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ECONOMIC IMPACTS ASSESSMENT OF PLEUROPNEUMONIA BURDEN AND CONTROL IN PASTORAL CATTLE HERDS OF NORTH-CENTRAL NIGERIA

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Abstract

Contagious bovine pleuropneumonia (CBPP) is a trans-boundary infectious and contagious respiratory disease of cattle caused by Mycoplasma mycoides subsp. mycoides. It is a disease of high economic importance because of its ability to compromise food security. Information on its economic burden in pastoral cattle herds of Niger State, North-central Nigeria is not readily available. This study was aimed at investigating the economic impacts of CBPP to pastoralists in Niger State, North-central Nigeria, by determining its burden, returns to investments in its control, and cost-effectiveness of the control interventions ex-post evaluation, to provide baseline estimates that will assist animal health authorities and international donors in making investment decisions on its control in Nigeria. A questionnaire-based cross sectional study was conducted in 125 pastoral cattle herds. Economic analyses were conducted using total economic cost, benefit-cost analysis and cost-effectiveness analysis models. The values of mortality and morbidity losses to the herders were 219,038.5 USD and 35,598.8 USD, respectively. The total economic cost of CBPP to pastoralists was estimated to be 294,800.3 USD. Return on investment in CBPP control by vaccination and treatment was positive, with a benefit-cost ratio of 6.4. The Average cost-effectiveness ratio value for treatment intervention was 13.7 USD per life cattle saved and for vaccination option was 0.6 USD per death/cull averted. The estimated economic costs due to CBPP have shown that the disease was of high economic importance and must be controlled.

Keywords: Benefit-cost analysis, CBPP, cost-effectiveness analysis, economic impact, pastoralist, Nigeria.

ÉVALUATION DES IMPACTS ÉCONOMIQUES DU FARDEAU ET DU CONTROLE DE LA PLEUROPNEUMONIE CHEZ LES TROUPEAUX BOVINS EN MILIEU PASTORAL DANS LE CENTRE-NORD DU NIGERIA

Résumé

La pleuropneumonie contagieuse bovine (PPCB) est une maladie respiratoire transfrontalière infectieuse et contagieuse des bovins, causée par Mycoplasma mycoides - sous-espèce mycoides. C'est une maladie d'une grande importance économique en raison de sa capacité à compromettre la sécurité alimentaire. Les informations sur son fardeau économique dans les troupeaux bovins pastoraux de l'État du Niger dans le nord-centre du Nigeria ne sont pas facilement disponibles. La présente étude avait pour objectif d'analyser les impacts économiques de la PPCB sur les pasteurs de l'État du Niger dans le nord-centre du Nigéria, en déterminant son fardeau, le rendement des investissements dans son contrôle et l'évaluation ex-post du rapport coût/efficacité des interventions de contrôle, dans le but de fournir des estimations de référence qui aideront les autorités de la santé animale et les donateurs internationaux à prendre des décisions d'investissement sur son contrôle au Nigeria. Une étude transversale fondée sur un questionnaire a été menée dans 125 troupeaux bovins pastoraux. Des analyses économiques ont été effectuées en utilisant des modèles d'analyse du coût économique total, du rapport coûts-avantages et du rapport coût-efficacité. Les valeurs des pertes subies par les éleveurs en raison de la mortalité et de la morbidité étaient respectivement de 219 038,5 USD et 35 598,8 USD. Le coût économique total de la

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PPCB pour les pasteurs était estimé à 294 800,3 USD. Le rendement des investissements dans le contrôle de la PPCB par la vaccination et le traitement était positif, avec un rapport bénéfice-coût de 6,4. La valeur du rapport coût-efficacité moyen pour l'intervention de traitement était de 13,7 USD par vie bovine sauvée et l'option de vaccination était de 0,6 USD par mortalité / abattage évité. L'estimation des coûts économiques liés à la PPCB a montré que la maladie était d'une grande importance économique, et qu'elle doit être contrôlée.

Mots-clés : analyse coûts/bénéfices, PPCB, analyse du rapport coût-efficacité, impact économique, pasteur, Nigeria.

