Organization of African Unity (OAU)
Inter African Bureau for Animal Resources (IBAR)
Pan African programme for the Control of Epizootic (PACE)

Economic impacts of Contagious Bovine Pleuropneumonia (CBPP) in Africa

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February 2004

Economics Unit

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Summary

CBPP is a disease of economic importance because of the high morbidity and mortality losses it causes 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.

Before a control program is implemented however, it is important to evaluate the economic impacts of CBPP and determine whether a control program would be economically viable. This analysis was undertaken to evaluate the economic cost of CBPP and estimate returns to investments in its control in a sample of twelve countries (Burkina Faso, Chad, Cote 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 disease control expenditures. Production losses comprised of cattle deaths and reductions in beef, milk and animal power. The estimated monetary value of production losses averaged 2.3 million Euros per country for endemic CBPP and 3.8 million Euros for epidemic CBPP. Estimated economic cost averaged 3.4 million and 5.3 million Euros for endemic and epidemic CBPP respectively. Ethiopia, Kenya and Mali each incur economic costs in excess of 5 million Euros.

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. Effective control of CBPP is economically viable with average net benefits that exceed 1.2 million Euros per country in the case of endemic CBPP and 2.3 million Euros in the case of epidemic CBPP. Indeed, control of CBPP during epidemic outbreaks has potential for greater benefits as the returns to

1. Introduction

Contagious Bovine Pleuropneumonia (CBPP) is a disease of cattle that affects production through mortality and reduction in productivity. It also retards genetic improvement and limits working ability of cattle. CBPP has been identified by the Pan African program for the Control of Epizootics (PACE) as the second most important trans-boundary disease in Africa after rinderpest. CBPP is now a major focus of activity for the program. However, before the program embarks on a control strategy, it is essential that the economic importance of the disease be established and the returns to investments in control be evaluated.

Unlike some parasitic diseases whose impacts are confined to a single farm, the impact of CBPP is often felt at and beyond a single farm. The occurrence of CBPP in one herd is a threat to neighboring herds in a production system where there is little or no control of cattle movements. The control of CBPP therefore goes beyond the ability of the single farmer, and needs to be looked at from a national or regional viewpoint. The economic impacts of CBPP need not be confined to the farm level only, but also to the national and regional level.

A framework for analyzing the economic impacts of CBPP needs to recognize the fact that the disease reduces cattle products and the productivity of cattle, making farm incomes to decline. The latter puts a downward pressure on demand for both farm inputs and consumption goods. However, effective control of CBPP increases cattle productivity and cattle products, which enhance human welfare through higher incomes, improved nutrition and health. Governed by the institutional, political, biophysical, economic and socio-cultural environments, increased output and incomes also affect the production system, resource use, the eco-system structure and function. Since changes in resource use in turn affect human welfare through consumption, assessing these impacts requires that CBPP be viewed from a wider context of the economy.

It is with the preceding in mind that we examine the economic impacts of CBPP in a number of countries. We have used a spreadsheet model developed in Excel (Microsoft Excel, 2000) to estimate the economic cost of CBPP and the possible returns to investments in its control. The analysis uses epidemiological and economic data from a number of studies to evaluate the economic impacts of the disease under endemic and epidemic conditions.

2. The disease

CBPP is an infectious disease of the lungs in cattle caused by a bacterium, *Mycoplasma mycoides* var.*mycoides* (Radostitis *et al.*, 2000). CBPP is spread almost exclusively by direct contact between animals although indirect spread is also possible (Windsor and Masiga, 1977). CBPP is classified as a list

"A" disease by the OIE (OIE, 2003). When the disease spreads for the first time within a sensitive cattle population, it generally causes high mortality.

2.1 Population at risk

Cattle (both *Bos Taurus* and *Bos indicus*) and to a lesser extent the Australian water buffalo (*Bubalus arnae*) are the only animal species affected by CBPP. The African water buffalo (*Syncerus caffer*) is refractory to CBPP, implying that in Africa, there is no reservoir of infection among other animals including wildlife.

2.2 Outbreaks and distribution

The first outbreak of CBPP in Africa occurred in the 1850s through cattle imports from the Netherlands to South Africa. The disease quickly spread to neighboring countries. In 1904 it was eradicated from Zimbabwe followed by South Africa in 1924 and Botswana in 1939. Angola and Namibia never managed to eradicate the disease. Today, CBPP is present in Central, East, West and parts of Southern Africa but only sporadically present in North Africa. O.I.E. reports indicate that there are about 27 sub-Saharan African countries with cases of CBPP. In the 1970s and 1980s, fewer countries experienced CBPP outbreaks, due in part, to the combined vaccination against rinderpest and CBPP under the Pan African Rinderpest Campaign (PARC). More countries began to experience CBPP outbreaks beginning in 1995 soon after some countries stopped vaccination.

