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Impact of drought-related vaccination on livestock mortality in pastoralist areas of Ethiopia

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Under a national Livestock Policy Forum in Ethiopia the impact of livestock vaccination during drought was assessed in order to inform the development of a best-practice guideline. For each of the different types of vaccine used during drought years there was no significant difference in livestock mortality, for any species, in vaccinated compared with non-vaccinated herds. The limited impact of vaccination on livestock mortality was attributed to weaknesses in the design and implementation of vaccination programmes, including use of inappropriate vaccines, low vaccination coverage, problems with vaccine dosing, incorrect timing of vaccination and problems with vaccine storage. If these weaknesses could be overcome vaccination could be a useful means to protect livestock assets, with considerable benefit-cost ratios. Vaccination should be conducted as a standard preventive measure during normal years, and programme design should be informed by participatory epidemiological studies.

Keywords: drought, livestock vaccination, mortality, participatory epidemiology

Introduction

Livestock vaccination as a drought response

Pastoralist areas of Ethiopia are characterised by their physical remoteness and under-development. Recent government statistics reflect this situation, with very limited data available from the Somali and Afar pastoralist regions of the country (CSA/EDRI/IFPRI, 2006). From a livelihoods perspective, pastoralists are vulnerable due to a combination of factors including recurrent drought, conflict, limited basic services and non-supportive development policies. For parts of the Somali region of Ethiopia, these issues are well described in a recent study on pastoralist livelihoods and vulnerability (Devereux, 2006).

In terms of drought response in pastoralist areas of Ethiopia, the need to protect livestock assets has been known for many years. The Government of Ethiopia proposed a range of livestock-related drought interventions in the National Policy for Disaster Prevention, Preparedness and Management in the early 1990s (Transitional Government of Ethiopia, 1993). Even before this policy emerged, one of the most common non-food responses to drought in pastoralist areas was the vaccination of livestock. This was implemented by the Food and Agriculture Organization of the United Nations, government departments and non-governmental organisations

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(NGOs), often working in partnership. Accurate figures on drought-related vaccination are difficult to compile, although a review conducted in early 2007 indicated that since 2000 at least six million doses of livestock vaccine were administered during emergency vaccination programmes in Afar, Borana and Somali pastoralist areas of Ethiopia (Meketa and Yimenu, 2007).

From the perspective of livelihoods-based programming, livestock vaccination in pastoralist areas at the onset of drought or during drought appears to make sense. As pastoralists are highly reliant on livestock as sources of food, income and social support, the protection of livestock assets might seem to be a reasonable if not priority intervention. Some diseases cause rapid death in livestock, and for many of these diseases vaccines have been available for 50 years or more. Livestock vaccines are also relatively inexpensive and for diseases that cause livestock mortality, preventive vaccination usually makes economic sense; the benefit-cost ratio is usually very high if vaccination is conducted properly.

Despite the apparent livelihoods rationale for vaccinating livestock, the design of vaccination programmes is complicated by the range of different diseases affecting livestock in pastoralist areas and by variation in the types of disease affecting different livestock species.[2] Pastoralists keep mixed herds and while some diseases might affect all species, others are more species-specific. Furthermore, the design of vaccination programmes should be based on an understanding of the epidemiology and economics of target diseases, including information on the seasonality of disease outbreaks and the relative economic importance of diseases in terms of mortality, reduced milk production, reduced sale value or other losses. From an epidemiological perspective, programme design requires an understanding of disease transmission and, specifically, the ways in which disease agents such as viruses or bacteria spread within and between herds, most usefully expressed by the basic reproductive number R_0. For each disease in question, a specific estimation of R_0 is required (Woolhouse et al., 1997). Epidemiologists combine information on the characteristics of the available vaccines (such as the duration of immunity invoked) with simple models based on R_0 for the diseases in question in order to define programme parameters such as the proportion and type of animals to be vaccinated, and the inter-vaccination period. It is also important that for each disease in question, the objectives of vaccination are clearly defined as this determines the design of the programme. Objectives can include: preventing the spread of a current outbreak to other areas; preventing disease outbreaks; or disease eradication.

Impact assessment and epidemiological approaches in pastoralist areas

For humanitarian programmes in general, a substantial body of literature is available describing weaknesses in monitoring, evaluation and organisational learning (for example, Hofmann et al., 2004). Although it is beyond the scope of this paper to review all of the issues concerning the monitoring and evaluation of humanitarian intervention, a set of methodological issues are relevant to the assessment of drought-related livestock vaccination in pastoralist herds.

