (%)	Mean (km)	Range	Mean (days)	Range
Kénédougou	7.2	12.4	1-45	30.1	1-365
Sikasso	34.0	15.1	1-118	128.5	1-1460
Significance	**0.000**, binomial	0.3785, t-test		**0.0002**, t-test	

Divagation

Only in Mandiana was divagation practised (the traditional practice of allowing trypanotolerant cattle to wander freely). This took place outside the season of cultivation (June to December).

Nutritional supplementation

Most farmers (95.2%) gave salt, and most of these (72.3%) gave it all the year round. Agricultural by-products (mainly cotton seed cake, bran and hulls) were given by 59.7% of farmers; among those giving by-products 68.5% did so weekly, and nearly half (49.0%) only in the dry season. Harvest residues (straw, stover, and the leaves and stalks of maize, legumes and groundnuts) were used by 74.1% of farmers; 95.0% of which gave them only after harvest in the dry season; most commonly they were given daily (70.0% of those supplementing). Food gathered in the uncultivated bush (leaves, fruits and seeds) was given by 73.7% of farmers; most giving only in the dry season (87.0% of those providing), most commonly on a daily basis (61.2% of framers supplementing). The most important plant given was *Khaya senegalensis*, which is believed by farmers to help prevent AAT. Only in Sikasso did a minority of farmers give cultivated fodder S*tylosanthes*, cowpea *(Vigna unguiculata)* and dolic (*Lablab prupureus*). Fodder cultivation had been introduced by the cotton parastatal as part of a package whereby farmers received two oxen and a plough on credit and in turn undertook to grow fodder and give trypanocide treatments. There were significant differences between Sikasso and Kénédougou, with higher supplementation levels in the former, as shown in Table 5.1.7.

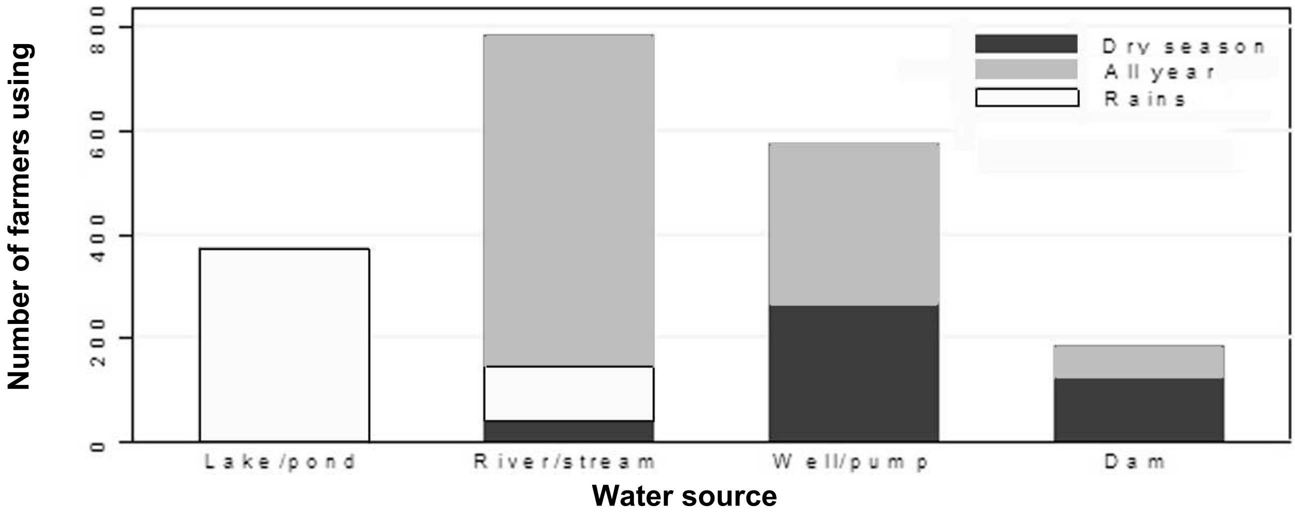
Table 5.1.7 Percentage of farmers giving different nutritional supplementation to cattle and significance of differences among countries

	Salt	Bush	By-products	Harvest residues	Fodder
Kénédougou	93.4	82.8	64.9	92.8	0.0
Sikasso	97.6	61.9	50.6	50.2	25.1
Pearson chi 2	**0.021**	**0.000**	**0.001**	**0.000**	**0.000**

Watering cattle

Farmers used up to four different sources of water for watering cattle (see Figure 5.1.5). Overall rivers and streams were most important; in the rainy season lakes and ponds were important, and wells and pumps were used by less than a third of farmers. The average distance of the water source was 1.7 km, and some farmers brought their cattle as much as 35 km. The nearest source were lakes/ponds (1.2 km) followed by wells/pumps (1.6 km), rivers/streams (1.8 km) and the furthest were dams (2.4 km).

Figure 5.1.5 Numbers of farmers using different water sources according to season



Making decisions about cattle husbandry and health

In terms of cattle husbandry decision making, the herder had the major say in deciding the place of pasture and watering, but the decision to treat sick animals was usually made by the household head or the person he appointed to be responsible for cattle (see Table 5.1.8). The latter was most commonly the son of the household head (56%), followed by the head of work (33%) or the brother of the household head (10%).

Table 5.1.8 Percentage of households with different actors making decisions over cattle feeding, watering and treatment of sick animals

Decision-maker	Watering place	Pasture	Treatment
Herder	63.1	63.5	12.4
Household head	33.4	32.8	80.3
Head of work	2.1	2.4	7.0
Joint decision	1.4	1.3	0.4

Differences in cattle-keeping between the three countries are summarized in Table 5.1.9. Cattle ownership was highest in Sikasso, and draft orientation highest in Kénédougou.

Table 5.1.9 Differences in cattle keeping among the three countries

Cattle-keeping statistics	Guinea	Mali	BF	G/M	G/B	B/M
Average number of cattle per household	9.5	21.2	13.8	**0.004**	0.094	**0.006**
% farmers with only male cattle	16.5	26.1	54.7	0.090	**0.000**	**0.001**
Cow to calf ratio	2.0	1.7	2.2	**0.005**	0.530	**0.028**
Oxen to bull ratio	1.5	1.3	3.2	0.179	0.096	**0.046**
Average number of roles for cattle	6.6	4.3	3.6	**0.000**	**0.000**	**0.011**
Average number of water sources used	3.7	2.0	2.2	**0.000**	**0.010**	**0.000**

5.1.3 Knowledge, attitude and practice of trypanosomosis management

Trypanosomosis was considered the most important cattle disease and was proactively managed by farmers in all three countries.

Importance of trypanosomosis

Farmers ranked the cattle diseases they had experienced in the last year in order of importance (Table 5.1.10). Most (94.5%) farmers had experienced disease (or signs of disease/syndrome: the distinction was not always obvious). Most farmers who had not experienced disease had only just started keeping cattle in the last few months or weeks.

Table 5.1.10 Percentage of farmers assigning different ranks to cattle diseases (%)

Disease	First	Second	Third	Fourth	Fifth	Sixth	Seventh	Eighth	Ninth
AAT	84.0	5.8	3.5	1.8	8.2	0.0	0.0	0.0	0.0
Worms	5.6	6.5	11.2	9.5	9.1	3.6	2.3	1.2	0.0
Digestive	1.9	8.5	9.3	7.9	19.7	12.4	19.1	9.8	83.3
Weakness	1.9	11.3	15.9	21.6	13.2	10.3	7.6	4.9	0.0
Ticks	1.7	36.6	23.7	15.1	0.0	3.6	0.8	1.2	0.0
Respiratory	1.7	5.6	5.3	4.7	9.7	17.0	12.2	4.9	16.7
Dermatitis	1.0	4.3	4.8	6.6	13.5	15.5	18.3	1.2	0.0
Abortion	1.0	3.9	5.2	7.2	7.3	6.2	8.4	19.5	0.0
Contagions*	0.7	3.1	3.0	2.6	2.9	4.1	4.6	12.2	0.0
Tick borne**	0.4	1.8	0.5	0.3	0.3	1.6	0.0	1.2	0.0
Trauma	0.2	0.8	1.0	0.5	2.6	10.8	9.2	29.3	0.0
Loco-motor	0.1	0.6	0.5	0.6	0.9	3.6	9.9	7.3	0.0
Black magic	0.0	11.0	15.7	21.3	12.6	10.3	6.9	4.9	0.0
Eye disease	0.0	0.0	0.5	0.3	0.0	0.5	0.8	2.4	0.0
Miscellaneous	0.0	0.1	0.1	0.2	0.0	0.5	0.0	0.0	0.0

*haemorrhagic septicaemia, anthrax, blackquarter and foot and mouth disease
** red urine (babesiosis) and jaundice/enlarged gall-bladder (anaplasmosis)

In all, 43 problems were reported, on average 4.5 problems (range 0 to 9, survey mean). Trypanosomosis was the disease most often assigned first place; it was experienced by 98.0% of the farmers having health problems, in second place was tick infestation (75.2% of farmers), next diarrhoea or worms (71.7%), weakness (53.3%), dermatitis (26.9%), respiratory problems (26.4%) and abortion (23.0%). Other diseases were reported by less than 10% of farmers.

The complex matrix of 43 diseases with up to nine rankings is difficult to interpret and an exploded logistic model was used to evaluate the relative importance of different diseases (Table 5.1.11). Only diseases reported by more than 10% of farmers were included in this model. It can be seen that the OR for trypanosomosis is of a higher order of magnitude than that of other diseases.

Table 5.1.11 Exploded logistic regression of cattle disease ranks accorded by farmers

Disease	Odds Ratio	SE	z	p	95% CI	
AAT	21.9	3.77	17.93	**0.00**	15.64	30.71
Ticks	3.5	0.57	7.61	**0.00**	2.53	4.82
Worms	2.6	0.42	5.91	**0.00**	1.89	3.55
Diarrhoea	2.0	0.33	4.4	**0.00**	1.48	2.80
Weakness	1.8	0.30	3.51	**0.00**	1.30	2.50
Dermatitis	1.0	0.18	0.11	0.91	0.72	1.44
Number of observations=7567			Pseudo R^2=0.2022			

Mortality and morbidity from AAT

Farmers reported that 28.1% of their herd were sick with trypanosomosis in the previous year and 6.2% died, corresponding to a case fatality of 22.0% (survey mean). There was no significant difference in perceived morbidity among countries, but there were large and significant differences in terms of mortality and case fatality (Table 5.1.12).

Table 5.1.12 Mortality and morbidity from AAT in the previous year reported by farmers with differences among countries

Disease statistics	Guinea	Mali	Burkina	G/M	G/B	B/M
Percentage herd sick AAT	30.7	26.3	27.7	0.351	0.507	0.719
Percentage herd died AAT	1.1	6.5	11.2	**0.000**	**0.000**	**0.032**
Case fatality	3.6	25.0	35.4	**0.000**	**0.000**	0.055

Exploratory Data Analysis using survey linear regression (weighted) to investigate the factors influencing mortality (see Table 5.1.13). The use of a trained service provider (veterinarian or paravet) and using ISMM in addition to DIM curatively were associated with less farmer-reported cattle mortality from AAT (Table 5.1.13). There was a tendency for farmers with larger households and living in high prevalence areas to experience more mortality from AAT.

Table 5.1.13 Survey linear regression exploring factors associated with mortality from AAT

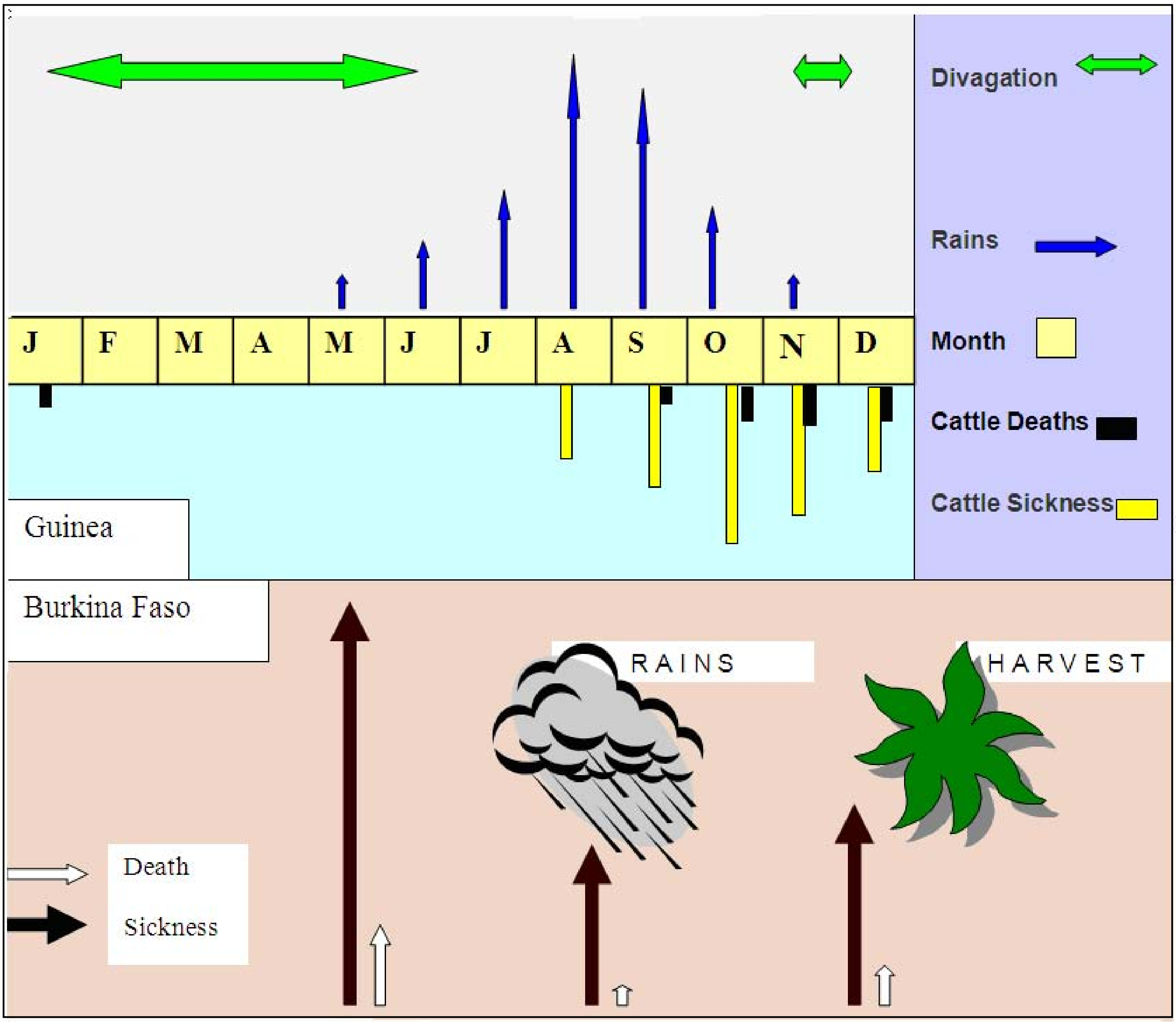
Farmer characteristic	Coef.	SE	t	p	95% CI	
Use of trained service provider (1,0)	-0.532	0.188	-2.830	**0.008**	-0.915	-0.149
Live in high prevalence area (1,0)	0.410	0.276	1.480	0.148	-0.154	0.974
No. of household members	0.011	0.006	1.940	**0.061**	-0.001	0.023
Use of ISMM curatively (1,0)	-0.386	0.207	-1.860	**0.072**	-0.809	0.036
_cons	0.784	0.244	3.210	**0.003**	0.286	1.282
Strata=3, PSU=34, Obs=701			Prob> F=0.0001 R^2=0.0698			

The R^2 was low; some data with possible explanatory value (including trypanocide resistance), were not available for all villages and were not included. Data on the quality of drugs, diagnosis and treatments for the animals sick with AAT are obviously important predictors of mortality but cannot easily be accurately collected in a recall survey, and were not included.

Farmer perception of AAT seasonality

In the participatory assessments disease calendars were constructed showing a highly seasonal pattern in Mandiana, but only moderately seasonal in Kénédougou (see Figure 5.1.6).

Figure 5.1.6 Participatory calendars of AAT morbidity and mortality for Mandiana and Kénédougou



Farmer knowledge of aetiology of trypanosomosis

Nearly all farmers (96.7%) were able to suggest one or more causes for AAT (average 4.6 causes, range 0 to 9). Overall 60.2% (survey proportion) of farmers believed that trypanosomosis was transmitted by tsetse or biting insects (correct). Tsetse was considered the most important cause of AAT by 58.7% of farmers (correct). Thirty-five different beliefs on AAT aetiology were suggested, but just six of these were suggested by a substantial number of farmers (more than

7.5%). Of these, two are directly involved in disease transmission (tsetse and biting flies), two are predisposing factors (malnutrition and tick infestation) and the remaining two (riverine galleries and presence of other sick cattle) are indicators of risk (Table 5.1.14). Just 5.2% (survey proportion) of farmers attributed supernatural causes to sickness; other idiosyncratic beliefs were types of food (new grass, mangoes), dirt, poisoning, coldness, overwork, harmattan wind and change of season.

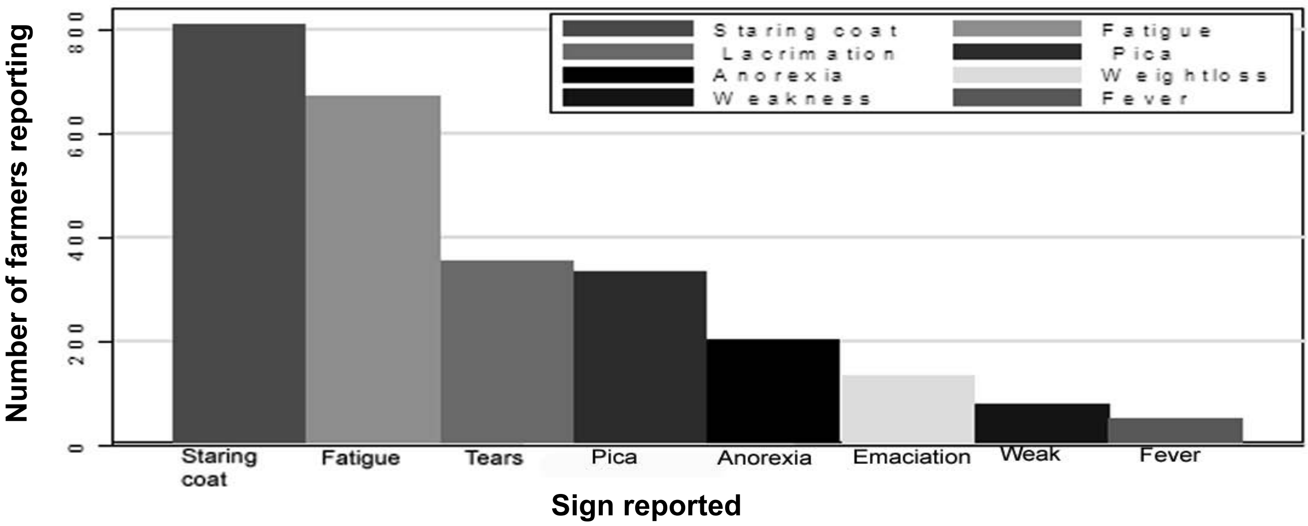
Table 5.1.14 Number (and percentage) of farmers with different beliefs on the cause of AAT

Belief about cause of AAT	Category of belief	No. farmers	% farmers
Tsetse flies	Important cause	751	83.9
Riverine galleries	Risk indicator	731	81.7
Other biting flies	Minor cause	629	70.3
Malnutrition	Predisposing factor	540	60.3
Ticks	Predisposing factor	534	59.7
Cattle sick with trypanosomosis	Risk indicator	248	27.7

Farmer recognition of AAT

The sign most farmers considered characteristic of AAT was a staring coat (piloerection), followed by anorexia and weight loss (see Figure 5.1.7). Farmers reported an average of 3.3 signs (range 0 to 8, survey mean). In total 1705 farmers gave signs of trypanosomosis and 49 different signs were cited, 46 of which are consistent with AAT according to the literature. Only 2.0% of farmers reported signs not likely to be due to AAT (such as cough, lameness and red urine).

Figure 5.1.7 Number of farmers reporting different signs of AAT



In the transversal survey in Sikasso, cattle believed by farmers to be sick with AAT were clinically examined and weight, temperature and PCV checked and BCT performed. In addition 147 animals attending village clinics in Kénédougou were clinically examined. Table 5.1.15 gives the odds ratios for the diagnostic signs in these animals. The signs most commonly recognised by farmers (staring coat and emaciation) were not significantly associated with disease (microscopic diagnosis). However, lacrimation, enlarged lymph nodes, fever (>39.5) and especially anaemia (PCV<24%) were predictive, being present in 33%, 59%, 18% and 36% of cases respectively.

Focus Group Discussions showed anaemia was not recognised by farmers, and only a minority detected fever by indirect signs (seeking shade). Some farmers had observed that lymph nodes were more prominent in animals sick with AAT, but attributed this to emaciation and not disease.

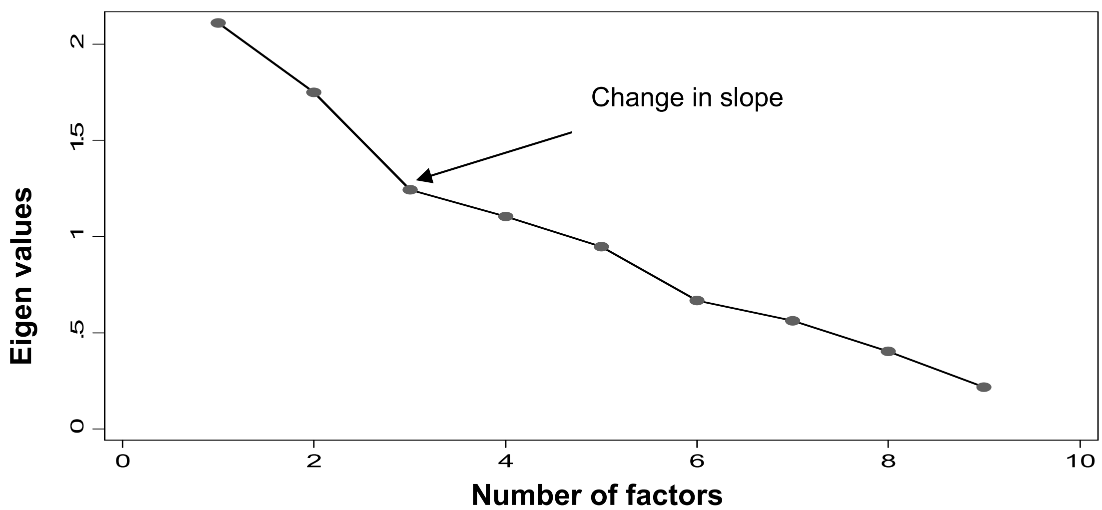
Table 5.1.15 Clinical signs found in cattle positive for AAT, with odds ratio for signs

Clinical signs	% with sign	Odds ratio	95% CI for OR	p=
Salivary/nasal discharge	10.7	1.3	0.56 to 2.83	0.445
Emaciation	64.0	1.2	0.77 to 1.88	0.402
Staring coat	67.8	0.8	0.53 to 1.25	0.306
Lacrimation	33.0	1.7	0.96 to 2.83	**0.050**
Enlarged lymph nodes	59.6	1.6	0.96 to 2.49	**0.043**
Temperature (>=39.5)	17.9	2.0	1.31 to 3.07	**0.001**
Anaemia (PCV<24%)	35.7	4.2	2.62 to 6.72	**0.000**

Comparing farmer diagnosis to parasitological diagnosis using BCT is complicated by the low sensitivity of the latter method. Among animals presented at clinics in Kénédougou, 29.5% were parasitologically positive and 49.7% had a PCV lower than 24%. Among animals thought to be sick presented in the cross-sectional survey in Sikasso only 7.4% were BCT positive, although a third (32.5%) had a PCV of less than 24%. In Sikasso where cattle were randomly selected from a sampling frame, then diagnosed sequentially by farmers and by BCT we were able to estimate accuracy of farmer diagnosis compared to BCT in the normal population. Farmer diagnosis had a sensitivity of 34.6 (95% CI: 31.4 to 37.8), specificity of 77.9% (CI: 76.3 to 76.7), positive predictive value of 34.8 and negative predictive value of 76.7.

Exploratory factor analysis was used to investigate whether farmers recognised the constellation of signs characteristic of AAT (pica, lacrimation and fever). To avoid obtaining non-positive definite correlation matrices we dropped signs reported by less than 10% of farmers. Four factors had Eigen values over one, but the scree graph of Eigen values (Figure 5.1.8) indicated three should be retained (accounting for 56.67% of variation).Oblique rotation was used as theory suggested factors were correlated (promax 1).

Figure 5.1.8 Scree graph of Eigen values for factors underlying diagnosis of AAT by farmers



There was no evidence for a factor corresponding to specific signs of AAT (fever, pica and lacrimation) (Table 5.1.16). Factors tentatively corresponding to digestive abnormalities, general ill health and visible signs of AAT were detected.

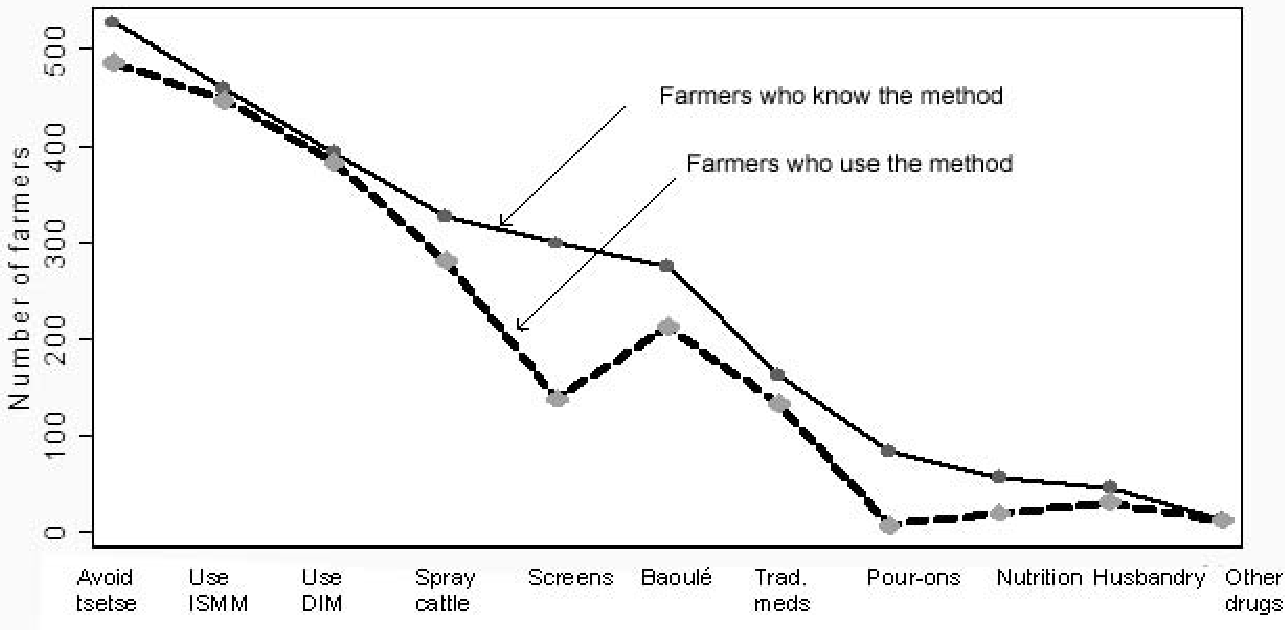
Table 5.1.16 Factor analysis of AAT signs reported by farmers

Variable	1	2	3	Uniqueness
Constipation	-0.14133	**0.22964**	0.11463	0.91415
Pica	-0.32069	**0.34634**	-0.15616	0.75282
Fever	0.10352	**0.80217**	0.13099	0.32864
Lacrimation	**0.74359**	0.02328	0.12121	0.43184
Weight loss	**0.47721**	0.12903	0.00871	0.75555
Anorexia	-0.11995	0.25289	**0.47469**	0.69633
Piloerection	0.18857	0.04950	**0.46277**	0.74783
Fatigue	0.32636	0.09277	**0.54247**	0.59060
Weakness	0.20236	-0.51076	**0.39326**	0.54352

Knowledge and practice of AAT prevention

Farmers in Sikasso and Kénédougou were aware of an average of 4.6 strategies for AAT prevention; of the strategies known an average of 3.6 were used (Figure 5.1.9).