Of the 27 countries reporting cases of CBPP between 1987 and 2000, 12 were in West Africa and two in Central Africa. Half of the 3,000 CBPP outbreaks officially reported during this period occurred in West Africa. Guinea-Conakry reported 30% of the total regional outbreaks followed by Nigeria with 26%. Mali reported a total of 158 outbreaks and 324 deaths from 1987 to 1997.

Tanzania is the single most important country affected in East Africa with 40% of the regional outbreaks and 87% of the deaths. Almost all of these outbreaks and deaths occurred after 1995 when the disease was reintroduced from Kenya (Windsor, 1998). In Southern Africa, Angola and Namibia are the hardest hit both in outbreaks and cattle deaths. Warfare in South West Africa and Angola has made it difficult to eradicate the disease from these countries.

2.3 Epidemiological trends

CBPP 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. After eradicating CBPP in 1939, the disease re-appeared in 1994. In 1995 the Government of Botswana eradicated CBPP through the slaughter of infected and in-contact stock and compensation of the owners. Other examples of epidemic outbreaks include Burundi and

Zambia in 1997; Guinea in 1995; Rwanda in 1994 and Tanzania in 1990, 1992 and 1994. Masiga *et al.* (1998) attributed these outbreaks to uncontrolled entry of cattle from known infected populations; a reflection of inadequate movement control, poor disease surveillance and vigilance.

The second trend of CBPP outbreaks is reflected in the increased number of areas that have become endemic to CBPP. Apart from Botswana, CBPP has not been properly controlled and so it has became endemic in many parts of Africa. 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 or become chronic carriers.

A country like Namibia where CBPP has been endemic for a long time posses a risk to Zambia, Zimbabwe, Lesotho, Swaziland, Botswana and South Africa. In eastern Africa, Rwanda, Burundi, most parts of Tanzania, Southern Sudan, Ethiopia and Somalia have remained endemically infected. Neighboring countries such as Malawi, Mozambique and Zambia are currently at risk. CBPP has also been 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 (Windsor, 1998).

2.3.1 Morbidity

CBPP morbidity (the proportion of animals affected in a given population) indicates the risk that an individual animal has in becoming infected. It includes prevalence (number of cases or outbreaks present in a population at a given time) and incidence (number of new cases or outbreaks that occur in a particular population in the course of a given time period), both of which measure the risk that a susceptible animal in a population has of contracting a disease (Toma, *et al.*, 1999; Putt *et al.*, 1987).

CBPP morbidity rates vary significantly between and within herds. Surveys conducted using the complement fixation test (CFT) show infection rates ranging from 1% in parts of West Africa to 70% in northern Rwanda (Masiga *et al.*, 1996). Other surveys reveal rates above 25% in Chad, Ethiopia, Guinea and Tanzania (Kane, 2002; Laval, 2001; Maho, 2001; Msami, 2001). Rates below 5% have been reported in Burkina Faso and Uganda (Byekwaso and Nyamatale, 2001; Kane, 2002).

2.3.1.1 Prevalence/incidence

The prevalence and incidence of CBPP vary according to the epidemiology of the disease as well as the cattle production system concerned. Higher rates occur during epidemics whereas in endemic situations, rates are much lower.

Prevalence rates are also higher in extensive cattle production systems compared to more intensive dairy and beef production systems where animals are confined.

In newly infected areas, prevalence can be very high – up to 90% in Ethiopia (Dejene, 1996). In epi-endemic areas of Ethiopia Desta (1997) has reported a prevalence of 48% while Laike and Roger (1997) and Gashaw (1998) have reported rates within the range of 17% to 46%. Still in epizootic areas, a prevalence rate of 12.7% has been reported in Kenya (Gitau, 2001), 12.9% in Cote d'Ivoire (Kane, 2002) and 28% in Tanzania (Msami, 2001).

In areas classified as endemic, relatively low rates of CBPP prevalence have been reported. In West Africa, Aliyu *et al.* (2000) estimated a prevalence rate of 0.29% from post morten examinations of lesions in 81 national abattoirs in Nigeria. Nawathe (1992) also estimated a prevalence rate of 0.51% in Nigeria while Kane (2002) reported rates of 2.9% for Burkina Faso, 5.4% for Mauritania and 10.5% for Mali. In East Africa, Wanyoike (1999) and Fikru (2001) reported prevalence rates of 2.8% and 4.0% in Kenya and Ethiopia respectively. Maho (2001) estimated a CBPP prevalence rate of 1.2% for cattle raised under the agro-pastoral production system in Chad and a rate of 1.6% for cattle on transhumance.

