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The use of a herd simulation model for the estimation of direct economic benefits of tsetse control. Application to the pastoral zone of Sideradougou, Burkina Faso

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RÉSUMÉ

BRANDL (F. E.). — Utilisation d'un modèle de simulation démographique pour l'estimation des bénéfices économiques directs de lutte contre les glossines. Application à la zone pastorale de Sidéradougou, Burkina Faso. *Rev. Elev. Méd. vét. Pays trop.*, 1985, **38** (4) : 364-370.

Un modèle de simulation démographique bovine a été utilisé afin d'estimer les bénéfices économiques directs d'une campagne de lutte contre la mouche tsé-tsé dans la zone de Sidéradougou au Burkina Faso.

Trois hypothèses au niveau de l'incidence de la trypanosomose sur la productivité du bétail ont été retenues pour calculer l'augmentation de la production. Après l'éradication, la valeur ajoutée de la production, sur une période de 10 ans suivant la campagne de lutte, dépasse respectivement de 1 000, 3 560 et 5 980 F CFA par hectare, selon l'hypothèse choisie, celle obtenue sans éradication et qui est de 8 100 F par hectare pour la même durée de 10 ans.

Mots clés : Glossina - Trypanosomose - Incidence économique - Burkina.

SUMMARY

BRANDL (F. E.). — The use of a herd simulation model for the estimation of direct economic benefits of tsetse control. Application to the pastoral zone of Sideradougou, Burkina Faso. *Rev. Elev. Méd. vét. Pays trop.*, 1985, **38** (4) : 364-370.

A herd simulation model is applied to estimate direct economic benefits of a tsetse eradication campaign in the pastoral zone of Sideradougou, Burkina Faso. Three hypotheses for the impact of trypanosomiasis on cattle productivity are tested in view of production increases after tsetse eradication. Value of additional production over a period of 10 years after tsetse eradication exceeds the value without eradication of 8 100 F CFA per hectare (by 1 000, 3 560 or 5 980 F CFA under the low, medium or high assumptions, respectively.

Key words : Glossina - Trypanosomiasis - Economic effects - Burkina.

INTRODUCTION

While the calculation of costs ot tsetse control programmes is a fairly simple exercise as soon as the technical components of a programme have been established, the estimation of benefits due to tsetse control proves to be difficult, both in view of the applicability of existing methods and with respect to the availability of data.

In a first approach of the problem JAHNKE (9) compared costs of tsetse control in Uganda with expenditures for chemotherapy and prophylaxis considering the savings of the latter as the benefits of control. PUTT *et al.* (15) estimated direct benefits of tsetse eradication measures in Nigeria by adding the values of avoided mortality, morbidity, and costs of treatment with trypanocidal drugs. CAMUS (5) compared theoretical annual revenue of trypanosomiasis infested and non-infested cattle of 4 different breeds on the basis of differing productivity parameters obtained in a survey of 200 herds in Northern Ivory Coast, using a herd model to calculate maximum off-take rates from stabilised herd structures.

None of these approaches considers milk production which plays an important role in the economies of pastoral societies throughout Africa, as has been demonstrated for the zone of Sideradougou by TOUTAIN *et al.* (16) in a preliminary study. The most important disadvantage, however, is their static view of the problem, not allowing for the fact that increased mortality and decreased fertility are not only immediate losses for the owner but also affect overall herd-development and production in future years.

This paper aims at a more dynamic approach by using a herd simulation model in order to estimate direct economic benefits of a tsetse eradication campaign in the pastoral zone of Sideradougou, in Burkina Faso.

THE MODEL

The model presented here includes both meat and milk production. It is purely deterministic and therefore applicable only to sufficiently large numbers of animals. It is suggested a herd of 1 000 head be used as the basis of calculation.

TABLE N° I - List of input parameters of the model

Parameter	Abbreviation
a) obligatory :	
Number of animals in age-class i at the beginning of year 1	$_1ATA_i$
Liveweight	GT i
Mortality rate	RM i
Calving rate	RAK i
Milk yield/lactating cow	GL
Marketing rate of animals	RFV i
b) optional :	
Home slaughter rate	RFS i
Salvage rate of fallen animals	RNM i
Milking rate	RNL
Marketing rate of milk	RLV
Subsistence rate of milk	RLS
Market price of animals	PFV i
Price for fallen animals	PFM i
Price for subsistence meat cons.	PFS i
Market price of milk	PLV
Price for subsistence milk cons.	PLS
Discount rate	RD

i = age-class number (see Table N°III)
For precise definitions of parameters see calculation formulas in Table N°II)

The model is based on 17 input parameters shown in table n° I. Six of these are obligatory for the simulation of the herd's physical production. Five more parameters can be included optionally :

— in cases where subsistence consumption needs to be considered separately from market production (RFS, RLS, RLV) ;

— to allow for the salvage value of fallen animals (RNM) ;

— if only part of the lactating cows are milked (RNL).