Introduction

Investing in livestock sub-sector development has increasingly been recognized as an effective way to contribute to broad-based poverty reduction for macro- and micro-economic reasons. At the macro-economic level, the livestock sub-sector is the single largest contributor to agricultural Gross Domestic Product (GDP) in developed countries accounting for over 50% of agricultural value-added and about 30% in developing countries. At the micro-economic level, a large share of the rural poor depends on livestock for their livelihoods (FAO, 2009). An important factor which militates against livestock productivity in developing countries is the prevalence of animal diseases (OAU/IBAR/PARC, 1998). Most governments of sub-Saharan Africa are unable to maintain effective surveillance and control programs against these diseases due to inadequate budgetary provisions to the animal health sub-sector (Tambi *et al.,* 1999), and depend on international donors when faced with challenges of epidemics or pandemics. One of the major disease challenges to cattle production in Nigeria is contagious bovine pleuropneumonia (CBPP) (Aliyu *et al.,* 2003; Adamu and Aliyu, 2006; Alhaji and Babalobi, 2016a).

CBPP impacts animal health and poverty of livestock-dependent people through decreased animal productivity, reduced food supply, and the cost of control measures. It is an OIE listed disease, and the Pan African programme for the Control of Epizootics (PACE) had identified CBPP as the second most important transboundary cattle disease in Africa after rinderpest (Tambi *et al.,* 2006), and a barrier to trade in many African countries as it reduces the value of livestock and the income of many value chain stakeholders (Danbirni *et al.,* 2010; Jores *et al.,* 2013). It is a disease of high economic importance and serious threat to livestock production and development in Sub-Saharan Africa (Tambi *et al.,* 2006). About 24.4 million cattle herders in 19 sub-Saharan African countries are at risk of CBPP and 30–50% of them are living below poverty levels (Thomson, 2005). Once introduced to a new area, initial losses can be very high and it requires major expenditure for control.

There are four essential tools in CBPP control: movement control, stamping out, vaccination, and treatment. Each control measure acts by reducing the effective reproductive number of the agent in the population (Tambi *et al.,* 2006). There are difficulties with movement control implementation in pastoral production systems due to their transhumance and socio-cultural practices (Masiga *et al.,* 1998; Alhaji and Babalobi, 2015; Alhaji and Babalobi, 2016b), as well as with stamping out policy because of the reluctance of owners to slaughter their animals and of governments to pay compensation (Mullins *et al.,* 2000; Thomson, 2005). It is, therefore, intuitively probable that the best approach to the control of CBPP would be to regularly vaccinate cattle in endemically infected areas and to treat 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 (Tambi *et al.,* 2006).

Economic information on CBPP in pastoral cattle herds of Niger State are not readily available and this is required for economic impact assessment necessary for development of surveillance and control strategies specific to this herding system. This study was aimed at assessing the economic impacts of CBPP burden, returns to investments in its control programmes, and to the cost-effectiveness of the control interventions against the disease by vaccination and treatment interventions in pastoral cattle herds in Niger State, North-central Nigeria. These were carried out as ex-post costs evaluations of CBPP effects in single year to provide baseline estimates that will assist the state, national animal health authorities and the international donors in making investment decisions regarding costs of CBPP control in the state and Nigeria as a whole. The last mass CBPP vaccination campaign in the state was carried out in November 2011. Therefore, pastoralists had resorted to use of private veterinarians for vaccination and treatment of their herds with T1/44 vaccine and antibiotics. Even the previous campaigns before the 2011 exercise were irregular due to logistic problems.

Materials and Methods

Study area

Niger State is located in the North-central geopolitical zone, at the Southern Guinea Savanna ecological zone of Nigeria, between latitude 8°20' N and 11°30' N, and longitude 3°30'E and 7°20'E. The State is one of the 36 states of Nigeria, a gateway between Northern and South-western and South-southern parts of the country, and provides transit routes for pastoral nomads on seasonal migrations from the northern parts of the country to the southern parts and back. It shares a common international boundary with the Republic of Benin in its western border and has three Agro-ecological zones: A (southern zone with eight local government areas, LGAs), B (western zone with nine LGAs) and C (northern zone with eight LGAs) with variable climatic conditions. According to the Nigerian Livestock Resources Survey, Niger State has an estimated cattle population of about 1.165 million in 1991 (RIM, 1992; Bourn *et al.,* 1994) and about 2.4 million in 2012 (MLFD, 2014). These cattle are kept by nomadic and sedentary pastoralists.

Study design and population

A cross sectional interview-based questionnaire study was conducted in nomadic and sedentary cattle production systems in the state, to evaluate a one year operational CBPP economic burdens, benefit-cost and cost-effectiveness of the two independent control interventions preceding the time of the survey, which began in January 2014.