2.3.2 Mortality

CBPP outbreaks have been associated with various levels of mortality. Because of the debilitating nature of the disease, mortality rates have been relatively low, particularly in endemic situations. Higher mortality rates are however not uncommon. Mortality rates above 10% have been reported in Guinea (Kane, 2002) and Ethiopia (Laval, 2001). Rates between 5 and 10% have been reported in Chad and Cote d'Ivoire (Kane, 2002) while rates below 5% have been reported in Tanzania, Uganda, Burkina Faso, Ghana and Mali (Byekwaso and Nyamutale, 2001; Msami, 2001; Turkson, 2001; Kane, 2002).

3. Economic impacts

CBPP is a disease of economic importance because of the financial losses to farmers, the economic losses to the nation and the associated socio-cultural implications of these losses. CBPP-associated losses also have economy-wide impacts through the reduction in export earnings and the decline in economic activity in industries dependent on the cattle sub-sector.

The concept of *economic cost* is often used to measure the economic importance of a disease. For CBPP, the economic cost is measured as the sum of the *direct* and *indirect* production losses from mortality and morbidity plus the *expenditures* incurred to *control* the disease. Economic cost shows the relationship between the value of output losses and the disease control expenditures. Higher levels of disease control (treatment and prevention) expenditures often lead to reduced disease incidence and hence lower production losses and *vice versa*.

A number of studies have attempted to evaluate the economic importance of CBPP. In Botswana, Townsend *et al.* (1998) estimated that a generalized 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 closure would be a 60% decline in beef and other export products. Using a Social Accounting Matrix (SAM) framework, they estimated the total cost to the Botswana economy to be 1billion Pulas (US$350 million).

In Tanzania, Anon (2000) assessed the value of direct and indirect losses due to CBPP to be over US$50 million. This estimate was based on deaths of 250,000 head of cattle, reduced milk yields, reduced growth, loss of weight through wasting, abortions, loss of draught power and manure, and overhead costs of disease control. Mlengeya (1995) also reports that the CBPP outbreaks that occurred in Tanzania from 1990 to 1995 resulted in deaths of 14,000 cattle valued at over US$1 million.

Based on losses of cattle from CBPP in northern Nigeria, Egwu *et al.* (1996) estimated the direct economic cost of CBPP to be more than US$1.5 million. In Nigeria still, Osiyemi (1981) reported economic losses due to CBPP of US$3.6 million.

3.1 Disease effects

CBPP is both an epidemic and an endemic disease in most regions of Africa. However, the erosive losses associated with endemic CBPP are more complicated and difficult to measure than those of epizootic CBPP. Other technical difficulties also complicate the measurement of losses such as the uncertain effects of chemotherapy and restrictions on control options imposed by the poor quality of available vaccines and diagnostic tools. The ineffectiveness of alternative control measures (e.g. immunization, antibiotic treatment, stamping-out, quarantine, movement controls and surveillance) makes it equally difficult to measure the effects.

CBPP-infected animals are sometimes subject to the influences of other animal diseases as well as malnutrition, making it difficult to isolate the effects of CBPP on productivity. Also, the death of an animal and the magnitude with which the productivity of an infected animal is affected may well depend on the level of risk to which it is exposed to CBPP and whether or not it has a high level of immunity. Given the complicating nature of these influences, the disease impact depends very much on the accuracy of the parameter assumptions used.

The effects of CBPP can be measured in terms of the *direct* and *indirect* losses due to mortality and morbidity plus the *costs* of control.

Direct losses are attributed to mortality, slow growth or decrease in weight gain, reduced milk yield, vaccination and treatment costs, disease surveillance and research costs. Indirect losses are due to loss of weight and working ability, delayed marketing, reduced fertility, losses due to quarantine and lost market opportunities through trade bans (Mlengeya, 1995; Masiga *et al.*, 1995). Other indirect losses include the risk of major epidemics that occur from time to time thus making farmers to move animals away from the threat or the sale of animals to reduce their exposure to loss.

3.1.1 Effects of endemic and epidemic CBPP

The epidemiology of CBPP indicates that prevalence, incidence and mortality rates are usually higher during epidemics than when the disease has become endemic in a given area. Disease effects can therefore be expected to be greater during epidemics than in endemic conditions.

Any area within a country or region can witness an epidemic depending on a number of risk factors such as proximity to a previously infected area. Areas classified as endemic to CBPP vary from one country to another depending on the frequency of outbreaks and the duration of infection in the area.

The proportion of cattle considered to be at risk of CBPP varies depending on their distribution in the areas where outbreaks occur. In Ethiopia for example, approximately 42% of the cattle are considered to be in endemic areas, 35% of which are thought to be at risk of CBPP (Afework, 2002). In Kenya and Tanzania, 40 and 25% of the cattle are considered to be in endemic areas respectively, and about 40% of these are considered to be at risk (Gitau, 2001; Msami, 2001).