Figure 5.1.9 Number of farmers knowing and using different strategies for AAT control



Strategy for trypanosomosis control

The most important primary strategy was use of trypanocidal drugs, either ISMM or repeated doses of DIM during risk periods (45.8% of farmers) followed by avoiding high risk areas (by watering at pumps or grazing where flies are fewer) (34.4%). In third place was insecticide sprays and in fourth trypanotolerant cattle (8.1%), (although 52.8% of farmers in these villages keep trypanotolerant cattle, only 35.5% used trypanotolerant cattle as a deliberate strategy for preventing AAT). Given the selective and unsynchronised usage of sprays this strategy was probably not effective against tsetse; it is visibly effective against ticks which most farmers believe can transmit AAT. The other 14 disease prevention strategies employed as the primary strategy were used by less than 5% of farmers. Farmers' most important backup strategy was use of drugs (48.7%), followed by use of sprays (15.3%), avoidance of high risk areas (12.6%) and keeping trypanotolerant cattle (12.4%). Overall, farmers used up to nine strategies; summing these the most important strategy was using drugs, followed by avoiding tsetse and keeping trypanotolerant cattle (Table 5.1.17).The strategies for AAT prevention known and used by farmers are shown in Figure 5.1.9. With the notable exception of screens and pour-ons, practice closely follows knowledge, with a small number of widely known and widely used strategies and a greater number of little known and little used strategies. The pattern of rankings indicates drugs are used as primary strategies (more first and second rankings), while sprays and keeping trypanotolerant cattle as secondary strategies (more second and third rankings).

Additional techniques for preventing AAT emerged during PRAs, noticeably that of lighting smudge fires to keep flies away and sending cows prone to AAT in "*confiage*" to healthier areas.

Table 5.1.17 Farmers (%) using different strategies for AAT prevention

Strategy	Overall	First method	Second method	Third method
Drugs	45.7	51.1	55.0	39.2
Avoid tsetse areas	23.5	36.2	13.5	24.0
Sprays	18.7	3.4	18.6	24.6
Trypanotolerant cattle	9.8	8.2	12.1	10.6
Good nutrition	1.1	1.0	0.7	1.0
Vector control	1.2	0.0	0.2	0.6

Knowledge and practice of disease treatment: farmer response to AAT

Farmers were questioned about the last case of illness from AAT in the herd. Nearly all (96.9%) farmers reported medicines were given. Other (not mutually exclusive) actions included: seeking advice (56.2% farmers); selling the animal (10.4%); and slaughtering the animal (8.6%). Slaughter was seen as an option of last resort if treatment failed and the animal was likely to die.

Most cattle treated in the community

The last sick bovine was most likely to have been treated by an "expert[1]" in the community; these included other farmers, Peuls, vaccinators, community animal health workers and drug sellers. Local 'experts' treated 41.8% of cases (see Table 5.1.18). In second place was the farmer or his herder (31.1% cases), followed by veterinarians who, according to farmers, treated 13.9% of cases. Farmers often explained that if many animals were ill they would ask the vet to come, but if only a small number were sick they would treat themselves. There were marked (and statistically significant) differences in treatment provision among countries, with farmers predominating in Sikasso, un-trained community members in Kénédougou and Community Animal Health Workers (paravets) in Mandiana. (Officially trained and recognised paravets were not found in Burkina Faso or Mali, where policy and legislation is unfavourable to primary animal health provision).

[1] An expert or "connaisseur" is someone who knows how to do the treatment

Table 5.1.18 Farmers (%) reporting treatment of the last case of AAT by different actors

	Farmer/herder	Non-trained	Paravet	Vet
Kénédougou	29.5	48.5	0.0	9.2
Mandiana	10.9	4.7	53.2	23.7
Sikasso	57.6	13.8	0.0	7.9
B/G	**0.000**	**0.000**	**0.012**	0.368
B/M	**0.002**	**0.000**	**-**	0.826
M/G	**0.000**	0.226	**0.012**	0.328

Most commonly the farmer reported that the last time an animal was sick it was treated by just one person. In Mandiana, sick cattle were more likely either not to have been treated at all or to have been given treatments by more than one person (Table 5.1.19).

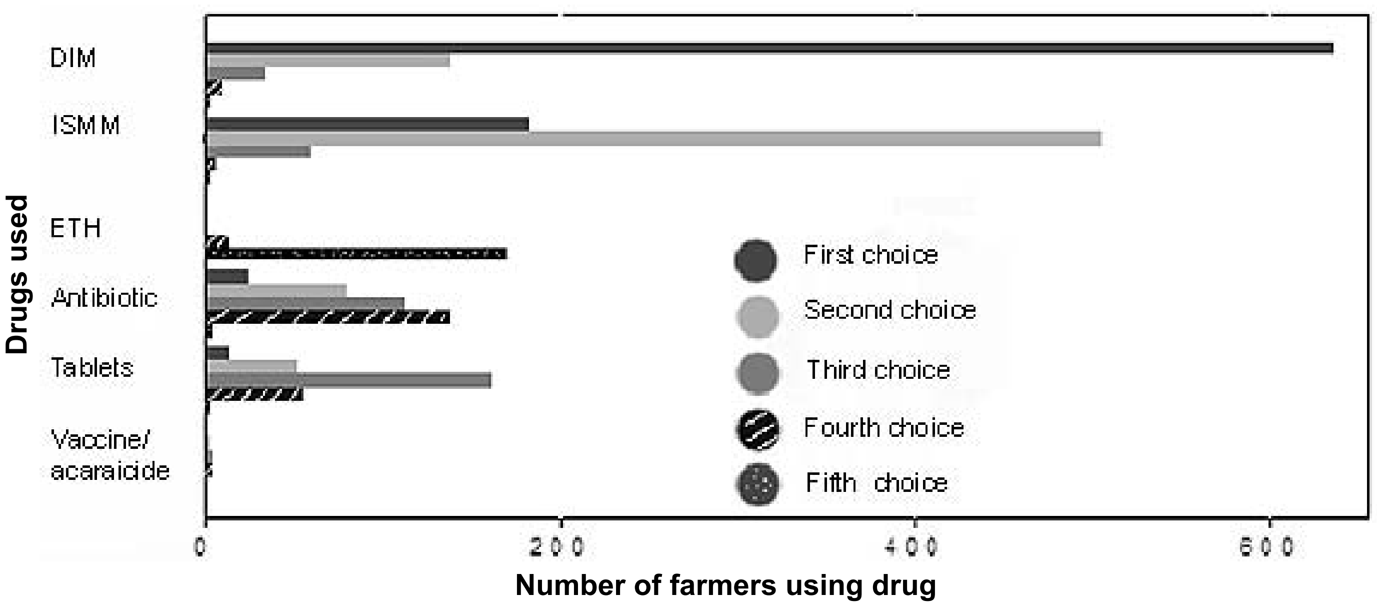
Table 5.1.19 Farmers (%) using no, one or multiple service providers for AAT treatment

Number of actors	Kénédougou	Mandiana	Sikasso	Total
None	3.2	6.3	0.0	3.4
One	96.8	77.7	98.8	91.0
Two or three	0.0	16.9	1.2	5.6

Medicines used to treat AAT

Farmers reported using a range of drugs used to treat AAT (Figure 5.1.10). The first-choice drug was DIM followed by ISMM. The most popular second choice was ISMM. Almost all (99.3%) of farmers used the dosage of one small sachet of trypanocide (ISMM or DIM) per adult bovine.

Figure 5.1.10 Number of farmers using different drugs for AAT, according to preference



A common practice was using DIM in the dry season and ISMM in the rains, because ISMM was believed to be a "strong" drug dangerous to use in cattle weak from malnutrition in the dry season. Only a minority of farmers reported sanative treatments. Figure 5.1.10 shows how trypanocides dominate other drugs in the treatment of AAT, and "*faut de mieux*" utilisation of other drugs: few farmers used non-trypanocidal drugs as their first choice (5.4%, survey mean) but many (47.9%)

used non-trypanocidal drugs as lower ranked choices (i.e. when preferred drugs were not available). A small minority reported unsafe practices (giving ISMM and DIM at the same time, mixing trypanocides with antibiotics and injecting them together).

Farmers in Kénédougou (where ISMM resistance is high) were significantly less likely to have used ISMM as the first choice of treatment, and had a tendency to use DIM as the first choice. Farmers in Mandiana (where drug availability is low) were significantly more likely to have used a non-trypanocidal (non-TC) drug as first choice. Farmers in Kénédougou used a narrower range of drugs, and this was true even if only trypanocidal drugs (TC) are included (Table 5.1.20).

Table 5.1.20 Treatment of AAT: Percentage of farmers using different drugs as their first choice, number of drugs used and number of trypanocides used

	Kénédougou	Mandiana	Sikasso	B/G	B/M	M/G
DIM first (% farmers)	76.5	45.1	64.0	0.064	0.506	**0.073**
ISMM first (% farmers)	2.8	35.1	34.4	**0.000**	**0.003**	0.942
Non-TC drug first (%)	0.2	14.5	0.9	**0.000**	0.476	**0.000**
No. vet drugs used	1.6	4.4	2.4	**0.000**	**0.027**	**0.000**
No. trypanocides used	1.4	2.6	1.9	**0.001**	0.116	**0.000**

Importance of traditional medicines

Many (49.4% survey proportion) farmers reported using traditional medicine, with most using in Mandiana (73.8%), followed by Sikasso (42.6%), then Kénédougou (31.4%); this difference was highly significant (p=0.000, survey proportions). Only 0.03% of farmers used exclusively traditional medicines; most gave traditional drugs as a complementary treatment alongside modern drugs. Five different modalities of traditional treatment were found, namely: physical treatments (burning, bleeding or scarifying); ethno-botanical treatments (plants or herbs); modern drugs or chemicals used non-canonically (injections of Nescafe®, oxytetracycline capsules for oral use in human medicine, or tonic beverages); nutraceuticals (chilli pepper, beer, salt, maize); and drekapotheke (treatment with urine). Eight different plants were used to treat trypanosomosis; we identified only the two most commonly used (*Khaya senegalensis* and *Parkia globosa*).

Complications and side-effects after treatments

Problems after treatments were not uncommon. In the cross-sectional survey in Mali, out of 403 cattle treated by farmers 24.6% has evidence of inflammation or sepsis when examined by veterinarians/technicians two weeks later, (although in most cases this was not severe). The same farmers treated (or had treated by others) 2914 cattle over the next 5 months, and reported that swelling occurred in 5.3% of cases.

Among farmers who usually treated animals themselves, just 62.2% had not experienced treatment failure, another indication of defective treatments. Among farmers who usually used a paravet as first choice 65.0% reported no treatment failures, and among those reporting using a vet as first choice 71.2% reported no treatment failures. Only the difference between those farmers usually treating themselves and those usually using a vet was significant (p=0.0416) (difference vet/paravet p=0.3679, differences paravet/farmer p=0.6758, test of two proportions).

Differences in knowledge among ethnic groups and countries

Farmers of pastoralist ethnicity has significantly greater knowledge of diseases, symptoms and treatments than non-pastoralists (see Table 5.1.21).

Table 5.1.21 Knowledge of animal health among pastoralists and non-pastoralists

Knowledge	Pastoralist	Non-pastoralist	Significance
Mean number of cattle diseases known	6.3	3.6	**p=0.000**
Mean number of signs of AAT known	3.9	3.1	p=0.000
Mean number of medicines known	4.0	2.2	**p=0.000**
Farmers knowing cause of AAT (%)	80.7	50.1	**p=0.000**

Farmers in Mandiana and Kénédougou were better informed about the signs and cause of AAT, but farmers in Sikasso could recognise more trypanocides (Table 5.1.22).

Table 5.1.22 Knowledge of AAT in different countries

Knowledge	Mandiana	Sikasso	BF	G/M	G/B	B/M
Mean no. signs of AAT known	3.8	2.9	3.1	**0.000**	0.455	**0.020**
Mean no. TC drugs known	1.9	2.6	1.4	**0.000**	**0.000**	0.116
Know tsetse is main cause (%)	85.1	21.9	62.3	**0.000**	**0.001**	**0.000**

5.1.4 Animal health services for trypanosomosis control

The animal health system determines the quantity and quality of inputs for AAT management and also influences the development of resistance. Farmer reports on the provision of clinical services in the three countries are shown in Table 5.1.18 (veterinarians have a minor role in treatments, but where paravets exist they are important providers of clinical services). The preferred sources of drugs are discussed in this section. Sources of advice are discussed later (5.2.4).

We found a wide variety of service providers (SPs) or actors. The most important were veterinary pharmacies, government veterinary agents, informal sector sellers, and other farmers. Findings concerning these service providers who together constitute the formal and informal animal health delivery system are presented in this section. As well as data from the KAP, we present findings from a survey of service providers in Kénédougou and Mandiana. In Mali a separate study on the same topic had been carried out by another student within the project (Babtounde, 2004) and information from this is available for comparison.

Formal veterinary sector: actors, qualifications, facilities

There were no veterinary pharmacies in the study area in Kénédougou, which was supplied by Bobo Dioulassou (with six independent veterinary pharmacies, two wholesalers and two branches of drug importing firms). In the study area in Sikasso there were 13 veterinary pharmacies, most staffed by livestock technicians who (but only in Mali), are authorised to practice as veterinarians. In Mandiana there was one vet pharmacy, run by a veterinarian. In Kénédougou there were three state veterinary agents, two centrally located in the district headquarters and one in a frontier post; only the latter was authorised to provide clinical services. In Mali, government veterinary agents had been replaced by general development agents, and were not important providers of services. In Mandiana, four state veterinary agents were located in the district headquarters (two veterinary graduates and two animal husbandry graduates), and eight agents in the field (one veterinarian, three animal husbandry graduates and three with higher level training in livestock).

Community Animal Health Workers (CAHWs) or paravets were found only in Guinea, where 47 are located in villages throughout the district; not all are active. The majority of paravets surveyed had attended primary school (62.5%), on average for 6.5 years; of the remainder 12.5% had received adult literacy training. Paravet training courses (initial and refresher) had been given from 1995 to 2003. The length of training was on average 14.1 days (range 5 to 19 days).

Formal sector service providers lacked facilities; no private veterinarians possessed a microscope or centrifuge which is needed for diagnosis of trypanosomosis (Table 5.1.23).

Table 5.1.23 Formal sector service providers (%) possessing business and veterinary facilities

Facility	Branch	Independent	Wholesale	Vet agent
Piped water	50	60	0	67
Electricity	50	60	100	67
Phone	50	40	100	33
Computer	0	40	100	0
Fax	0	20	50	0
Consulting room	0	60	0	33
Stable	0	20	0	33
Operating theatre	0	0	0	33
Fridge	50	60	50	100
Freezer	0	20	50	67
Microscope	0	0	0	33
Centrifuge	0	0	0	0

There were marked deviations from the roles envisaged in policy/regulation and practice:

- In Burkina Faso, the four wholesalers/importers sell direct to the public, although in theory wholesale and retail are separate. Only six of nine pharmacies surveyed (out of a total population=11) were run by veterinarians, the rest by technicians or animal husbandry graduates.
- In Mali, nine of the 13 pharmacies were “depots”, branches of wholesalers/importers. Again this is considered unfair competition and is not allowed in the legislation.
- In Mali, technicians (third level education), unemployed or otherwise employed, treated animals and sold drugs (here referred to as “private vets”).
- In Burkina Faso and Mali, government and parastatal veterinarians have officially withdrawn from service provision but are still involved in drug provision (making up 8.1% of all sources).
- In Mandiana, there is ambiguity on whether paravets they are legally entitled to independently diagnose and treat trypanosomosis, although in practice this is tolerated.
- In Mandiana, 14 technicians who had three years training in animal health were employed by the private veterinarian during vaccination campaigns. During the rest of the time they sold drugs and gave treatments, although not theoretically entitled to engage in independent practice.

Informal private sector – actors, qualifications and facilities

The informal sector was sub-divided into drug sellers (market-based or itinerant) who rarely provide clinical services and injectors who sell drugs but also treat animals. Ascertaining numbers of actors in this illegal sector was difficult. In Kénédougou, drug sellers and injectors estimated there were 20-50 drug sellers and injectors. In Mali a survey of markets found that in the 92 markets in Sikasso, 33.7% had some drug sellers and 9.8% had many, suggesting 50 to 60 drug sellers. In Mandiana there were estimated 70-80 informal sector service providers. Generally training and qualifications are low in the informal sector (Table 5.1.24).

Table 5.1.24 Qualification/training of animal health service providers (number and percentage)

Education/training	Drug sellers		Injectors	
	Number SPs	Percentage	Number	Percentage
No formal education	6	55	4	40
Primary or Franco-Arab schooling	4	36	3	30
Koranic only	3	27	3	30
Training in livestock	0	0	5	50

Many injectors had worked for veterinary agents during vaccination campaigns, and received training from projects in animal husbandry. Injectors generally had better relations with authorities than drug sellers; when asked about business constraints eight of the eleven drug sellers mentioned problems with authorities but only one of the ten injectors.

In terms of equipment, ten out of eleven injectors had a selection of syringes and needles, four had a thermometer and two a weighband. Only one of the twelve drug sellers had a syringe and none had thermometer or weighband.

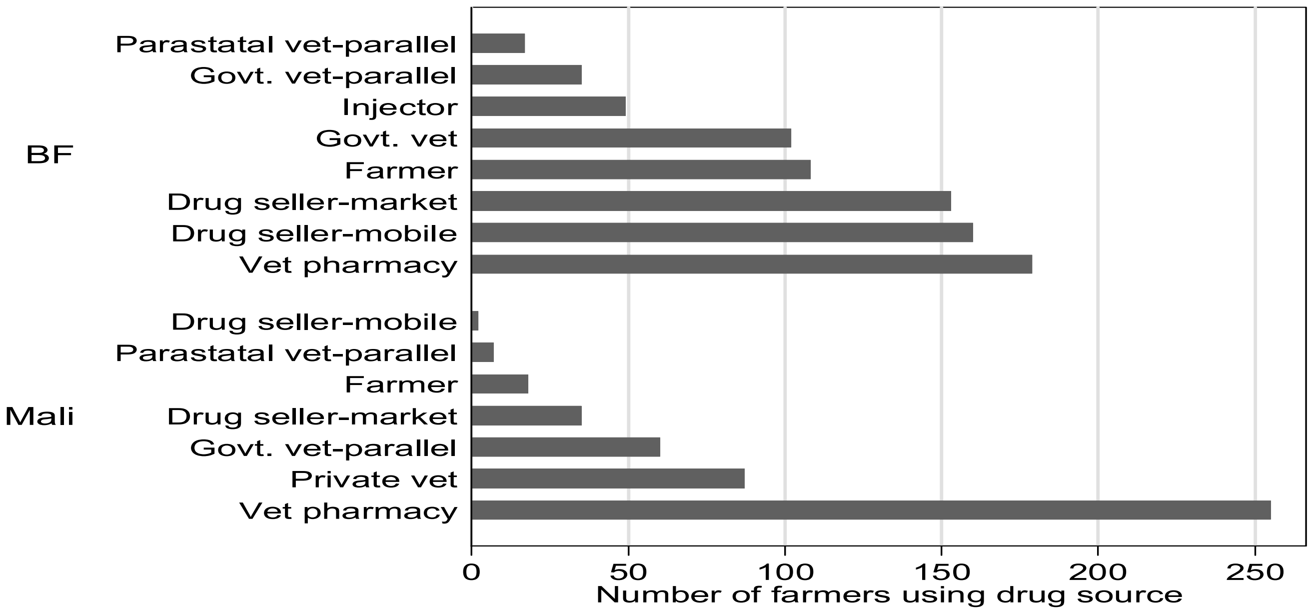
Informal sector – non-commercial actors and their facilities

Other farmers (especially Fulani) often provide drugs on an informal basis, without charging a profit. During the survey a significant minority (19.3%) of farmers had modern drugs in their houses. The most commonly kept drugs were trypanocides, antibiotics and acaricides. A minority of farmers stocked vaccines, vitamins or de-wormers. Most drugs were of good (44%) or acceptable (25%) quality, as determined by examining the package and storage conditions. However, 31% of drugs were in bad condition and a quarter of these were trypanocides. On 59% of the drugs (n=45) an expiry date was visible and 15% of these were date expired, including one trypanocide.

Most preferred source of drugs

Sources of drugs used by farmers in Mali and Burkina Faso are shown in Figure 5.1.11. Farmers in Kénédougou had significantly more sources than farmers in Sikasso (2.3 versus 1.9 sources, p=0.000, t-test with unequal variances. The single most preferred source of drugs in both Sikasso and Kénédougou was veterinary pharmacies; in Sikasso these comprise 73.1% of sources, while in Kénédougou, where a much greater variety of sources was used, they make up only 35.8% of the total. There are many veterinary pharmacies in the Sikasso region, whereas there are none in south Kénédougou. Many farmers in Kénédougou (30.5%) bought drugs in Mali. Farmers with more cattle, and experiencing higher levels of disease were more likely to buy drugs in Mali (both differences highly significant, p=0.000, binomial test).

Figure 5.1.11 Numbers of farmers using different drug sources in Kénédougou and Sikasso



In Mandiana, the importance of different actors in the supply of drugs was obtained from service provider interviews. No data existed for the untrained informal sector, and it was estimated as follows: the total number of annual trypanocide treatments for Mandiana was calculated as the product of the number of cattle and the proportion of cattle reported by farmers to be treated with trypanocides. From this was subtracted the product of average treatments given by each actor by the number of actors. Remaining treatments were attributed to the untrained informal sector (Table 5.1.25). A subsequent longitudinal study confirmed the level of transactions in the formal sector.

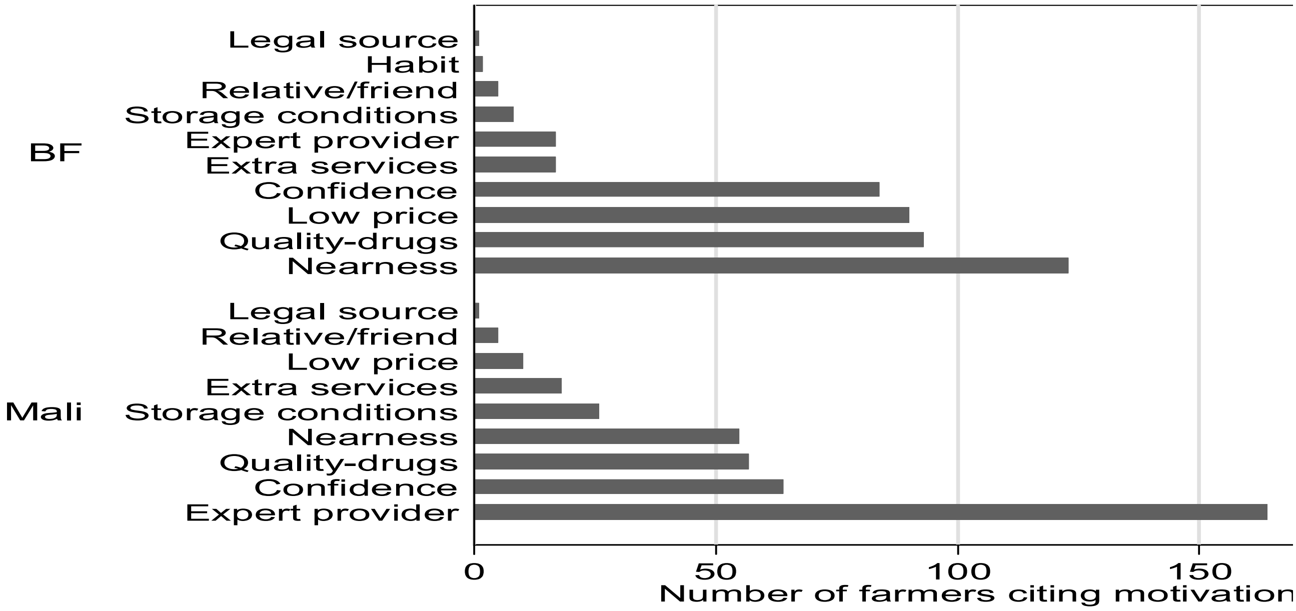
Table 5.1.25 Sources of drugs in Mandiana: service provider category, number and transactions

Actor (SP)	Number	Transactions/SP/year	Total transactions
Paravet	47	142.5	6698
Vet agent	12	224.3	2692
Private vet	1	2080	2080
Trained informal	14	147	2058
Untrained informal	60	not available	23 038

Farmer motivation for choosing service providers

Farmers gave from one to four motivations for choosing their preferred drug supplier (see below). Most frequently cited was seller expertise (26.1%), followed by proximity (20.7%), confidence in the drugs (19.5%) range of drugs (15.7%) and low price (10.2%). There were important differences among countries (Figure 5.1.12). The legality of the source was rarely cited as a motivation for use, and added value services were only a secondary consideration (<4% of farmers). These services included: advice (3.2% of farmers); credit; ability to return unsatisfactory products; clinical services; availability of specific drugs or brands; and facility to make group orders.

Figure 5.1.12 Number of farmers with motivations for preferring the service provider of first choice



Comparative advantage of different service providers

Farmers regarded different service providers as having different advantages (Table 5.1.26): Veterinarians were rated highly for expertise and inspiring confidence; but informal sector providers rate higher on affordability and accessibility. Expertise and confidence were not only accorded to veterinary doctors and technicians but also to vaccinators and farmers.

Table 5.1.26 Farmers (%) assigning different characteristics to service providers

Actor (SP)	Expertise/confidence	Low price	Nearness	Quality of drugs
Private vet	62	11	21	25
Govt vet	60	0	2	2
Vaccinator	33	11	61	0
Farmer	23	12	73	8
Itinerant seller	10	43	65	43
Market seller	10	49	41	17

Assessment of service provider performance

An assessment was made of service provider performance on two criteria relevant to performance (accessibility and affordability) and two criteria relevant to development of drug resistance (expertise and drug quality). Although the sample size was small, the sampling fraction was relatively large, so the results can be considered credible.

The first criterion, accessibility, was indicated by the number of actors and their location, while affordability was indicated by the price of a small sachet of trypanocide. Locations were categorised as: "village", (around 5km distant from an average farmer); "division" corresponding to 5-20 km distant from the client; "district" (up to 50 km); and "outside" to 70-90 km. Except for Sikasso, formal sector service providers are distant (see Table 5.1.27 for details).