Target populations were the nomadic and sedentary households domiciled in the state during survey. Each household derived its socio-economic livelihoods mainly from herding cattle. Study eligibility was based on a participant being a household head or spouse. Participants had to be 30 years of age and above. They were expected at these ages to possess existing veterinary knowledge and traditional oral history on livestock health and production management (Meriner and Paskin, 2000).

For the purpose of this research, a nomadic pastoral household was defined as a household that kept mainly cattle, usually a large herd of one hundred cattle and above and took part in year-round long movements over large ranges for grazing without a permanent homestead. A sedentary (agro-pastoral) pastoral household was defined as a semi-settled household with less than one hundred cattle in herd, cultivating few crops, and having limited movements on low-range grazing within their environments.

Sample size determination and selection of participants

The simple random sampling method (Thrusfield, 2007) was used to determine the sample size for the pastoralist participants, with expected CBPP prevalence of 8.7% (Alhaji, 2011), at 95% confidence level and 5% margin of error. In mathematical notation: n = Z2 x Pexp(1 – Pexp) / d2. Where: n, is the required sample size; Z2, is standard deviation at 95% confidence level (1.96); Pexp, is expected prevalence; and d is desired absolute precision. There were 125 herd owners who are the primary sampling units that participated in the survey.

A two-stage sampling method was conducted to select pastoral herd owners. In the first stage, the state was stratified into the existing three agro-ecological zones A, B and C where LGAs in each zone were considered. In the second stage, 40 pastoral herds were selected in each of the Agro-ecological zones A and C (with eight LGAs each), and 45 in Agro-ecological zone B (with nine LGAs). In total, in all the zones, 125 pastoral cattle herds were randomly selected. The lists of herds from each of the LGAs in each zone were obtained from the Zonal Animal Health Officers. Herds visited were randomly selected from the lists and questionnaires were administered on heads (owners) of the selected herds.

Questionnaire development, pre-testing and data collection

A structured questionnaire was designed containing closed and open-ended questions to gather information on epidemiological and economic parameters. The questionnaire contained questions on the herd population, number of sick cattle (morbidity) in a year, estimated annual costs of treatment, estimated annual costs of vaccination, estimated annual costs of production losses, number of cattle lost (mortality) in a year, and market values of healthy and sick cattle.

The questionnaire was pre-tested prior to the study based on the recommendation that pre-testing should be performed in the same population in which the actual study is to be carried out (Thrusfield, 2007). Questionnaires were administered by the researchers on the selected pastoralists whose cattle herds were presumed to be single and independent of others. During the survey, each pastoral herder who attested CBPP clinical manifestations to be cough, rapid and difficult breathing, nasal discharge, hyperthermia, and sneezing in the questionnaire response were considered as appropriate understanding of clinical manifestations of the disease (Alhaji and Babalobi, 2016b). Understanding of this case definition by the respondents helped in getting good responses to other economic attribute questions.

Data were collected using semi-structured, interviewer-administered, paper-based questionnaires on pastoralists' demographics, knowledge about and attitudes towards CBPP control and socio-economic characteristics, such as estimates of costs of the control measures, losses, among others. Further information was concurrently obtained through interviews of the pastoralists on the composition of herds, husbandry management system and production losses attributable to the disease. Before commencement of each questionnaire administering and semi-structured interview, informed consent was verbally obtained from the respondents who were assured of voluntary participation, confidentiality of their responses and the opportunity to withdraw at any time without prejudice in line with the Helsinki Declaration (WMADH, 2001).

Costs and benefits

Only avoidable production losses due to morbidity and mortality from the disease were considered. Appropriate vaccination and treatment eliminates or reduces morbidity and mortality losses and the death/culls averted were considered as benefits, and the livestock values were measured in terms of their replacement costs. A CBPP-infected animal experiences a loss in productivity due to poor condition, lowered milk production, and a reduction in ability to work for draught animals. Elimination of the disease permits the animal to achieve its potential productivity.

The benefit–cost and cost-effectiveness analyses were limited to these costs as well as benefits that arose from the morbidity and mortality losses avoided. They only assumed a 'with control' program for CBPP.

Economic analyses

The generated economic data were analyzed using three economic models: total economic cost, benefit-cost analysis, and cost-effectiveness analysis. Total economic cost estimates the economic impact (burden) of the disease to pastoralists; benefit–cost analysis evaluates returns to investments in

CBPP control; and cost-effectiveness analysis evaluates the most cost effective intervention options against the disease. Financial costs tend to be most thoroughly used in these analyses due to relatively abundant livestock market prices information.