For the purposes of this analysis, cattle in CBPP-infected areas (epidemic and endemic) are divided into three classes namely, calves and yearlings below 3 years, adult males and reproductive females. Various estimates of cattle herd composition and structure are available in the literature, and vary from one country to another. For example, estimates by *GRM International* (1994) show that the Ethiopian cattle herd comprises of 32% calves and yearlings, 27% adult males and 38% reproductive females. Other studies have reported the percentage of reproductive females to be within the range of 37 to 45% (de Leeuw and Wilson, 1987; Mukasa-Mugerwa *et al.*, 1989).

Losses due to CBPP (epidemic and endemic) are measured as the number of deaths that occur per class of animal, the quantity of beef lost for each class of animal, the quantity of milk lost from reproductive females and the loss in draft power from oxen. Losses in manure, though important, are not included in this analysis because of shortcomings in the data.

3.1.1.1 *Mortality losses*

Mortality losses are estimated under two scenarios. The first involves the use of mortality rates observed under endemic situations while the second involves the use of mortality rates observed under epidemic situations. In each case, cattle deaths are calculated by applying the CBPP mortality rate to each class of cattle at risk or exposed to CBPP. Cattle exposed to CBPP are derived by applying the effective contact rate to the number of cattle available in CBPP-infected areas. The effective contact rate of 0.126 used for this purpose was simulated by Mariner (2003) from field data collected in Sudan and parts of Ethiopia.

3.1.1.2 *Milk loss*

In each scenario, milk loss due to CBPP was estimated from two components: (i) loss arising from dead cows that are no longer producing milk and (ii) loss arising from diseased milk cows that can no longer produce the same quantity of milk because of being sick.

In the former case, the CBPP specific mortality rate was applied to the percentage of reproductive females that are exposed or are at risk of CBPP to determine the number of deaths. This was then multiplied by the calving rate to establish the number of dead cows that are no longer producing milk. The product was again multiplied by the daily milk yield per cow and the lactation length as reported in the literature. In Ethiopia for example, *GRM International* (1994) followed a total of 422 complete lactations over a three-year period and reported a mean lactation length of 328 days and a mean lactation yield of 447 kg (1.36 kg/day).

In the latter case, the reduction in milk production was estimated from the number of reproductive females that are infectious to CBPP. These are the number of animals showing clinical signs; derived by multiplying the number of reproductive females at risk by the transition rate from exposed to infectious state. A rate of transition from exposed to infectious of 0.0238 was simulated by Mariner (2003) from data collected using participatory epidemiology methods and used for this purpose. This figure was multiplied by the calving rate to determine the number of infectious cows that are losing milk. Diseased milking cows were assumed to lose all of their milk during the entire lactation period.

3.1.1.3 *Beef loss*

The loss in weight gain was used as a measure of the loss in beef production because diseased animals do not gain weight and may even lose weight depending upon the severity of the infection and level of immunity. The loss in beef production was estimated from the number of cattle considered to be infectious to CBPP and not from the number of dead cattle; the latter being accounted for under mortality.

The number of infectious cattle was estimated by multiplying the number of calves and yearlings, adult males and reproductive females at risk by the transition rate from exposed to infectious state. Infectious calves and yearlings were assumed to lose a daily weight gain of 0.110 kg while infectious adult males and reproductive females were assumed to lose a daily gain of 0.063 kg (Laval, 2001) for a period of 183 days. This is the duration of infection defined to include the combined length of infectious and carrier states. Studies on the length of illness indicate that clinical disease persists for a period ranging from 4 to 12 months with an average of 6 months (Mariner, 2003; Parker, 1960; Huddart, 1960). Because of varying levels of immunity and disease challenge, not all cattle were assumed to lose their weight gain. In endemic situations 80% of the infected animals were assumed to lose their weight gain whereas in epidemic situations, all infected cattle were assumed to lose their weight gain.

3.1.1.4 Losses incurred to control disease

Controlling a disease involves expenditures in terms of finances, human and material resources. It also involves the application of appropriate technology. These constitute an expense to the farmer and to the nation as a whole and should be considered as a loss if there was no disease in the first place. Losses incurred to control CBPP include expenditures on vaccination, treatment, stamping out, quarantine, movement control and surveillance.

3.1.1.4.1 Vaccination

CBPP can be controlled by immunization using the T1/44 and T1/SR vaccines. However, these vaccines are not 100% efficacious and confer immunity only for a relatively short period of time. Mariner (2003) tested the impact of mass immunization 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% (Wesonga and Thiaucourt, 2000; Masiga *et al.*, 1978; Gilbert *et al.*, 1970). Another trial involving the T1/44 strain in cattle challenged two years post vaccination found a protection of 80% (Windsor *et al.*, 1972).