In Mandiana participatory mapping was used to evaluate sources, numbers and accessibility of drug sources. The combined map is shown in Figure 5.1.13.

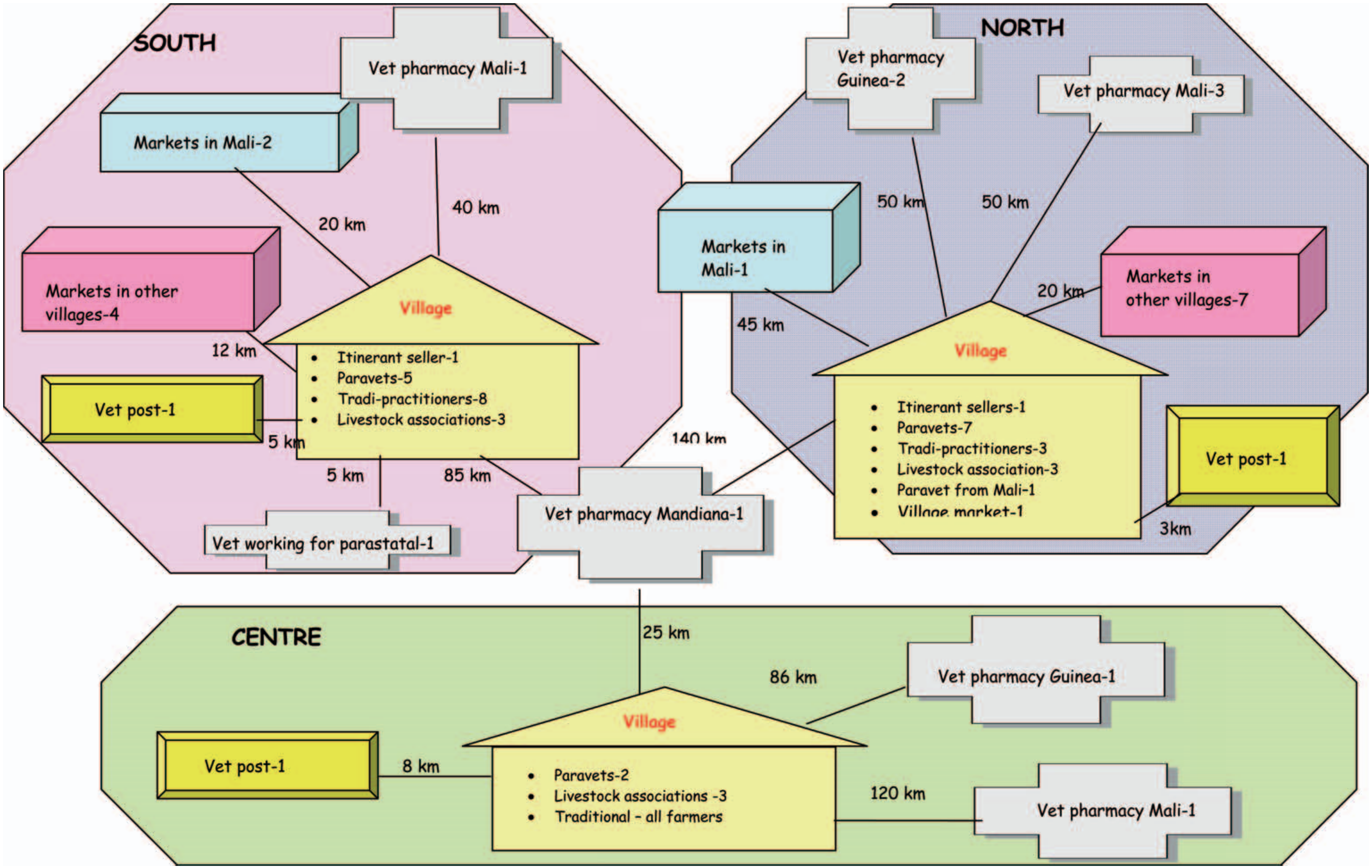


Figure 5.1.13: Accessibility and availability of different service providers in the three study sites in Guinea

Prices are much lower in Mali than in neighbouring countries. Prices in the formal and informal sector in Kénédougou were compared using a clustered t-test (clustering on seller). A small sachet of DIM in the formal sector was significantly more expensive (652 FCFA vs 518 FCFA, p=0.0039). On this product formal sector actors made an average profit of 77 FCFA, significantly lower than the informal sector profit of 138 FCFA (p=0.024, clustered t-test). Curative treatments are cheaper than preventative (572 FCFA for a small sachet vs 792 FCFA, p=0.000).

Prices in villages were significantly higher than in towns or provincial capital (696 FCFA vs 599 FCFA for a small sachet ISMM/DIM, p=0.0492).

Table 5.1.27 Assessment of the accessibility and affordability of animal health sector service providers (actors), and number of actors sampled out of the total population

	Actor (SP)	Location	Mean price DIM	Price range	Sample	Population
Burkina Faso	Branch	Outside	675 FCFA	550-800	2	2
	Independent	Outside	672	600-750	4	6
	Wholesaler	Outside	533	500-550	2	3
	Public vet	District	650	650-650	3	3
	Injector	Village	430	300-550	10	40
	Drug seller	Division	425	350-500	11	40
Mali	Retailers	Division	296	250-400	6	13
Guinea	Paravet	Village	494	361-721	10	47
	Vet officer	Division	665	553-721	3	9
	Private sector	District	705	601-841	3	8

Supplier-induced demand is most likely where profit as a percentage of the price at which sellers bought drugs was significantly higher. This was the case for DIM vs ISMM and small vs large sachets (24.8 vs 19.9, p=0.0095 and 25.8% vs 20.9% p=0.0043 respectively). Overall the retail margin for trypanocides was 23.5%.

Expertise was judged by qualifications and a simple test in which service providers were asked to give the dosage of trypanocide for three categories of animal. Only in the private sector in Kénédougou were qualified veterinary doctors a majority (Table 5.1.28).

Table 5.1.28 Assessment of the qualification/competence of SPs and provision of quality drugs

	Actor (SP)	% vet doctors	Exam score	DIM brands	% ML brands
Burkina Faso	Branch	50	2.00	2	100
	Independent	75	1.25	3	67
	Wholesaler	100	0.50	4	50
	Public vet	0	1.67	2	67
	Injector	0	1.30	6	33
	Drug seller	0	0.91	8	29
Mali	Retailers	10	n/a	17	18
Guinea	paravet	0	1.11	4	50
	Vet officer	33	1.33	3	67
	Private sector	33	1.33	2	50

Knowledge of drug dosage and weight estimation was poor, and lowest among the least qualified: the formal sector scored significantly higher than the informal (average mark 2.5 versus 1.4, p=0.039, t-test).

Quality was assessed by calculating the percentage of Market Leader (ML) brands among all DIM sold: ML brands have provided most evidence of quality over the longest time. Drug quality was higher in Kénédougou and higher in the formal sector. Actors with the highest percentage of ML brands tend to be the most expensive, and actors who stock more brands tend to be cheaper (Table 5.1.27 and 5.1.28). (In this analysis the quasi-formal sector technicians in Mandiana were included with the private veterinarian under the category private sector.)

5.1.5 Understanding and management of trypanocide resistance

Farmer understanding and capacity to manage drug resistance was evaluated (Table 5.1.29). Of those farmers who responded (90.7%), around a third (32.4%) had experienced drug failures (survey proportions). More said that ISMM always or almost always worked (83.2%), than said that DIM always/almost always worked (77.4%); p=0.0055, test of two proportions. In Kénédougou only 45.7% of farmers said ISMM always worked, less than in Sikasso (68.0%) and Mandiana (62.1%, all survey proportions).

Table 5.1.29 Number of farmers citing different reasons for drug failures

Reason for drug failure	No. farmers citing	Reason for drug failure	No. farmers citing
Malnutrition	96	Wrong administration	266
Advanced disease	29	Expired drugs	187
Animal too weak	6	Poor quality of drugs	140
Animal too old	3	Badly stored drugs	92
Zebus too susceptible	2	Wrong dosage	91
		Incorrect diagnosis	65
Re-infection	202	Other disease	57
		Under-dosage	32
Don't know	41	Fake drugs	17
Witchcraft	2	Poor husbandry	6
Fate	1	Wrong choice of drug	5
		Wrong diagnosis	4
DRUG RESISTANCE	5	Other drug problem	4

Farmers beliefs on the causes of failure (mean 1.76 reasons), were related to drug use, high infection pressure and inability of animal to respond to treatment. Only a very small proportion of farmers (0.4%) were aware of the phenomenon of drug resistance.

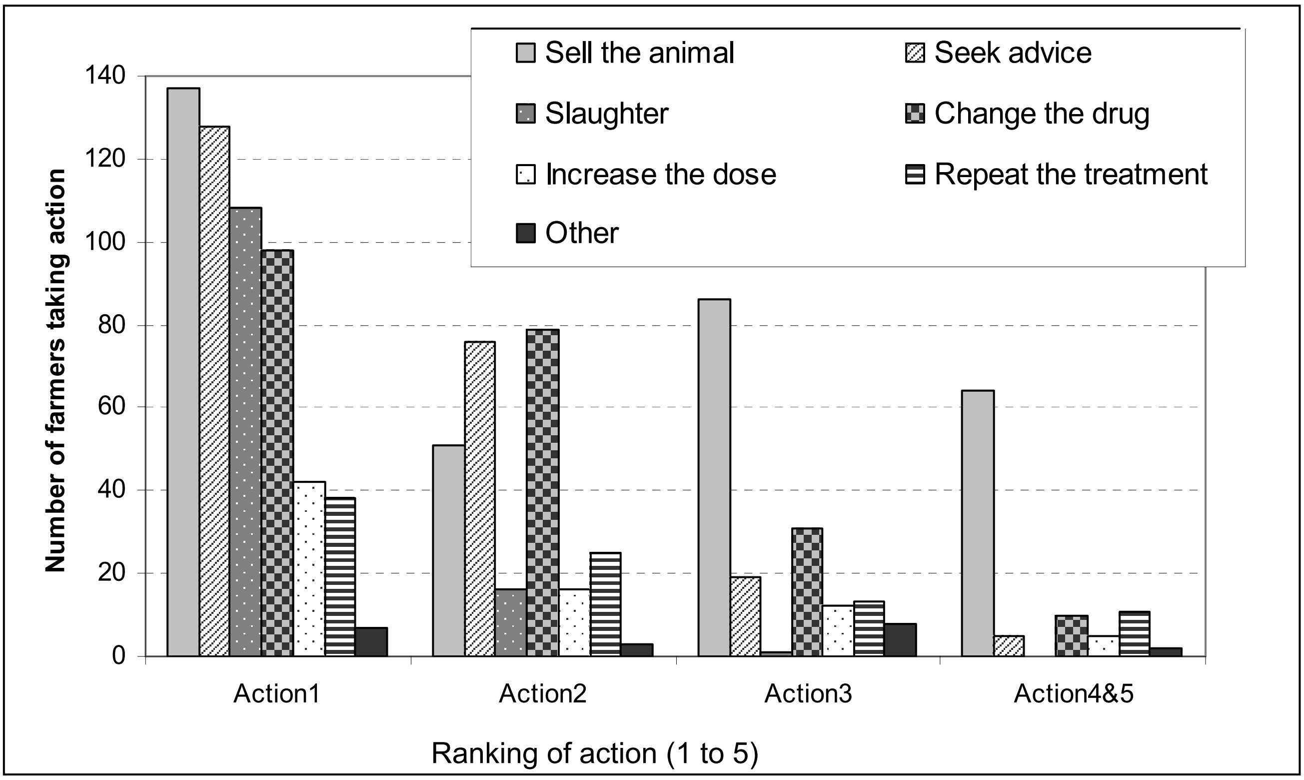
Service providers estimated a fail rate of 14.6% for DIM and 11.0 for ISMM (significantly different, paired t-test p=0.026). There was no significant difference between Kénédougou (where resistance is high) and Mandiana (where resistance is not detected). In Kénédougou, paravets and the informal sector reported significantly higher levels of DIM failure than the private and public sector ($21.4\%^{ad}$, $13.2^{abc}\%$, $9.2^{bd}\%$ and $7.5^{ac}\%$ respectively; ANOVA, significant differences at p=0.05

indicated by superscript). For ISMM, paravets and public vets reported higher levels of failure than other service providers but this was not significant.

Response to treatment failure

Farmers had various responses to treatment failure; many sought advice (56.2%); slaughtering or selling the animal were used after unsuccessful treatments, (8.6% and 10.5% respectively). Farmers also changed the treatment strategy by repeating the dose (13.4%), repeating with an increased dose (15.6%) or changing the drug (39.1%)

Figure 5.1.14 Number of farmers citing different actions after treatment failure and their priority



Service providers' responses to treatment failure were similar to farmers (see Table 5.1.30). Common responses in both the formal sector (public vets, technicians and private vets) and the community service providers (paravets, drug sellers and injectors) were giving other treatments, changing the trypanocide and slaughtering or selling the animal. Community service providers, but not formal sector providers, were also likely to seek advice.

Table 5.1.30 Percentage of service providers citing different responses to treatment failure

Response to treatment failure	% respondents		n=	
	Formal	Community	Formal	Community
Give other treatment e.g. antibiotic, anti-parasite	50	43%	9	23
Change the trypanocide	22	32	4	17
Slaughter or sell the animal	22	51	4	27
Increase the dose of trypanocide	17	21	3	11
Refer to vet or colleague	6	51	1	27
Question the diagnosis	11	0	2	0
Treatment never fails	6	0	1	0

Professional service providers believed that resistance was due to improper use of drugs, presence of poor quality drugs, continued use of the same drugs, under dosage, auto-medication by farmers and the existence of a parallel sector of drug sellers and treatment providers. One veterinarian said it was due to over-dosage.

Relation between socio-economic factors and resistance

A straightforward comparison was made between high and low resistance villages, dichotomous variables are summarised in Table 5.1.31. There were highly significant differences in knowledge, drug sources and treatments. Demographic factors showed fewer differences.

Table 5.1.31 Socio economic differences between high and low resistance villages

Farmer characteristics	**High Resistance**	**Low resistance**	**Chi 2 p=**
Consider AAT is priority disease	83.8	77.8	0.141
Know the cause of AAT	44.8	60.6	**0.000**
Believe in supernatural origin	11.5	3.3	**0.000**
Know specific sign (lacrimation)	9.0	28.9	**0.000**
Treat animals themselves	43.4	30.5	**0.000**
Use a veterinarian	5.0	30.4	**0.000**
Use a paravet	0.0	9.9	**0.000**
ISMM is first choice for treatment	5.0	27.4	**0.000**
DIM is first choice for treatment	77.8	62.7	**0.000**
Report ISMM always works	74.9	64.9	**0.002**
Buy drugs in the informal sector	62.4	24.2	**0.000**
Informal sector is main drug source	32.3	12.2	**0.000**
Seek advice for sick animals	32.6	48.3	**0.000**
Use traditional medicines	43.4	35.1	**0.018**
Traditional pastoral ethnic group	8.2	30.0	**0.000**
Participation in formal education	11.1	10.7	0.860

Continuous variables were compared using the t-test. In high resistance villages the household head was younger (3.2 years, p=0.0038), households had more scooters (mean 0.17, p=0.04), farmers recognised fewer types of cattle disease (0.7 diseases, p=0.000), knew fewer signs of AAT (0.2 signs, p=0.021), used a narrower range of trypanocides (0.6 drugs, p=0.000), reported more animals sick with AAT (1.0 animal or 26% more sick animals, p=0.025) and more animals dying from AAT (0.9 animals or 127% more deaths, p=0.000).

There was no significant difference in number of household members (p=0.158), number of bicycles (p=0.503) owned or number of cattle (p=0.256). In high resistance areas fewer trypanocidal drugs were used (1.5 versus 2.0, p-0.000).

Survey logistic regression was next carried out to investigate the relation between drug failures as reported by farmers and socio-economic factors (Table 5.1.32). Twelve socio-economic variables were tested covering ethnicity, education, household demographics, transport means and wealth; only age was significant. Parameters relating to farmer experience and knowledge of disease were tested and believing AAT to be the most important disease was found to be significant. Farmers who treated themselves and who regularly used trained animal health service providers (veterinarians and community animal health workers) had substantially less failure, compared to the reference group (using untrained service providers). There was an association between farmers who considered ISMM their drug of choice and fewer failures, and a tendency for use of a wider range of drugs to be associated with fewer failures. Farmers who could give more reasons for failure were less more likely to have experienced failures. The influence of AAT prevalence was tested but was not significant. Information on resistance status and use of the illegal sector to source drugs was missing for several villages and so was not included.

Table 5.1.32 Survey logistic regression relating AAT treatment success and predicting variables

Farmer characteristic	Odds Ratio	SE	t	p	95% CI	
Priority of AAT (1,0)	0.39	0.128	-2.860	**0.008**	0.200	0.764
Age of farmer (years)	1.02	0.007	2.480	**0.019**	1.003	1.032
Self treats (1,0)	2.10	0.614	2.530	**0.017**	1.154	3.811
Uses vet/paravet (1,0)	2.48	0.648	3.480	**0.002**	1.456	4.224
ISMM as curative (1,0)	2.69	0.998	2.660	**0.012**	1.259	5.731
No. drugs used	1.22	0.144	1.670	0.106	0.957	1.552
No. causes failure known	0.49	0.057	-6.120	**0.000**	0.386	0.621
Strata=3 PSU=34 Observations=888				Prob>F 0.000		

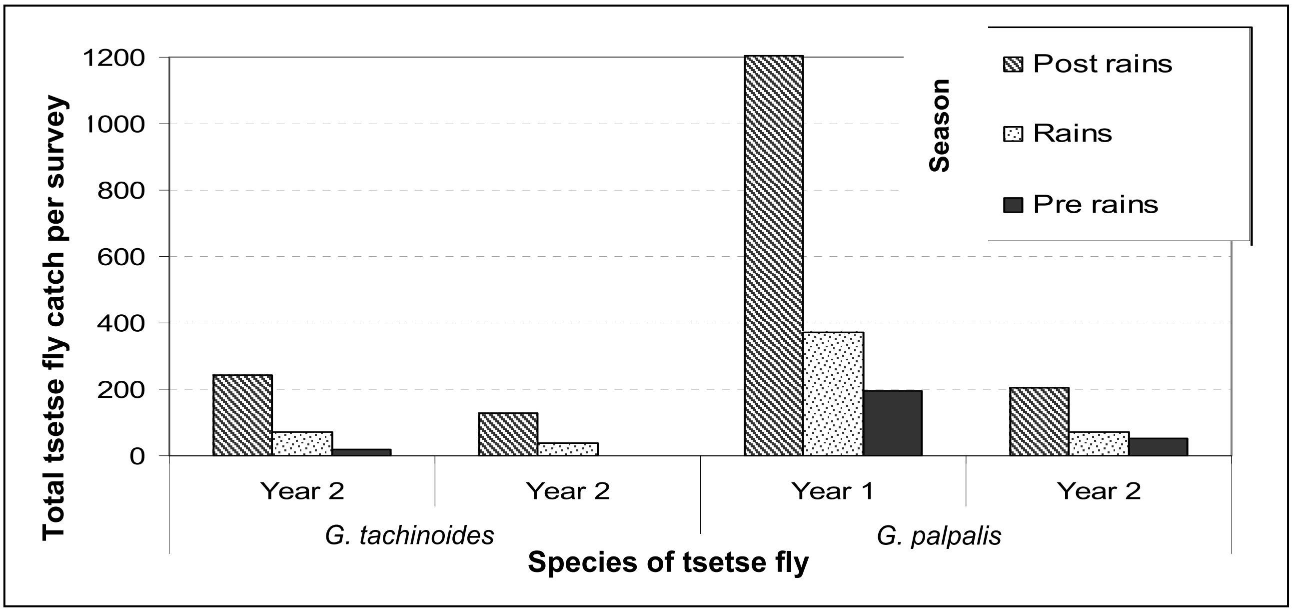
5.1.6 Epidemiological surveys

Epidemiological surveys were carried out to assess trypanosomosis prevalences, pressure of infection (tsetse and other biting fly density) and presence of other cattle diseases.

Entomological surveys – tsetse flies by species, season and zone

In Kénédougou entomological surveys were carried out three times a year for two years in six villages and four times in two additional villages.

Figure 5.1.15 Tsetse catches in Kénédougou by species, year and season



Only *Glossina tachinoides* and *G. palpalis* were found; the latter accounting for 80.6% of the total number of flies, with a median of 7.5 flies per village-survey for *G. tachinoides* and 63.5 for *G. palpalis*. The difference was highly significant (Mann Whitney Test, p=0.0036). There was a marked seasonal trend with most flies found after the rains, and also a marked, highly significant annual trend with fewer flies in the second year (Mann Whitney, p=0.0097). Greatest reduction in the case of *G. palpalis* (villages with ongoing vector control are not included in this analysis).

In Sikasso, *G. palpalis* was less dominant (75.5% of all flies), but still significantly higher than *G. tachinoides* (median flies/survey 12 and 2 respectively, p=0.0001, Mann Whitney test). There were more flies at the start of the rains but seasonal and annual trends were less marked than in Burkina Faso, and differences in fly density not significant (Kruskal Wallis, p=0.1534 and 0.1044 respectively). In western Mali *G. palpalis* constituted 74.3% of tsetse, *G. tachinoides* 24.9% and *G. morsitans* 0.8%. *G. morsitans* were only found in two villages.

In all, and excluding villages with ongoing vector control, there was marked and highly significant variation from village to village (AD 0.0 to 42.9), and among seasons, zones and years; Kruskal Wallis test used as data were non-normal and Bartlets test p was<0.05, see Table 5.1.33.

Table 5.1.33 Differences in Apparent Density according to year, season and geographical zone

Year	AD (flies/trap/day)	Season	AD (flies/trap/day)	Zone	AD (flies/trap/day)
2002	3.4	Post rains	23.8	East	24.8
2003	15.9	Pre rains	7.9	Central	4.0
2004	3.4	Rains	3.7	West	2.2
p=**0.0001**		**p=0.0001**		**P=0.0001**	

Infection rates in tsetse

Infections were significantly higher in west Mali (0.21; 95%CI 0.14-0.30) than in east Mali (0.04; 95% CI: 0.03-0.06) and in Burkina (0.07; 95% CI: 0.05-0.09). Most (70.6%) infections in flies were of both gut and mouth (*T. congolense*); the remainder (29.4%) were of the mouth only (*T. vivax*). No infections in the salivary glands were detected. Infection rate was negatively correlated with AD (-0.01). There was no significant difference in the infection rate of *G. palpalis* (8.5%) and *G. tachinoides* (9.0%). As blood meal analysis was not done, the product of tsetse relative density and trypanosome infection rate were used to estimate tsetse challenge (Leak *et al.,* 1999); this was highest in Kénédougou (1.36) followed by west Sikasso (0.46) then east Sikasso (0.05).

Sex and age of tsetse

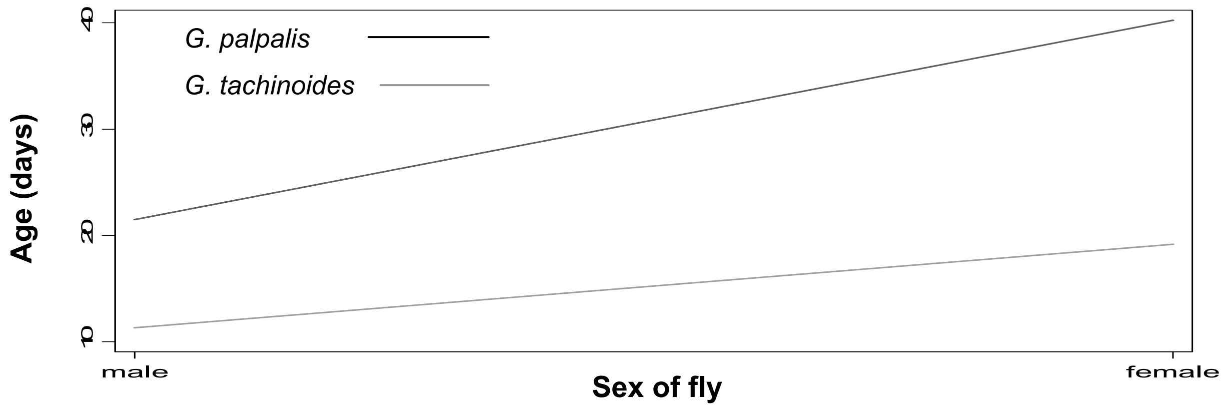
A minority of *G. palpalis* (49.3%), a majority of *G. tachinoides* (56.7%) and all *G. morsitans* were female. Data on age were only available from Kénédougou (n=769 flies): females were older than males (30.8 versus 17.0 days) and *G. palpalis* older than *G. tachinoides* (30.6 vs 15.2 days). ANOVA showed a significant effect of species, sex and interaction between species and sex (Table 5.1.34). The R^2 was 0.38 and the adjusted R^2 was 0.36.

Table 5.1.34 Relation among age of tsetse and species, sex and sex-species interaction

Variable	Partial SS	DF	Mean square	F	Prob > F
G. palpalis	7174	1	7174.364	37.180	**0.000**
Female	5205	1	5204.860	26.970	**0.000**
G.p*female	874	1	873.573	4.530	**0.036**

Sex/breed interaction is shown graphically in Figure 5.1.16. The greater age of female flies, more pronounced in the case of *G. tachinoides* than *G. palpalis* has implications for vector control.

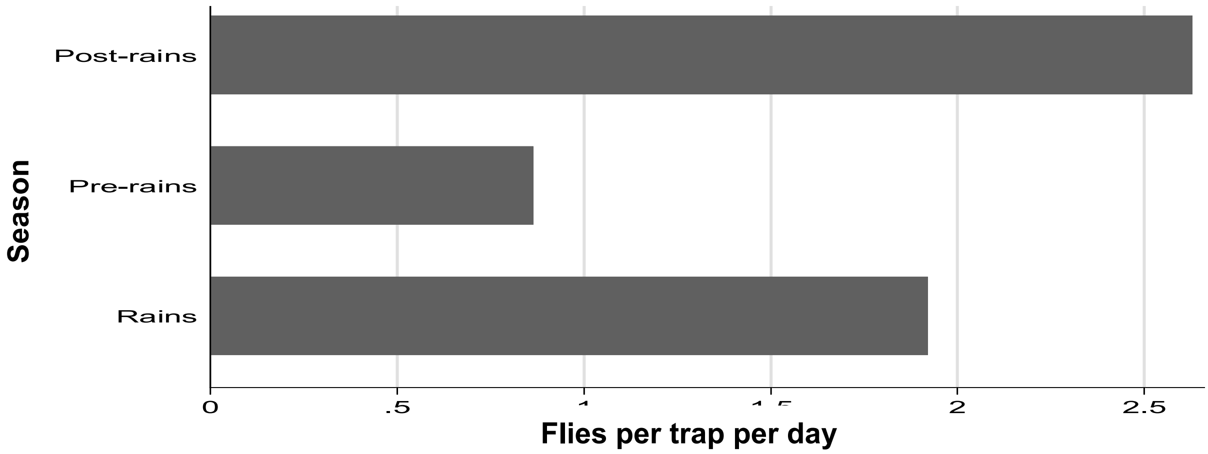
Figure 5.1.16 The interaction between species and sex and fly age



Entomological surveys - biting flies

An average AD of 0.70 flies per trap per day was found, with no significant difference (p=0.695) between Burkina Faso (AD=0.72) and Mali (AD=0.68). Nineteen species of biting flies were found but two families made up 96.6% of the total: specifically *Tabanidae* (*Atylotus, Chrysops and Tabanus*) and *Muscidae* (*Stomoxys*). As for tsetse flies, there was a seasonal trend with most biting flies found in the rains and post-rain period (see Figure 5.1.17).

