An estimation of the economic impact of contagious bovine pleuropneumonia in Africa

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Summary

Contagious bovine pleuropneumonia (CBPP) is a disease that causes high morbidity and mortality losses to cattle. The financial implications of these losses are of great significance to cattle owners. Control of CBPP is therefore important as a way to salvage the losses and increase the incomes of cattle owners. This study estimated the economic cost of CBPP and the benefits of its control in twelve sub-Saharan African countries using a spreadsheet economic model developed in Microsoft Excel®. The value of morbidity and mortality losses was estimated at 30 million euros (2.5 million per country) while the total economic cost (direct and indirect production losses plus disease control costs) was estimated at 44.8 million euros (3.7 million euros per country). An investment of 14.7 million euros to control CBPP would prevent a loss of 30 million euros. The financial return on investment in CBPP control is positive, with benefit-cost ratios that range from 1.61 (Ghana) to 2.56 (Kenya).

Keywords

Benefit-cost analysis – Contagious bovine pleuropneumonia – Disease control – Economic impact – Production losses – Sub-Saharan Africa.

Introduction

Contagious bovine pleuropneumonia (CBPP) is a disease of cattle that affects production through mortality and reduced productivity. It also retards genetic improvement and limits the ability of cattle to work. The Pan African programme for the Control of Epizootics (PACE) (this programme is implemented by the African Union Interafrican Bureau for Animal Resources [AU-IBAR] in 32 African countries and is funded principally by the European Commission with the support of the participating African countries) has identified CBPP as the second most important transboundary disease in Africa after rinderpest. Contagious bovine pleuropneumonia is now a major focus of activity for the programme. However, before the programme embarks on a control strategy, it is essential that the economic importance of the disease be established and the returns to investments in its control be estimated. National veterinary authorities and donor organisations require this information for decision-making in CBPP control.

Unlike some parasitic animal diseases whose impacts are confined to a single farm, the impact of CBPP is often felt beyond a single farm. The outbreak of CBPP in one herd poses a threat to neighbouring herds in a production system where there is poor control of cattle movements. The control of CBPP therefore goes beyond the ability of an individual farmer and should be undertaken at the national or regional level. The economic impact of CBPP should therefore be examined beyond the farm level.

This study estimates the economic impacts of CBPP in 12 sub-Saharan African countries (Burkina Faso, Chad, Côte d'Ivoire, Ethiopia, Ghana, Guinea, Kenya, Mali, Mauritania, Niger, Tanzania and Uganda). These countries were chosen because of the increasing number of outbreaks of CBPP reported to the World Organisation for Animal Health (OIE) and to AU-IBAR in the last decade. For example, these countries reported a total of 2,612 outbreaks between 1995 and 2002, representing 96% of the total number of outbreaks reported by all the countries in West, Central and East Africa. Contagious bovine pleuropneumonia is therefore a major threat to cattle production and the lives of millions of cattle owners. The veterinary authorities of these countries regard CBPP as a disease of strategic importance and are seeking internal and donor funding for its progressive control. The purpose of this study is to provide estimates that will assist both the veterinary authorities and donors in making investment decisions regarding the control of CBPP.

The disease

Contagious bovine pleuropneumonia is a highly infectious acute, sub-acute, or chronic disease, primarily of cattle, affecting the lungs and occasionally the joints. It is caused by a bacterium, *Mycoplasma mycoides mycoides* sc (small colony, bovine biotype) (21). It is spread almost exclusively by direct contact between animals, although indirect spread is also possible (43). Contagious bovine pleuropneumonia is an OIE notifiable disease and was included among the former List 'A' diseases (44). When the disease spreads for the first time within a sensitive cattle population, it generally causes high mortality.

Population at risk

Cattle (both *Bos taurus* and *Bos indicus*) are the main species that are susceptible to CBPP. The domestic buffalo (*Bubalus bubalus*) is also susceptible although the disease is difficult to produce experimentally in this species (31). The African water buffalo (*Syncerus caffer*) is resistant to CBPP.

Outbreaks and distribution

Contagious bovine pleuropneumonia was introduced in the Cape Province of South Africa in 1853 through cattle imports from the Netherlands and in 1868 it was introduced in East Africa by British troops. It is not clear if CBPP had existed in sub-Saharan Africa before that time. Following the first outbreak, CBPP quickly spread to neighbouring countries and is now present in many parts of Africa. In 1904 it was eradicated from Zimbabwe followed by South Africa in 1924 and Botswana in 1939. Angola has never managed to eradicate the disease. Namibia succeeded in eradicating the disease in the southern part of the country although it remains endemic in the northern part because of incursions from neighbouring Angola where the disease is endemic. Civil strife in Angola has made it difficult to control the disease that is now a major threat to Zambia and northern Botswana.

During the 1960s and 1970s, extensive research on CBPP in Kenya, Chad and other African countries, coupled with the massive efforts of the international campaign Joint Project 16, resulted in the disappearance of clinical disease from most parts of Africa. However, because of the economic and financial difficulties that affected the ability of governments to adequately fund Veterinary Services, the disease came back in the late 1980s and early 1990s. Today, CBPP is present in Central, East, West and parts of Southern Africa but is absent in North Africa. Reports from the OIE indicate that there are about 27 sub-Saharan African countries with cases of CBPP. During the Pan African Rinderpest Campaign (PARC), which started in 1986, fewer countries experienced outbreaks of CBPP, due in part, to the combined vaccination against rinderpest and CBPP. Many countries however, began to experience outbreaks in 1995 when some countries stopped the combined rinderpest and CBPP vaccination.