CBPP control by vaccination is therefore important for reducing associated production losses. For this to happen however, vaccination coverage must attain at least 80%. The AU-IBAR policy for CBPP control is that "blanket vaccination" over a period of about 5 years can be used to reduce the prevalence of infection to insignificant levels. Thereafter the infection can be finally eliminated by a "search and destroy" policy. This option is somehow problematic in that even if vaccination and active surveillance are conducted efficiently, re-introduction from adjacent foci is almost impossible to prevent.

Expenditures incurred to vaccinate cattle against CBPP add to the economic cost of the disease. The unit cost of CBPP vaccination used in this analysis was obtained from Tambi *et al.* (1999). This cost was calculated from the vaccinations undertaken during the Pan African Rinderpest Campaign (PARC) using the bivalent rinderpest-CBPP vaccine. Unit vaccination costs were calculated for a sample of ten countries and found to vary from 0.27 Euros for Ethiopia to 1.71 Euros for Cote d'Ivoire with an average cost of 0.42 Euros.

3.1.1.4.2 Treatment

CBPP is a treatable disease of cattle. Traditionally, farmers have used antibiotics to treat CBPP in the field with various levels of success. The actual degree of effectiveness of these treatments has not been well established for a number of reasons. First, several types of antibiotics from various sources (often unknown to the farmers) are available in the field and at various price levels. Some of the products have either expired, are fake or are poorly stored. Secondly, it is difficult for some farmers and veterinary staff to make the appropriate choice of which antibiotic to use, the proper dosage to apply and the interval of application. As a result, antibiotic use has been less efficient, leading to chronic infections, carrier cases and increased spread of the disease.

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 (2003) 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 by reduced by at least half when an appropriate treatment regime is used.

This analysis assumes the use of a standard recommended antibiotic treatment regime at an estimated cost of 8 Euros per head of cattle.

3.1.1.4.3 Stamping-out

Successful control and eradication of CBPP was achieved in Europe in the 19th Century using the "stamping-out" policy. In Africa, there is only one authenticated case of CBPP having been eradicated in Botswana in 1995/96 where 320,000 head of cattle were destroyed and buried at a cost exceeding US$350 million. Although theoretically sound, slaughtering animals with clinical signs and compensating their owners is a very expensive option that most African Governments cannot afford. Even if this were financially affordable, without fencing, prevention of re-introduction would be impossible. If governments were to slaughter animals without compensation, the owners would be unwilling to cooperate. Sick animals will be smuggled in order to escape the surveillance and detection of CBPP.

Stamping out, is certainly a feasible control option but because of the cost involved and the fact that many governments lack the financial resources to compensate farmers, this option is currently not feasible in Africa. 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 climate, movement control is unlikely to contribute significantly to CBPP eradication. In view of these, we have not considered this option as part of the economic cost of CBPP.

3.1.1.4.4 Quarantine, movement controls and surveillance

Increased trade and cattle movements have fueled the spread of CBPP in Africa. In pastoral production systems, effective control of cattle movements is next to impossible. Cattle movements are favored by climatic, environmental, feed, water and market conditions. In some countries rules and regulations for cattle movements exist but enforcement is difficult owing to limited resources, vast geographical areas and lack of cooperation by cattle owners and traders. Inadequate resources also limit the extent to which surveillance of the disease can be carried out. Proper definition of stock routes; establishment of quarantine areas (along the stock routes, near cattle markets and near abattoirs); and adherence to existing rules and regulations could help control the spread of CBPP.

3.1.2 Valuation of effects

The effects of CBPP are valued in terms of the production losses and the costs of disease control. In terms of the direct and indirect losses, only cattle deaths, reduced milk production, slow growth or decrease in weight gain and reduction in draft power have been considered. Other losses such as reduced fertility and delayed marketing have not been considered because of data limitations.

Disease control costs include expenditures on vaccination, antibiotic treatment, movement control, quarantine, movement control and surveillance. However, due to data limitations, only the costs of vaccination and antibiotic treatment are considered in this analysis.

Losses due to cattle deaths[1] are valued using the market prices for each of the classes of cattle. Losses in milk and beef are also valued using the market prices of these commodities. The total economic cost (C) of CBPP is thus obtained by summing all the values of the direct and indirect production losses (L) from mortality and morbidity plus the control expenditures (E), represented as

$$C = L + E$$

[1] When some of the meat value of an animal is salvaged after its death, or through emergency slaughter, this residual value should be deducted from the cost of mortality. In this analysis, we have not done so because of lack of appropriate data.