Figure 5.1.17 Variation of biting flies (flies per trap per day) according to season



Trypanosomosis prevalence by species, season and zone

From the cross-sectional and longitudinal studies, results on trypanosomosis prevalence were available for 16 934 samples taken in 12 different surveys over three years in 57 villages in two countries. We excluded: animals positive two weeks after being detecting positive (likely to be resistant infections); animals in villages with ongoing vector control programs (prevalence is low); and additional animals tested because farmers thought they were sick (not randomly selected and would bias the prevalence). Prevalence varied from 0.6% to 31.8% by village, with an average of 9.2% (95% CI 8.76-9.72). *T. congolense* dominated (63.6% of infections) followed by *T. vivax* (34.8%) and with *T. brucei* only 0.5%. Mixed infections were rare (1.1%). Most infections were found during and after the rains (see Table 5.1.35).

Table 5.1.35 AAT prevalence (%) by trypanosome species and season

	Rains	Cold dry	Hot dry	Total
T. brucei	42.9	57.1	0.0	100
T. congolense	24.5	60.5	15.0	100
T. vivax	28.3	61.9	9.8	100
Mixed	28.6	57.1	14.3	100

During and after the rains *T. vivax* was relatively more important (35.1% of infections compared to 25.0% in the hot dry season, p=0.0064, test of two proportions).
There was a marked east-west trend: towards the east (Burkina Faso) prevalence and proportion of *T. congolense* infections were highest (Table 5.1.36).

Table 5.1.36 AAT prevalence, species prevalence and PCV according to zone (%)

	Kénédougou	East Sikasso	Bougouni	Yanfolila	Total
AAT prevalence	13.7	9.3	4.1	3.7	8.3
T. congolense	82.6	67.4	27.5	42.0	65.8
T. vivax	17.3	32.0	71.6	58.0	33.8
PCV	22.4	25.2	27.3	27.6	25.3

Repeated surveys were carried out in all villages (range 2-11). In surveys where animals were selected by judgment, prevalence was significantly higher than surveys in the same villages where animals were selected by random (11.9% versus 10.2%; p=0.0017, chi 2). Where the sample size was less than 50 animals, prevalence was 15.9%, significantly and substantially higher than when the sample size was more than 50 cattle (7.9%; t-test with unequal variance, p=0.0053).

Relation between tsetse density, tsetse infection and prevalence

There was a moderate positive correlation between AD and prevalence (0.24), and a weak correlation between prevalence and infection in tsetse (0.14). *T. congolense* predominated both in cattle and in tsetse flies (82.6% of cattle infections and 70.6% of tsetse infections).

Pathogenicity of infections

T. vivax infections were associated with a higher parasitaemia, 28.4% of infections having high parasitaemia compared to 12.3% for *T. congolense* (p=0.0000, test of two proportions). However, PCV was higher for *T. vivax* infections: 24.4% versus 21.9% for *T. congolense* (p=0.0000, t-test), indicating less severe disease.

Trypanosomosis risk factors

Data on age, sex and breed was available for 12 157 observations from 57 villages in Mali and Kénédougou. The important risk factors were breed (N'Dama cattle had only 19.6% of the chance of being positive) sex (males were 144.6% times more likely to be positive), age (9.3% decrease with each year) and PCV (14.7% less likely to be positive for every 1% increase in PCV). The interaction between PCV and trypanotolerance was also positive (Table 5.1.37).

Table 5.1.37 Survey logistic regression of AAT positive animals on risk factors

Positive	Odds Ratio	SE	t	p>|t|	95% CI	
N'Dama (1,0)	0.20	0.124	-2.580	**0.013**	0.055	0.696
Male (1,0)	1.45	0.154	3.460	**0.001**	1.168	1.790
Age (yrs)	0.92	0.018	-4.390	**0.000**	0.881	0.954
PCV (%)	0.85	0.009	-15.400	**0.000**	0.836	0.871
PCVxN'dama	1.04	0.024	1.880	0.066	0.997	1.092
Pseudo R^2=10.93 Strata=2, PSU=57, Observations=12 157			Correctly classified: 90.72% Prob>F=0.0000			

Internal parasites

In all, 1462 faecal samples were examined for presence of helminth eggs and coccidian oocysts. The most common finding was strongyle eggs (Table 5.1.38). Eggs detected infrequently were *Paramphistomum* (10.9%), *Dicrocoelium* (4.9%), *Monieza* (2.0%), *Fasciola gigantica* (0.1%), *Nematodirus* (0.2%) and *Toxocara vitulorum* (0.3%). Lung worm larvae were not detected. Coccidian oocysts were found in a minority of samples (4.0%).

Table 5.1.38 Cattle (%) with different levels of infection on coprological examination

Parasite species	No infection	Light infection	Heavy infection
Strongyle spp.	28.0	58.7	13.2
Strongyloides	96.7	2.5	0.8
Eimeria oocysts	96.0	3.3	0.7

Most (73.4%) of cattle had an infection with at least one pathogenic gastrointestinal parasite (i.e. excluding *Paramphistomum*, *Dicrocoelium* and *Monieza*), but there was no significant difference in the PCV between positive and negative animals. Infections were significantly higher in young stock (1 to 4 years) than in older cattle (>4 yrs); 80.7% in the former vs 74.6% in the latter (p=0.0363). There were also significantly more heavy infections in younger animals (16.9% in calves, 15.2% in young stock and 10.1% in adults; chi 2 p=0.05). Infections were significantly lower in N'Dama (60.3%) than in Métis and Zebu (75.0%), p=0071; but not in Baoulés. Females tended to have more infections than males, and more heavy infections than males; however these differences were significant only at the p=0.1 level. There was a marked seasonal trend with most infections in the post-rains period (78.2%) followed by the rains (70.8%) and fewest in the dry season (61.6%), with a highly significant difference between post-rains and dry season (p=0.000). Animals with heavy infections of strongyles (4+) were significantly more likely to be positive for AAT than animals with lighter or no infections (27.0 versus 11.1% respectively, p=0.006, chi 2).

Haemoparasites

Blood smears were examined for 883 cattle. *Anaplasma marginalis* was the most common haemoparasite detected (26.2%; eight infections identified only as *Anaplasma spp*.) followed by *Babesia bovis* (13.8%), *B. bigemina* (2.0%) and trypanosomes (3.7%). However, 15.0% of the animals whose blood smears were negative, were positive using the BCT method. Most haemoparasite infections were classified by the examining technician as light (35.2%), or moderate (58.7%). Only a minority (7.1%) of the animals had multiple infections. Risk ratios were calculated for haemoparasite infection in female versus male, trypanotolerant versus trypanosusceptible and AAT-positive versus AAT-negative cattle, but no significant differences were found. However, the risk of having a haemoparasite infection was less in trypanotolerant than trypanosusceptible (7.7 vs 19.5; p=0.034). No significant relation was found between haemoparasite infection and PCV.

Influence of AAT, haemoparasites, worm infections and their interactions on PCV

Linear regression was carried out to investigate the effect of infections on PCV (Table 5.1.39). Being positive for AAT had most effect on PCV, but presence of another haemoparasite infection was significant and important. Evidence of heavy infection with pathogenic gut parasites (strongyles 3+ or 4+, coccidian oocysts 2+, strongyloides 2+, nematodirus 2+ on coprology) was significant only at p=0.1. There was no significant interaction among the three variables.

Table 5.1.39 Influence of internal parasites, trypanosome and haemoparasite infections on PCV

	Coef.	**Std. Err.**	**t**	**p**	**95% CI**	
Heavy worm infection (1,0)	-1.085	0.600	-1.810	0.071	-2.263	0.093
Trypanosomes (1,0)	-4.776	0.683	-6.990	**0.000**	-6.118	-3.434
Haemoparasite (1,0)	-1.365	0.618	-2.210	**0.028**	-2.578	-0.151
_cons |	26.607	0.259	102.630	**0.000**	26.098	27.117
Observations=77			R^2=11.09 Adjusted R^2 =10.09			

5.2 Evaluation of AAT control strategies

In the second section, the results of the evaluations of three best-bet strategies for the control of trypanosomosis under risk of resistance are presented. The strategies were: participatory vector control in Kénédougou, Burkina Faso; keeping trypanotolerant cattle in Kénédougou, southern Mali and Mandiana Guinea; and promoting rational drug use (by informing farmers of RDU in southern Mali; training paravets in integrated trypanosomosis control in Kénédougou and training service providers in RDU in Mandiana, Guinea).

Strategies were evaluated firstly for their effectiveness in controlling trypanosomosis, secondly for impact (improvements in cattle production, service provision and benefits to farmers) thirdly for acceptability to users (this is an indicator of viability of the control method without external support) and lastly for appropriateness (or practicability and feasibility). Appropriateness was assessed firstly by a standardised benefit-cost analysis for each intervention (with benefits based on reduction in mortality rates); secondly, the usefulness of the strategy in the presence or risk of trypanocide resistance was evaluated.

5.2.1 Evaluation of participatory vector control

Effectiveness of vector control (VC) was assessed by periodic measuring of AAT prevalence and fly numbers, The benefits of VC were assessed by measuring PCV (an indicator of health), cattle mortality (all causes) and production parameters (draft, birth rate, abortions, cost of trypanocide inputs). Acceptability and sustainability of VC was assessed by farmer expressed and revealed behaviour. As the effectiveness and positive impacts of VC are well established, focus was on the acceptability of VC; specifically why VC is never spontaneously adopted by farmers or continued with, n the absence of external support.

Efficacy of control

Efficacy of VC was assessed by monitoring changes in tsetse apparent density, age and infection rates and trypanosomosis prevalence. Post-vector control levels were compared to levels in control villages and in intervention villages before the start of vector control.

Efficacy of control in reducing AAT prevalence

Classical analysis of longitudinal controlled trials with dichotomous outcome (comparing the difference in proportion between test and control group at each follow-up using chi-square tests or calculating relative risks) was carried out. This preliminary analysis is shown in Table 5.2.1. There was no significant difference between groups before the start of VC; but at eight months after control there was significantly less risk in the VC group, and risk continued to decline until the last survey 16 months after the start of VC.

Table 5.2.1 Comparing AAT prevalence (%) in vector control (test) and non-intervention villages

	Prevalence		**Number of cattle**		**Relative Risk**	**p=**
	Test (VC)	**Control**	**Test (VC)**	**Control**		
Pre-control	11.3	16.4	378	45	1.45	0.0552
Post control 1	4.0	13.9	295	54	3.50	**0.0028**
Post control 2	13.7	3.8	286	14	0.28	**0.0038**
Post control 3	14.1	3.5	230	35	0.25	**0.0006**
Post control 4	12.5	2.5	199	51	0.20	**0.0005**

This naïve analysis does not take into account clustering within village or within individuals, and cross-sectional time series analysis was performed to allow for multiple levels and repeated measures. Results are shown in Table 5.2.2.

Table 5.2.2 CSTS regression of AAT prevalence on intervention, controlling for clustering

Positive	**OR**	**SE**	**z**	**p**	**95% CI**	
Vector control	0.22	0.063	-5.320	**0.000**	0.126	0.384
Village 2	4.64	1.527	4.660	**0.000**	2.433	8.841
Village 4	0.50	0.235	-1.470	0.141	0.200	1.256
Village 8	4.86	1.398	5.510	**0.000**	2.770	8.544
Observations=1667 Groups=600		Rho=0.170 (0.076-0.339) Likelihood test=0.003			Wald chi 2=97.88 p=0.0000	

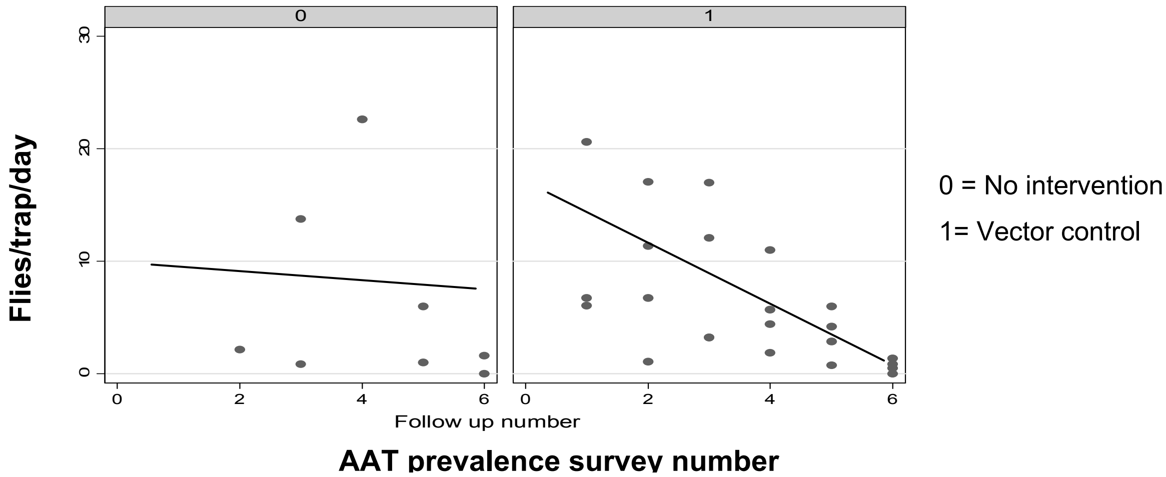
Clustering at village level was accommodated by dummy variables. A random effects model was chosen as distributions are assumed to exist for the levels of factors (Petkova and Everitt, 2002).

Moreover, fixed effects models cannot contain time-invariant independent variables (such as village). Being in a village with ongoing VC was associated with a decrease of nearly 80% in risk of being positive for AAT There was also an important clustering effect; the substantial rho (panel-level variance component) and the wide variation in OR among villages indicated that geographical location was the most important risk factor. The presence of trained farmers was dropped from the model as this had no significant effect on the prevalence of infection.

Efficacy of control in reducing fly populations

Trapping showed a continuous decline in tsetse in vector control villages, while the pattern in villages without vector control was erratic. There was a very high Apparent Density (AD) in one of the intervention villages and two of the non-intervention villages at the first follow-up. If these outliers are removed then the trends become more obvious (Figure 5.2.1).

Figure 5.2.1 Apparent Density (flies/trap/day) in VC and other villages (outliers removed)



In villages with ongoing VC the Apparent Density (AD) was 4.7 flies/trap/day, while in those without it was 17.1 (t-test, p=0.042). CSTS analysis was carried out using random effects, and a Poisson regression model (more appropriate for count data). The model showed that vector control had a significant effect on fly counts per village (total flies per village), see Table 5.2.3.

Table 5.2.3 CSTS regression of tsetse fly count per village on intervention (VC)

Fly count	Coef.	Std. Err	. z	p>|z|	95% CI	
Intervention	-0.869	0.415	-2.090	0.036	-1.683	-0.055
_cons	2.948	0.337	8.760	0.000	2.289	3.608
Observations=580		Alpha=0.216 (0.063-0.735) Likelihood test p=0.000			Wald chi 2=4.27 p=0.0365	

Glossina tachinoides and *G. palpalis* were the only species of tsetse found. *G. tachinoides* was less important in villages with ongoing control (2.8% of tsetse compared to 7.8% in villages without ongoing control, p=0.000, binomial test). There was a tendency for average age of tsetse to decrease in the presence of control, but this was not significant (Table 5.2.4). There was no significant difference in infection rate or location (indicating species of trypanosome) in VC villages, but because of the small sample size, power to detect difference was low.

Table 5.2.4 Age of flies (days) according to sex in villages with and without ongoing vector control

Sex	No vector control	Ongoing vector control
Female tsetse	27.0	20.0
Male tsetse	18.1	14.6

There were significantly fewer biting flies in villages with ongoing control compared to those without (0.055 flies/trap/day versus 0.097 flies/trap/day, binomial test p=0.028), but overall numbers were small (n=160), precluding more detailed analysis.

Impact of vector control

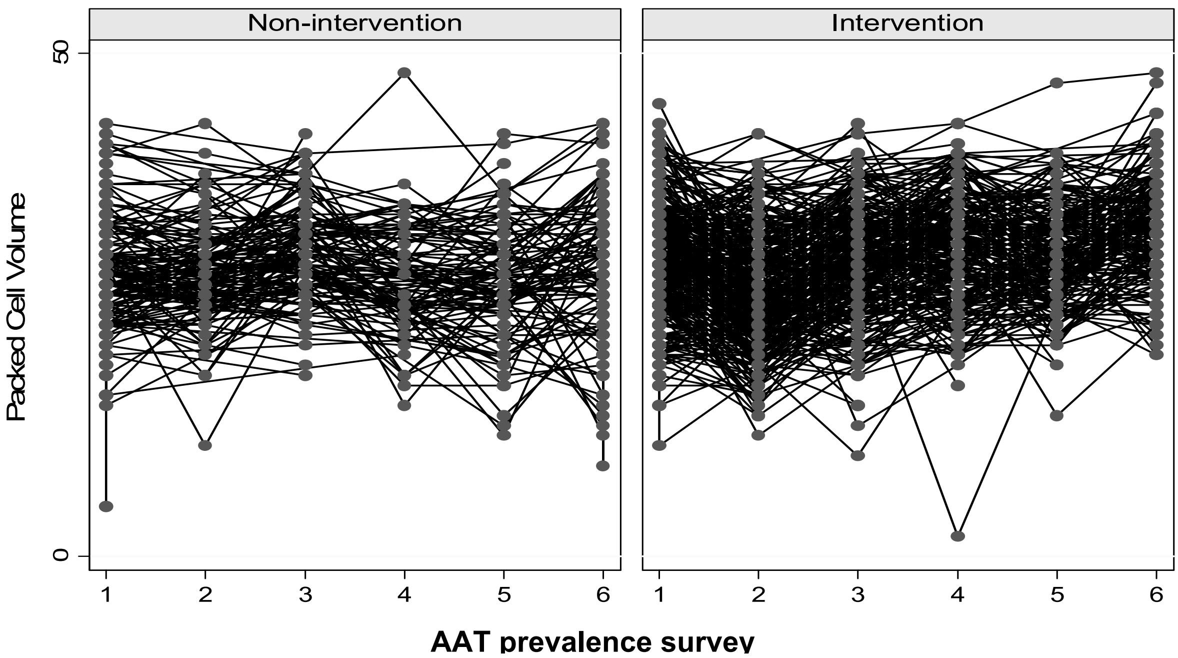
The impact of VC was assessed by monitoring changes in PCV, mortality and production in the cohort of animals followed throughout the study and by pre- and post-comparison of farmer-reported production and health parameters (PRA and KAP study).

In our study two interventions were tested in Kénédougou: in villages with VC, farmers were also trained in integrated trypanosomosis control in year one; in three villages without control farmers were also trained in the second year of the project; and in one village there was no intervention. Comparing the situation before control gives an estimate of the combined benefits of the two interventions, while comparing to villages with only trained farmers gives an estimate to the benefits of vector control over improving health and nutrition.

<u>Impact of vector control on PCV</u>

PCV is a good proxy for health and as such it is a measure of impact. It is also an indirect measure of effectiveness, as in AAT endemic areas anaemia is strongly correlated with prevalence. Figure 5.2.2 plots individual PCV changes over the six follow-ups; an upward trend is evident in the intervention (VC) group after VC started (last four follow-ups).

Figure 5.2.2 Trends in haematocrit in non-intervention and intervention villages



Before the intervention there was no significant difference in PCV between groups (clustered t-test, p=0.323), although PCV tended to be lower in the VC group (26.2% vs 27.8%). Response feature analysis was used for preliminary analysis, constructing a single number that characterises a relevant aspect of the subject response profile. For data with a peaked distribution, such as PCV, the mean of responses over time is a suitable measure. Comparing the groups using the t-test with equal variances (intervention variance=20.7, non-intervention variance=25.9), shows a significant difference of 1.8% (0.92-2.61), p=0.000 between intervention and non-intervention villages. However, this analysis ignores clustering; the intra-cluster correlation coefficient (ICC) was 0.05 (95% CI 0.00-0.12) suggesting moderately high correlation and an important effect of clustering. Also the naïve analysis does not make full use of the longitudinal nature of the data.

Next a panel data analysis was carried out using a random effects model, (given the inclusion of time invariant independent variable and that the Lagrange Multiplier test suggested random effects model was the best (null hypothesis that σu2=0 strongly rejected, p=0.000)). The model showed a significant effect of vector control (ongoing vector control, i.e. follow up>2); *caeteris paribus,* villages with vector control had an increase of nearly 2% in PCV. The presence of trained farmers was also positive and significant, and being in high disease or low disease villages was associated with significant decrease or increase of PCV. A precision variable (cattle positive for AAT at any time) was found to be highly significant and associated with a drop of nearly 3% in PCV. The results are shown in Table 5.2.5.

Table 5.2.5 Regression of PCV against intervention controlling for time and clustering and with parasitological status as a predictor.

	Coef.	**SE**	**z**	**p>|z|**	**95% CI**	
Ongoing VC (1,0)	1.874	0.501	3.740	**0.000**	0.893	2.856
Trained paravet (1,0)	0.920	0.367	2.510	**0.012**	0.201	1.640
Positive for AAT (1,0)	-2.830	0.392	-7.220	**0.000**	-3.598	-2.062
Village (1,0)	-1.289	0.614	-2.100	**0.036**	-2.492	-0.087
Village (1,0)	1.395	0.563	2.480	**0.013**	0.291	2.499
_cons |	28.499	0.352	80.980	**0.000**	27.809	29.189
Observations=2665		R^2 overall 0.1476 Rho=0.408			Wald chi 2=160.61 p=0.0000	

Impact of vector control on survival

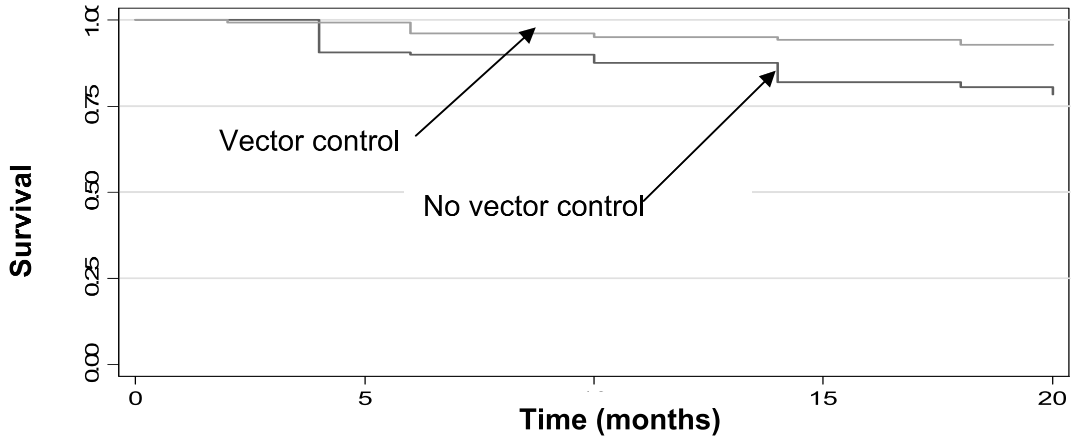
Initially 580 cattle were selected, ear-tagged and followed for a period of 20 months; over this time the drop-out was 29.1% (Table 5.2.6).

Table 5.2.6 Reasons for cattle exiting from the cohort study

Outcome	**Number of cattle**	**Percentage**
Initially selected	580	100
Present to end of the study	411	70.9
Sold (in good health)	66	11.4
Died or emergency slaughter	60	10.3
Left the study (migration or desisted)	18	3.1
No Information	25	4.3

Most loss was due to sale, followed by death, and farmers who left the village or did not wish to continue to participate. Drop-outs increased with time. At six months 92.9% of the initial cohort was present, at 12 months 81.0% were present and by 18 months only 75.7%. Plotting Kaplan Meier curves showed a difference between vector control and non intervention villages and the log rank test was highly significant (p=0.000).

Figure 5.2.3 Comparing survival curves of cohort cattle in villages with and without vector control



A Cox Proportional Hazard Model was constructed, with robust standard error to allow for clustering on village. The model was stratified on another intervention being tested (training paravets) to avoid attribution errors. The Efron method of ties was used because although the occurrence of events was continuous, recording of events was at intervals. Examination of Schoenfeld residuals indicated that the assumption of proportionality was reasonable; the test of proportional hazard assumption showed no evidence for departure from proportionality (p=0.7574). The model showed a highly significant and substantial effect of ongoing vector-control on survival: animals in vector control villages were less than one third as likely to die as those in non-intervention villages. The hazard ratio for ongoing VC was 0.312 (95% CI: 0.19-0.51), p=0.000.

Impact of vector control on cattle production

Draft and reproductive performance were assessed. Firstly, a panel data analysis was carried out to assess the effect of ongoing vector control on days worked; results are shown in Table 5.2.7.

Table 5.2.7 CSTS regression of days worked/month on VC (controlling for age and breed)

Draft (days)	Coef.	Std. Err.	z	p>|z|	95% CI	
Age (years)	0.344	0.090	3.830	**0.000**	0.168	0.520
Baoule (1,0)	1.765	0.832	2.120	**0.034**	0.135	3.396
Metis (1,0)	1.026	0.501	2.050	**0.041**	0.044	2.009
Ongoing VC (1,0)	3.813	0.516	7.390	**0.000**	2.801	4.825
Village (1,0)	2.604	0.760	3.430	**0.001**	1.115	4.093
_cons	-1.132	0.728	-1.550	**0.120**	-2.558	0.295
Observations=1183 Groups=313		R^2=0.0631 Rho=0.0			Wald chi 2=79.23 p=0.000	

A random effects model was used given the inclusion of time-invariant independent variables. The model showed a highly significant effect of vector control on number of days worked and a significant effect of cattle age and breed. There was no significant interaction between the pre-test number of days worked and the dependent variable and no significant interaction between the pre-test measure and treatment group (VC or no VC), supporting the assumption of no difference between treatment groups before the intervention. There also was no significant effect of presence of paravets and this variable was dropped.

Data on birth rates and abortions were collected but the small number of adult female cows and infrequency of births, precluded CSTS analysis. However, there was significantly less abortion in the vector control group in the last year of control (surveys 4, 5 and 6): abortion more than halved, whereas in the non-intervention group there was no significant difference (see Table 5.2.8).

Table 5.2.8 Percentage cows aborting before and after VC and with and without VC

	6 months before intervention	**Last 18 months of intervention**
Non intervention group	10.2	12.1[a]
Intervention group	10.6[b]	4.1[ab]

For comparison a, p=0.0096, for comparison b, p=0.0296

Data on (recalled) births was available for 14 months. Although birth rate was higher in the vector control group, this difference was not significant (Table 5.2.9). In both groups there was an increase in the birth rate in the last 18 months of the project, relative to the 14 months before intervention. However, this difference was significant only at p=0.1.