Economic burden

The economic burden was estimated in terms of total economic cost, which is the relationship between the value of production output lost in the presence of the disease and costs of disease controls applied. The total economic cost (C) of a livestock disease is the sum of the value of both direct and indirect production losses (L), and the control expenditures (E) (Rushton *et al.,* 1999; Tambi *et al.,* 2006). This is presented as:

$$C = L + E \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where: C, is the total economic cost; L, is the value of production losses (direct and indirect); and E, is the costs of control measures.

In this survey, only direct production losses were considered, and were estimated from mortalities (values of cattle that died or culled due to CBPP) and morbidities (estimated losses from dropped in sales of milk of lactating cows with CBPP signs, sales of emaciated cattle with CBPP signs, and decrease value of draught power in cattle with the disease). The definition of indirect losses varies from author to author; however, these are usually associated with reduced fertility, loss of market opportunities through trade bans, quarantine costs and delayed marketing (Alhaji and Babalobi, 2016b). However, indirect losses were not considered in this study because of difficulty in accessing and quantifying their variables since they are mostly intangible. Therefore, only direct costs were used.

CBPP control costs in this research included costs of vaccination, obtained from estimated costs of CBPP vaccines purchased and payments for vaccinating the animals by professionals, in both the nomadic and sedentary cattle herds, as well as costs of treatment of all sick cattle with antibiotics, obtained from estimated cost of antibiotics purchased and payments for administering the drugs by professionals. All production losses were valued using the approximated current market prices of cattle products and values of sick animals due to the disease in the respective localities during the period of survey.

Benefit-cost analysis

The benefit-cost analysis was presented in a benefit-cost ratio, which involves aggregating all costs associated with the control interventions and comparing these costs with the total value of benefits generated attributable to the interventions. Since costs and benefits occur over a period of time, these values were also appropriately discounted to account for the time value of money (Putt *et al.,* 1988; Rushton *et al.,* 1999; Tambi *et al.,* 2006; Rushton, 2009) from year 0 when the interventions were instituted to year 1.

Benefit-cost ratio (BCR) was computed by dividing the sum of the present value of benefits by the sum of the present value of costs as follows:

$$BCR = [\sum Bt / (1 + r)t] / [\sum Ct /(1 + r)t] \ldots\ldots(2)$$

Where: BCR, is the benefit–cost ratio; B, is the benefit accruing from the control intervention; C, is the cost of disease control; r, is the discount rate; and t, is the number of years in the future (0 to n years). A benefit–cost ratio greater than one (BCR>1) indicates that contagious bovine pleuropneumonia control was economically viable while a value below one (BCR<1) suggests that it was not beneficial.

Cost-effectiveness analysis

Cost-effectiveness analysis (CEA) was used to evaluate and compare the most cost-effective CBPP control strategy among treatment and vaccination options that were used by pastoral cattle herders. However, health outcomes in terms of number of morbidity and mortality averted with treatment or vaccination were considered. It relates cost to specific intervention effectiveness. CEA model was presented in a cost-effectiveness ratio (CER), which is expressed by dividing total costs discounted by units of effectiveness (Briggs *et al.,* 1994; Fenwick *et al.,* 2006).

That is:

CER =Total cost/ Units of effectiveness…...….(3)

Unit of effectiveness (benefits or number of dropouts averted) was considered as a measure of quantifiable outcomes central to the control's objectives, which is the number of cattle deaths/culls averted with application of treatment or vaccination per Nigerian naira (NGN) value. Those cattle saved from dying/culling were considered as assumed benefits. They are actual benefits because they were really presumed to be prevented by control interventions of treatment or vaccination.

Average cost-effectiveness ratio (ACER), one of the analytical tools of cost-effectiveness analysis, was used. It is defined as total implementation costs divided by the total benefits. It deals with interventions that are independent of each other; a single intervention at a time and evaluates that intervention against its baseline option (common practice) (Fenwick *et al.,* 2006).

The ACER is expressed thus:

ACER = PVC / Units of effectiveness…...….(4)

Where: PVC, is the present value of costs discounted; and Unit of effectiveness, is the number of death/cull averted or live cattle saved.