4. Benefits and costs of CBPP control

The estimation of costs and benefits in this analysis assumes the existence of a CBPP (combined vaccination and treatment) control program for comparison with a baseline scenario of no control program. Costs and benefits are measured as the *incremental changes* between the control program and the *no-program* option. Incremental costs are the difference in expenditure incurred between the control program and the no control (cost savings) program. Incremental benefits on the other hand are the difference in production value (avoided losses) obtained with the control program and the value obtained without a control program (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 benefits accruing from the control program, 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 then one indicates that CBPP control is economically beneficial whereas a value below one would suggest otherwise.

4.1 Costs

The cost of CBPP control/eradication varies depending upon the strategy adopted. There are several such strategies that may include one or a combination of the following: (i) treatment using an appropriate antibiotic regime; (ii) effective immunizaton using the T1/44 and or T1/SR vaccine; (iii) stamping out through slaughter and compensation of the owners of CBPP-infected cattle; and (iv) quarantine, cattle movement control and surveillance. The advantages and disadvantages of each of these measures have been alluded to above.

The AU-IBAR PACE CBPP eradication and surveillance strategy consists of mass vaccination (vaccine to be administered twice a year to ensure a vaccine coverage of at least 80%) over a 5-year period. This would reduce the prevalence of the infection to a level where it could be eradicated by stamping out of the residual foci. This would then be followed by effective movement control of cattle.

Due to lack of data, this analysis takes into account only the expenditures on antibiotic treatment and vaccination. No expenditure data are available for slaughter and compensation of owners of CBPP infected cattle, quarantine, control of cattle movements and surveillance.

4.2 Benefits

There are two types of benefits from CBPP control or eradication -- direct and indirect benefits.

4.2.1 Direct benefits

These originate from (i) avoided production losses caused by mortality and morbidity and (ii) savings in control/eradication costs. Appropriate vaccination and treatment eliminates or reduces the danger of CBPP and prevents the animal from death. The value of the surviving animal represents a benefit, the value of which can be 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 realize the benefits of these productivity potentials. However, because of the varying response of individual animals to infection, these benefits may vary as well. Successful eradication of the CBPP eliminates the future control costs of vaccination, treatment, quarantine, movement control and surveillance, thus providing benefits to farmers and the nation.

4.2.2 Indirect benefits

These accrue when the control/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 European Union market, leading to 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 the slaughter and compensation policy in 1995 led to a re-opening of this lucrative market, thus making it possible for both farmers and consumers to reap the benefits of export trade. Moreover, the cost of enforcing movement control and quarantine procedures is also significant, and further curtails the benefits.

This analysis is restricted to the estimation of direct benefits arising from savings in control/eradication costs and avoided mortality and morbidity losses.

5. Results

Estimates of the economic impacts of CBPP are presented in this section. First, the physical losses from endemic and epidemic CBPP are presented in terms of cattle deaths and reductions in beef, milk and animal 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.

5.1 Losses in cattle and cattle products

Losses in cattle and cattle products caused by CBPP under endemic and epidemic situations are presented in Table 1 for each of the twelve countries. In general, losses incurred under epidemic conditions are greater (one and half to two times greater) than losses incurred under endemic conditions.

Under endemic conditions, each country would lose on average 3,222 cattle (range from 950 – Ghana to 8,372 – Ethiopia), 266 and 2,010 metric tones of beef and milk respectively. In terms of animal power, an average of 396,000 ox days are lost per country. Cote d'Ivoire experiences the smallest loss in beef and milk while Ghana experiences the smallest loss in animal power.

Under epidemic conditions average estimated losses are 6,316 cattle deaths, 355 metric tones of beef, 3,351 metric tones of milk and 503,000 ox days of animal power.

Ethiopia experiences the largest number of cattle deaths and reduction in cattle products under both endemic and epidemic conditions compared to the other countries, due probably to its large cattle population.

5.2 Value of losses in cattle and cattle products

The average value of production losses caused by CBPP under endemic conditions is estimated at 2.3 million Euros per country with a range from 0.61 million Euros in Cote d'Ivoire to 6.2 million Euros in Ethiopia (Table 2). Losses attributed to morbidity (reductions in beef, milk and animal power) account for 65% of the total value of loss while losses due to mortality account for 35%.

Under epidemic conditions, an average value of 3.8 million Euros is lost per country (range from 1.1 million – Cote d'Ivoire and Ghana to 10.1 million Euros for Ethiopia). Estimated losses in Kenya and Mali exceed 6 million Euros. Note that even though morbidity losses (59%) jointly exceed mortality (41%) losses, the latter are greater under epidemic than under endemic conditions.

5.3 Economic cost of CBPP

The economic cost of CBPP in terms of production losses and disease control expenditures is estimated at 3.5 million Euros per country (Table 3) under endemic conditions. The economic cost for Ethiopia is 9.5

million Euros compared to 5.0 million for Chad, Kenya and Mali and about 1 million Euros for Cote d'Ivoire, Ghana and Mauritania. Production losses account for two thirds of the economic cost whereas the cost of disease control accounts for the remaining one third.