Of the 27 countries that reported cases of CBPP between 1995 and 2002, 13 were in West Africa, two in Central Africa, six in East Africa and the rest in Southern Africa. In West, Central and East Africa where the PACE programme is being implemented, a total of 2,719 outbreaks were reported between 1995 and 2002. Countries in East Africa reported 66% of the total outbreaks (58% in Ethiopia and Tanzania and 8% in other countries in the region). Countries in West and Central Africa accounted for 33% and 1% of the total number of outbreaks respectively. The twelve countries considered in this study reported 2,612 outbreaks between 1995 and 2002 (Table I). This accounts for 96% of the total number of outbreaks reported in West, Central and East Africa.

Epidemiological trends

Contagious bovine pleuropneumonia outbreaks exhibit two distinct epidemiological trends in Africa. The first is reflected in cases of epidemic outbreaks in areas hitherto considered to be CBPP-free. Botswana is a good example. Following the eradication of CBPP in 1939, the disease re-appeared in 1994. In 1995 the Government of Botswana once again eradicated the disease by slaughtering all infected and in-contact stock and compensating their owners. Other examples of epidemic outbreaks include Burundi and Zambia in 1997, Ethiopia in 1998, Guinea in 1995, Rwanda in 1994 and Tanzania in 1996 and 1999. Masiga *et al.* (22) attributed these outbreaks to uncontrolled entry of cattle from known infected populations due to poor movement control and surveillance.

The second trend of CBPP outbreaks is reflected in the increased number of areas in which the disease has become endemic. When CBPP is introduced into a clean area, numerous foci occur. Many animals become infected and develop the acute clinical form of the disease. Mortality rates can be as high as 50%. After some time however, the disease will have a less explosive character, the severity of the symptoms will decline and many animals will recover

Table I
Number of outbreaks of contagious bovine pleuropneumonia in a sample of Member Countries of the Pan African programme for the Control of Epizootics, 1995-2002

Country	Number of outbreaks per year								Total	Percentage of total
	1995	1996	1997	1998	1999	2000	2001	2002		
Burkina Faso	24	33	35	42	16	20	10	12	192	7.4
Chad	1	5	2	2	4	n.a.	n.a.	3	17	0.7
Côte d'Ivoire	12	11	10	8	11	7	8	5	72	2.8
Ethiopia	48	96	43	187	94	56	27	32	583	22.3
Ghana	1	5	49	51	23	21	4	26	180	6.9
Guinea	50	30	36	11	6	0	1	1	135	5.2
Kenya	12	11	8	7	9	14	18	18	97	3.7
Mali	32	12	15	9	15	12	15	5	115	4.4
Mauritania	5	7	10	3	3	1	4	1	34	1.3
Niger	5	9	0	7	1	1	0	1	24	0.9
Tanzania	30	274	70	67	286	180	n.a.	15	922	35.3
Uganda	37	32	42	15	18	13	30	54	241	9.2
Total	**257**	**525**	**320**	**409**	**486**	**325**	**117**	**173**	**2,612**	**100.0**
Percentage of total	9.8	20.1	12.3	15.7	18.6	12.4	4.5	6.6	100.0	

n.a. figures not available
Source: compiled from Bidjeh (3) and Seck *et al.* (33)

or become chronic carriers. In East Africa, Rwanda, Burundi, most parts of Tanzania, southern Sudan, Ethiopia and Somalia have remained endemically infected. Neighbouring countries such as Malawi, Mozambique and Zambia are at risk. In West Africa, CBPP has become endemic in eastern Guinea (since its introduction into the north in 1974), Mali, Niger and Mauritania and is a threat to disease-free Senegal and Sierra Leone (R.S. Windsor, 1998, unpublished). In southern Africa, the presence of large endemic areas in Angola and Zambia constitutes a potential risk to Zimbabwe, Lesotho, Swaziland, Botswana and South Africa.

Morbidity

Morbidity refers to the proportion of animals affected in a given population. It includes prevalence and incidence, both of which measure the risk that a susceptible animal in a population has of contracting a disease (32, 37).

Morbidity rates for CBPP vary significantly between herds. Complement fixation test (CFT) results obtained from field surveys differ significantly from one study to another. For example, McDermott *et al.* (17) reported a CBPP CFT seropositive rate of 8.1% in Sudan. Using the standard procedure of the Kenya Veterinary Laboratory and an antigen from the Muguga (Kenya) Veterinary Research Laboratory to test sera, Zessin and Baumann (45) reported an infection rate of 8.3% among cattle in Sudan. Other surveys reveal rates above 25% in Chad, Ethiopia, Guinea and Tanzania (15, 16, 18, 26). Rates below 5% have been reported in Burkina Faso and Uganda (4, 15).