Key field data obtained from pastoralists

Key estimates of epidemiological variables and parameters obtained from the field survey were used for the economic analyses. These include:

a. Total number of herds surveyed: 125 herds or households [nomadic - 81 (64.8%) and sedentary – 44(35.2%)];
b. Total cattle population in the herds: 9,979 cattle [nomadic – 8,634 (86.6%) and sedentary – 1,338 (13.4%);
c. Total number of sick animals due to CBPP treated with antibiotics in the two husbandry management systems: 2,320 heads;
d. Total annual cost of treating all sick cattle with antibiotics: 5,464,330.0 NGN;
e. Total number of cattle apparently healthy and vaccinated in the herds: 7,659 heads [nomadic - 6,634(86.6%) and sedentary - 1,025(13.4%)];
f. Total annual cost of vaccinating these herds: 769,820.0 NGN;
g. Estimated costs of decreased production (dropped in milk, weight loss, etc) due to CBPP in surveyed herds in one year: 9,110,000.0 NGN (nomadic - 5,280,000.0 NGN and sedentary - 3,830,000.0 NGN);
h. Number of cattle loss (deaths/culls) in the surveyed herds in one year: 289 heads [(nomadic – 224 (77.5%) and sedentary – 65 (22.5%)]
i. Social discount rate of 10% was used (Putt *et al.,* 1988).
j. Number of years in the future: one year for the health management interventions (treatment with antibiotics is a routine practice, while CBPP vaccination campaign is often done annual in Nigeria).

Discounting

To put all relevant costs and benefits on a common temporal footing for benefit-cost and cost-effectiveness analyses of the two interventions, we used time value of money, by converting the future expected streams of costs and benefits in one year time into present value amount in year zero using 10% discount rate. The discounting process is presented thus:

$$PV=FV/(1+r)t$$

$$PV = FV * (1 + r)-t \quad \ldots\ldots\ldots\ldots(5)$$

Where: PV, is the present value; FV, is the value of amount of money in years ahead; r, is the social discount rate; and t, is the number of years from the present date. When all benefits and costs are converted to present values, comparison is possible especially on decision-making criteria for cost-effectiveness ratio and benefit-cost ratio.

Sensitivity analysis

Responses from the participants were based on their existing veterinary knowledge, which sometimes may not be accurate (estimates). Because BCA and CEA must rely on estimates (assumptions) that are sometimes best guesses, it is critical that they contain an explicit sensitivity analysis that discusses key assumptions in the standard base case and varies those assumptions to see how a change affects the analysis (Fenwick *et al.,* 2006). Discount rate parameter, which determined certain level of variability with potentials of affecting the study results, was used. This was subjected to one-way deterministic sensitivity analysis, an approach that varies only one assumption or one parameter at a time, holding all else constant to assess its impact and determine the robustness of the results. The values were recalculated using 5% lower limit (best case scenario) and 15% upper limit (the worst case scenario) discount rates for a year for both costs and benefits of benefit-cost ratio and costs of average cost-effectiveness ratio.

Exchange rates

Central Bank of Nigeria (CBN) exchange rates of One Hundred and Fifty Six Nigerian naira (156 NGN) to One American dollar (1 USD) and 212 NGN to 1 EUR were used (CBN, 2014).

Results

Demographic information

A total of 125 pastoralists participated in the survey, with mean age of 52.1±10.9 SD, and the majorities (30.4%) were in the age group of 41-50 years. All respondents were married and majority (97.6%) was male. Majority (64.8%) was of Fulani tribe and most (66.4%) were nomadic pastoralists. Other tribes that participated in the survey were Nupe (7.2%), Hausa (12.8%) and other tribes (15.2%), who were sedentary pastoralists. Over two-thirds (69.9%) never had formal education, whilst in all 31.1% had formal education, however 8.0% stopped at primary level, 10.4% went to get secondary education, and 12.8% progressed further to obtain tertiary education.

Total economic cost

The total value of output loss incurred by pastoralists engaged in the two production systems was estimated to be 254,837.3 USD, giving an average of 2,038.7 USD per herd (Table 1). The value of losses due to morbidity (production losses) accounted for 14% of the total value of losses while mortality losses accounted for 86%. The physical losses are the results of morbidity and mortality associated with the disease. Morbidity losses in this survey had two components. The first was the declining productivity that led to losses in milk production, meat production (or live weight), and draught power. The second was the loss of output as a result of animals' dead or culled.

The total annual economic impact of CBPP in both nomadic and sedentary pastoral cattle herds in Niger State, Nigeria was estimated at 294,800.3 USD. The average annual economic cost per herd was 2,358.4 USD (Table 2).