Economic cost under epidemic conditions is estimated at 5.4 million Euros on average. Again, Ethiopia experiences the largest economic cost of 14.2 million Euros followed by Kenya, Mali, Chad and Tanzania in that order. Production losses make up 71% of the total economic cost whereas disease control cost accounts for the rest.

5.4 *Benefit-cost analysis of CBPP control*

Results of benefit-cost analysis obtained by comparing the incremental benefits (avoided production losses) with the incremental costs (disease control cost savings) are presented in Table 4. Effective control of CBPP in endemic areas at an average incremental cost of 1.1 million Euros would generate an incremental benefit of 2.3 million Euros per country. This will give an average net benefit of 1.2 million Euros. Ethiopia, Mali and Kenya would have net benefits in excess of 2 million Euros. Chad, Uganda, Burkina Faso, Niger and Guinea would derive net benefits of about 1 million Euros.

In terms of returns to investments control of CBPP in endemic areas appears to be beneficial with an average benefit-cost ratio of 2.2. Returns to investments are greatest for Mali (2.97) and Burkina Faso (2.82) and lowest for Tanzania.

Control of CBPP during epidemic outbreaks has great potential for benefits as the estimates in Table 4 indicate. Net benefits average 2.3 million Euros per country with a range from 0.65 million Euros for Ghana to 6.0 million Euros for Ethiopia. The benefit-cost ratio for epidemic CBPP control is 2.8 on average with Mali having the highest return to investment (3.99) compared to Tanzania (1.33.

6. Conclusion

CBPP is a disease of economic importance because of the high morbidity and mortality losses it causes 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.

Before a control program is implemented however, it is important to evaluate the economic impacts of CBPP and determine whether a control program would be economically viable. This analysis was undertaken to evaluate the economic cost of CBPP and estimate returns to investments in its control in a sample of twelve countries (Burkina Faso, Chad, Cote 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 obtained from a number of field studies were used to model the impacts of CBPP under endemic and epidemic conditions.

Economic cost was evaluated in terms of the direct and indirect production losses attributed to morbidity and mortality plus the disease control expenditures. Production losses comprised of cattle deaths and reductions in beef, milk and animal power. The estimated monetary value of production losses averaged 2.3 million Euros per country for endemic CBPP and 3.8 million Euros for epidemic CBPP. Estimated economic cost averaged 3.4 million and 5.3 million Euros for endemic and epidemic CBPP respectively. Ethiopia, Kenya and Mali each incur economic costs in excess of 5 million Euros.

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. Effective control of CBPP is economically viable with net benefits that exceed 1.2 million Euros in the case of endemic CBPP and 2.3 million Euros in the case of epidemic CBPP. Indeed, control of CBPP during epidemic outbreaks has potential for greater benefits as the returns to investment are greater than those obtained from endemic CBPP.

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Table 1. Losses in cattle and cattle products caused by CBPP under endemic conditions.

Country	Losses			
	Cattle deaths (number)	Beef (metric tonnes)	Milk (metric tonnes)	Animal power (1,000 ox days)
Burkina Faso	2,020	199	1,231	337
Chad	3,242	436	2,697	738
Cote d'Ivoire	1,007	63	500	106
Ghana	950	81	579	137
Guinea	2,554	126	1,059	213
Mali	5,066	432	3,563	730
Mauritania	2,047	87	856	148
Niger	2,485	212	1,981	358
Ethiopia	8,372	823	5,086	1,393
Kenya	4,330	249	3,430	180
Tanzania	3,777	277	1,544	238
Uganda	2,812	206	1,592	177
Average	3,222	266	2,010	396

Table 1 con't. Losses in cattle and cattle products caused by CBPP under epidemic conditions.

Country	Losses			
	Cattle deaths (number)	Beef (metric tonnes)	Milk (metric tonnes)	Animal power (1,000 ox days)
Burkina Faso	4,053	249	2,012	422
Chad	6,485	545	4,373	922
Cote d'Ivoire	2,014	79	833	133
Ghana	1,900	101	953	171
Guinea	4,816	157	1,785	266
Mali	9,630	540	5,863	913
Mauritania	3,344	109	1,367	184
Niger	4,971	265	3,260	448
Ethiopia	16,743	1,029	8,310	1,742
Kenya	8,659	320	6,016	300
Tanzania	7,554	356	2,678	306
Uganda	5,624	265	2,761	227
Average	6,316	335	3,351	503

Table 2. Value of losses in cattle and cattle products caused by CBPP under endemic conditions.