Table 5.2.9 Percentage of cows giving birth before and after VC and with and without VC

	14 months pre intervention	**Last 18 months of intervention**	**p**
Non intervention group	42.0	54.4	0.094
Intervention group	47.9	58.9	0.068

Impact of vector control perceived by farmers

Pre- and post-intervention data from the KAP survey existed for 284 farmers. A clustered t-test on change scores was used to analyse differences in herd size, AAT morbidity and AAT mortality in vector control and non-intervention villages.

Table 5.2.10 Comparing herd production before and after and with and without VC

Household	**Non intervention**	**VC**	**ICC**	**p (one sided)**
Initial herd size (cattle)	11.8	13.2	0.0146	0.691
Increase in herd size (cattle)	1.9	2.8		0.197
Baseline morbidity(cattle/yr)	3.3	3.3	0.0010	0.966
Decrease in morbidity (cattle/yr)	0.4	1.7		0.049
Baseline mortality (cattle/yr)	0.9	1.2	0.0302	0.401
Decrease in mortality(cattle/yr)	0.2	1.1		**0.028**

There was significantly greater improvements in morbidity and mortality in the vector control group; results are shown in Table 5.2.10. The moderate intra-class correlation coefficients reflect variation within the village herd.

There was no baseline data for expenditure on trypanocides, but in villages with ongoing VC farmers spent significantly less on trypanocides (p=0.044, clustered t-test); data was positively skewed (skew=5.51) and normalised by a square root transformation). Farmers in VC villages spent on average 2810 FCFA on ISMM and 6505 FCFA on DIM, whereas farmers in villages without VC spent on average 7540 FCFA on ISMM and 9163 on DIM.

Participatory analysis of the benefits of trypanosomosis control in the previous year was carried out. Analyses were repeated separately for livestock-rich farmers and livestock-poor farmers (Table 5.2.11). Livestock-poor farmers had fewer benefits as most did not have female cows and so did not benefit from more milk or calves. Ranking and pair-wise comparisons were used to prioritise benefits. Farmers considered the main benefit was more traction and more manure, followed by less expense on medicines. Additional milk, meat and skins were not important.

Table 5.2.11 Benefits of VC over one season observed by farmers (PRA results, n=161 farmers)

	Livestock-poor farmers	**Livestock-rich farmers**
Fewer biting insects	70% reduction in flies	70% reduction
More days draft	15 extra days draft	6 extra days
Less expense on medicine	3125 FCFA less spent on drugs	32 500 less spent
More milk	0	1.23 litres more milk
Fewer deaths	0.4 fewer deaths	2 fewer deaths
More births	0	2 more births
More manure	0.13 more wheelbarrows	2.5 more cartloads

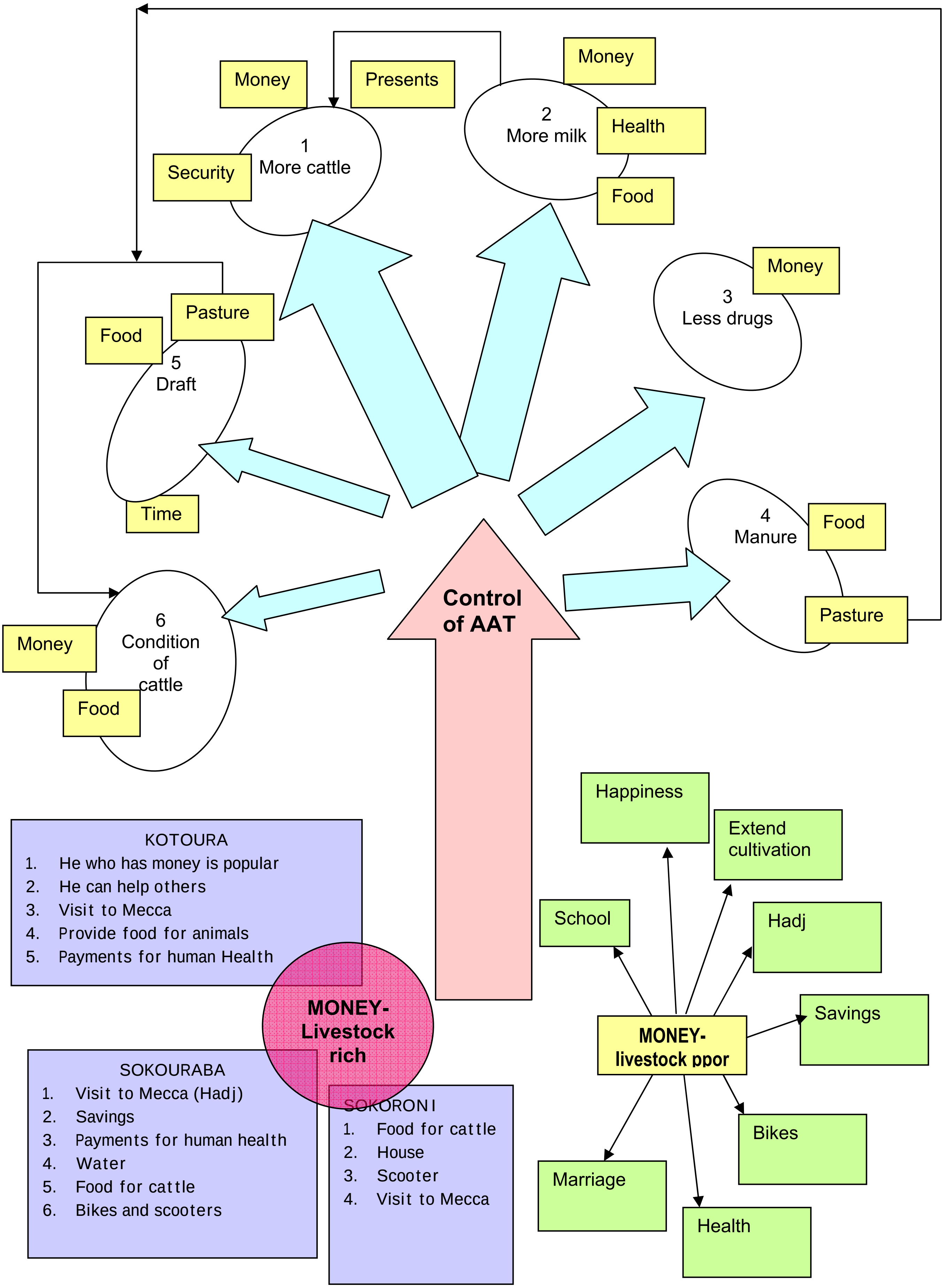
Weighted averages were calculated using the proportion of livestock rich and poor farmers. The value of benefits was estimated using the prices in local markets (Table 5.2.12).

Table 5.2.12 Benefits of VC per household assessed by PRA (n=161 farmers)

Annual benefit	**Weighted average**	**Unit value (FCFA)**	**Total (FCFA)**
More days draft	12.48 days	1000	12 480
Less expense on medicine	8706 FCFA	8706	8706
More milk	0.234 litres	125	350
Fewer deaths	0.704 head	50 000	35 200
More births	0.38 calves	12 000	4560
More manure	1.285 barrows	2150	2762

During the PRAs a modified problem/solution tree was used to assess the livelihood benefits of VC (Figure 5.2.4). Vector Control is the trunk of the tree, the advantages are the main branches, and benefits from the advantages are the sub-branches, (branches and sub-branches may inter- and intra-link). The advantages, and then the benefits from the advantages are ranked in order of importance. farmers anticipated that benefits of control would be firstly invested in the farm enterprise, secondly used for household consumption and lastly sold for money. Livestock-rich farmers more frequently mentioned investing money in cattle, while livestock-poor farmers said money would be invested in increasing cultivation. Both groups anticipate benefits on education and health but also on social capital (presents, helping others, popularity and marriage).

5.2.4 Benefits of vector control and their livelihood impacts mapped by farmers



Comparing different methodologies for assessing benefits of control

Impacts of VC were assessed using: epidemiological cohort studies with repeated measures on selected cattle; formal questionnaires based on recall data (KAP); and participatory assessment. The results of the different methods were comparable (see Table 5.2.13), while costs of carrying out PRAs were much less than that of epidemiological or questionnaire surveys.

Table 5.2.13 Comparing methodologies for assessing impact of VC

Annual benefit	Cohort	KAP Survey	PRA
More days draft	14.41	n/a	12.48
Less expense on medicine (FCFA)	n/a	3668 *	8706 **
Fewer cattle deaths	1.14	1.05*	0.70**
Fewer sick animals	0.60	0.51	n/a
More births	0.56	0.36	0.38
Less flies (% reduction)	90	n/a	70

* compared to control villages ** compared to level before vector control

Acceptability of vector control

The most important question for the vector control study was, given effectiveness and high benefit cost ratio, why do communities fail to adopt and continue with vector control? Acceptability of VC was assessed firstly by reviewing and visiting previous projects in Burkina Faso; secondly by evaluating farmer participation in activities, satisfaction with vector control, and continuation with vector control after the handover of activities to the community in the project being evaluated; and thirdly through stakeholder feedback at the meetings for communicating project results.

Acceptability of VC to farmers inferred from review of previous projects

A review of previous vector control projects in Kénédougou showed that participatory vector control was in all cases effective and in no case continued. In all projects reviewed (eight) and visited (four) activities stopped immediately the project withdrew.

The literature on participatory vector control suggested different reasons for this sustainability failure: firstly low-level of participation; secondly low priority of disease; thirdly lack of capacity to carry out control; fourthly lack of incentives to continue because farmers can 'free-ride' and not contribute. We investigated these hypotheses through Focus Group Discussions (FGD) with communities who had abandoned VC. The findings were:

1. **Vector control had low priority**: Although AAT was the most important cattle disease, its overall priority was low; and certainly less than when the projects had started. In only one of four FGD was AAT ranked as the number one livestock problem. Communities were not dependent on vector control, illustrated by their use of 14 different endogenous strategies to manage AAT (based on trypanotolerance, risk avoidance and traditional or modern treatments).

2. **Lack of capacity to carry out control**: Communities believed they were competent to carry out AAT control using screens and animal baits, but they had forgotten the exact details of inputs needed, dosages, and treatment intervals, because reference material was not left.

3. **Low-level of participation:** Farmers reported that outsiders controlled most project processes (see Table 5.2.14), the exception being carrying out of field activities. This would be considered low-level participation.

Table 5.2.14 Villager perceptions of power in previous VC projects in Burkina Faso (n=8)

	Identification	**Cost contribution**	**Management**	**Activities**
Villagers	75% of projects	0-30% of costs	0% of projects	60% of activities
Outsiders	25%	70-100%	100%	40%

4. **Lack of contributions from farmers**: For continuation, VC activities need to generate contributions of funds and labour. In the projects reviewed contributions by the community were small and less than anticipated. Table 5.2.15 gives examples from three projects, for which complete data were available.

Table 5.2.15 Planned and actual contributions of farmers to VC in previous projects

	Input	**Real cost**	**Intended cost sharing**	**Actual contribution reported**
Bondukuy	Screens Sprays Pour-on	3 000 000 FCFA 75 FCFA/head 350 FCFA/head	None 75 FCFA 350 FCFA	None 30 FCFA 40 FCFA
Dafinso	Traps Drugs	200 000 FCFA 75-350 FCFA/head	100 000 FCFA 30-75 FCFA	None None
Padema	Screens Drugs	4 000 000 FCFA 325 FCFA /head	70% of the costs Nearly all the costs	30% of cost (50% in year 1) 30% of cost (DIM was free)

Communities themselves attributed the failure of vector control as follows: vector control with pour-ons did not continue because it was prohibitively expensive; control with spraying of cattle did not continue because it was not compatible with the way farmers used sprays (they preferred to treat only valuable animals, only when ticks are present, only during the rains, and giving individual un-synchronised treatments) and control with screens did not continue firstly because it was too expensive, secondly because of lack of knowledge and thirdly because of difficulties to organise the process of treating, placing and monitoring screens.

Acceptability of VC indicated by participation in vector control activities

Participation in activities of the project evaluated here was high, sustained, and greater than in previous low-level participatory projects; Table 5.2.16 gives the number of participants at the initial workshop to decide whether to undertake vector control, the planning meeting and the evaluation meeting. On average one person attended for every 1.21 farming households (but more than one household member could attend the meeting).

Each village developed its own institutions for service delivery, as the formulaic imposition of "farmer associations" generally used in west Africa (Madjedje, 1997) was not compatible with a high-level participatory approach. In two villages existing associations were used (n=137 farmers). The average number of days worked was 2.5 and the average monetary contribution was 222 FCFA. However, contributions were skewed: 19.0% of farmers gave both money and labour, 46.7% gave labour but no money and 34.3% gave neither, indicating 81.0% of farmers were 'free-riding', at least to some extent. Among those contributing the average number of days worked was 3.8 and money contributed 1128.8 FCFA. There was a small (0.23) but highly significant (p=0.007) positive correlation between contributions of labour and of money.

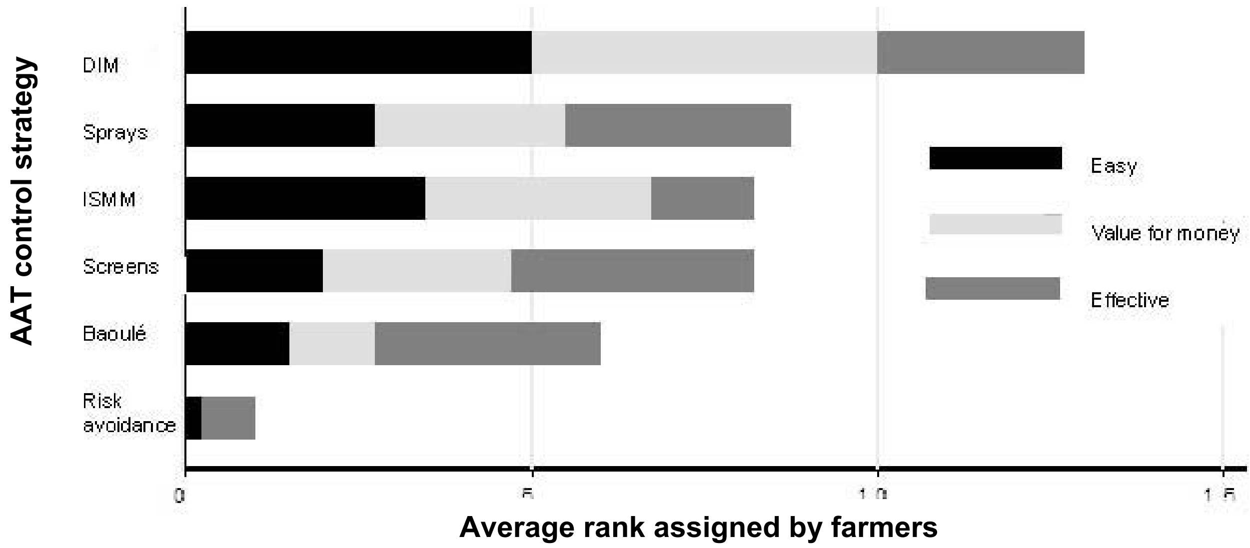
Table 5.2.16 Participants attending vector control activities compared to households with cattle

	Initial workshop	Planning workshop	Evaluation workshop	HH with cattle
Sokoroni	97	56	36	83
Kotoura	40	36	46	24
Sokouraba	33	49	54	80
Mbie	29	34	25	28

Acceptability of vector control as self- evaluated by farmers

To provide insight on sustainability, farmers assessed the attractiveness of vector control relative to other methods of AAT managment, by scoring each method according to the criteria which they had identified as most important. (Figure 5.2.5). Vector control with screens scored highest on effectiveness but was seen as less financially attractive and more difficult than alternatives.

Figure 5.2.5 Farmer ranking of different trypanosomosis control strategies



The participatory evaluation asked farmers how confident they were in their ability to continue with VC. Farmers in one village were "fully confident" and in two villages were "somewhat confident" VC would continue. In one village they were "somewhat confident" VC would not continue. To date VC has continued only in the villages that were "somewhat confident". Project field workers were "somewhat confident" that VC would continue in two villages, and "somewhat confident" it would not continue in the other two villages.

Acceptability of VC as shown by continuation with activities

Participation in treating cattle with insecticide declined from a high of 88.8% (subsidised spraying during the rains) to a low of 38.3% (non-subsidised after rains). The village which initially decided to use pour-ons stopped after the first treatment. The price of spraying was 35 FCFA and the price of pour-ons 200 FCFA, which farmers found too expensive to justify the extra convenience of application. Two villages opted to stop synchronised spraying after four months (after the rains) and all villages chose to stop after six months. During the next rainy season farmer participation in spraying more than halved (see Table 5.2.17).

Table 5.2.17 Participation of farmers in cattle-spraying activities (number and percentage)

Village	Total farmers	Rains 2003		Rains 2004	
Sokoroni	66	65	98.5%	45	68.2%
Kotoura	70	65	92.9	29	41.4
Mbie	33	32	97.0	10	30.3
Sokouraba	80	32	40.0	5	6.2
Total	249	194	77.9	89	35.7

In the first year (2003), all screens were placed by farmers, and 98.3% were removed before the rains. The next year, farmers were responsible for buying insecticide to treat screens, re-treating screens, repairing and replacing damaged/lost screens and placing and monitoring screens. Nearly all screens (229 out of 232) were placed. Before the rains, 226 screens were removed and stored; four were damaged (three torn, one burnt). In the third year (2005) only two villages were able to organise payment for and placing of screens.

Villages which continued longer with vector control did not consistently differ from those which did not continue in socio-economic or epidemiological parameters, as shown in Table 5.2.18.

Table 5.2.18 Characteristics of villages continuing with (short-term) and abandoning VC

	Abandoned	Abandoned	Continued	Continued
Village name	Sokoroni	Sokouraba	Kotoura	Mbie
Active household members	11.4	7.6	12.7	5.2
Proportion of tin roofs (wealth proxy)	0.17	0.54	0.17	0.36
Contribution to communal activities (FCFA)	62 248	7802	107 381	3281
Contribution to communal activities (days)	25.8	8.5	28.0	4.9
Confidence in continuation of control	High	Low	Moderate	Moderate
Baoulé (% village herd)	27.7	31.8	22.4	1.9
Resistance to ISMM (%)	17-25	50	100	11
Prevalence AAT 2 months pre control (%)	8.3	20.3	5.3	31.7
Prevalence AAT last 2 months of control (%)	1.4	4.5	1.0	5.8

Acceptability of vector control to other stakeholders

The strategy of vector control was evaluated by stakeholders at the series of workshops reporting project results. Vector control was an acceptable and popular intervention with all stakeholder groups, receiving an overall rating of 7-8 (maximum 10). Even in situations where vector control would probably not be economically or justified (e.g. Guinea) stakeholders strongly recommended that this strategy be adopted (with external support).

Appropriateness of vector control

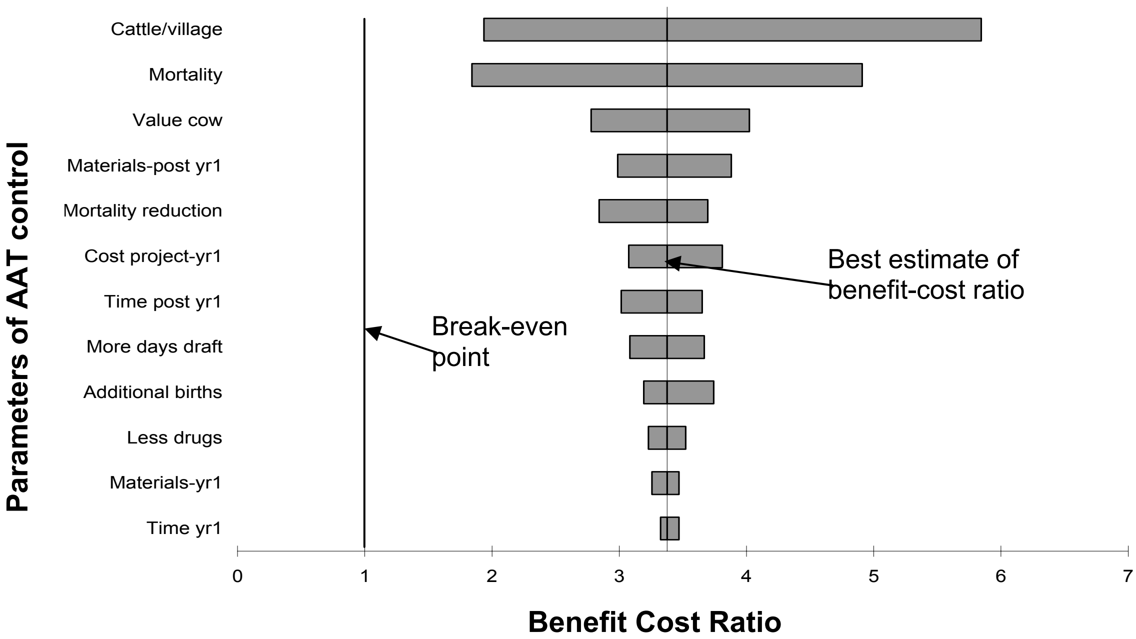
Vector control was effective at reducing disease in the two villages of confirmed high resistance as well as the two villages with non-confirmed (not present or low-level) resistance. There was no consistent significant difference in the effectiveness, benefits or sustainability of vector control related to trypanocide resistance status (see Table 5.2.19).

Table 5.2.19 Efficacy, impact and sustainability of VC in high and low resistance villages

	High resistance	Low resistance	p
Prevalence last two months of control	2.67	3.30	0.7069
Mortality rate/per year after control	0.018	0.024	0.6168
Continuation with control	One village	One village	

A benefit cost analysis of the strategy of participatory vector control was also carried out, based on the benefits shown in Tables 5.2.13 and 5.2.14 showing a benefit cost ratio of 3.4. Sensitivity analysis was performed based on the confidence intervals of values (mortality, days draft, birth, less expenditure) and the likely ranges in price of inputs (project activities, control materials, time needed), value of cattle and number of cattle per village (Annex 2). This suggested that over the range likely to be encountered the benefit cost ratio was consistently above one.

Figure 5.2.6 Sensitivity analysis of benefit cost ratio for participatory vector control



5.2.2 Evaluation of trypanotolerant cattle

The effectiveness of this strategy for control of AAT under risk of trypanocide resistance was assessed by comparing AAT prevalence in trypanotolerant and non-trypanotolerant cattle, and the impact of the strategy was assesed by comparing production parameters; acceptability to farmers was assessed through expressed preference and revealed behaviour. As the resistance to AAT and production of trypanotolerant cattle are well studied, the main emphasis was on the attractiveness of this strategy to farmers and its appropriateness for the cotton belt of west Africa.

Effectiveness of trypanotolerance in decreasing risk of trypanosomosis

Baoulé cattle (a trypanotolerant breed of West African Shorhorn) had the highest prevalence of AAT. The prevalence in Zebus (trypanosusceptible) was 10.3%, only slightly higher than that in cross-breeds (9.4%). Prevalence in N'Dama cattle (a trypanotolerant West African Longhorn) was substantially lower than other breeds (see Table 5.2.20)

Table 5.2.20 AAT prevalence (%) in different cattle breeds (survey proportions)

Breed	Mean prevalence	SD	Number of animals
Baoulé	15.1	35.9	311
Métis	9.4	29.2	10073
N'Dama	4.3	20.3	816
Zebu	10.3	30.4	1031

Survey regression was used to assess the prevalence in different breeds allowing for survey design and clustering. Weighting was not used as the results were interpreted as applying to the survey population rather than the regional population. There were significant differences in prevalence among all breeds except Métis and Zebu (Table 5.2.21).

Table 5.2.21 Comparing difference in AAT prevalences (%) among cattle breeds

	Baoulé		**Métis**		**N'Dama**	
	Difference (%)	p=	Difference (%)	p=	Difference (%)	p=
Métis	5.7	**0.029**				
N'Dama	10.8	**0.001**	5.1	**0.001**		
Zebu	4.8	**0.034**	0.9	0.520	6.0	**0.005**

The (unanticipated) higher prevalence in Baoulés was further investigated. Comparing prevalences only in villages where Baoulés, Métis and Zebu were present together decreased the sample size and hence precision of estimates, but also reduced confounding epidemiological or socio-economic factors. This analysis found evidence for lower AAT prevalence in Baoulés, (15.1% in Baoulés versus 20.0% in Métis and 17.7% in Zebus; p=0.110; survey proportion difference B/Mé p=0.295, difference B/Z p=0.567, difference Mé/Z p=0.650; n=2284 cattle). Given a sample size of 1641 Métis and 320 Baoulés, and test only had power of 66% to detect difference (one-sided); however, the power to detect a difference as great as that found between N'Dama and Métis/Zebu was 99% showing that trypanotolerant cattle in Kénédougou (Baoulés) had not the same resistance to disease as N'Dama cattle in Mali.

Baoulés have more infections with *T. vivax* than *T. congolense*

We next calculated survey means for prevalence of *T. vivax* and *T. congolense* (there were insufficient *T. brucei* infections for meaningful analysis). Results are shown in able 5.2.22.

Table 5.2.22 Prevalence (%) of *T. congolense* and *T. vivax* in different breeds.

	***T. congolense* (mean and 95% CI)**		***T. vivax* (mean and 95% CI)**	
Baoulé	12.9	7.51 to 18.21	1.6	0.24 to 2.98
Métis	6.2	4.17 to 8.32	3.1	2.64 to 3.57
N'Dama	1.4	0.57 to 2.13	2.9	1.16 to 4.72
Zebu	6.0	2.85 to 9.18	3.9	2.72 to 5.04

Infections with *T. congolense* were significantly higher in Baoulés than in cross-breeds (p=0.009), N'Dama (p=0.000) and Zebus (p=0.002) (Table 5.2.23). *T. congolense* infections were significantly lower in N'Dama than in cross-breeds (p=0.000) and Zebus (p=0.005). However, in the case of *T.*

vivax infections, prevalence was significantly lower in Baoulés than in Métis (p=0.023) or in Zebus (p=0.023) and not significantly different from infection rates in N'Dama cattle (p= 0.239).

Baoulés may be more exposed to infection risk

Exploratory Data Analysis was carried out on number of Baoulés owned and factors considered *a priori* to be confounders (high prevalence, few ISMM treatments, resistance and incompetent treatments) and check factors (AAT morbidity, DIM treatments and mortality). Robust standard errors were used to allow for clustering. The results are shown in Table 5.2.23.

Table 5.2.23 Regression of number of Baoulés kept on explanatory variables

	Coeff.	SE	t	p	95% CI	
Cattle sick AAT/yr	0.281	0.094	3.000	**0.003**	0.097	0.466
Cattle dead AAT/yr	-0.125	0.090	-1.390	**0.166**	-0.303	0.052
ISMM as cure (1,0)	-0.452	0.139	-3.250	**0.001**	-0.726	-0.179
No. DIM doses	0.196	0.027	7.160	**0.000**	0.142	0.250
Use untrained SP (1,0)	0.449	0.146	3.070	**0.002**	0.161	0.736
Prevalence (%)	0.009	0.007	1.320	0.189	-0.005	0.023
Resistance (1,0)	0.257	0.134	1.920	0.055	-0.006	0.520
_cons	-0.126	0.174	-0.730	0.469	-0.469	0.216
Observations =316		R^2=28.15	Adjusted R^2= 26.43		Prob>F =0.000	

The number of Baoulés, sick animals, and DIM treatments were transformed (square root) because of positive skew. Residual/leverage plots were performed and three variables were removed because of high leverage and residuals (farmer number 37, 177 and 182). Farmers with more Baoulés reported more sick animals and used more curative treatments; this agrees with the finding of higher AAT prevalence in Baoulés. Farmers with more Baoulés gave fewer ISMM treatments, and tended to live in areas with drug resistance and high prevalence, possible risk factors for disease. They were more likely to use untrained service providers for treatments, a risk factor for incorrect treatments. However, farmers with more Baoulés experienced less mortality.