Prevalence and incidence

The prevalence of CBPP is the number of infections (old and new) that occur in a given cattle population at a given time. Incidence is the number of new cases that occur in a known population over a specific time period. Like prevalence, incidence refers to the number of cattle infected expressed in relation to the number of cattle at risk. The prevalence and incidence of CBPP vary according to the cattle production system concerned. Prevalence rates tend to be higher in extensive cattle production systems compared to more intensive dairy and beef production systems where animals are confined. In Chad, Maho (18) estimated a CBPP prevalence rate of 1.6% for cattle raised in a transhumance farming system and a rate of 1.2% for cattle raised in agro-pastoral production systems. In Nigeria, Aliyu *et al.* (2) estimated a prevalence rate of 0.29% from post-mortem examinations of lesions in 81 national abattoirs. Nawathe (27) also estimated a prevalence rate of 0.51% in Nigeria, while Kane (15) reported rates of 2.9% for Burkina Faso, 5.4% for Mauritania and 10.5% for Mali. Wanyoike (40) and Fikru (6) reported prevalence rates of 2.8% and 4.0% in Kenya and Ethiopia respectively.

Mortality

Outbreaks of CBPP have been associated with various levels of mortality. In endemic situations mortality rates are generally low. However, higher mortality rates are not uncommon. In its acute form, the mortality rate can reach 50% (21). Mortality rates above 10% have been reported in Guinea (15) and Ethiopia (16). Rates between 5% and 10%

have been reported in Chad and Côte d'Ivoire (15), while rates below 5% have been reported in Tanzania, Uganda, Burkina Faso, Ghana and Mali (4, 15, 26, 39).

Control measures

There are four essential tools in CBPP control and eradication. These are movement control, stamping out, vaccination, and treatment. Each control measure acts by reducing the effective reproductive number of the agent in the population. However, not every country uses all of these control measures. The current policy advocated by AU-IBAR for the control of CBPP is as follows:

– collection of epidemiological data and information to determine and detect foci of infection

– effective control of animal movements from and towards these foci

– mass vaccination of cattle regularly for at least five consecutive years

– repeat vaccination of the same cattle each year.

This implies close to 100% vaccination of all cattle twice a year for five years in addition to effective movement control.

Socio-economic conditions in many African countries have changed drastically in the last two decades. Many African governments are facing acute economic and financial problems that have affected their ability to fund programmes of national or regional importance in the animal health field. Livestock and animal health budgets are already small and are being cut further; this makes it necessary for countries to focus on less expensive control strategies. Control strategies involving movement control and stamping out are considered too costly and logistically difficult to apply. Many governments cannot afford the cost of compensation to the cattle owners whose cattle are slaughtered and cannot logistically police national borders that stretch for thousands of kilometres. This leaves vaccination and treatment as the main possibilities for CBPP control.

During the 1980s and 1990s CBPP control benefited significantly from the PARC, which promoted combined rinderpest and CBPP vaccination. When the programme came to an end in 1999, many countries also stopped the use of the combined vaccine. However, some countries continue to carry out annual CBPP vaccinations using the T1/44 and T1/SR vaccines. These vaccines are not 100% efficacious and confer immunity for a relatively short period of time. Mariner *et al.* (19) tested the impact of mass immunisation on the persistence of infection (herd level prevalence) and found that vaccination reduced the percentage of herds persistently infected by 53% to 81%. Efficacy trials using the T1/44 vaccine strain conducted at 12 to 15 months post vaccination found a protection against macroscopic pathologic lesions of between 66% and 75% (10, 20, 41). Another trial involving the T1/44 strain in cattle challenged two years post vaccination found a protection of 80% (42). Based on data collected in nine countries in West Africa, the average CBPP vaccine coverage varied from 23% in 1994 to 47% in 1998. Notwithstanding the low efficacy of available vaccines and the low vaccine coverage, vaccination remains one of the control strategies of choice in Africa.

Antibiotic treatment of clinical CBPP cases is now standard field practice in many African countries and veterinarians, livestock owners and Community Animal Health Workers attest to its beneficial effects. Effective control of CBPP using a feasible treatment regime can reduce transmission by decreasing the duration of infection and the effective reproductive number. Recent studies by Mariner *et al.* (19) reveal that using treatment to reduce the infectious period by 50% resulted in a 64% reduction in mortality and a reduction in the prevalence of infected herds from 75.4% to 33.2%. The disease effects of CBPP can therefore be reduced by at least half when an appropriate treatment regime is used.

It is intuitively probable that the best approach to the control of CBPP would be to regularly vaccinate cattle in endemically infected areas or those at risk of being infected while treating and, if possible, isolating individual animals when they develop clinical disease. In this way the benefits of both vaccination (creation of high levels of herd immunity) and treatment (enabling animals that would otherwise die or be seriously debilitated to recover) would hopefully act synergistically to reduce losses. In view of this, it seems prudent to enable cattle owners to vaccinate and, where necessary, treat their animals to control CBPP. However, some form of management of the movement of cattle from infected areas to areas that are free would favour better control than vaccination and treatment alone.

Due to lack of data on movement control, this estimation of the economic impact of CBPP only took into account CBPP control by vaccination and treatment. The authors assumed a vaccination policy that involves a coverage of 80% over a five-year period with a vaccine of 65% efficacy. The authors selected this level of coverage because first, it is unlikely that all cattle in any country could be consistently vaccinated and secondly, most countries have zones within the country where vaccination is not traditionally practiced because CBPP has little or no impact in those zones. With regard to treatment, the authors found it unlikely that all cattle owners would identify clinical disease and so they assumed that 80% of all the clinical cases would be treated.