Benefit-cost returns to investments

The avoided losses were also presented as benefits together with the costs of control and net benefits. The estimates showed that investment of 39,963.0 USD in CBPP control yielded a gross return of 254,837.3 USD and a net benefit of 214,875.0 USD. This was equivalent to a net benefit of 1,719.0 USD for a herd in any of the production systems. The annual benefit-cost ratio from the control of CBPP by both vaccination and treatment in the pastoral cattle herds was 6.4 (Table 3). The value was positive and therefore the two control methods were economically viable.

Table 1: Estimated value of annual losses (in USD) in cattle (deaths/culls) and cattle production losses due to contagious bovine pleuropneumonia in 125 pastoral cattle herds of Niger State, Nigeria

Production system	Value of cattle culled/death	Value of production losses	Total losses
Nomadic	144,038.5	32,485.3	176,523.8
Sedentary	75,000.0	3,313.5	78,313.5
Total	219,038.5	35,598.8	254,837.3
Mean/herd	1,752.3	284.8	2,038.7

Table 2: Estimated annual economic cost (in USD) of contagious bovine pleuropneumonia in 125 pastoral cattle herds of Niger State, Nigeria

Production system	Total value of losses	CBPP control cost by vaccination	CBPP control cost by treatment	Total economic cost
Nomadic	176,523.8	4,502.6	31,198.1	212,224.5
Sedentary	78,313.5	432.1	3,830.2	82,575.8
Total	254,837.3	4,934.7	35,028.3	294,800.3
Mean/herd	2,038.7	39.5	280.2	2,358.4

Table 3: Estimated annual benefits and costs (in USD) of contagious bovine pleuropneumonia control by both treatment and vaccination in 125 pastoral cattle herds of Niger State, Nigeria

Production system	Undiscounted benefits	Discounted benefits	Undiscounted costs	Discounted costs	Net benefits	Benefit-cost ratio
Nomadic	176,523.8	160,476.3	35,700.4	32,455.2	140,823.4	4.9
Sedentary	78,313.5	71,194.3	4,262.2	3,874.4	74,051.3	18.4
Total	254,837.3	231,670.6	39,962.5	36,329.6	214,875.0	6.4
Mean/herd	2,038.7	1,853.4	319.7	290.6	1,719.0	

Table 4: Estimated annual cost-effectiveness (in USD/live cattle saved) of contagious bovine pleuropneumonia interventions in 125 pastoral cattle herds of Niger State, Nigeria

Intervention	Undiscounted cost	Discounted cost	Benefit (deaths/culls averted)	ACER (USD/life saved)
Treatment	35,027.8	31,843.4	2,320	13.7
Vaccination	4,934.8	4,486.1	7,659	0.6

Cost-effectiveness of CBPP interventions

The ACER outcome value for treatment was 13.7 USD per life saved) and that of vaccination that was 0.6 USD per death/cull averted (Table IV). There is an indication that there was a cost saving with vaccination option compared with treatment option, meaning that vaccination was less costly and with simple dominance and could be more effective than treatment at the perspective of the pastoralists. One intervention is more cost effective if it is less costly with equal or better outcome or, it is more costly with better outcomes, and the added benefit is worth the added cost.

Partial deterministic sensitivity analysis

This exercise re-estimates the benefit-cost ratio and average cost-effectiveness ratio for the treatment and vaccination by adopting lower and upper limits (5% and 15%) for discount rate parameter. The outcomes of benefit-cost ratio with both scenarios (discount rates) did not apparently vary, as BCR remained 6.4, but relatively varied in average cost-effectiveness ratio, in which 5% discount for treatment was 14.4 USD/life saved and vaccination was 0.6 USD/life saved; and 15% discount treatment was 13.1 USD/cattle saved and vaccination was 0.6 USD/life saved).

Discussion

Increasing pastoralists' awareness about costs of CBPP mitigation and benefits accruing from interventions has been a major issue of concern. This cross-sectional study has provided a useful means for collecting economic information about the disease, assessment of its economic burden and return to investments in control in the pastoral cattle herds of Niger State, Nigeria.