Because prevalence was measured at village, rather than at herd or animal level, a population-level analysis was also carried out (Table 5.2.24). Confirmatory Data Analysis using linear regression and controlling for other known and pre-determined confounding factors (pressure of infection, ongoing vector control and treatments), found a highly significant and substantial relation between proportion of trypanotolerant cattle in the herd and prevalence of infection. The proportion was transformed using arcsin (recommended for percentage and proportions when n> 50).

Table 5.2.24 Regression of AAT prevalence on explanatory factors by village

AAT prevalence	Coef.	SE	t	p>|t|	95% CI	
PCV (%)	-2.108	0.308	-6.850	**0.000**	-2.727	-1.490
Proportion TT	-9.566	2.455	-3.900	**0.000**	-14.503	-4.630
Number flies	0.692	0.353	1.960	0.056	-0.018	1.401
Vector control (1,0)	-8.277	3.118	-2.650	**0.011**	-14.547	-2.008
No. TC treatments	-0.006	0.002	-2.870	**0.006**	-0.010	-0.002
_cons	78.237	8.725	8.970	**0.000**	60.694	95.779
Observations = 54		R^2=62.80	Adjusted R^2= 58.92		Prob> F = 0.0000	

Impacts of strategy of keeping trypanotolerant cattle

Impacts of keeping trypanotolerant cattle on mortality, morbidity and production were assessed.

Mortality is lower in herds with trypanotolerant cattle

We compared the annual AAT mortality reported by farmers in herds with only trypanotolerant cattle with those of herds with only trypanosusceptible cattle (n=502 herds). Villages in Kénédougou with ongoing vector control were excluded from this analysis. Annual mortality was 11.0% in herds with only trypanosusceptible cattle and 2.4% in those with only trypanotolerant cattle. The difference was significant (8.5, 95%CI: 1.59 to 15.43, p=0.018, survey means). Survey linear regression showed a constant of 11.0 (4.19-17.70) and a coefficient for only trypanotolerant herds of -8.59 (-1.59 to -15.43). Mortality in exclusively trypanotolerant herds in Kénédougou was 5.0%, considerably lower than in exclusively trypanosusceptible herds in Kénédougou (14.8%) but considerably higher than in exclusively trypanotolerant herds in Guinea (0.8%).

Trypanotolerant cattle positive for AAT have better control of anaemia

Severity of anaemia indicates severity of disease caused by trypanosomosis. N'Dama cattle parasitologically positive for trypanosomosis had significantly higher PCV than Métis or Zebus (Table 5.2.25), and there was also a tendency for Baoulés to have higher PCV than Métis or Zebus; but the confidence intervals were wide due to small sample size.

Table 5.2.25 Haematocrit (%) of cattle parasitologically positive for AAT according to breed

Breed	n=	Mean PCV	SE	95% CI	
N'Dama	35	25.2	0.719	23.74	26.66
Baoulé	47	24.2	0.742	22.72	25.71
Métis	949	22.9	0.170	22.54	23.20
Zebus	106	22.8	0.459	21.89	23.71

Benefits of trypanotolerance under different AAT risk

The cohort study in Kénédougou (580 cattle followed for 20 months) showed that:

1. Baoulé cattle worked an average 6.2 days/month compared to 3.6 days for Zebu and 4.8 days for crossbred (considering only cattle aged greater than 1 year at the start of the study). The impact of breed was significant, (see Table 5.2.7).

2. Before vector control, a higher proportion of trypanotolerant cows had calves than crossbreeds or Zebus (0.65 versus 0.55 and 0.46 respectively), but the difference was not significant (Baoulé/Métis p=0.248, Baoulé/Zebu p=0.130, Métis/Zebu p=0.397).

3. When the majority of the herd consisted of Zebus, farmers spent significantly more on preventative trypanocides than when herds had a higher proportion of trypanotolerant cattle (175 FCFA more per bovine per year, p=0.031).

Results form the repeated cross-sectional study in Mali indicated that:

1. Zebus (and to a lesser extent Métis) had greater seasonal weight gain than trypanotolerant cattle (ANOVA: 24kg, 20kg and 7kg respectively, the difference between crosses and

trypanotolerant and between Zebu and trypanotolerant were significant using Bonferroni *post hoc* comparisons). Trypanotolerant cattle showed greater gain than crossbreeds or Zebus (ANOVA: 3.0%, 1.5% and 0.3% respectively, all differences with Bonferroni *post hoc* comparisons).

2. N'Dama cattle had significantly lower intestinal parasite egg/oocyst counts than other breeds; there was no difference in the prevalence of haemoparasites among breeds.

3. The AAT prevalence in N'Dama was 5.1% less than Métis. Using the formula relating incidence to prevalence and duration this is the equivalent of 10.1% reduction in AAT incidence per year.

Acceptability of keeping trypanotolerant cattle

Farmer preference for trypanotolerant cattle as a strategy of trypanosomosis control under different conditions of AAT prevalence and resistance was assessed using a variety of direct and indirect indicators. In the high prevalence/high resistance zone of Kénédougou, farmer preference was assessed as follows:

1. Breed preference was directly assessed by asking farmers their preferred breed; 16% of farmers prefer Baoulé cattle, 22% prefer Zebus but most (64%) prefer Métis (KAP results).
2. Breed preference was measured by revealed behaviour: farmers reported 50.0% of the herd were Métis, 30.5% Zebus and 19.5% Baoulés (KAP). More Zebu males are un-castrated (68% vs 62% of crossbreeds and 56% of trypanotolerant) an indication farmers prefer Zebus for breeding.
3. A preference index for farmer breed preference was constructed by assigning a score of 4 to the first reason, 3 to second, 2 to third and 1 to fourth, multiplying by the number citing the reason then dividing by the number of farmers preferring this breed. As Table 5.2.26 shows, trypanotolerant cattle have fewer advantages compared to Zebus and Métis.
4. Most farmers (64%) consider keeping trypanotolerant cattle a strategy for AAT prevention; however, of the seven disease prevention strategies used, its median rank is only four.

Table 5.2.26 Number of farmers citing reasons for preferring different breeds

Reason for preferring breed	Baoulé	Métis	Zebu
Resist disease in general	235	107	16
Work well	151	110	68
Resist AAT	84	54	0
Grow fast	22	25	89
Docile temperament	16	29	71
Good sale price	11	72	219
Large size	11	49	79
Works quickly	11	25	14
Inherited this breed	11	0	13
Readily available to buy	10	55	0
Beautiful	0	9	68
High gait so doesn't damage crops	0	8	32
Good milk production	0	4	21
Easy to feed	0	11	6
Adapted to the area	0	8	0
Cheap to buy	0	27	0
Total	**561**	**593**	**696**

In the low prevalence and low resistance area of Mandiana, farmer preference was assessed as follows:

1. Revealed behaviour showed N'Dama cattle are the majority, with 98.7% N'Dama, 1.0% Métis and 0.2% Zebu (KAP study). Though only a small minority (3%) of farmers have introduced cross-breeds or Zebus, a substantial minority (21% of farmers) plan to keep them in future.
2. A substantial minority of farmers keep N'Dama because of inheritance, lack of choices (poverty not other breeds available) or lack of knowledge rather than from proactive choice (Table 5.2.29).

Table 5.2.29 Number of farmers with different reasons for preference of N'Dama

Proactive choice	**No. responses**		**Force of circumstances**	**No. responses**
Adapted to the area	95		Inheritance	43
Easy to care for	31		Ignorance of other breeds	33
Easy to feed	30		Poverty	17
Resist AAT	16		Only breed available	14
Resist disease	11		Don't know	1
Like the N'Dama breed	4			
Total	187		Total	108

3. Pair-wise ranking showed that disease resistance as a criterion for breed choice ranked joint first, fifth and third respectively in the three areas surveyed. (This is a PRA tool in which farmers agree a list of factors which are then used to construct a grid on the ground using pictures or *objets trouvés* and then comparisons made between each pair of factors. Finally the number of preferences are summed. Table 5.2.30 shows pair-wise ranking for one area.)

Table 5.2.30 Pairwise ranking of factors farmers consider important for breed choice

	Power	**Profit**	**Resist disease**	**Good temper**	**Rapid growth**	**Fertile**	**Milk**	**Score**
Powerful	X	X	X	X	X	X	X	6
Profitable	Power	X	X	X	X	X	X	5
Resist disease	Disease	Disease	X	X	X	X	X	6
Good temper	Power	Power	Disease	X	X	X	X	1
Rapid growth	Power	Power	Disease	Growth	X	X	X	2
Fertile	Power	Power	Fertility	Fertility	Fertility	X	X	4
Good milkers	Power	Power	Disease	Milk	Growth	Fertility	X	2
Coat colour	Power	Power	Disease	Temper	Coat	Coat	Milk	1

In Mali, prevalence varies from low in the west to high in the east:

1. Zones with earlier introduction of Zebus and cross breeds have higher adoption rates (Table 5.2.27), suggesting the proportion of trypanotolerant cattle will decrease with time.
2. Most (64.3%) farmers keep mainly Métis, some (28.6%) have mainly N'Dama and a minority have mainly Zebu (7.1%). In terms of population, trypanotolerant breeds are a minority except in Yanfolila, the zone adjacent to Guinea.

Table 5.2.27 Comparing herd structure, prevalence and health parameters among zones

Zone	% N'Dama (census*)	% N'Dama (farmer*)	Introduction of Métis/Zebu	Prevalence AAT (%)	Herd size (cattle)
Koumantou	0.0	9.1	1967	3.2	19.9
Bougouni	11.2	15.3	1978	3.2	26.3
Sikasso	0.1	21.2	1965	13.7	21.2
Niena	1.3	23.9	1967	4.6	17.7
Garalo	14.2	33.1	1991	2.8	20.6
Yanfolila	57.8	91.1	1986	2.2	30.9

*The proportion of N'Dama was assessed by technicians in sample of cattle randomly selected from a census of the village herd and also by interviews with farmers; there was some discrepancy in results so both are presented.

3. Farmers in Mali preferring trypanotolerant cattle did so because they resist disease (57% cited) and are good for traction. Farmers who preferred Zebus did so because they fetched a good price and were good for traction. Métis cattle had most desirable characteristics: resisting disease, good workers, easy to feed and profitable (see Table 5.2.28).

Table 5.2.28 Farmers (%) citing reasons cited for preferring different breeds

	Métis	Baoulé	Zebu
The breed resists disease	57	57	0
Breed is good for traction	48	40	33
Easy to feed	25	11	6
Fetches a good sale price	23	0	39

Using data from the three countries, farmer reasons for preferring their favourite breed were analysed using an exploded logistic model (Table 5.2.31). It can be seen that attributes on which Zebus and Métis rated higher (price and production traits) were more important than traits on which all breeds rated high (traction) or on which trypanotolerant cattle rated higher (accessible, adapted to climate/resist disease, inherited or no particular reason). Production traits comprised: large size, fast growth, high-stepping gait, fast-working pleasing appearance, high milk production.

Table 5.2.31 Exploded logistic regression of farmer reasons for choosing preferred breed

Reasons	OR	Std. Err.	z	p>z	95% CI	
High sale price	6.40	2.34	5.08	**0.00**	3.13	13.10
Traction	3.80	1.29	3.92	**0.00**	1.95	7.40
Production traits	3.41	1.25	3.35	**0.00**	1.66	6.99
Available	3.02	1.09	3.06	**0.00**	1.49	6.13
Adapted/resistant	2.02	0.63	2.27	**0.02**	1.10	3.71
None/inherited	0.44	0.17	-2.11	**0.04**	0.21	0.94
Observations =1170		Pseudo R^2=0.0929			Lr chi 2=76.49 p=0.0000	

Acceptability to other stakeholders

The strategy of keeping trypanotolerant cattle as a method of controlling trypanosomosis was recommended by other stakeholders (veterinarians and decision makers) at the project workshops.

Appropriateness of the strategy of keeping trypanotolerant cattle

Trypanotolerant cattle in the presence and risk of resistance

There is lower prevalence of disease in N'Dama cattle, and farmers with trypanotolerant cattle use less drugs; both these factors can slow the development and deterioration of drug resistance.

In villages in Mali and Kénédougou logistic regression (with robust standard errors to allow for clustering on village) showed a significant relation between ISMM resistance and breed (Table 5.2.32). Villages with high resistance had fewer Baoulés and tended to have more Métis, suggesting farmers are not returning to the "fall back technology" of keeping trypanotolerant cattle.

Table 5.2.32 Relation between level of ISMM resistance and cattle breed

Breed	Coef.	Robust SE	z	p>|z|	[95% Conf. Interval]	
Baoulé	-0.048	0.013	-3.700	**0.000**	-0.074	-0.023
Métis	0.010	0.005	1.880	0.060	0.000	0.021
Zebu	0.003	0.009	0.370	0.711	-0.014	0.020
_cons	-0.744	0.106	-6.990	**0.000**	-0.952	-0.535
Observations = 865		Pseudo R^2=0.0363			Wald chi 2 =21.07 p=0.0001	

The finding that farmers in high resistance areas are not spontaneously switching to trypanotolerant breeds was supported by the absence of a significant difference between high and low resistance villages in the percentage of farmers who kept trypanotolerant calttle either as their main strategy for trypanosomosis prevention or as one of a bundle of strategies for AAT prevention (10.4% vs 7.0%; p=0.159 and 36.4% vs 39.8%; p=0.451, respectively). It may be relevant that in areas with high resistance, *T. congolense* predominated, and the trypanotolerant breed in these areas (Baoulé) was susceptible to infection with *T. congolense* (although Baoulé did show better control of anaemia). The high overall prevalence of AAT in Baoulé (not significantly different from Zebus or Métis), suggests that the benefits of trypanotolerance in terms of reduced morbidity and possibly mortality are less in the very situations where resistance is more likely.

5.2.3 Evaluation of rational drug use initiatives

Three different trials were carried out: providing information to farmers, establishing primary animal health services (paravets) and training animal health service providers.

The effectiveness of providing information to farmers was evaluated by assessing changes in farmer knowledge and practice in short and medium term (two weeks and five months). The impact or positive benefit was assessed by measuring health outcomes in treated cattle at two weeks and herd health at five months. Acceptability of the intervention was assessed by farmer and stakeholder expressed preference.

Effectiveness of RDU information in improving farmer knowledge

The effectiveness of RDU information on improving farmer knowledge was assessed by a test on key aspects of AAT management before farmers received the information, two weeks after receiving information and five months later.

The first question tested farmers recognition of diagnostic signs relatively specific for AAT (anaemia, lacrimation, enlarged lymph nodes and loss of tail hair) using photo cards; the maximum score was 4 (all correct) and the minimum 0. Farmers scored higher on the second test; the score in the third test was lower but still higher than baseline (see Table 5.2.33).

Table 5.2.33 Farmer diagnosis of trypanosomosis before and after intervention

Time	**Score 1-Baseline**		**Score2-Two weeks**		**Score3-Five months**	
Group	Control	Test	Control	Test	Control	Test
Mean	1.08	1.07	2.28	3.35	1.93	2.68
95% CI	0.96 to 1.20	0.96 to 1.17	2.09 to 2.48	3.22 to 3.47	1.74 to 2.12	2.53 to 2.84
N	220	213	201	192	215	206

One way regression of initial score on village showed a substantial intra-class correlation coefficient of 0.167, (CI: 0.074 to 0.260). Confirmatory GEE analysis was used to test the effect of RDU on change in knowledge. The Gaussian family was used as data were continuous and kernel density plotting showed that data were approximately normal. (This is usually the case for change scores, even when the scores themselves are not normal.) The identity is the default link for Gaussian family. An exchangeable correlation structure was assumed as this implies all measurements on the same unit (in this case village) are equally correlated, which is plausible for spatially clustered data. The results are shown in tables 5.2.34 and 5.2.35.

Table 5.2.34 Improvement in farmer knowledge of diagnosis two weeks after intervention

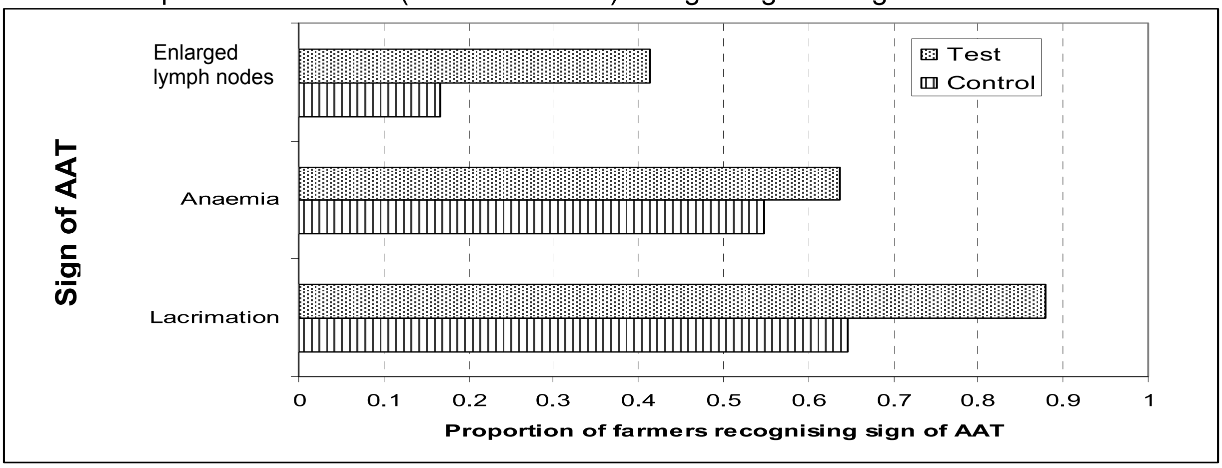
	Coef.	**SE**	**z**	**p>|z|**	**95% CI**	
Intervention	1.053	0.285	3.700	**0.000**	0.496	1.611347
_cons	1.205	0.201	6.000	**0.000**	0.811	1.599497
Observations 388, Groups 46		Scale parameter = 1.826		Wald chi 2=13.7 p=0.0002		

Table 5.2.35 Improvement in farmer knowledge of diagnosis five months after intervention

	Coef.	**SE**	**z**	**p>|z|**	**95% CI**	
Intervention	0.857	0.299	2.860	**0.004**	0.271	1.444
_cons	0.748	0.214	3.49	**0.000**	0.328	1.167
Observations 415, Groups 46		Scale parameter=3.274		Wald chi 2=8.20 p=0.0042		

Five months after receiving information most farmers in the test group were able to recognise key signs of trypanosomosis (Figure 5.2.7).

Figure 5.2.7 Proportion of farmers (test and control) recognising AAT signs after the intervention



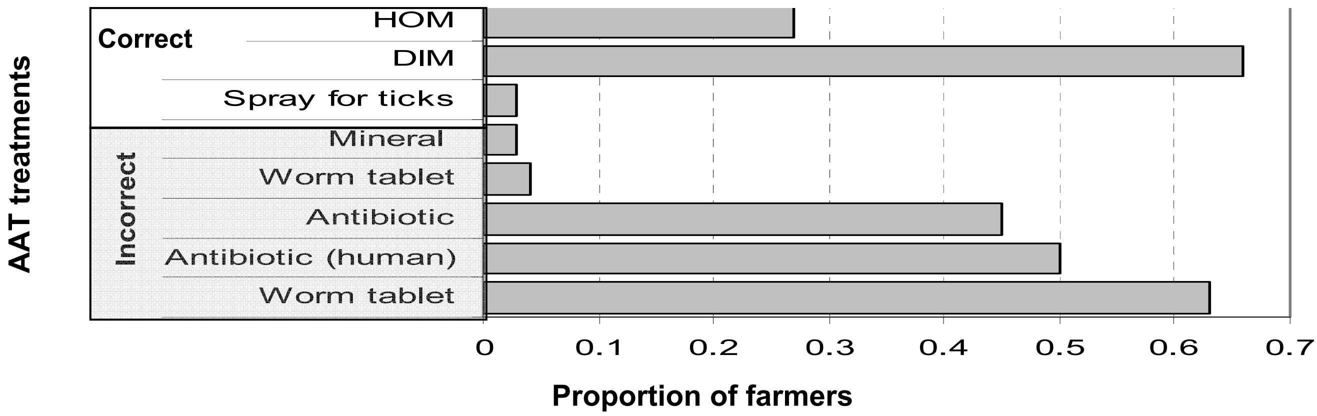
The second question tested farmers recognition of trypanocides using photo cards. The maximum score was nine, corresponding to correct identification of the two trypanocides and the six non-trypanocides, one mark was added for ease of calculation (see Table 5.2.36). Farmers scored higher on the second test; the score in the third test was reduced but still higher.

Table 5.2.36 Farmer recognition of trypanocides before and after training

Time	Score 1-baseline		Score2-Two weeks		Score3-Five months	
Group	Control	Test	Control	Test	Control	Test
Mean	6.352	6.147	7.445	8.352	5.244	5.887
95% CI	6.156 6.548	5.947 6.348	7.282 7.608	8.208 8.496	4.887 5.601	5.536 6.240
N	213	190	191	196	201	196

At baseline most farmers identified Lobazen® (a DIM product) as a trypanocide but only a minority recognised Ethidium (see Figure 5.2.8). Non-trypanocides were frequently believed to be effective against AAT, including worm tablets, antibiotic injections and antibiotic capsules (oxytetracycline) for oral human use but sold widely and cheaply without prescription.

Figure 5.2.8. Baseline proportion of farmers identifying different drugs as trypanocides



Two weeks after the intervention 95.4% of farmers in the test group recognised a DIM product compared to 88.4% in the control group, while recognition of Ethidium was 16.7% in the test group compared to 4.1% in the control. At the same time erroneous recognition of non-trypanocides was lower in the test group than in the control. For example only 11.7% of farmers in the test group believed oxytetracycline injectible was a trypanocide compared to 26.2% in the control group.

One way regression of initial score on village showed a large intra-class correlation coefficient of 0.461, with CI: 0.332 to 0.58 ICC. Confirmatory GEE using Gaussian family, identity link and exchangeable correlation structure showed a significant effect of information provision at both two weeks and five months after receiving information (see tables 5.2.37 and 5.2.38).

Table 5.2.37 Improvement in farmer knowledge of drugs two weeks after intervention

	Coef.	SE	z	p>|z|	95% CI	
Intervention	1.199	0.414	2.890	**0.004**	0.387	2.011
_cons	0.977	0.289	3.380	**0.001**	0.411	1.544
Observations=349, Groups=41	Scale parameter=3.102				Wald chi 2=8.38 p=0.0038	

Table 5.2.38 Improvement in farmer knowledge of drugs five months after the intervention

	Coef.	**SE**	**z**	**p>|z|**	**95% CI**	
Intervention	0.634	0.680	0.930	0.351	-0.699	1.967
_cons	-1.053	0.469	-2.240	**0.025**	-1.972	-0.134
Observations=359, Groups=42		Scale parameter=5.063			Wald chi 2=0.87 p=0.351	

The third question was concerned injection sites. Before receiving the information 86.6% of farmers were able to indicate injection sites, the remainder saying they did not give injections. However, only a minority of farmers were aware of the rump injection site, and a majority of farmers indicated incorrect sites. In the group receiving information, knowledge of correct sites substantially increased and number of incorrect sites decreased (see Table 5.2.39)

Table 5.2.39 Farmer ability to identify injection sites before and after the intervention

Injection site	**Baseline farmers identifying (%)**		**Identifying at two weeks (%)**	
	Control	Test	Control	Test
Neck	46.1	50.0	42.6	59.0
Rump	27.9	29.2	26.2	41.5
Other (incorrect)	56.2	68.5	54.0	54.9

One way regression of initial score on village showed an intra-class correlation coefficient of 0.143 with CI: 0.056 to 0.232. Confirmatory GEE (Gaussian family, identity link, exchangeable correlation) showed a significant effect of information provision at both two weeks and at five months after receiving information (see Tables 5.2.40 and 5.2.41).

Table 5.2.40 Improvement in farmer knowledge of injections sites two weeks after the intervention

	Coef.	**SE**	**z**	**p>|z|**	**95% CI**	
Intervention	0.520	0.239	2.170	**0.030**	0.051	0.988
_cons	-0.076	0.169	-0.450	0.652	-0.407	0.255
Observations=389, Groups=46		Scale parameter=2.605			Wald chi 2=4.72 p=0.0298	

Table 5.2.41 Improvement in farmer knowledge of injections five months after intervention

	Coef.	**SE**	**z**	**p>|z|**	**95% CI**	
Intervention	0.465	0.235	1.980	**0.048**	0.004	0.926
_cons	1.230	0.166	7.400	**0.000**	0.904	1.556
Observations=435, Groups=46		Scale parameter=1.999			Wald chi 2=3.91 p=0.0480	

Impact on farmer behaviour, clinical outcomes and herd health

The impact of RDU information on farmer behaviour and animal health outcomes was evaluated by assessing farmer treatment of animals believed sick with AAT. Farmers identified 20 sick cattle per village. In these animals PCV, BCT, temperature, girth and clinical signs were assessed by veterinarians/technicians before treatment. Farmers carried out treatments with trypanocides and two weeks later PCV, BCT, temperature and girth were reassessed, cattle checked for treatment side effects and trypanocide dose given by farmers recorded. At five months a follow-up questionnaire on herd health was administered to farmers.

Farmers in the control group gave an average of 11.8ml of DIM per animal compared to 15.7ml in the group receiving information. As the same amount of trypanocide was given to each village (two sachets or enough to treat 20 animals at 300kg) and the average weight of sick cattle was 240kg, it is likely that farmers in the control village used the trypanocide to inject additional sick animals. Farmer dosage in test villages was in line with the information given, encouraging farmers to make generous estimates of cattle weight.

The ICC was high (0.789, CI: 0.716-0.861), reflecting the co-ordination and consensus needed to give injections. The data was non-normal, with positive skew and an initial GEE using a Gaussian distribution estimated the parameter phi at 22.26 indicating severe over-dispersion. Therefore, a Poisson model was fitted (identity link, exchangeable correlation, see Table 5.2.42). This showed a significant effect of receiving information on dosage given by farmers.

Table 5.2.42 Effect of intervention on trypanocide dosage given by farmers (GEE model)

	Coef.	SE	z	p>|z|	95% CI	
Intervention	3.930	0.961	4.090	**0.000**	2.046	5.814
_cons	11.882	0.629	18.880	**0.000**	10.649	13.116
Observations=814, Groups=46		Scale parameter=1			Wald chi 2=16.71 p=0.0000	

At baseline the average temperature was 39.0°C and 25.4% of cattle had a temperature above 39.5°C. The average PCV was 25.4%, with 6.5% positive for AAT, and the average weight 239.3kg. Two weeks after treatment, the average temperature was 38.8°C, with only 6.6% having a temperature above 39.5°C. The average weight was 248.5kg, the average PCV 26.4%, and the prevalence of AAT was 1.4%. The two groups are compared in Table 5.2.43.