Baseline data

Compared with the body of research available on livestock diseases in developing regions generally, very little research has been conducted on livestock diseases in pastoralist areas of Africa. In part this deficit is explained by the difficulty of using conventional epidemiological methods in pastoralist areas because pastoralists tend to be relatively small, mobile communities moving in large, cross-border ecosystems with limited infrastructure and harsh environment (Catley, 1999; de Leeuw et al., 1995). Many pastoralist areas in Africa are also characterised by conflict. A further constraint has been that researchers have not always conducted research on those diseases that pastoralists perceive as important, leading to weak collaboration between researchers and pastoralist communities. During drought these problems are heightened because there may be a need for urgent action and limited time available to use conventional epidemiological approaches. These issues help to explain why in both normal years and drought situations there is limited baseline data available on disease-related livestock mortality. Similarly, important epidemiological variables such as R_o are rarely available.

Attribution, association, causation

Ideally, when aid agencies are trying to understand the impact of interventions they need to relate changes in people's livelihoods to specific programme activities. Often called 'attribution' in the literature on programme monitoring and evaluation, this relationship between intervention and effect relates to the concepts of association and causation in epidemiology. In epidemiological research, the effect of an intervention is often measured by the statistical comparison of treatment (intervention) groups with control groups. However, this key element in the design of much epidemiological research is highly problematic for aid agencies due to various ethical, cost and logistical reasons. Ethically, it is often assumed that the use of controls means the deliberate exclusion of communities or sub-sets of communities from a humanitarian response, and if so, this clearly contradicts humanitarian principles. In terms of cost and logistics, the use of control groups increases the amount of time and money needed to conduct an assessment. An alternative type of control measures a relevant variable before and after an intervention, and assumes that a significant change after the intervention is evidence of programme impact. This approach requires either the collection of baseline data before the intervention, or the retrospective measurement of the 'before' situation. In an emergency context the collection of baseline data is difficult (as outlined in the previous section), whereas a retrospective baseline measurement is subject to recall bias and other types of non-sampling errors.

Participatory epidemiology

Participatory epidemiology (PE) evolved in the mid-1990s as a means to overcome some of the limitations of conventional epidemiological approaches in marginalised pastoralist areas, and to improve the involvement of communities in the design and assessment of livestock programmes (Thrusfield, 2005). Initially, PE adapted the methods of participatory rural appraisal and applied these methods according to the principles of clinical investigation, which is a qualitative process. However, over time further adaptation included the standardisation and repetition of methods, attention to sampling issues and the use of conventional statistical tests to analyse data derived from PE. In the Horn of Africa, PE has been used to diagnose diseases of unknown cause (Catley et al., 2001, 2004); describe the basic epidemiology of diseases, including incidence and mortality estimates (Catley et al., 2002, 2004; Elnasri, 2005; Gizaw, 2004; Mochabo et al., 2005; Rufael et al., 2008); measure association between disease and possible causal factors (Catley et al., 2004); assist the modelling of epidemic diseases and assess control strategies (Mariner et al., 2005); and estimate the benefit-cost of epidemic disease control (Barasa et al., 2008). Some of this work has been conducted in protracted crises in southern Sudan and Somalia (for example, Barasa et al., 2008; Catley et al., 2001; Mariner et al., 2005).

In terms of data validity, PE has at least two important advantages over questionnaire surveys. First, PE uses local livestock disease terminology and recognises that pastoralists describe diseases using similar clinical, pathological and epidemiological information to veterinarians (Catley, 2006). Second, for mortality and incidence estimates PE uses a comparative approach in which different diseases are compared with one another, and in which informants are not aware that a particular disease is of interest to the researchers. This helps to overcome the exaggerated responses when researchers focus on a single disease, and reduces expectations that researchers or their associated agencies will provide vaccines or medicines to address a particular animal health problem. Although not widely known outside the livestock sector, the use of PE is supported by the Office international des epizooties (World Organisation for Animal Health), the Food and Agriculture Organization, and various national veterinary services and international NGOs. Regarding the impact assessment of humanitarian livestock programmes, PE-type approaches have been influential in pastoralist areas of Ethiopia (Admassu et al., 2005), South Sudan (Catley et al., 2008) and southern Somalia (Leyland et al., 2006).