The total annual economic impact of CBPP due to production losses and costs of control measures from treatment and vaccination to pastoralists in the state was estimated to be 294,800.3 USD (216,928.2 EUR) (CBN, 2014). This is very high for Niger State, which is a unit state out of 36 states in Nigeria, when compared with the Tambi et al. reported total estimated economic cost of 45 million EUR for CBPP in twelve countries with average economic cost of 3.7 million EUR per country (Tambi *et al.,* 2006). Some authors have reported variable economic burdens of the disease. Osyemi (1981) reported economic losses due to CBPP to be 3.6 million USD in Nigeria, while Egwu et al. (1996) estimated the direct economic cost of CBPP in the northern part of Nigeria to be 1.5 million USD. Furthermore, Townsend et al. (1998) estimated the total cost to the Botswana economy to be 350 million USD due to decline in beef and other products, and Masiga et al. (1998) estimated the annual losses directly or indirectly attributable to CBPP in Africa to be around 1.2 billion USD. Further, Jiuqing et al. (Jiuqing *et al.,* 2011) also reported that between 1949 and 1989, China lost an estimated 178,570 cattle due to CBPP estimated at 33.5 million USD. All these overviews indicate that CBPP is a disease of very high economic significance and every possible effort must be made to control it.

It is important to note that in this survey about 86.4% of the economic cost of CBPP was due to morbidity and mortality losses while the remaining 13.6% was due to the cost of disease control. The total cost of disease control was estimated to be 39,963.0 USD with the cost of treatment accounting for 87.7% and cost of vaccination accounting for 12.3%. These estimates suggested that by spending 39,963.0 USD (29,406.4 EUR) annually to control CBPP in the state, a net loss of about 254,837.3 USD (187,521.8 EUR) would be averted, translating to average annual averted loss of a 2,038.7 USD (1,509.4 EUR) in each herd if CBPP were to be controlled using only treatment and vaccination.

CBPP was found to be a disease of high economic importance because of the observed considerable losses in productivity that translated to heavy financial losses. This observation was in consonant with the reports of Aliyu and Kyari (2005) on the heavy financial losses due to this disease in northern Nigeria. In 2003, the Nigeria Animal Diseases Information System under the auspices of the Pan-African Programme for the Control of Epizootics (PACE) classified Nigeria as CBPP infected zone based on her CBPP status (PACE, 2003).

Estimates of annual benefit–cost ratios of CBPP control by treatment and vaccination were found to be beneficiary economically to pastoralists in the state. The avoided losses were presented as benefits together with control costs and net benefits. The estimates showed that an investment of 39,963.0 USD on CBPP control in Niger State yielded a gross return of 254,837.3 USD and a net benefit of 214,875.0 USD. This was equivalent to a net benefit of 1,719.0 USD per herd in the state. The return to investment was positive in both nomadic and sedentary production systems with an overall benefit–cost ratio of 6.4. The obtained BCR value in this survey was higher than the values obtained in other African countries: Burkina Faso 1.91, Chad 1.61, Côte d'Ivoire

1.59, Ethiopia 2.19, Ghana 1.66, Guinea 1.98, Kenya 2.56, Mali 1.85, Mauritania 1.95 Niger 1.95, Tanzania 2.24, and Uganda 1.80 (Tambi *et al.,* 2006). The survey economic estimates revealed that CBPP control by treatment with antibiotics and vaccination was economically beneficial to pastoralists. Nevertheless, the estimated benefits greatly underestimated the actual benefits that would be attained if movement control, stamping out, quarantine and surveillance were to be instituted in the state. Tambi et al. reported CBPP control by stamping out followed by strict movement control to be the most effective and beneficial control and eradication strategy (Tambi *et al.,* 2006). However, because of the cost involved and the fact that Niger State government lacks the financial resources to compensate pastoralists, these options are currently not feasible, not only in the state but in Nigeria at large. And even if total cost is not put into consideration by the state, instituting effective movement control would still be difficult since the state's borders stretch for hundreds of kilometers with other states and the Republic of Benin.

In comparing the ACER outcomes, ACER value for treatment intervention was found to be 13.7 USD per death/cull averted or life saved, while the value for vaccination option was 0.6 USD per deaths and/or culls averted or life saved. There was an indication of cost saving for vaccination option over treatment option, meaning that vaccination was less costly and effective in protecting (saving) cattle lives at individual pastoral herd level.

Cost effective interventions and benefit-cost return on CBPP control investment were subjected to the best and worst scenarios sensitivity analysis using only discount rate parameter in both cases. The outcomes of sensitivity analysis of benefit-cost ratio with both scenarios did not change, BCR remains 6.38. However, these relatively varied with average cost-effectiveness ratio, in which 5% discount for treatment was 14.4 USD/life saved and vaccination was 0.6 USD/life saved; while with 15% discount treatment was 13.1 USD/cattle saved and vaccination was 0.6 USD/life saved). This indicates that variation in discount parameter in BCR did not significantly influence overall results but did in ACER. In the later model it provided estimate threshold values above and below, of which the highest discount would be preferred because it gave a lower cost for the intervention with same output effectiveness.