There was a greater decrease in temperature and a greater increase in weight in cattle belonging to farmers receiving information, but a smaller increase in PCV; distributions of change scores were normal. The range of values for weight and PCV change was greater than physiological, indicating measurement error. The ICC coefficients were 0.186 (C I0.104 to 0.269) for weight at baseline, 0.131 (CI: 0.063 to 0.199) for PCV and 0.3 (CI: 0.195 to 0.405) for temperature.

Table 5.2.43 Effect of intervention on clinical parameters in cattle treated by farmers

	Measure	Increase weight	Increase PCV	Decrease temperature
Intervention	Mean	8.4kg n=379	0.59% n=366	0.17°C n=376
Control	Mean	8.2kg n=390	1.20 n=416	0.10 n=379
Intervention	Range	-58 to 76.5	-16 to13	-2.8 to 2.7
Control	Range	-80.5 to 69	-13 to 16	-2.7 to 2.4

GEE analysis (Gaussian, identity, correlation) results are shown in Table 5.2.44. Given the suspicion of measurement error, Pearson Residual Analysis was performed for variables with outliers (weight and PCV); subjects with a Pearson residual greater than 4 were omitted (Rabe-Hesketh and Everitt, 2004). There was no significant difference in change in weight, temperature and PCV between groups.

Table 5.2.44 Change in health parameters in cattle treated by farmers in test and control groups

Variable	Increase weight (kg)	Increase PCV (%)	Decrease temperature (°C)
Coefficient	0.059	-0.49	1.093 coefficient
SE	2.890	0.53	0.147
p=	0.984	0.348	0.507
Pearson residual >4	154	140	1.093

In the test group, inflammation was detected in 14.3% of cattle injected by farmers while in the control group it was present in 24.6% of cattle. Severe inflammation was found only in the control group (three cases). GEE analysis showed a significant reduction in complications in the test group (see Table 5.2.45). As data was dichotomous, family was binomial and link logit.

Table 5.2.45 Difference in side-effects in cattle treated by test and control farmers

	Coef.	SE	z	p>|z|	95% CI	
Intervention	-0.629	0.296	-2.130	**0.033**	-1.209	-0.050
_cons	-1.126	0.187	-6.030	**0.000**	-1.492	-0.759
Observations=821, Groups=46		Scale parameter=1			Wald chi 2=4.53 p=0.0334	

There were more cases of treatment failure in the control group (1.6% versus 1.0%), but the difference was not significant (coefficient = 0.498, SE = 0.803, p=0.535). Failure occurred in less than 5% of cases and so a rare event logistic regression model was constructed to explore the predictors of treatment failure, with clustering on village. Two observations were dropped because of high standardised and deviance residuals (cow number 53, and 243). The results showed that as weight relative to dosage increased, the probability of failure increased, i.e. there was a significant relation between low dosage and treatment failure. As temperature increased, failure increased, while as haematocrit increased, failure decreased; both relations were highly significant, indicating animals more sick on clinical indicators were more likely to have treatment failures.

Table 5.2.46 Rare events logistic regression of treatment failure on dosage and clinical state

	Coef.	SE	z	p>|z|	95% CI	Coef.
Temperature	1.862	0.822	2.270	**0.023**	0.251	3.474
PCV %	-0.214	0.041	-5.210	**0.000**	-0.295	-0.134
Weight/dosage	0.115	0.043	2.660	**0.008**	0.030	0.200
cons	-74.799	31.942	-2.340	**0.019**	-137.405	-12.193
Observations=413		Pseudo R^2=0.37 Hosmer Lemshow GoF= 0.962				

Medium term assessment of impact on herd health and farmer behaviour

Herd health was also re-assessed at five months. The preliminary data analysis on village level showed that haematocrit increased at five months. There was no significant difference in change scores although there was a tendency for greater PCV increase in test villages. Due to the small sample size (n=23 villages) power to detect significant difference was low (95% for detecting significant improvement in PCV). Next, GEE analysis (Gaussian, identity, exchangeable correlation) was carried out on individual cattle (excluding non-randomly selected animals). The difference scores were normal. The initial PCV was 27.2% in the control and 26.6% in the test group; five months later it was 28.4 and 28.2% respectively. A conservative method of imputation for missing data was used, carrying forward the last measure. The group receiving information had a significantly greater increase in PCV than the control (Table 5.2.47).

Table 5.2.47 Difference in PCV increase between control and test villages

	Coef.	**SE**	**z**	**p>|z|**	**95% CI**	
Intervention	1.231	0.595	2.070	**0.038**	0.066	2.397
_cons	0.496	0.419	1.180	0.236	-0.325	1.318
Observations=3057, Groups=46		Scale parameter=5.21			Wald chi 2=4.29 p=0.0384	

The follow-up survey was carried out during the post-rains period and prevalence had increased in both test and control villages. There was no significant difference in the prevalence, although there was a tendency for intervention villages to have lower prevalence (OR 0.86, p =0.531).

Farmers were asked about herd health and treatments in the last five months. Farmers in the test group detected more animals sick with AAT and reported higher recovery rates. They used slightly more treatments with DIM and substantially more treatments with ISMM (see Table 5.2.48).

Table 5.2.48 Sickness, treatments and recovery per herd in the five months after the intervention

	AAT detction	**Recovered**	**Treatments DIM**	**Treatments ISMM**
Overall mean	3.76 cows	3.62 cows	10.30 treatments	6.05 treatments
Control mean	2.80 cows	2.67 cows	9.72 treatments	4.50 treatments
Test mean	4.65	4.51	10.83	7.50
Variance	52.79	52.09	332.72	294.09
Skew	5.52	5.61	2.72	4.17
Median	1	1.00	2	0

GEE analysis was used to test the effect of RDU information on herd health, including AAT detection, recovery from AAT, mortality from AAT and usage of DIM and ISMM. The data was highly skewed, over-dispersed and with excess zeros, so a negative binomial family was chosen, with the default log link function; results are shown in Table 5.2.49.

Table 5.2.49 Differences of sickness and treatments between control and test villages

	AAT detection		**Recovery**		**Mortality**		**Use ISMM**		**Use DIM**	
	Test	Cons.	Test	Cons.	Test	Cons.	Test	Cons.	Test	Cons.
Coef.	0.296	0.811	0.365	1.108	-0.133	-2.228	0.536	1.511	0.268	2.111
SE	0.093	0.075	0.167	0.130	0.349	0.245	0.132	0.098	0.371	0.293
Z	3.200	10.880	2.180	8.530	-0.380	-9.100	4.060	15.360	0.720	7.200
p	**0.001**	0.000	**0.029**	0.000	0.702	0.000	0.000	0.000	0.470	0.000
95% CI	0.115	0.665	0.036	0.853	-0.817	-2.707	0.277	1.318	-0.459	1.536
95% CI	0.478	0.957	0.693	1.362	0.550	-1.748	0.794	1.704	0.994	2.685
Obs	403 (46 groups)		426 (46 groups)							
Scale p	1		1		1		1		5.48	
Wald chi 2	10.22		4.74		0.15		16.47		0.52	

There was significantly greater detection of disease and recovery of sick animals in the group receiving information. Mortality was rare in both groups, reported by 9.8% of farmers in the control group and 8.6% in the test group. A binomial family was selected with the default log link function, and herd size included as a confounding parameter. The odds ratio was 0.84, suggesting that odds of experiencing mortality were around 16% lower for farmers receiving the information, however this was not significant. Farmers in the test group used significantly more ISMM as shown in Table 5.2.49 (GEE, negative binomial family, log link, exchangeable correlation) but not DIM (GEE, Guassian family, log link, correlation exchangeable after square root transformation).

Acceptability of providing farmers with RDU information

Farmers were satisfied with extension leaflets as a means of passing RDU information. In Kénédougou, where the leaflets were field-tested, a knowledge and information system (KIS) survey carried out found leaflets were ranked highest by farmers (Table 5.2.50). Other highly-rated ways of receiving information were from the drug seller, through training courses and in adult literacy classes. In terms of current usage, most farmers get information from the person selling drugs and around two thirds from the trypanocide package. Mass media is not used but most farmers have a radio (yet few use newspapers or television as a source of information). A substantial minority of farmers have access to adult literacy classes. The agreement between farmers was 0.25 using Kendall's coefficient of concordance (a measure of association between rankings, it ranges from 0 to 1, with 0 meaning no agreement across raters, here the farmer). The Friedman statistic was 174 (p=0.000) rejecting the null hypothesis that farmers do not distinguish between different types of information, and showing that different media get different ranks and correlation exists between judgers (farmers).

Table 5.2.50 Farmer preference and utilisation of different means of information

	Mean rank	Median rank	First preferences for AAT information (%)	Access to media (%)
Extension leaflet	3.9	5	62.5	0.0
Seller	3.2	4	22.7	96.6
Training courses	3.1	4	48.9	0.0
Adult literacy	2.9	4	25.0	38.6
Radio	2.6	3	8.0	64.8
Drug packet	2.1	2	10.2	62.5
Newspapers	1.1	1	2.3	19.3
Television	0.1	0	2.3	2.3

In the cross-sectional study farmers tended to show higher satisfaction concerning the health improvement of the sick animal when they received information (mean improvement score 4.4 versus 4.2, GEE regressing satisfaction score against intervention, coefficient 0.183, p=0.218).

The results of the strategy of providing RDU information to farmers was presented to stakeholders during a series of regional meetings. Separate workshops were held for farmers, animal health service providers and decisions makers. In all areas the strategy of informing and training farmers was approved by farmers. In two study sites (Kénédougou and Mali), it was not approved by veterinarians or decision makers, who recommended as follows: all stakeholders should be informed on the problem of drug misuse and the general principles of RDU; specific training and information on drug use should only be given to formal sector service providers; no training of farmers should be carried out; and campaigns should be launched against treatments of animals by farmers and sales of drugs by non-professionals. In Guinea, veterinarians and service providers as well as farmers approved of giving information on AAT treatment to farmers.

Appropriateness of the strategy of RDU information provision

RDU information reduces risk factors for drug resistance

The finding that farmer knowledge and practice, as well as clinical outcomes could be significantly improved by simple information messages implies this strategy could be useful in reducing drug resistance; under-dosage is a major cause of drug resistance and this was considerably less in the group receiving information. Moreover, incorrect drug administration resulting in inflammation/abscessation may prevent or slow absorption of drugs resulting in effective under-dosage, and the group receiving information had fewer cases of inflammation (14% vs 24%).

RDU information does not lead to inappropriately high drug use

Providing information on drug use might foster inappropriately high levels of drug use. To investigate current level of drug use and determine if it was appropriate, too high, or too low for the level of disease we calculated the incidence of infections from data on the prevalence and the duration of disease. Duration of infection, based on farmer reports, was on average 35.9 days (95% CI: 32.27 to 39.55, n=780). The expected number of cases of AAT in the five month period was calculated from the formula: Incidence=(PrevalencexDuration)/(1-Prevalence), as shown in Table 5.2.51. Prevalence was calculated from number of BCT positive cattle at the five month survey (underestimating true prevalence). In the central area, treatments were higher than cases, in the east and north area they were comparable and in the west they were fewer. In the west a high proportion of cattle were trypanotolerant N'Dama which have the ability to self-cure. Less than a third of the herd were treated with ISMM and where N'Dama predominated less than a tenth.

Table 5.2.51 Farmer treatment level compared to estimated number of cases of AAT

Area	Central	East	North	West
Prevalence %	4.4	14.0	5.1	3.5
Estimated incidence in 5 months	0.3	0.9	0.3	0.2
Estimated cases in 5 months	6.9	20.1	6.2	6.6
DIM treatments in 5 months	14.0	15.1	4.7	2.6
ISMM treatments in 5 months	7.9	8.0	3.5	2.6
Herd size (number of cattle)	25.9	21.3	19.9	31.5
Proportion of N'Dama	0.2	0.2	0.2	0.9
ISMM treatments/herd	**0.3**	**0.4**	**0.2**	**0.1**
DIM treatments/sick cow	**2.0**	**0.8**	**0.8**	**0.4**

Evaluation of establishing primary animal health services

In all 32 farmers from seven villages were selected by their communities on the basis of criteria agreed with the project. One week residential paravet training was followed by four training clinics in each village (Farmer Field School). After ten months another residential refresher training of one week was given. In Guinea, 47 paravets were present as part of the animal health system. Impacts of paravets on cattle mortality was evaluated through the KAP survey.

Effectiveness of training farmers/paravets

Skill-based tests were given to farmers before training, at the end of the residential training and ten months later. The exam covered: diagnostic signs, temperature, dilution of trypanocides, injection sites and spraying cattle with insecticides for vector control. Four questions on core competencies were repeated in each test. Twenty farmers were present at all three evaluations and a paired t-test was performed on their score on these questions. At baseline farmers scored an average of 92.0, at the end of the first training 382.2 and before the second training 429.9. Differences between farmers before any training and at the end of the first training were significant at p=0.000 and difference between before training and ten months later was significant at p=0.0064. Training was most effective in increasing knowledge/skill in the areas of drug administration, differential diagnosis and vector control (Table 5.2.52). Where the subject taught was novel, and training was followed by practical application (vector control) improvements were marked.

Table 5.2.52 Farmer examination marks (%) before and after training according to subject

	Diagnosis AAT	**Vector control**	**Other cattle diseases**	**Administration of drugs**	**Total (%)**
Before training	50	29	25	13	29
End training	59	82	73	88	76
After 10 months	54	95	66	86	75

The knowledge and skill of farmers ten months after training was also compared to a control group of farmers selected by the communities for training as paravets. The mean score of trained farmers (n=20) was 83.3%, of untrained 26.7% (n=17). This difference was highly significant, p=0.000, difference 53.8, 95% CI: 61.53-45.97. (The score of trained farmers differs from that in Table 5.2.53, because it includes all questions, not just the four core questions repeated at each test.)

During participatory meetings farmers and facilitators assessed farmer competence to manage and carry out vector control: results are shown in Table 5.2.53. The overall score was 1.75, between fully confident and fairly confident of capacity. Owners of large herds were more confident of their capacity, and facilitators were less confident than farmers.

Table 5.2.53 Capacity of farmers to carry out vector control assessed by farmers and facilitators

Village	**Small herds**	**Large herds**	**Leaders**	**Facilitators**
Mbie	2.00	n/a	1.00	2.00
Kotoura	1.75	1.50	1.75	1.75
Sokoroni	1.00	1.50	1.00	1.50
Sokouraba	1.00	1.00	1.75	1.75

Impact of establishing primary animal health services

The "Four As" model was used to evaluate the availability, accessibility, affordability and acceptability of paravets relative to other service providers. The survey covered 55 subjects: 23 paravets, 21 informal sector actors (market sellers, injectors and itinerant sellers) and 12 professionals (private or government veterinarians); information regarding these actors has been presented earlier. The KIS study involved 100 farmers, selected on the basis of being 'expert' and 'leaders of opinion'. Communities identified which farmers they considered to fit these criteria.

Availability of paravets relative to other service providers

The availability of drugs, clinical services and advice, and the quality of advice and drugs was assessed, and the results are described below.

Availability of drugs and clinical services for the management of AAT

Paravets ranked moderately in terms of total number of transactions per actor but highly in terms of proportion of clinical services; these comprised more than half their transactions, higher than for any other service providers, apart from veterinary agents (who are not allowed to sell drugs). The difference in the mean number of transactions per actor per week was significant (Kruskal Wallis, 0.0408), see Table 5.2.54, and the difference in the proportion of clinical services between paravets and formal and informal veterinary services was highly significant (p=0.000).

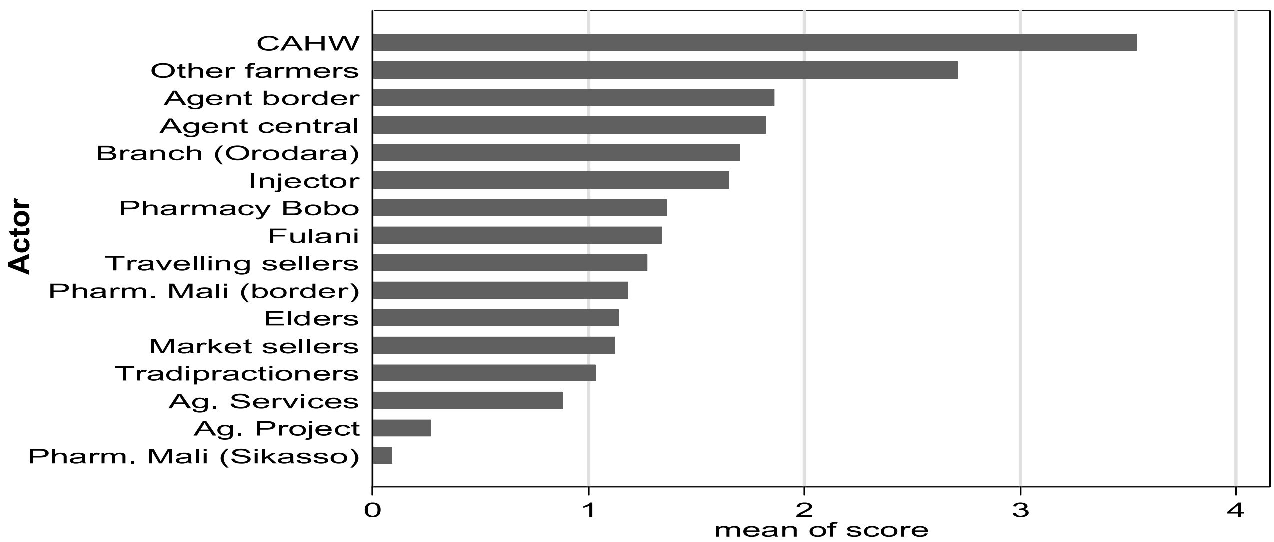
Table 5.2.54 Mean number of transactions involving trypanocides per week (sale and administration) for different actors

	Sell DIM	Sell ISMM	Give DIM	Give ISMM	All transactions	Proporiton clinical services
Paravet	1.6	0.4	2.6	0.5	5.2	0.60
Formal	10.6	5.8	1.0	0.5	22.8	0.07
Informal	35.9	5.5	7.1	0.9	51.0	0.15
Public	0.0	0.0	1.7	0.7	2.3	1

Availability and quality of advice on AAT from paravets

Paravets (CAHWs) were the most important source of information on AAT in the community. Farmers identified sixteen different sources of information; mean ranks are shown below.

Figure 5.2.9 Mean score for utilisation for different sources of information on AAT



Actors were grouped in four categories for statistical analysis. Data was non-normal (mean 1.43, s.d. 1.69, skew 0.73 and kurtosis 2.7), and Bartlett's test was highly significant (p=0.000) so Kruskal Wallis was used to compare groups. There was a significant difference (p=0.000) in the results (see Table 5.2.55), so a Mann Whitney test was performed to compare paravets to the next most used source (formal sector). This difference also was highly significant (p=0.000).

Table 5.2.55 Comparing usage scores of different service providers

Group	Actors	Median	Average rank	Z
Paravet	Trained farmers	4	301.8	10.2
Community	Farmer, Peuls, elders, traditional	1.5	172.2	-2.78
Formal	State services, vet pharmacies	2	178.9	-2.1
Informal	Drug sellers, injectors	1	146.8	-5.33

The quality of service was indirectly assessed by a test in which service providers were asked to estimate cattle weight and trypanocide dosage. One mark was given for a correct answer and the results of the five questions summed to make an overall score (Table 5.2.56). As the score was non-normal, Kruskal Wallace was used (with ties); showing a highly significant difference among service providers (p=0.0005). Repeating for subgroups, the difference between paravets and informal sector was highly significant (0.0001), that between informal and professional significant only at p=0.059, and the difference between paravets and professionals not significant (p=0.1719)

Table 5.2.56 Percentage correct responses by SPs (estimating weights and calculating doses)

Question	Informal	Paravet	Professional
Zebu weight	10	41	67
Zebu dosage	43	77	50
Métis weight	19	77	58
Métis dosage	29	45	42
Calf dosage	38	86	33
Average total correct	28	65	50
Median correct answers	1 (out of 5)	3 (out of 5)	3 (out of 5)

Another indicator of quality is the percentage of high price brands stocked; 46.3% of all brands stocked by the informal sector were high quality, 46.4% by paravets, 46.5% by formal private sector and 33.3% by vet agents. These differences were not significant (Kruskal Wallis, p=0.094).

Accessibility of services provided by paravets relative to other service providers

Accessibility is related to the number of service providers, distance from the farmers, opening times and ownership of transport.

- Paravets were the second most numerous service provider in the area (32 paravets, an estimated 20-50 informal sector sellers, three veterinary agents and one private pharmacy.)
- Paravets were found in villages and most (90.9%) provided services in their village and surrounding hamlets. Drug sellers were in markets at 5-10 km from farmers, or made regular tours of villages. Government agents were at the divisional capital (two agents) or frontier with Mali (one agent), (at 10-70 km). Formal private sector actors were in the provincial capital, (70-120 km). Differences between paravets and other actors was highly significant (p=0.000, Mann Whitney).

- Paravets had least access to transport. All the paravets had bicycles, but only 23% had scooters/motorcycles, significantly less than for the other two groups (p=0.0055).
- The informal sector and paravets were available for longer hours (see Table 5.2.57), many were available whenever needed. Comparing paravets, formal sector and informal sector by the Kruskal Wallis test showed a significant difference between groups (p=0.0028). The difference between paravets and the informal sector was not significant (Mann-Whitney test, p=0.1403, but that between paravets and the formal sector was (p=0.0013).

Table 5.2.57 Availability of different service providers in terms of opening hours per day

	Hours per day			**Days per week**		
	Average	Median	Range	Average	Median	Range
Paravet	14.3	17	4 to 17	6.4	17	5 to 7
Formal	8.3	8	2 to 17	6.0	12	4 to7
Informal	12.1	12	7.5 to 17	6.7	8	5 to 7

Affordability of services offered by paravets relative to other service providers

Paravets were less expensive than formal sector actors, other than wholesalers, but more expensive than informal sector service providers (see Table 5.2.58). There was a highly significant difference between groups (Kruskal Wallis, p=0.0001). Comparing paravets to the informal sector there was a significant difference (Mann Whitney, p=0.0000) but compared to the formal sector there was no significant difference (Mann Whitney, p=0.9318).

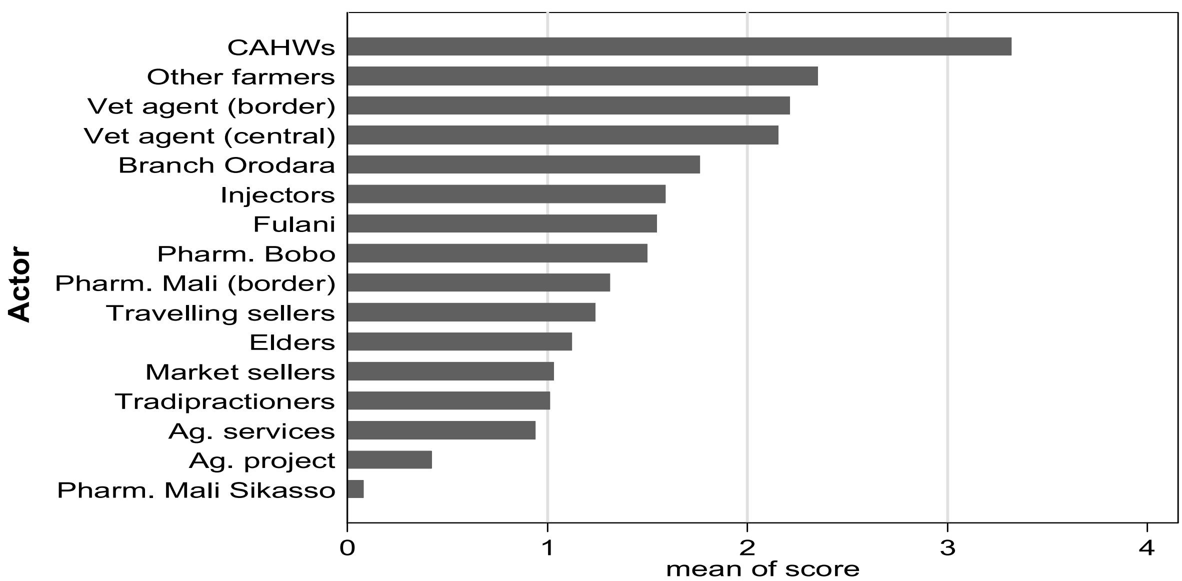
Table 5.2.58 Price characteristics (FCFA) of small sachet of trypanocide sold by different actors

	Mean price	**Median price**	**Price range**	**Rank sum**	**N=**
Paravet	652	675	375 to 1250	5152	62
Formal	707	650	500 to 800	2309	27
Informal	518	500	300 to 1100	2408	51

Acceptability of services offered by paravets relative to other service providers

Paravets (CAHWs) were the highest ranked in terms of confidence or trust inspired (see below).

Figure 5.2.10 Farmer mean ranking of their confidence in sources of information on AAT



Individual comparison with other actors showed paravets ranked significantly higher than farmers, formal sector or informal sector (KW, p=0.000, all comparisons); see Table 5.2.59.

Table 5.2.59 Trust score (0 to 5) assigned by farmers to paravets and other service providers

	No. respondants	Mean	Median	Rank
Paravets	100	3.32	4	293.8
Farmers	99	1.51	1.25	167.2
Formal	99	1.91	2	193.1
Informal	100	1.29	1	143.5

In summary, paravets ranked highly in terms of availability, accessibility, affordability and acceptability. Over the four criteria, compared to other actors, they had the highest number of first rankings and the lowest number of last rankings, see Table 5.2.60.

Table 5.2.60 Rankings of paravets and other service providers on “4 A” criteria (1=highest)

4A criterion	Indicator	Paravet	Public	Formal	Informal
Availability of quality services	Sales trypanocide per week	3	4	2	1
	Proportion clinical services	2	1	4	3
	Farmer rating of use	1	2	3	4
	Test of dosages and weight	2	1	3	4
Affordability	Cost of small sachet	2	4	3	1
Accessibility	Closeness to farmers	1	3	4	2
	Opening hours	1	4	3	2
Acceptability	Farmer rating of trust	1	2	3	4

Acceptability of establishing primary animal health services

Training paravets was appreciated by communities. Farmers are aware of lack of knowledge on treating animals, and in the AKIS questionnaire identified and ranked the topics on which they wanted more information about trypanosomosis; shown in Table 5.2.61. Farmers would like technical information as well as general information on drug use.

Table 5.2.61 Farmer ranking of their needs for information on different aspects of AAT

Need for information	Rank	Need for information	Rank
Care of sick animals	4.27	Withdrawal periods for drugs	3.46
Diagnosis of diseases	4.17	Administration of drugs	3.45
Quality of drugs	4.00	Nutrition of animals	3.44
Drug resistance/treatment failure	3.89	Cause of trypanosomosis	3.41
Drug dosages	3.76	Drugs for different diseases	3.22
Prevention of trypanosomosis	3.73	Drug storage	3.19
Drug side-effects	3.68	Drug prices	2.69
Drug dilution	3.56		

At both participatory planning and participatory evaluation workshops farmers ranked the strategy of training highest (above strategies of vector control with screens and control with baits).

However, although training was very acceptable to farmers, feedback at the stakeholder meetings showed it was not acceptable to service providers and decision makers in two out of three project areas (Kénédougou and Mali), who recommended that paravets should not be trained. Negative comments came mainly from veterinary professional associations and private veterinarians. Recorded at a stakeholder workshop in Burkina Faso, the following are typical: "*There is a risk that illegal actors may be legitimised by this type of work*" and "*To train farmers in veterinary techniques is a suicide for our country".* Conversely, in Guinea, farmers, professionals and decision-makers all recommended further training of paravets.