Economic impact

Estimates provided by the Food and Agriculture Organization (7) indicate that animal diseases cause losses of up to 30% of the annual livestock output in developing countries. The economic impact of this on the economies of developing countries is phenomenal. Contagious bovine pleuropneumonia is considered to be a disease of economic significance because of its ability to:

a) compromise food security through loss of protein and draft power

b) reduce output

c) increase production costs due to costs of disease control

d) disrupt livestock/product trade

e) inhibit sustained investment in livestock production

f) cause pain and suffering to animals (30).

The financial and economic losses it causes to cattle owners and to the nation, the associated socio-economic implications of these losses and the economy-wide impacts (resulting from reduced export earnings and a decline in economic activity in those industries that depend on cattle and their products), mean that the disease cannot be left uncontrolled.

Masiga *et al.* (22) estimated the annual losses directly or indirectly attributable to CBPP to be around US$ 2 billion. For some countries, the losses can disrupt the entire livestock sub-sector and other economic sectors that depend on it. In Botswana, Townsend *et al.* (38) estimated that a generalised outbreak of CBPP would result in a closure of its access to the European Union (EU) market and that the economy-wide effects of such a closure would be a 60% decline in beef and other export products. Using a social accounting matrix framework, they estimated the total cost to the Botswana economy to be 1 billion pulas (US$ 350 million). In Nigeria, Osiyemi (28) reported economic losses due to CBPP of US$ 3.6 million. In the northern part of Nigeria, Egwu *et al.* (5) estimated the direct economic cost of CBPP to be US$ 1.5 million.

Data and method of analysis

The input data on epidemiological and economic parameters and their sources are presented in Table II. The epidemiological data were collected from CBPP field studies conducted in countries in Central, East and West Africa (1, 6, 9, 11, 15, 18, 26, 40) and from a model on the dynamics of CBPP transmission in East Africa (19). The data on production and reproduction parameters (e.g. calving rate, milk and beef production, herd composition) as well as economic parameters were derived both from the literature and expert opinion.

A spreadsheet model was developed in Excel for Windows (Microsoft Excel®, 2000) and the data in Table II were used to estimate the economic impact of CBPP. Benefit–cost analysis was also carried out to determine returns to investments in CBPP control.

The economic impact of CBPP was estimated in terms of its economic cost. The latter depicts the relationship between the value of output loss and the cost of disease control. Total economic cost (C) was obtained by summing the value of the direct and indirect production losses (L) resulting from mortality and morbidity and the cost of control (E), represented as:

$$C = L + E$$

Direct production losses were considered as reductions in cattle numbers, beef, milk and draft power while costs of control were considered as the cost of vaccination and antibiotic treatment. Indirect losses resulting from reduced fertility, lost market opportunities through trade bans, quarantine costs and delayed marketing (25) were not considered due to data limitations.

Mortality losses

Mortality losses were estimated by applying the CBPP-specific mortality rate to each class of cattle at risk (three classes of cattle were considered: calves, adult males and reproductive females; their respective herd compositions were used to estimate the number of cattle in each class). The latter was derived as the product of the effective contact rate and the number of cattle in CBPP-infected areas. Considering that cattle production in each of the countries considered involves large pastoral communities, the effective contact rate estimated by Mariner *et al.* (19) for pastoral transhumant production systems in East Africa was used and extrapolated to all the other countries.

Morbidity losses

Reductions in the production of milk, beef and draft power were considered as morbidity losses. The loss in milk was estimated from two components:

a) reductions due to dead cows that no longer produce milk

b) reductions due to diseased milk cows that do not produce the same quantity of milk as before.

In the former case, the CBPP-specific mortality rate was applied to the proportion of reproductive females that are at risk in order to determine the number of dead cows.