Pastoralist Livelihoods Initiative

In late 2005 the Pastoralist Livelihoods Initiative began in Ethiopia as a two-year programme aimed at reducing vulnerability in pastoralist areas. One component of the programme was to support the Ethiopian government to develop a national best-practice guideline on emergency livestock interventions in pastoralist areas, with emphasis on livelihoods-based programming. A multi-stakeholder National Livestock Policy Forum was established and convened by the Ministry of Agriculture and Rural Development. Within this forum, working groups were formed to review experiences and lessons learned from specific livestock-related relief interventions. These working groups also received technical support and funding to conduct impact assessment of past interventions, with a view to feeding results into the best-practice guidelines. By late 2006 five working groups had been established, which comprised more than 90 individuals from the Ethiopian government, NGOs, academic and research institutes, donors, international organisations and the private sector. One of the working groups was assigned to examine emergency animal health interventions and part of this process involved a review of the literature, for Ethiopia and elsewhere, on the impact of emergency drought-related livestock vaccination. One finding of this review was that although livestock vaccination figures were available, there was virtually no information on the impact of vaccination in terms of livestock mortality or the benefits (if any) of reduced livestock mortality on human livelihoods.

This paper describes a study that aimed to assess the impact of livestock vaccination during drought on livestock mortality in pastoralist herds. The paper assumes that funding and programming decisions related to livestock vaccination during drought are often made by non-veterinarians, and therefore we propose some key questions that programme managers or coordinators need to answer to help ensure the effectiveness of vaccination. Although the paper focuses on recent vaccination practice in pastoralist areas of Ethiopia, the findings may be relevant to other countries in the Horn of Africa.

Methodology

Mortality estimates

After the drought in Ethiopia from late 2005 to early 2006, aid agencies reported the use of three types of livestock vaccine. These vaccines, as named by the agencies concerned, were pasteurellosis vaccine, blackleg vaccine and anthrax vaccine. In the project documents describing the vaccination, it was difficult to identify specific objectives of vaccination such as preventing spread of current outbreaks, disease prevention or disease eradication, although a common approach seemed to be to vaccinate as many animals as possible within time and budget constraints. Emergency appeals from regional governments typically requested support to vaccinate 20 per cent of the livestock population, although this figure was not justified in the appeals. Similarly, in agency reports we could find no baseline data on the diseases in question, such as mortality in normal or drought years. For these reasons, we assumed that the general strategy of agencies (although unwritten) was probably to prevent livestock mortality, but we were also aware of the lack of baseline data. Therefore, a retrospective cohort study was used to compare mortality in herds receiving one or more types of vaccine, and mortality in non-vaccinated herds. The study also compared vaccinated and non-vaccinated herds in a 'normal' non-drought year, in which a wider range of vaccines were used. The specific type of vaccines varied in different areas, and these vaccines were identified at field level as the study was implemented.

Participatory epidemiological methods were standardised and used with conventional random sampling. The study was conducted in Afar, Borana and Somali areas, which are the three main pastoralist areas of Ethiopia. Within each area, a district was selected where it was known by the researchers that drought-related emergency livestock vaccination had been conducted in recent years. These districts were Dalifagae and Amibara in Afar, Dire in Borana, and Filtu in the Somali region. In each region, informal discussions with pastoralists were used to identify and define one year representing a typical 'normal year' and one year representing a 'drought year'. These discussions were assisted by the use of time lines that enabled an historical record of drought years to be produced; from these different drought years one commonly recognised drought year could be identified. The normal years and drought years identified by pastoralists were: in Afar, normal year 2002/3, drought year 2001/2; in Borana, normal year 2002/3, drought year 2005/6; in Somali, normal year 2004/5, drought year 2005/6.

Proportional piling was used to estimate livestock mortality caused by different diseases in vaccinated and non-vaccinated herds. Once a herd was selected, vaccination and mortality data were collected for the pre-selected normal and drought years. Local livestock disease names were used, as described when validating proportional piling for estimates of livestock disease incidence and mortality in pastoralist areas of Kenya (Catley et al., 2002) and Tanzania (Catley et al., 2004). This approach assumes that in terms of clinical diagnosis, pastoralists diagnosed livestock diseases using similar clinical and epidemiological information as veterinarians, and that such clinical diagnoses are valid (Catley, 2006). The proportional piling method was repeated for different livestock species, and for the normal year and the drought year. Informants were also asked if and when their herds had been vaccinated, and the proportion of animals vaccinated in the normal year and the drought year.