Appropriateness of primary animal health services in the context of resistance

Improper use of drugs is a major factor in the development of drug resistance. Whether training paravets is a useful intervention in this context depends how this affects quantity and quality of drug use. In this study, training improved knowledge and skills of drug use, and paravet practice was better than non-trained service providers and comparable to that of professionals. Quality of drug used can therefore be said to be inproved. To investigate the effect of training on quantity of drug use we compared drug use between trained and untrained farmers. Overall, trained farmers spent slightly less on trypanocides per animal than untrained farmers (935 FCFA/head versus 1116 FCFA/head) and slightly more on non trypanocidal drugs (2344 FCFA versus 2300 FCFA/head) but these differences were not significant (survey mean, p=0.474 and 0.587 respectively), suggesting quantity of use was not significantly increased by training. Comparing trypanocide use by trained farmers with the results of AAT prevalence surveys, suggests that the level of treatments after training was not inappropriate.

Table 5.2.64 Expenditure (FCFA) on selected veterinary drugs by paravets and untrained farmers

	Untrained	**Trained**	**p**	**Greater Use**
ISMM	4038	11 297	**0.001**	2.80
DIM	7013	12 732	**0.024**	1.81
Tablets	2332	4135	**0.013**	1.77
Antibiotic	3050	7536	**0.009**	2.47
Vaccines	2227	4563	0.061	2.05
Acaricides	3738	6060	**0.042**	1.62

There is frequently expressed concern that paravets (CAHWs) are incompetent to provide services and will have negative impacts on animal health. This was investigated using data on treatments and outcomes after animals were treated by different service in 5260 transactions over a three month period in Guinea. Most treatments by CAHWs (90.7%) were appropriate to the disease diagnosed; (versus 95.0% of treatments by veterinarians). Correct dosage of trypanocides was given in 94.2% of cases (compared to 94.3% of cases treated by vets). Diagnosis of AAT was considered inappropriate if there were one or more signs inconsistent with AAT and no signs consistent with AAT; only 0.7% of CAHW diagnoses were inappropriate (compared to 0.4% of vet diagnoses). Diagnosis of AAT was considered insufficient if made on the basis of only one non-specific sign; 7.1% of treatments were insufficient (compared to 3.9% of diagnoses by vets). Data were also available on farmer reports of mortality from AAT. Farmers who used only CAHWs to treat their animals had lower mortality from AAT than farmers who used only amateurs (0.9% per year compared to 3.2%), p= 0.031 (difference 2.3%, 95%CI: 0.03-4.9).

Evaluation of training existing service providers

All the active and accessible formal sector service providers in Mandiana were included in this study, comprising 10 veterinary agents, eight private sector actors (the single private veterinarian and five technicians) and 30 paravets. For three months before the training, SPs recorded all transactions, providing information on the baseline context. During this time SPs treated 3490 sick animals and gave advice and drugs for another 499. Most sick cattle were N'Dama (98.0%), the average age was 7.0 years, and male cattle were significantly more likely to be presented than female (63.3% of cases, p=0.000 binomial test). In all, 77 different diseases/problems were recorded; trypanosomosis comprising 49.4%, GIT parasites 22.2%, abscess/wounds 9.3% and babesiosis 5.8%. Overall 93.8% of treatments were appropriate). Most dosages for treatment of AAT were correct (94.3%). Service providers also gave 11425 and sold 4425 preventative treatments. Again treatments for AAT predominated (3289 doses of DIM and 1788 of ISMM), followed by wormers (4991 cattle doses) and antibiotics (3522 cattle doses).

Effectiveness of training service providers

An examination was given at the end of the workshop, covering trypanocide dosage (3 questions), drug use and contraindications (5 questions), diagnosis of AAT (3 questions) and resistance (2 questions). The average score was 74.4% (range 60 to 90). Participants also evaluated how much they learned: 70% considered it to be "a lot", 30% "somewhat" and 0% "nothing".

Impact of training service providers on diagnosis and treatment

Impact of training service providers was evaluated by assessing a) diagnosis; b) appropriateness of medicine used or prescribed and c) dosage given.

Service providers diagnosed 2793 cases of AAT in the three months following the intervention. Trained service providers gave an average of 3.40 diagnostic signs per case of AAT and untrained 3.26 signs (difference 0.0002, t-test). Using Poisson regression without accounting for clustering showed a significant effect of training (p=0.047). However, the influence of training was not significant when clustering was taken into account.

Trained service providers used specific diagnostic signs (fever, anaemia and lymph node enlargement) in 19.8% of AAT cases and untrained service providers in 5.5% of cases. Logistic regression showed this effect was highly significant (p=0.000); a Genealised Linear Latent and Mixed Model (GLLAMM) taking into account clustering on three levels (transaction, actor, cluster) also showed a significant effect of training (Table 5.2.65).

Table 5.2.65 Significance of training on improving use of specific signs in AAT diagnosis

Specific Signs	Coefficient	SE	Z	p	95% CI	
Trained	6.678	2.83	2.36	0.018	1.122	12.23
Constant	-9.117	2.51	-3.63	0.000	-14.044	-4.193
Level 1 units 2793 Level 2 units 59 Level 3 units 12		Level 2 var: 18.323 (9.331) Level 3 var: 4.569 (9.348)			Log likelihood -541.279 Condition no. 8.106	

The appropriateness of the diagnosis to the clinical signs described was judged by comparing the signs reported with the diagnosis (Table 5.2.66).

Table 5.2.66 Appropriateness of diagnosis for clinical signs reported

Diagnosis	At least one of the following signs should be present
AAT	Enlarged lymph nodes, anaemia, lacrimation, pica (or at least two among fever,emaciation, appetite loss, staring coat, fatigue)
Babesiosis	Anaemia, fever, haematuria, diarrhoea, nervous signs
GIT parasite	Diarrhoea, bottle jaw, anaemia, pot-belly, weight loss
Colic/indigestion	Bloat, rumen atony, constipation, diarrhoea, colic
Pasteurellosis	Neck swelling, bloody diarrhoea, high fever, respiratory signs, nervous signs

In the test group 96.0% of diagnoses were appropriate, in the control 91.1%. This difference was highly significant (p=0.000) on initial logistic regression, so a GLLAMM model with clustering on three levels (transaction, actor, cluster) was run showing significance at p=0.039 (Table 5.2.67)

Table 5.2.67 Significance of training on inappropriate diagnoses

Specific Signs	Coefficient	SE	Z	p	95%CI	
Trained	-2.478	1.201	-2.06	0.039	-4.832	-0.124
Constant	-4.173	0.852	-4.90	0.000	-5.844	-2.502
Level 1 units 4382 Level 2 units 70 Level 3 units 12		Level 2 var: 5.467 (2.067) Level 3 var: 2.164 (2.270)			Log likelihood -652.809 Condition no. 3.598	

The effect of training on the appropriateness of drugs used was assessed as follows: service providers reported using a total of 67 different drugs in a total of 8342 treatments/sales. These were divided into nine categories as shown in Table 5.2.68. Overall trypanocides (DIM and ISMM) were the most important, together making up 34.2% of all treatments. Treatments were considered correct if they were appropriate for the type of problem diagnosed (see Table 5.2.68) for classification. (The “other” category comprises atropine and anti-tetanus serum. Treatments other than branded drugs (e.g. soapy water, mineral oil, charcoal, sugar, salt) are not included).

Table 5.2.68 Number and frequency of treatments used and diseases they are appropriate for

Treatment	Number given	Percentage	Correct treatment for
Wormer	2800	33.6	Parasitic GIT infection
DIM	2262	27.1	AAT or babesiosis
Antibiotic	2144	25.7	Bacterial infection, wound or abscess
ISMM	594	7.1	AAT
Disinfectant	341	4.1	Wound, abscess
Anti-tick	90	1.1	Ticks
Anti-inflammatory	68	0.8	Arthritis, lameness
Vitamin	21	0.3	Malnutrition, fatigue
Other	21	0.3	As appropriate

For trained service providers, 94.1% of treatments were correct according to this criteria, and for untrained 92.6%; a highly significant difference on logistic regression (p=0.000) which ignores clustering. GLLAMM modeling was carried out using a four level model (drug, transaction, actor and cluster); this was significant only at p=0.10 (see Table 5.2.69).

Table 5.2.69 Significance of training on choice of medicine

Specific Signs	Coefficient	SE	Z	p	95% CI	
Trained	1.334	0.765	1.74	0.082	-0.167	2.834
Constant	2.879	0.547	5.26	0.000	1.807	3.951
Level 1 units 1550 Level 2 units 1542 Level 3 units 61 Level 4 units 12		Level 2 var: 3.005 (3.867E9) Level 3 var: 1.664 (1.037) Level 4 var: 7.294 (0.809)			Log likelihood -374.72 Condition no. 4.19	

The effect of training on appropriateness of dosage was assessed as follows. The tropical livestock units (TLU) equivalent of cattle treated was calculated using the following conversion formula, based on data collected by another project study in the case of trypanosusceptible cattle and on the literature for N'Dama cattle (Diallo, 1990): adult Zebu=1.2 TLU, adult Métis=1.02 TLU, adult N'Dama=1 TLU; Zebu from 1 to 3.99 yrs=0.7 TLU, Métis (1 to 3.99 yrs)=0.5 TLU, N'Dama (1 to 3.99 yrs)=0.4 TLU; Zebu calf (<1 year =0.3 TLU, Métis calf=0.21 TLU, N'Dama calf =0.1 TLU). The standard dose of medicine per TLU were taken from manufacturers' recommendations, and used to calculate the standard TLU dose per actual TLU. (Dosages of >3 doses/TLU were excluded as probably representing stocking of medicines.)

Trained SPs gave on average 1.24 doses per TLU and untrained SPs 1.14. During training, SPs were advised to give 'generous doses' that is, slightly more than manufacturers' recommend should be given to a single adult animal, in order to allow for heavier than average animals. This was based on studies on Burkina Faso and Mali showing that a substantial minority of cattle weighed more than allowed for in the standard treatment dose (75% of adult male cattle weighing more than 250 kg, the standard ISMM dose and 44% of adult males weighing more than 300kg, the standard dose for DIM; n=3006 cattle). Among trained service providers 34.8% of treatments were generous doses, among untrained 28.0%. The difference was highly (p=0.000) using logistic regression. GLLAMM analysis was carried out to allow for clustering at four levels (drug, transaction, actor and cluster); and was significant at 0.033 (see Table 5.2.67).

Table 5.2.70 Significance of training on improving dosage

Specific Signs	Coeff	SE	Z	p	95% CI	
Trained	0.656	0.308	2.13	0.033	0.052	1.260
Constant	-0.900	0.247	-3.64	0.000	-1.384	-0.416
Level 2 var 2.35(2.57e11) Level 3 var 0.501(0.160) Level 4 var 0.198 (0.158)		Level 1 units 5825 Level 2 units 4130	Level 3 units 47 Level 4 units 11		Log likelihood: -3498 Condition no. 4.343	

Appropriateness of training service providers on diagnosis and treatment

This strategy was well accepted by both service providers and other stakeholders. It is relatively inexpensive as formal service providers are few relative to farmers and animals, and it is often in the interest of drug companies to underwrite training costs. As for training farmers and paravets, this strategy is oriented towards prevention or living with trypanocide resistance, and will not eliminate established resistance.

5.2.5 Benefit-cost analysis of strategies for AAT control

A standardised (partial) benefit-cost analysis was carried out for the strategies for controlling AAT under resistance risk. Only in the case of participatory vector control were there comprehensive production data (longitudinal cohort), but mortality data were available for all interventions. But in the detailed impact analysis carried out for participatory vector control, reduced mortality was the single biggest benefit, and made up around half the total benefits so to allow comparison across studies, benefits were assessed therefore in terms of reduced mortality. Costs were based on the financial records of the project and in the case of trypanotolerant cattle a study on price related to breed; specifically, the cost of switching to trypanotolerant cattle was considered the difference in value between a village herd consisting of Métis and one consisting of N'Dama/Baoulé. Costs and benefits were assessed over a period of ten years, using a discount rate of 10%. Calculations were based on an average village in the study zone, with 26 farmers and 427 cattle (KAP study, survey mean). The assumptions and method of calculation are given in Annex 2.

Over ten years, and using a discount rate of 10%, the Benefit Cost Ratio (BCR), Net Present Value and time to break-even of the strategies are shown in Table 5.2.71.

Table 5.2.71 Benefit-cost ratio for different strategies for control of resistance (per village)

	Vector Control	**Trypanotolerant Cattle**	**Rational Drug Use**		
			Farmers	**SPs**	**Paravet**
Start up costs ($)	2094	6320	106	13	243
Net Present Value ($)	3968	13 953	3456	3328	6751
Benefit Cost Ratio	1.84	3.21	22.21	23.68	6.43
Pay-off period (years)	2	2	1	1	1

Sensitivity analysis showed that BCR was relatively insensitive to the price of cattle or AAT control inputs (details in Annex 2). However, the strategy of keeping trypanotolerant had costs greater than benefits when mortality was low in trypanosusceptible cattle and the strategy of vector control had costs greater than benefits where the number of cattle per village was low and also where the mortality from trypanosomosis was low. Estimations of the effectiveness of all interventions were sufficiently accurate to be confident that the BCR was greater than one, with the exception of the intervention of provision of RDU to farmers, where the short follow-up period resulted in imprecise estimates of mortality reduction with wide confidence intervals.

5.3 Mathematical model

A mathematical compartment model was constructed with three modules: cattle, alternative hosts and tsetse. Cattle populations were divided into three compartments: susceptible cattle; infectious cattle and recovered cattle who were not yet susceptible because they had received treatment (or prophylaxis). Tsetse were divided into two compartments: susceptible flies and infected flies, and there was no recovery from infection and no pathogenic effects of infection. Alternative hosts comprised two comparable compartments. Cattle could enter the susceptible compartment through being born, being purchased as untreated and un-infected animals or by the protection from DIM or ISMM lapsing. Cattle could leave the susceptible compartment by becoming infected or by being treated with a trypanocide or by dying. Cattle could enter the diseased compartment by being infected or by being purchased while sick. Cattle could leave the diseased compartment by dying, by being successfully treated with trypanocide or by self-curing. Cattle could enter the recovered/protected compartment by being treated with a trypanocide (either prophylactic or therapeutic), and could leave it as protection lapsed, or by dying. Tsetse entered the susceptible compartment through population growth, they left either by normal mortality, additional mortality imposed by vector control or by being infected by alternative hosts or cattle. On infection, tsetse entered directly the infected compartment (no incubation period); they left either by normal mortality or by additional mortality imposed by vector control. The population of alternative hosts was assumed to be stable, i.e. entry balanced exit. Susceptible alternative hosts became infected by tsetse and remained infectious (but not sick) until death.

This model makes the following simplifications: tsetse flies are assumed to remain infected (i.e. no self cure); all infections result in illness; infections do not increase mortality in the vector; there is one generic species of tsetse and of trypanosome; there is no age-structure differences in susceptibility of infectivity in the host or fly; only one infection occurs at a given time in host and fly. Incubation periods in cattle and flies are ignored.

The model incorporated the following system parameters, derived from the KAP study:

- 25% of trypanosusceptible and 10% of trypanotolerant cattle receive ISMM prophylaxis
- 40% of sick trypanotolerant and 80% of cross-breeds are treated with curative drugs
- Mortality from AAT is 20%
- 80% of N'Dama self cure, 15% of cross breeds self-cure

Initial parameters derived from the literature were:

- Duration of protection is 10 days for DIM and 90 days for ISMM
- Transmission coefficient (tsetse to cattle) of 0.01 (estimates 0.008 to 0.28)
- Transmission coefficient (infected host to vector) of 0.02, estimates range from 0.025 to 0.11
- Chemo-resistance is a function of drug use, there is a threshold below which drug usage does not lead to resistance

The relations between the components are shown in Figure 5.3.2. The differential equations underlying the model are given in Annex 1.

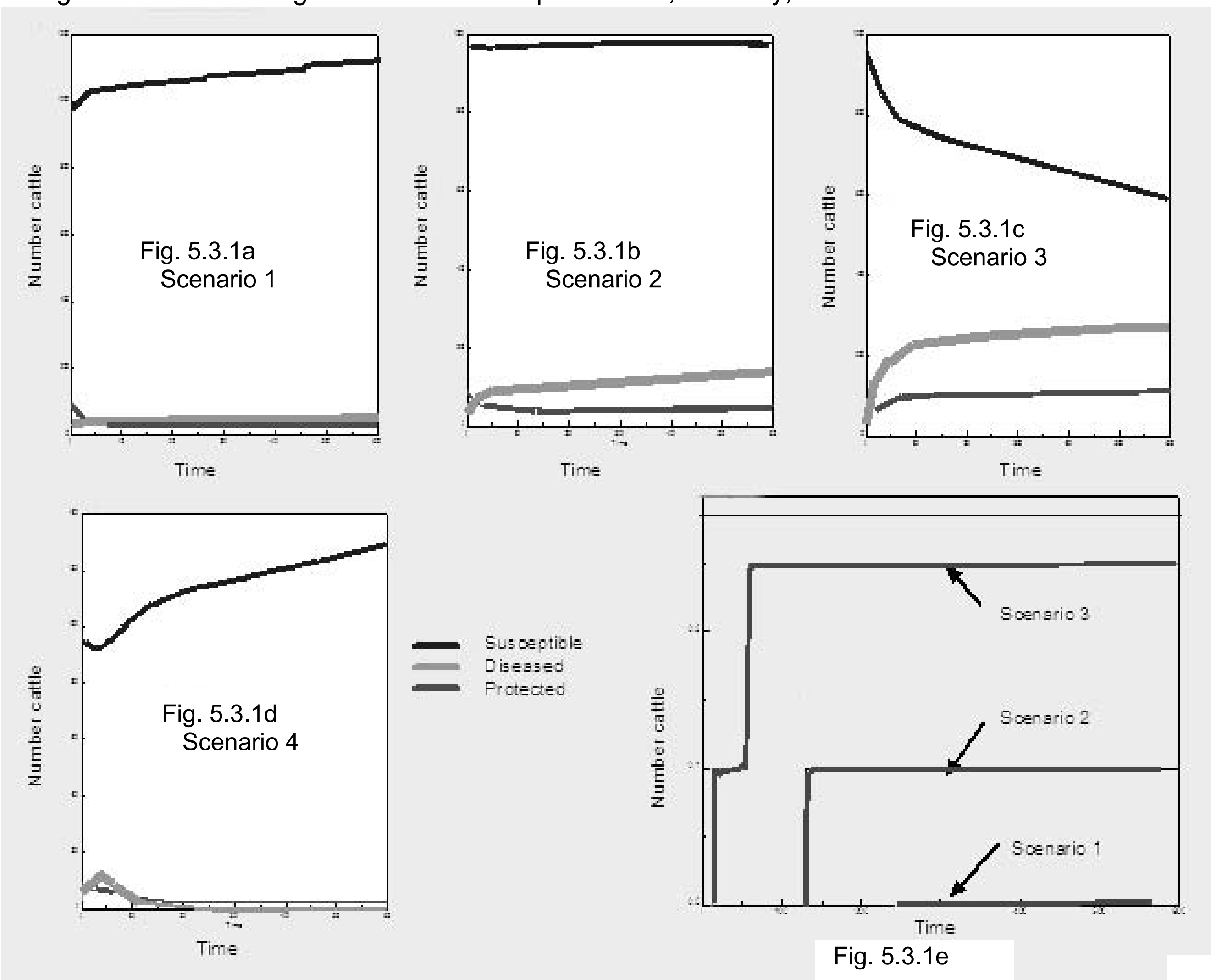
Model building

The model was initialized using parameters from a typical village in Guinea. This assumes there are 1000 cattle of which 30 are infected with AAT and 90 protected by ISMM. There are 50000 tsetse flies of which 48510 are susceptible and the remainder infected. There are 1100 alternative hosts, 100 of these are infected. The values for case fatality from AAT (0.2), proportion of sick animals treated with trypanocides (0.8), proportion of animals of each category treated with ISMM, herd exit and entry per year were derived from the KAP and PRA. In the case of trypanotolerant cattle it is assumed that 50% of infections are not detected by the farmer. The duration of ISMM is from manufacturers information; that of DIM from the literature. The threshold theory of resistance, whereby below a certain level of use resistance is not found was adopted as consistent with field results (Seppela *et al.,* 1997); it was arbitrarily assumed that where treatment were less than 10% of the herd then resistance would not develop.

Model outputs

Four scenarios were run, with ten thousand iterations each. Under the first scenario cattle are trypanotolerant. The model stabilizes at a low prevalence and a low treatment level (the protected category is an indicator of drug use, but underestimates treatment numbers). Prevalence is around 3% and cattle population grows continuously (Figure 5.3.1a). This corresponds to the situation found in Guinea, or point of departure. Under the second scenario, the only change to model specification is that cross-breeds have now entered the herd. Prevalence is higher (around 10%) and herd growth is slowed, but still positive (Figure 5.3.1b).

Figure 5.3.1 Modelling scenarios for AAT prevalence, mortality, and herd size



Under the third scenario the only change is cattle are now fully trypanosusceptible (Zebus). Prevalence reaches high levels (40%) and treatments have greatly increased (Figure 5.3.1c). However, even with bought in animals populations are declining rapidly. This worse case scenario is not found in the study sites. For the fourth scenario we add vector control sufficient to impose 0.02% of additional mortality to the worst case scenario (Figure 5.3.1d). This low rate of additional mortality rapidly controls the problem: disease and drug use fall to almost zero and population increases

Resistance to trypanocides was modelled under the three scenarios. This was a threshold model, and under the first scenario (high trypanotolerant cattle, low prevalence, few treatments) resistance does not emerge. With a prevalence of 10%, resistance emerges but stabilizes at a low level. In the high prevalence scenario, it stabilized at a much higher level (Figure 5.3.1e).

The model predictions and results of epidemiological surveys show reasonable agreement (Table 5.3.1). To validate the first scenario, Sikasso and Kénédougou were chosen. The second scenario was validated by excluding trypanotolerant cattle from villages of Kénédougou without ongoing vector control, and the third was validated using results from villages in Kenedougou with ongoing vector control.

Table 5.3.1 Comparing model predictions of AAT prevalence to epidemiological survey results

	Characteristics	**Epidemiological surveys (AAT %)**	**Model**
Scenario 1	Trypanotolerant dominate	3.0	initialising
Scenario 2	Cross-breeds predominate	11.2	10
Scenario 3	Trypanosusceptible	30.6	40
Scenario 4	Vector control	2.5	<1

Sensitivity analysis was carried out to assess the dependence of the model on assumptions and starting conditions. The model was re-run with parameters of interest allowed to vary as shown in Table 5.3.2. With one exception (transmission coefficient), the model converged and gave coherent results within the range of values tested. However, the model was sensitive to changes in the transmission coefficient from host to vector.

Table 5.3.2 Sensitivity testing of model parameters

Parameter	**Model stability**
Alternative hosts	10 to 1000 infected alternative hosts in the village
Tsetse number	500 to 50 000 tsetse in the village
Transmission coefficient (fly to host)	0.01 to 0.10
Transmission coefficient (host to fly)	0.001 to 0.500
Case fatality	5% to 50%
Self cure	0 to 100%
Prophylaxis and treatment with DIM	0 to 100%

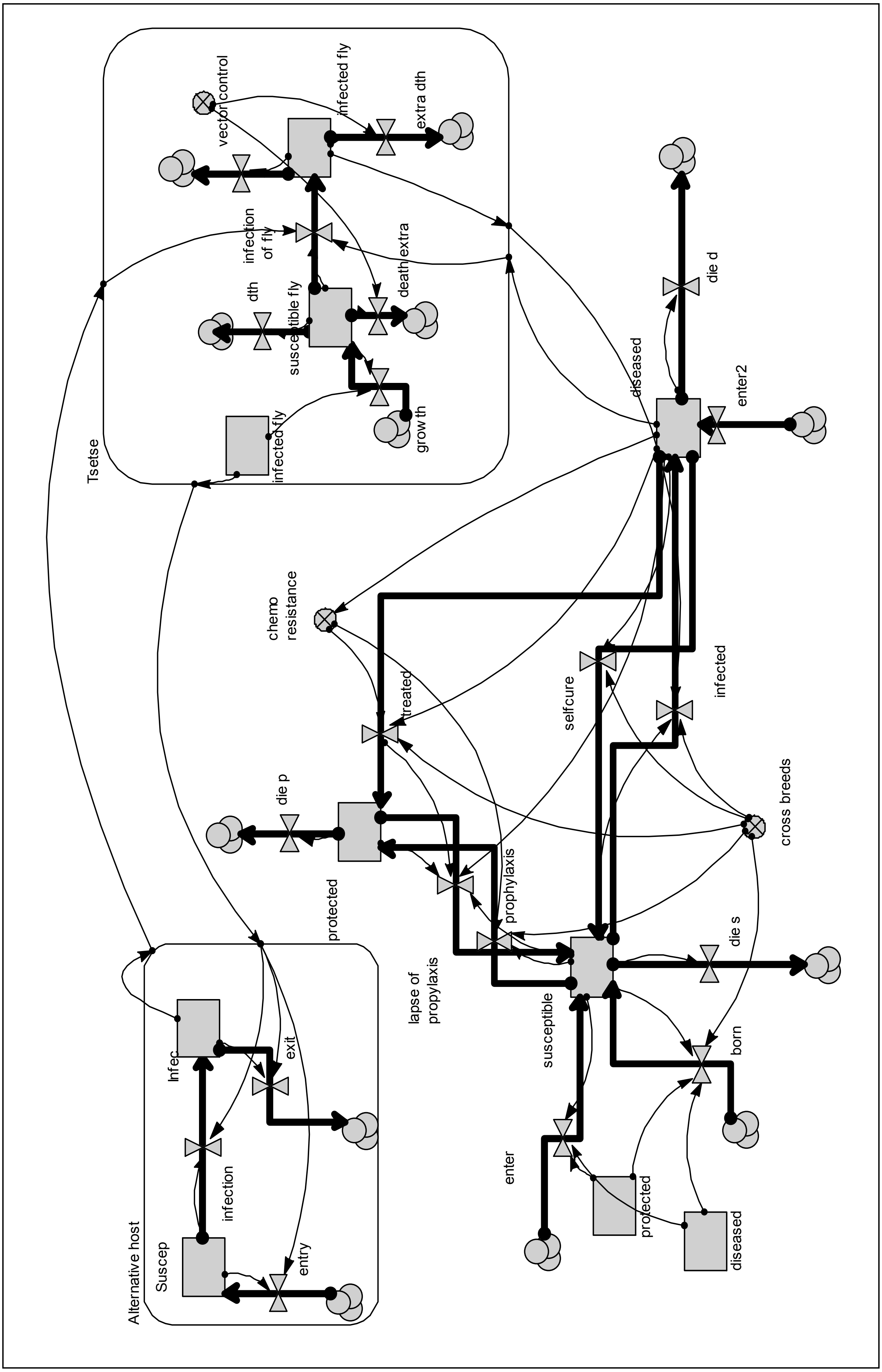


Figure 5.3.2 Diagram for mathematical model of AAT, incorporating drug resistance