Table II
Epidemiological and economic parameters used in the spreadsheet model

Parameters	Burkina Faso	Chad	Côte d'Ivoire	Ethiopia	Ghana	Guinea	Kenya	Mali	Mauritania	Niger	Tanzania	Uganda
National cattle population (× 1,000) (a)	5,200	6,400	1,460	38,103	1,365	3,285	12,000	7,500	1,600	2,260	17,800	6,100
Proportion of cattle population in endemic areas (b)	0.4	0.45	0.55	0.42	0.45	0.55	0.4	0.45	0.45	0.45	0.25	0.4
Proportion of cattle population at risk (b)	0.376	0.376	0.376	0.35	0.376	0.376	0.4	0.376	0.376	0.376	0.4	0.4
Annual disease incidence (% of population at risk) (b)	0.029	0.016	0.129	0.04	0.02	0.02	0.028	0.105	0.054	0.105	0.028	0.028
Effective contact rate (c)	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Rate of recovery (c)	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045
Transition rate from exposed to infectious state (c)	0.0357	0.0357	0.0357	0.0357	0.0357	0.0357	0.0357	0.0357	0.0357	0.0357	0.0357	0.0357
Immunisation rate (c)	0.661	0.661	0.661	0.661	0.661	0.661	0.661	0.661	0.661	0.661	0.661	0.661
Rate of loss of vaccinal immunity (c)	0.00091	0.000913	0.000913	0.000913	0.000913	0.00091	0.00091	0.00091	0.000913	0.00091	0.000913	0.00091
Rate of recovery from infection (c)	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045
Length of infectious and carrier states (days) (c)	183	183	183	183	183	183	183	183	183	183	183	183
Vaccine efficacy (%) (c)	65	65	65	65	65	65	65	65	65	65	65	65
Contagious bovine pleuropneumonia persistence rate (c)	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044
Proportion of reproductive females (d)	0.38	0.38	0.38	0.4	0.38	0.38	0.4	0.38	0.38	0.38	0.4	0.4
Proportion of breeding females (d)	0.65	0.65	0.65	0.55	0.65	0.65	0.55	0.65	0.65	0.65	0.55	0.55
Calving rate (%) (d)	60	60	60	60	60	60	60	60	60	60	60	60
Milk yield (litres/day) (e)	1.8	1.8	1.8	1.8	1.8	1.8	2	1.8	1.8	1.8	1.8	1.8
Lactation length (days/year) (e)	210	210	210	210	210	210	220	210	220	220	220	220
Proportion of calves (d)	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Proportion of adult males (d)	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
Proportion of beef cattle (d)	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62
Beef production calves (kg/head)	55	60	70	54	63	55	82	65	60	68	54	75
Beef production adults (kg/head) (a)	110	120	139	108	125	109	163	130	120	135	107	150
Weight gain calves (kg/day) (f)	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
Weight gain adults (kg/day) (f)	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063
Proportion of oxen (d)	0.20	0.20	0.20	0.15	0.20	0.20	0.15	0.20	0.20	0.20	0.15	0.15
Oxen work (days/year) (e)	120	120	120	120	120	120	120	120	120	120	120	120
Mortality (% of clinical cases):												
Calves and yealings (g)	0.1	0.15	0.15	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Adult cattle (g)	0.05	0.075	0.075	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Milk loss (proportion of clinical cases of milking cows losing milk) (e)	0.8	0.8	0.8	0.8	0.8	0.8	0.6	0.8	0.8	0.8	0.7	0.7
Milk loss (% of milk lost) (e)	90	90	90	90	90	90	90	90	90	90	90	90
Loss of weight (proportion of clinical cases) (e):												
Calves and yealings (e)	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.7	0.7
Adult beef cattle (e)	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.7	0.7
Loss of traction (proportion of clinical cases) (e)	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.7	0.7
Cattle vaccinated (proportion of cattle at risk) (c)	0.661	0.661	0.661	0.661	0.661	0.661	0.661	0.661	0.661	0.661	0.661	0.661
Cattle treated (proportion of clinical cases) (e)	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Prices/values used (euros):												
Milk (euro/litre) (e)	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.5	0.5	0.5	0.5	0.5
Beef (euro/kg) (e)	2	2	2	2	2	2	2.5	2	2	2	2	2
Cost of dairy cow mortality (euro/head) (e)	350	350	350	350	350	350	400	350	350	350	350	350
Cost of beef cow mortality (euro/head) (e)	260	260	260	260	300	260	300	260	260	260	260	260
Cost of dead calves (euro/head) (e)	130	130	130	130	150	130	150	130	130	130	130	130
Cost of vaccination (euro/head) (h)	0.48	0.71	0.71	0.27	0.58	0.46	0.32	0.5	0.48	0.4	0.3	0.4
Cost of treatment (euro/clinical case) (e)	12	12	12	12	12	12	12	12	12	12	12	12
Cost of draft power (euro/day) (e)	0.32	0.32	0.32	0.5	0.32	0.32	0.5	0.32	0.32	0.32	0.5	0.5

a) Food and Agriculture Organization (8)
b) Byekwaso and Nyamutale (4), Kane (15), Laval (16), Maho (18), Msami (26), Turkson (39), Wanyoike (40)
c) Mariner *et al.* (19)
d) GRM International (13), Ministry of Agriculture, Livestock Development and Marketing (24), Ministry of Agriculture (23), Government of the Republic of Uganda (12)
e) Expert opinion
f) Laval (16)
g) Tambi *et al.* (34)
h) Tambi *et al.* (35)

This was then multiplied by the calving rate to establish the number of dead cows that no longer produce milk. The product was again multiplied by the daily milk yield per cow and the lactation length as reported in the literature.

In the latter case, the reduction in milk production was estimated from the number of infected reproductive females. These are the animals that show clinical signs, estimated as the product of the number of reproductive females at risk and the transition rate from exposed to the state of infection. The rate of transition from exposed to state of infection was obtained from Mariner *et al.* (19). This figure was multiplied by the calving rate to determine the number of infectious cows that lose milk. Based on expert opinion, infected milk cows were assumed to lose 90% of their milk during the entire lactation period.

The loss in beef production by infected animals was used as a proxy for the absence of weight gain since diseased animals are assumed not to gain weight. They may even lose weight depending upon the severity of the infection. The loss in beef production was estimated from the number of infected cattle and not from the number of dead cattle; the latter having been accounted for under mortality. The number of cattle infected was estimated by multiplying the number of calves, adult males and reproductive females at risk by the transition rate from exposed to state of infection. Infected calves were assumed to lose a daily weight of 0.11 kg while infected adult males and reproductive females were assumed to lose a daily weight of 0.063 kg (16) for a period of 183 days. This is the duration of infection that includes the combined length of infectious and carrier states. Studies on the length of illness indicate that clinical disease generally persists for a period ranging from 4 to 12 months, with an average of 6 months (14, 19, 29). Due to varying levels of immunity and disease challenge, not all the cattle were assumed to lose weight. In endemic situations expert opinion suggests that 80% of the infected animals will lose weight.

The loss in draft power was estimated as the product of the number of infected oxen and the number of workdays per year. The former was obtained by multiplying the proportion of oxen in the herd by the number of oxen with clinical disease. All physical losses in cattle, beef, milk, and draft power were valued using market prices.