It is safe to say that vaccination was attained at a lower cost than treatment, making it a more cost effective and beneficial control investment. The reduced cost-effectiveness of treatment may make it to be excluded so that it does not consume limited resources in possession of the poor pastoralists. Treatment should be excluded because it cannot provide good outcomes in terms of elimination of sequestrated lesions in chronic cases (Provost *et al.,* 1987), and therefore whatever added benefit from its application may not be worth the added cost. This view has the support of observations made by Gekonge (1990) and Oyaya and Rifkin (2003), who considered that non dominant intervention may be excluded to save limited available resources. Further, vaccination may have been more cost-effective but not without its own short-comings, as the conventional annual mass vaccination campaigns are often associated with complex logistics and result in irregular coverage of pastoral cattle in subpopulations. In the absence of comprehensive vaccination coverage, these pastoral foci are often left to the treatment option with antibiotics.

Arguments can be made for and against the variables used for burden, benefit-cost and cost-effectiveness assessments, yet obtained data are still the best in the circumstance of the economic evaluation approaches in veterinary practice at the local rural settlements because most of these herds are nomadic in nature. What was obtained in this study was a good epidemiological survey. Tambi et al. (2004) observed that disease intelligence information from a good epidemiological surveillance system is essential for developing a cost-effective animal disease control program from selective low cost interventions as opposed to a blind intervention using mass vaccination.

Both benefit-cost and cost-effectiveness tools are user-friendly economic models, as they use benefit and effectiveness of measures that reflect interests of people involved in the processes and that can be estimated and used for real-time decision-making.

In assessments of animal health and production, benefit-cost analysis can be used at both ex-ante appraisals and ex-post evaluations, where costs and benefits are estimated in monetary terms, such as programs dealing with livestock diseases (Goldbach and Alban, 2006). But when benefits include welfare changes for humans and/or animals that are complex to measure in monetary terms, CEA is the best alternative tool that can capture more appropriately the desired outcomes from a change such as programs that target control of zoonoses and interventions in diseases of high economic importance, with an impact on animal welfare, human health or on the environment (Lyons *et al.,* 2012; Babo Martins and Rushton, 2014).

The values presented in this study are mainly estimations of the economic impacts of the disease and the figures may grossly underestimate its real economic impact considering that only two control options were considered, which underscore the economic interest in controlling CBPP in the state. In view of the limitations of this study, there may be need for a more detailed study that will consider other control methods such as movement control, stamping out and epidemio-surveillance to derive reliable data on the economic impact of CBPP with backup sensitivity analysis of the different parameters to take care of uncertainties or assumptions where necessary. The limitations notwithstanding, we believe our findings represent an alarming paucity of evidence and reflect the concerns of others in the field that there is a gap in economic assessment research on CBPP interventions in developing countries. This cost-effectiveness study is the first of its kind on CBPP control interventions as no report of this nature, to our knowledge, has been documented in the recent past. Since no study has been documented on the cost-effectiveness of the disease control methods, it was not possible to make comparisons.

Conclusion

CBPP is a disease that causes high morbidity and mortality losses to pastoral cattle herds in Nigeria. This economic assessment was undertaken to estimate the economic cost of CBPP and the benefits of its control in pastoral cattle herds of Niger State, Nigeria. Following the growing interest of policymakers and animal health stakeholders in improving the access and quality of cattle production in sub-Saharan Africa, this empirical research conducted on the total economic cost, benefit-cost and cost-effectiveness of CBPP controls by treatment and vaccination in pastoral cattle herds is required and timely. However, much can be learned about an intervention in creating a framework to consider benefits and costs: simply attempting to identify them, measure them, and value them can provide important information for the decision maker. Adding a sensitivity analysis and a clear explanation of each assumption (estimate) and estimate, CEA and CBA can be extremely effective tools in CBPP and other trans-boundary animal diseases control interventions evaluation. The financial and economic losses CBPP causes to pastoral cattle herders in the state have been shown to be so enormous that the disease cannot be left uncontrolled. Control of this disease is therefore important as a way to salvage the losses and increase the incomes of cattle pastoralists, not only in Niger State but also in Nigeria as a whole.

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