Country	Value of losses (1,000 Euros)				
	Cattle deaths	Beef	Milk	Animal power	Total
Burkina Faso	503	399	492	108	1,502
Chad	801	872	1,079	236	2,987
Cote d'Ivoire	250	126	200	34	609
Ghana	235	162	232	44	673
Guinea	634	251	424	68	1,376
Mali	1,254	863	1,425	234	3,776
Mauritania	507	174	343	47	1,071
Niger	615	424	792	115	1,946
Ethiopia	2,077	1,647	2,034	446	6,204
Kenya	1,157	622	1,715	90	3,584
Tanzania	878	553	618	119	2,168
Uganda	760	412	637	88	1,897
Average	806	542	832	136	2,316

Table 2 con't. Value of losses in cattle and cattle products caused by CBPP under epidemic conditions.

Country	Value of losses (1,000 Euros)				
	Cattle deaths	Beef	Milk	Animal power	Total
Burkina Faso	1,005	498	805	135	2,443
Chad	1,601	1,090	1,749	295	4,736
Cote d'Ivoire	499	157	333	43	1,032
Ghana	471	202	381	55	1,109
Guinea	1,191	314	714	85	2,304
Mali	2,378	1,079	2,345	292	6,094
Mauritania	827	218	547	59	1,651
Niger	1,231	529	1,304	143	3,207
Ethiopia	4,153	2,059	3,324	557	10,093
Kenya	2,314	799	3,008	150	6,271
Tanzania	1,757	711	1,071	153	3,692
Uganda	1,520	529	1,104	114	3,267
Average	1,579	682	1,390	173	3,825

Table 3. Economic cost of CBPP under endemic conditions (1,000 Euros)

	Value of production losses	Disease control costs		Total economic cost
		Vaccination	Treatment	
Burkina Faso	1,502	369	165	2,035
Chad	2,987	1,470	315	4,772
Cote d'Ivoire	609	172	52	833
Ghana	673	328	67	1,068
Guinea	1,376	473	104	1,953
Mali	3,776	915	356	5,047
Mauritania	1,071	353	72	1,496
Niger	1,946	857	175	2,978
Ethiopia	6,204	2,787	566	9,557
Kenya	3,584	1,325	180	5,089
Tanzania	2,168	1,560	204	3,932
Uganda	1,897	708	152	2,756
Average	2,316	943	201	3,460

Table 3 con't. Economic cost of CBPP under epidemic conditions (1,000 Euros)

	Value of production losses	Disease control costs		Total economic cost
		Vaccination	Treatment	
Burkina Faso	2,443	553	206	3,202
Chad	4,736	2,058	405	7,199
Cote d'Ivoire	1,032	258	65	1,354
Ghana	1,109	374	84	1,567
Guinea	2,304	558	130	2,992
Mali	6,094	1,081	445	7,621
Mauritania	1,651	403	90	2,144
Niger	3,207	979	218	4,405
Ethiopia	10,093	3,373	708	14,174
Kenya	6,271	1,987	240	8,498
Tanzania	3,692	2,496	272	6,460
Uganda	3,267	1,133	202	4,602
Average	3,825	1,271	255	5,352

Table 4 Benefit-cost analysis of CBPP control under endemic conditions

	Incremental benefits	Incremental costs	Net benefits	Benefit-cost ratio
Burkina Faso	1,502	533	968	2.82
Chad	2,987	1,785	1,203	1.67
Cote d'Ivoire	609	224	385	2.72
Ghana	673	394	278	1.71
Guinea	1,376	576	800	2.39
Mali	3,776	1,271	2,505	2.97
Mauritania	1,071	425	646	2.52
Niger	1,946	1,032	914	1.89
Ethiopia	6,204	3,353	2,851	1.85
Kenya	3,584	1,505	2,079	2.38
Tanzania	2,168	1,764	404	1.23
Uganda	1,897	860	1,037	2.21
Average	2,316	1,143	1,173	2.19

Table 4 con't. Benefit-cost analysis of CBPP control under epidemic conditions

	Incremental benefits	Incremental costs	Net benefits	Benefit-cost ratio
Burkina Faso	2,443	759	1,684	3.22
Chad	4,736	2,463	2,273	1.92
Cote d'Ivoire	1,032	323	709	3.20
Ghana	1,109	458	651	2.42
Guinea	2,304	688	1,616	3.35
Mali	6,094	1,526	4,568	3.99
Mauritania	1,651	493	1,157	3.35
Niger	3,207	1,198	2,010	2.68
Ethiopia	10,093	4,081	6,013	2.47
Kenya	6,271	2,227	4,043	2.82
Tanzania	3,692	2,768	924	1.33
Uganda	3,267	1,335	1,932	2.45
Average	3,825	1,526	2,298	2.77