Disease control cost

Many governments in Africa are currently using public funds to carry out vaccination campaigns against CBPP. Thomson (36) has stated that the cost of controlling CBPP using a regional mass vaccination programme in countries of Central, Eastern and Western Africa is quite high (300 million euros) and that even if half of this cost were to be recovered from cattle owners, many governments will still not be able to afford the rest. Tambi *et al.* (35) estimated the cost of CBPP control by vaccination in ten African countries during the PARC period and found unit costs to vary from 0.27 euro in Ethiopia to 0.71 euro in Côte d'Ivoire, with an average of 0.42 euro.

In many countries, treatment of clinical disease is at the exclusive cost of cattle owners, despite the fact that the efficacy of treatment is largely unknown as are the epidemiological consequences. Studies into this issue are ongoing at AU-IBAR and the results are anxiously awaited. Pending the outcome of these studies, it is intuitive to assume that treatment costs would vary among cattle owners between and within countries depending on the type of antibiotic used, the dosage and method of application and the source of the product. Among the veterinary experts consulted in some of the countries, there was general consensus that the cost of antibiotic treatment was within the range of 10 to 14 euros per head of cattle.

In the absence of other cost estimates on CBPP vaccination in any of the countries considered, the cost estimates provided in Tambi *et al.* (35) were assumed to still be relevant for the purposes of estimating the economic impact of CBPP. In terms of treatment costs, an average cost of 12 euros per head of cattle was assumed.

Benefits

Two types of benefits were considered – direct and indirect benefits. Direct benefits were estimated from:

a) avoided production losses due to mortality and morbidity

b) control cost savings.

Appropriate vaccination and/or treatment eliminates or reduces mortality and morbidity losses. The surviving animal is considered a benefit, and its value is measured in terms of its replacement cost. A CBPP-infected animal experiences a loss in productivity due to poor condition, lowered milk production, decreased fertility and a reduction in work force. Elimination of the disease permits the animal to achieve its potential productivity. However, because of the varying response of individual animals to infection, these productivity gains may vary. In terms of eradication, successful eradication of CBPP eliminates any future control cost (vaccination, treatment, quarantine, movement control and surveillance) thus providing benefits to producers and the nation.

Indirect benefits accrue when the control or eradication of CBPP opens up avenues for renewed or initial trade with countries or regions that was previously not possible because of the disease. For example, the outbreak of CBPP in Botswana in 1994 led to a closure of its access to the

EU market, resulting in a 60% decline in beef and other export products. This was a loss of economic benefits to both potential sellers and buyers. The eradication of CBPP by slaughter and compensation in 1995 led to a re-opening of this lucrative market, thus making it possible for both producers and consumers to reap the benefits of export trade. However, the cost of enforcing movement control and quarantine procedures is significant and this curtails the benefits.

This benefit–cost analysis was limited to the direct benefits arising from savings in the cost of control and the mortality and morbidity losses avoided. It assumed a 'with control' versus a 'without control' programme for CBPP. Costs and benefits were measured as the incremental changes between the 'with control' programme and the 'without control' option. Incremental cost was considered as the difference in expenditure incurred between the 'with control' programme and the 'without control' (cost savings) option. Incremental benefit on the other hand was the difference in production value (avoided losses) obtained with the control programme and the value obtained without a control programme (losses).

Benefit–cost analysis was used to compare the value of the incremental benefits with the value of the incremental costs in order to establish whether or not CBPP control is economically viable as follows:

$$BCR = [\sum B_t / (1 + r)^t] / [\sum C_t /(1 + r)^t]$$

where BCR is the benefit–cost ratio, B is the benefit accruing from the control programme, C is the cost of disease control, r is the discount rate and t is the number of years in the future. A benefit–cost ratio greater than one indicates that CBPP control is economically viable whereas a value below one suggests otherwise.

Results and discussion

Estimates of the economic impact of CBPP are presented in this section. First, the physical losses are presented in terms of cattle deaths and reductions in beef, milk and draft power. This is followed by the monetary value of these losses. Next is the economic cost of CBPP, estimated as the combined value of lost production and the cost of disease control. Finally, the benefits and costs of CBPP control are presented.

Production losses

Production losses in cattle and cattle products are presented in Table III. The total number of dead cattle in all twelve countries was estimated at about 30,900 head, giving an average of 2,573 head per country (range from 474 in Ghana to 10,112 in Ethiopia). The estimated total loss in beef and milk was 3,810 MT (318 MT per country) and 24,132 MT (2,011 MT per country) respectively. The loss in draft power was estimated at 445,000 workdays per country.

Table III
Estimated annual losses in cattle and cattle products caused by contagious bovine pleuropneumonia

Country	Losses			
	Cattle deaths (number)	Beef (metric tonnes)	Milk (metric tonnes)	Draught power (1,000 ox days)
Burkina Faso	1,606	216	1,312	365
Chad	3,335	299	1,927	506
Côte d'Ivoire	930	83	537	141
Ethiopia	10,112	1,350	8,500	1,645
Ghana	474	64	387	108
Guinea	1,395	188	1,140	317
Kenya	3,033	373	2,316	494
Mali	2,606	350	2,129	593
Mauritania	556	75	476	126
Niger	785	106	672	179
Tanzania	4,499	526	3,527	641
Uganda	1,542	180	1,209	220
Total	**30,873**	**3,810**	**24,132**	**5,335**
Average	2,573	318	2,011	445

The total value of output loss incurred by all twelve countries was estimated at 30.1 million euros, giving an average of 2.5 million euros per country (Table IV). The value of output loss ranged from 0.5 million euros for Ghana to 10.3 million euros for Ethiopia. The losses due to morbidity (productivity reductions in beef, milk and draft power) accounted for 74% of the total value of loss while mortality losses accounted for 26%.