The physical production can be linked with prices for subsistence and marketed meat and milk to obtain the monetary output of the herd. The model allows for up to 14 age-classes of female and 10 of male animals. The input parameters are to be specified for every age class except for parameters of milk production which are assumed to be constant for all lactating cows.

Table n° II shows the output parameters of the model and their calculation. These are listed per age-class and as totals for every year and for the entire calculation period. Monetary outputs are listed as undiscounted and discounted values if a discount rate is specified.

The model was originally designed for cattle, but can be applied to other species of livestock such as goat, sheep and camel.

APPLICATION TO SIDERADOUGOU

The pastoral zone of Sideradougou covers some 3 500 km² of Southern Sudan and Northern Guinea savannah, southwest of Bobo Dioulasso, Burkina Faso. The cattle population has been estimated as 38 000 head with seasonal variations from 32 000 to 45 000 (6). The large majority of the cattle are Zebu with some degree of crossbreeding with taurin breeds such as Baoule and — to a lesser extent — N'Dama (16). Prior to an integrated eradication campaign using insecticide-impregnated screens followed by mass release of sterile male, the area was infested by the riverine tsetse species *Glossina palpalis gambiensis* (VANDERPLANK) and *Glossina tachinoides* (WESTWOOD), and in the southeastern part by the savannah species *Glossina morsitans submorsitans* (NEWSTEAD) (14). Building up of the

TABLE N°II - Output parameters of the model and their calculation

Parameter	Abbreviation	Calculation formula
Number of animals at beginning of the year	${}_{k}ATA_{i}$	${}_{k-1}ATE_{i-1}$
Number of mortalities	${}_{k}AM_{i}$	${}_{k}ATA_{i} \times RM_{i}$
Number of salvaged fallen animals	${}_{k}ANM_{i}$	${}_{k}AM_{i} \times RNM_{i}$
Liveweight of salvaged fallen animals	${}_{k}GNM_{i}$	${}_{k}ANM_{i} \times GT_{i}$
Monetary value of salvaged animals	${}_{k}WNM_{i}$	${}_{k}GNM_{i} \times PFM_{i}$
Number of animals sold	${}_{k}AFV_{i}$	${}_{k}ATA_{i} \times PFV_{i}$
Liveweight of animals sold	${}_{k}GFV_{i}$	${}_{k}AFV_{i} \times GT_{i}$
Monetary value of animals sold	${}_{k}WFV_{i}$	${}_{k}GFV_{i} \times PFV_{i}$
Number of home slaughters	${}_{k}AFS_{i}$	${}_{k}ATA_{i} \times RFS_{i}$
Liveweight of home slaughtered animals	${}_{k}GFS_{i}$	${}_{k}AFS_{i} \times GT_{i}$
Monetary value of home slaughtered animals	${}_{k}WFS_{i}$	${}_{k}GFS_{i} \times PFS_{i}$
Number of animals at end of the year	${}_{k}ATE_{i}$	${}_{k}ATA_{i} \times (1 - RM_{i} - RFV_{i} - RFS_{i})$
Number of calvings	${}_{k}AK_{i}$	$({}_{k}ATA_{i} + {}_{k}ATE_{i}) \times RAK_{i} \times 0.5$
Increase in number of animals	${}_{k}DA_{i}$	${}_{k+1}ATA_{i} - {}_{k}ATA_{i}$
Liveweight of increase in number	${}_{k}DG_{i}$	${}_{k}DA_{i} \times GT_{i}$
Monetary value of increase in number	${}_{k}DW_{i}$	${}_{k}DG_{i} \times PFV$
Number of milked cows	${}_{k}ANL$	${}_{k}\Sigma AK_{i} \times RNL$
Milk yield	${}_{k}GLE$	${}_{k}ANL \times GL$
Milk sold	${}_{k}GLV$	${}_{k}GLE \times RLV$
Monetary value of milk sold	${}_{k}WLV$	${}_{k}GLV \times PLV$
Milk home consumption	${}_{k}GLS$	${}_{k}GLE \times RLS$
Monetary value of milk home consumption	${}_{k}WLS$	${}_{k}GLS \times PLS$

i = age-class number; k = year number.

tsetse colonies and preparatory work began in 1980. The actual campaign started in January 1983 with the first releases of sterile males in May. As there have been no catches of wild flies in the river galleries since December 1983, the zone could be considered free of flies with the exception of a few small but very dense forests of *Ficus* spp. (14). The latter were successfully treated during the first months of 1984.

Table n° III shows parameters of cattle production in the zone obtained in a survey in 1982 (6). As there was little information available on home slaughter and subsistence milk consumption, these parameters had to be estimated on the basis of data from similar locations in nearby Northern Ivory Coast (1, 11, 13).

The prices indicated in table n° III are market prices and were obtained in an informal market survey of the zone in 1984, except for the prices of slaughter animals which were taken from the purchase records of a feedlot on the border of the zone.

Due to lack of precise data from the zone of Sideradougou, the impact of trypanosomiasis on cattle productivity was estimated mainly on the basis of 2 extensive surveys done by CAMUS (3, 4) in Northern Ivory Coast. The data obtained in a survey of 90 herds in 1979 showed mortality rates of 15.5 p. 100 and 2.7 p. 100 in infested herds and 10.5 p. 100 and 1.2 p. 100 in non-infested herds for calves and adult animals respectively (3). Corresponding figures from an analysis of some 200

TABLE N° III - Parameters of cattle production in the Sidéradougou zone (from CHARTIER (6))

Age-class	Age (years)	ATA	GT (kg)	RM	RNM[1]	RAK	RFV	RFS[2]	PFV (FCFA)	PFS (FCFA)
1	0- 1	102	85	0.26	0.30	0.00	0.00	0.00	250	250
2	>1- 2	81	145	0.10	0.30	0.00	0.00	0.01	230	230
3	>2- 3	74	170	0.04	0.15	0.00	0.00	0.01	210	210
4	>3- 4	67	195	0.04	0.15	0.14	0.03	0.01	220	220
5	>4- 5	63	210	0.03	0.15	0.59	0.03	0.01	220	220
6	>5- 6	60	220	0.02	0.15	0.59	0.04	0.01	230	230
7	>6- 7	56	230	0.02	0.15	0.59	0.04	0.01	230	230
8	>7- 8	50	230	0.02	0.15	0.59	0.04	0.01	230	230
9	>8- 9	45	230	0.02	0.15	0.59	0.04	0.01	220	220
10	>9-10	42	230	0.02	0.15	0.59	0.04	0.01	210	210
11	>10-11	44	220	0.02	0.15	0.59	0.04	0.01	200	200
12	>11	20	210	0.02	0.15	0.50	0.98	0.00	190	190
13	0 - 1	102	100	0.28	0.30	0.00	0.00	0.00	250	250
14	>1 - 2	81	140	0.08	0.30	0.00	0.00	0.00	220	220
15	>2 - 3	62	175	0.04	0.15	0.00	0.30	0.01	195	195
16	>3 - 4	32	210	0.04	0.15	0.00	0.55	0.01	260	260
17	>4 - 5	13	260	0.03	0.15	0.00	0.55	0.01	285	285
18	>5 - 6	5	285	0.02	0.15	0.00	0.55	0.01	290	290
19	> 6	1	290	0.02	0.15	0.00	0.98	0.00	300	300

Constant for all age-classes : RNL[3] = 0.5
RLV[3] = 0.5
RFM = 100 FCFA
PLV = PLS = 100 FCFA

Constant for age-classes 4 - 12 : GL = 200 kg

1 Estimate based on data from BONNET (1), CHARTIER (6) and PETIT (13)
2 Estimate based on data from PETIT (13)
3 Estimate based on data from PETIT (13), and LANDAIS and POIVEY (11).

herds in 1981 were 15.3 p. 100 and 3.1 p. 100 for the infested and 10.4 p. 100 and 1.5 p. 100 for the non-infested herds (4). Mean trypanosomiasis infection rates were 8 p. 100 (3) and 6 p. 100 (6) which is in the same magnitude as figures reported for the Bobo Dioulasso area (8, 10). While the results of 1979 and 1981 correspond well as far as mortality is concerned, findings in regard of reproductive performance differed considerably. The 1979 figures revealed calving rates of 40 p. 100 and 49 p. 100 for infested and non-infested herds, respectively, whereas the 1981 figures were some 42 p. 100 for both groups of herds. An analysis of production traits of trypanotolerant cattle under different management systems and levels of trypanosomiasis challenge using data from 30 locations throughout West Africa demonstrated a significant difference of mean calving rates being 73 p. 100 for 13 low challenge locations, and 55 p. 100 for 10 medium challenge locations (7).