Economic cost

The total economic cost of CBPP in the twelve countries was estimated at about 45 million euros. The average economic cost per country was 3.7 million euros (Table V). This is close to the US$ 3.6 million (2.8 million euros) reported by Osiyemi (28) as the economic cost of CBPP in Nigeria. Our estimates for Chad and Mali do not significantly differ from those of Osiyemi. However, estimates for Ethiopia, Kenya and Tanzania are significantly higher while those for Côte d'Ivoire, Ghana, Mauritania and Niger are significantly lower. Egwu *et al.* (5) reported an economic cost of CBPP in northern Nigeria of US$ 1.5 million (1.1 million euros), which is similar to the cost obtained for Côte d'Ivoire, Niger and Uganda.

Table IV
Estimated value of annual losses in cattle and cattle products caused by contagious bovine pleuropneumonia

Country	Value of losses (1,000 euros)				
	Cattle deaths	Beef	Milk	Animal power	Total
Burkina Faso	397	432	656	117	1,601
Chad	824	598	964	162	2,547
Côte d'Ivoire	230	167	269	45	710
Ethiopia	2,521	2,700	4,250	823	10,294
Ghana	124	128	194	35	480
Guinea	344	375	570	102	1,391
Kenya	867	933	1,390	247	3,437
Mali	643	701	1,064	190	2,598
Mauritania	137	149	238	40	565
Niger	194	211	336	57	798
Tanzania	1,121	1,051	1,764	320	4,256
Uganda	384	360	604	110	1,459
Total	**7,786**	**7,805**	**12,299**	**2,248**	**30,136**
Average	649	650	1,025	187	2,511

Table V
Estimated annual economic cost of contagious bovine pleuropneumonia (1,000 euros)

Country	Value of production losses	Disease control costs		Total economic cost
		Vaccination	Treatment	
Burkina Faso	1,601	660	178	2,439
Chad	2,547	1,333	247	4,126
Côte d'Ivoire	710	377	69	1,156
Ethiopia	10,294	3,597	1,097	14,987
Ghana	480	235	53	768
Guinea	1,391	549	155	2,095
Kenya	3,437	1,015	329	4,781
Mali	2,598	1,115	289	4,003
Mauritania	565	228	62	855
Niger	798	323	87	1,208
Tanzania	4,256	1,412	488	6,156
Uganda	1,459	645	167	2,271
Total	**30,136**	**11,489**	**3,221**	**44,845**
Average	2,511	957	268	3,737

It is important to note that two thirds of the economic cost of CBPP was due to losses arising from morbidity and mortality while the remaining one third was due to the cost of disease control. The total disease control cost was estimated at 14.7 million euros with the cost of vaccination accounting for 78% and the cost of treatment accounting for 22%. These estimates suggest that by spending 14.7 million euros to control CBPP in the countries concerned, a net loss of about 30 million euros would be avoided. On average, each country would avoid a loss of about 2.5 million euros if CBPP were to be controlled using vaccination and antibiotic treatment.

Benefit–cost ratios

Estimates of benefit–cost ratios are presented in Table VI. The avoided losses are also presented as incremental benefits together with the incremental costs and net benefits. The estimates show that an investment of 14.7 million euros in CBPP would yield a gross return of 30.1 million euros and a net benefit of 15.4 million euros. This is equivalent to a net benefit of 1.3 million euros per country. Net benefits ranged from about 200,000 euros in Ghana to 5.6 million euros in Ethiopia. The return to investment was positive in all cases with an overall benefit–cost ratio of 1.94. Benefit-cost ratios ranged from 1.61 in Chad to 2.56 in Kenya.

The estimates presented in this study reveal that CBPP control is economically beneficial. However, it should be borne in mind that the values reported are approximations of the economic costs and the benefits arising from CBPP control using vaccination and treatment only. The estimated benefits greatly underestimate the actual benefits that would be realised if other control methods such as stamping out, followed by movement control, quarantine and surveillance were used. Experience reveals that CBPP control by stamping out followed by strict movement control is the most effective and beneficial control and eradication strategy. However, because of the cost involved and the fact that many governments lack the financial

Table VI
Estimates of annual benefits and costs of contagious bovine pleuropneumonia control (1,000 euros)

Country	Incremental benefits	Incremental costs	Net benefits	Benefit–cost ratio
Burkina Faso	1,601	838	763	1.91
Chad	2,547	1,579	968	1.61
Côte d'Ivoire	710	446	265	1.59
Ethiopia	10,294	4,693	5,600	2.19
Ghana	480	288	192	1.66
Guinea	1,391	704	687	1.98
Kenya	3,437	1,344	2,093	2.56
Mali	2,598	1,405	1,194	1.85
Mauritania	565	290	275	1.95
Niger	798	410	388	1.95
Tanzania	4,256	1,900	2,357	2.24
Uganda	1,459	812	646	1.80
Total	**30,136**	**14,709**	**15,428**	
Average	2,511	1,226	1,286	1.94

resources to compensate farmers, this option is currently not feasible in Africa. Even if countries were able to bear the cost, preventing cattle from re-infection through effective movement control would still be difficult for many countries with borders that stretch for thousands of kilometres. With the current pastoral system of production, levels of movement control consistent with sustainable pastoral livelihoods are unlikely to have a major impact on the incidence of CBPP and, in the current socio-economic situation, movement control is unlikely to contribute significantly to CBPP eradication.