Based on the cited information 3 hypotheses for the development of both calving rate and mortality were established and used for model simulation (see table n° IV). With regard to the mortality of adult animals CAMUS' findings *e.g.* a reduction by 1.5 p. 100 (3, 4) were considered as medium assumption (H 2) and associated with a more conservative (H 1 = − 0.5 p. 100) and a more optimistic (H 3 = − 2.5 p. 100) estimate. In view of the relatively high mortality of calves in the Sideradougou zone [(27 p. 100) (6) compared to some 15 p. 100 reported by CAMUS (3, 4)], it seemed to be justified to assume a moderately stronger decrease of this parameter by eliminating trypanosomiasis than found by CAMUS (3, 4). Calf mortality was therefore set to 23, 19 and 15 p. 100 for hypotheses 1, 2 and 3, respectively. The calving rate in Sideradougou of 52 p. 100 exceeds those found by CAMUS (3, 4). An increase of the calving rate in the range of 10 p. 100 was therefore considered as an optimistic estimation (H 3) for the Sideradougou zone. Under hypothesis 1 it was suggested that trypanosomiasis had no influence on reproductive performance. An increase of the calving rate by 5 p. 100 was taken as medium assumption (H 2).

TABLE N° IV - Modification of productivity parameters due to tsetse eradication

Scenario	W.E.	H 1	H 2	H 3
Mortality rate (0 - 1 y.)	0.27	0.23	0.19	0.15
Mortality rate (mean, >1 y.)	0.040	0.035	0.025	0.015
Calving rate (mean, >3 y.)	0.52	0.52	0.57	0.61

W.E. : without tsetse eradication
H 1-3 : see text

RESULTS

Figure n° 1 shows the theoretical development of herd sizes with and without tsetse eradication over a period of 10 years. Under hypothesis 3, the reference herd of originally 1 000 cattle would reach 2 788 head in year 10.

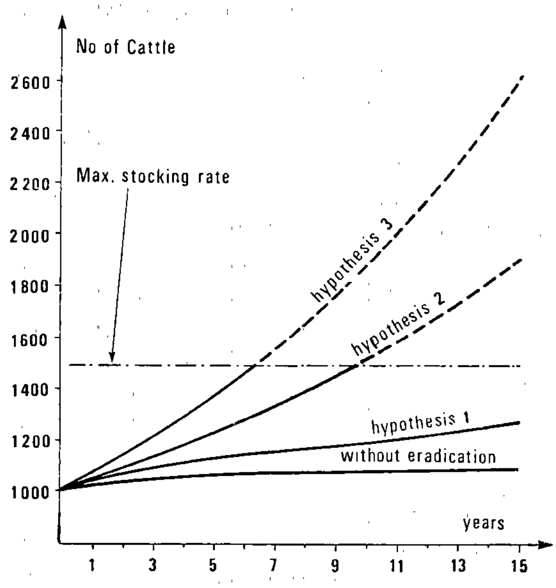

Figure 1: Development of herd size

Assuming that neither immigration nor emigration would take place, this would increase the stocking rate in the zone of approximately 10 ha/head at present by the factor 2.8 and thereby seriously exceed the carrying capacity of the area.

As the cropping area in the zone increases, maximum stocking rate in future years is supposed to be in the order of 7 ha/head. This cattle density would be reached in year 7 under hypothesis 3 and in year 10 under hypothesis 2.

Table n° V shows monetary herd output with and without tsetse eradiction under the assumption that any herd growth exceeding 1 500 head (which corresponds with some 7 ha/head) is marketed, without changing the — by then for all three hypotheses stable — herd structure. According to this, production of the reference herd over the period of 10 years after eradication would increase by 12, 44 or 74 p. 100 in comparison to production without eradication under hypotheses 1, 2 or 3, respectively. Value of additional production exceeds the value without eradication by 10 000, 35 600 or 59 830 F CFA per head of the reference herd and by 1 000, 3 560 or 5 983 F CFA per hectare, based on the initial stocking density of 10 ha/head. Corresponding figures are 350, 1 230 and 2 100 F CFA per hectare at a discount rate of 10 p. 100. If the lenght of the calculation period is extended to 15 years after eradication, discounted values of additional production are 511, 1 745 and 2 805 F CFA per hectare under low, medium and high assumptions.

TABLE N°V-Monetary herd output over periods of 10 and 15 years after tsetse eradication
(F CFA x 1 000; herd size not exceeding 1 500 head)

Period	10 years	15 years
Without eradication	81,282	122,785
Hypothesis 1	91,286	141,596
Hypothesis 2	116,884	186,879
Hypothesis 3	141,111	221,031

Milk production accounts for about 19 p. 100 of the total value of production in any of the scenarios.

DISCUSSION

Precise data on the impact of trypanosomiasis on livestock productivity are scarce.

They require long-term studies with sufficiently large numbers of animals, and it is only recently that large scale studies on this topic have been carried out or started (3, 4, 7, 12). The « Trypanotolerance Network » coordinated by ILCA in cooperation with ILRAD and ICIPE, which has been underway since 1982 will hopefully in the long run provide precise information on impacts of the disease at various locations in Africa and under different levels of trypanosomiasis challenge. There is also a considerable amount of work being put into the study of the host-vector-parasite interface in view of the development of predictive models for this complex. However, the state seems still to be far away in which effects of tsetse control measures on livestock productivity at a given location can be determined with an acceptable degree of exactitude on the basis of some key information obtainable in a short-term field study, such as cattle breeds and densities, tsetse species and densities, *Trypanosoma* species and infection rates.

Thus, most — and especially any *ex ante* — analyses must depend of the transmission of data from one location to another, on assumptions and « educated guesses ». It is obvious that the « calculation » of benefits aiming at a « one-figure-result » does not make sense on such a weak empirical basis. The creation of different scenarios of assumptions (low, most likely, high) in combination with a suitable simulation model can, however, lead to a range of results that may provide enough information for decision-makers. This approach seems suitable not only for tsetse control but can be applied to any other animal health improvement programme.

In the case of the pastoral zone of Sideradougou only very conservative asumptions (H 1) lead to discounted benefits below the total discounted costs of the campaign — which have been estimated in the order of 1 400 F CFA per hectare of reclaimed area (2) — if it is assumed that the negative impact of trypanosomiasis would have continued for 15 years after tsetse eradication. If the calculation period is reduced to 10 years after eradication only hypothesis 3 with the high assumptions results in benefits well beyond costs, which could be decreased, however, to less than 800 F CFA by an extension of the eradication zone leading to a more economic use of the project investments. Savings of trypanocidal drugs and indirect benefits, not included in this study, would further change the ratio of costs and benefits in favour of the latter.

The herd simulation illustrates, however, that tsetse control tends — as any other improvement of animal health — to lead to increased livestock numbers. This harbours the risk of over-stocking, resulting in pasture degradation and eventually desertification, if off-take rates remain on the initial levels. Measures to increase off-take rates such as improvement of marketing facilities should therefore be an integral part of any project aiming at animal health improvement in areas where livestock densities are likely to approach natural carrying capacity.

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RESUMEN

BRANDL (F. E.). Utilización de un modelo de simulación demográfica para valorar los beneficios económicos directos de lucha contra las glosinas. Aplicación a la zona pastoral de Sideradugu, Burkina Faso. *Rev. Elev. Méd. vét. Pays trop.*, 1985, **38** (4) : 364-370.

Se utilizó un modelo de simulación demográfica bovina para valorar los beneficios económicos directos de una erradicación de la mosca tsetsé en la zona de Sideradugu, Burkina Faso.

Se probaron tres hipotesis concernientes a la incidencia de la tripanosomiasis en la productividad del ganado para calcular la aumentación de la producción. Durante un período de 10 años después de la erradicación, el valor añadido de la producción sobrepasa respectivamente de 1 000, 3 560 y 5 980 F CFA por hectárea, según la hipotesis escogida, la de 8 100 F CFA obtenida sin erradicación.

Palabras claves : Glossina - Tripanosomiasis - Incidencia económica - Burkina.

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