Conclusion

Contagious bovine pleuropneumonia is a disease that causes high morbidity and mortality losses to cattle. The financial implications of these losses are of great significance to both cattle owners and to the nation. Control of CBPP is therefore important as a way to salvage the losses and increase the incomes of cattle owners.

This analysis was undertaken to estimate the economic cost of CBPP and the benefits of its control in twelve sub-Saharan African countries (Burkina Faso, Chad, Côte d'Ivoire, Ethiopia, Ghana, Guinea, Kenya, Mali, Mauritania, Niger, Tanzania and Uganda). A spreadsheet economic model was developed in Microsoft Excel and CBPP epidemiological and economic data were used to estimate the impact of CBPP under endemic conditions.

Economic cost was evaluated in terms of the direct and indirect production losses attributed to morbidity and mortality plus the disease control cost. Production losses comprised of cattle deaths and reductions in beef, milk and draft power. The monetary value of production losses for all twelve countries was estimated at 30.1 million euros (2.5 million euros per country) while the total economic cost was estimated at 44.8 million euros (3.7 million euros per country). By investing 14.7 million euros to control CBPP in the countries concerned, a loss of 30 million euros could be avoided. Each country would avoid a loss of about 2.5 million euros if CBPP were to be controlled using vaccination and antibiotic treatment. Benefit–cost analysis revealed that CBPP control using vaccination and antibiotic treatment was economically beneficial as all the benefit–cost ratios were positive (range from 1.61 in Ghana to 2.56 in Kenya).

It should be noted that the values presented in this study are mainly approximations of the economic impact of CBPP. The figures greatly underestimate the real economic impact of CBPP considering that only two control strategies were considered. However, they underscore the economic interest in controlling CBPP in each of the countries. In view of the shortcomings of this study, there is a need for a more detailed study to derive reliable data on the economic impact of CBPP. Such a study will need to consider other control strategies such as stamping out, movement control, surveillance and quarantine and will need to undertake sensitivity analysis of the different parameters.

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Une estimation des conséquences économiques de la péripneumonie contagieuse bovine en Afrique

N.E. Tambi, W.O. Maina & C. Ndi

Résumé

La péripneumonie contagieuse bovine (PPCB) occasionne des taux élevés de morbidité et de mortalité dans les élevages de bovins. Les conséquences financières de ces pertes sont souvent très lourdes pour les éleveurs. Il convient donc de maîtriser la PPCB afin de limiter ces pertes et d'accroître les revenus des éleveurs. Dans la présente étude, le coût de la PPCB et les avantages de sa prophylaxie ont été évalués dans douze pays d'Afrique sub-saharienne, en utilisant un modèle économique construit sur une feuille de calcul Microsoft Excel®. Les pertes directes dues à la morbidité et à la mortalité ont été estimées à 30 millions d'euros (soit 2,5 millions d'euros par pays) tandis que le coût économique total (pertes de production directes et indirectes et coût de la prophylaxie) était évalué à 44,8 millions d'euros (soit 3,7 millions d'euros par pays). Un investissement de 14,7 millions d'euros dans la prophylaxie de la PPCB permettrait d'empêcher des pertes de 30 millions d'euros. Le rendement de la prophylaxie de la PCCB s'avère positif, avec un ratio avantages-coûts compris entre 1,61 (au Ghana) et 2,56 (au Kenya).

Mots-clés
Afrique sub-saharienne – Analyse avantages-coûts – Impact économique – Péripneumonie contagieuse bovine – Pertes de productivité – Prophylaxie.

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Estimación de las consecuencias económicas de la perineumonía contagiosa bovina en África

N.E. Tambi, W.O. Maina & C. Ndi

Resumen
La perineumonía contagiosa bovina (PNCB) es una enfermedad que provoca grandes pérdidas ligadas a sus índices de morbilidad y mortalidad en el ganado bovino. Las consecuencias económicas de esas pérdidas son muy gravosas para los ganaderos. De ahí la importancia que reviste para ellos la lucha contra la enfermedad para ahorrarse pérdidas y obtener ingresos más elevados. Los autores estimaron el coste económico de la enfermedad y los beneficios que reporta su control en doce países del África subsahariana, utilizando para ello un modelo económico elaborado con una hoja de cálculo Microsoft Excel®. Las pérdidas por morbilidad y mortalidad se cifraron en 30 millones de euros (2,5 millones por país), mientras que el coste económico total (pérdidas directas e indirectas de producción más coste de las medidas de control zoosanitario) ascendían a 44,8 millones (3.7 millones por país). Una inversión de 14,7 millones de euros en el control de la PNCB evitaría pérdidas por valor de 30 millones, o dicho de otro modo, reportaría beneficios económicos, con un cociente entre beneficios y costos que oscila entre 1,61 (Ghana) y 2,56 (Kenya).

Palabras clave
África subsahariana – Análisis de la relación beneficios-costos – Consecuencias económicas – Control de enfermedades – Pérdidas de producción – Perineumonía contagiosa bovina.

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