Sample size was calculated using the formula for assessing vaccine impact by measuring proportional differences in disease mortality between vaccinated and non-vaccinated herds (Thrusfield, 2005).

$$n = \frac{\left\{M_{\alpha/2}\sqrt{2p(1-p)} + M_{\beta}\sqrt{p_1(1-p_1)+p_2(1-p_2)}\ \right\}^2}{(p_2-p_1)^2}$$

n = sample size for each population;
p_1 = disease mortality in unvaccinated herd, assumed to be 5%;
p_2 = disease mortality in vaccinated herd, assumed to be 1%;
$p = (p_1+p_2)/2$;
$M_{\alpha/2}$ = multiplier associated with the required significance level α, set at 5% so $\alpha = 0.05$;
M_{α} = 1.64 because the hypothesis is one-tailed (see Thrusfield, 2005);
M_{β} = multiplier associated with β, the probability of a Type II error; confidence of detecting difference = 80%, test power $(1-\beta) = 0.80$, $\beta = 0.20$ and $M_{\beta} = 0.84$ (see Thrusfield, 2005).

Using this formula, mortality in at least 223 vaccinated animals per species and 223 non-vaccinated animals per species in each region should be compared. It was assumed that camels were the least numerous species across the three regions with, on average, five head per herd: therefore 45 vaccinated and non-vaccinated herds should be sampled per region. The total number of informants (herds) by region was 60 in Afar, 60 in Borana and 70 in Somali region. The vaccination status of each herd could not be predetermined and therefore it was assumed that approximately 50 per cent of herds were vaccinated and 50 per cent non-vaccinated. Mean mortality and 95 per cent confidence intervals were calculated using the Statistical Packages for the Social Sciences Version 13.0 (SPSS, 2004). Comparison of the number of disease outbreaks in vaccinated and non-vaccinated herds in normal and drought years was conducted using the McNemar test for paired samples (SPSS, 2004).

Pastoralist's preferences for veterinary interventions

Each informant who conducted the mortality estimates described above was also asked to rank different types of veterinary intervention during drought according to their preference. In each study area, different combinations of veterinary treatments and vaccines were used. These treatments and vaccines were listed, and a simple ranking method was used to show the relative preferences. Semi-structured interviews were then used to seek informants' views on the reasons for their ranking.

Results

Estimates of vaccination coverage are provided in Table 1. In Borana, vaccination coverage in terms of herd coverage and within-herd coverage was similar in the normal year and drought year. In Afar and Somali areas, vaccination coverage was low

Table 1 Vaccination coverage in normal and drought years

Area and livestock species	Normal year		Drought year	
	Proportion (%) of herds vaccinated	Proportion (%) (95% CI) of animals vaccinated within vaccinated herds	Proportion (%) of herds vaccinated	Proportion (%) (95% CI) of animals vaccinated within vaccinated herds
Borana herds				
Cattle (n=60)	56.7	84.4 (74.22, 94.54)	40.0	66.9 (53.94, 79.98)
Sheep and goats (n=60)	20.0	65.2 (49.48, 80.86)	26.7	65.9 (48.54, 83.33)
Somali herds				
Cattle (n=59)	0.0	0.0 (0, 0)	86.4	79.6 (71.83, 87.39)
Sheep and goats (n=71)	0.0	0.0 (0, 0)	81.7	81.9 (75.09, 88.66)
Afar herds				
Cattle (n=60)	20.0	51.4 (36.72, 66.12)	40.0	45.4 (31.63, 59.12)
Sheep and goats (n=60)	0.0	0.0 (0, 0)	26.7	58.8 (46.75, 70.87)

Notes:
No camels were vaccinated in any area during normal or drought years.
CI = confidence interval.

Source: authors.

Table 2 Mortality in vaccinated and non-vaccinated pastoral herds

Area, livestock species and diseases	Mean mortality (%) (95% CI)			
	Normal year		Drought year	
	Vaccinated	Non-vaccinated	Vaccinated	Non-vaccinated
Borana herds				
Cattle (n=59)				
Anthrax	2.1 (1.34, 2.90)	1.5 (0.58, 2.42)	na	2.5 (1.54, 3.55)
Blackleg	2.3 (1.41, 3.20)	1.9 (0.95, 2.89)	na	0.6 (0.31, 0.98)
Pasteurellosis	1.4 (0.61, 1.94)	1.3 (0.48, 2.06)	1.3 (0.56, 2.02)	1.3 (0.56, 1.95)
Sheep and goats (n=60)				
CCPP	4.0 (2.31, 5.69)	6.7 (4.93, 8.52)	na	4.4 (2.28, 6.45)
Clostridial disease	1.4 (0.22, 2.61)	1.8 (1.07, 2.47)	na	1.5 (0.73, 2.27)
PPR	3.3 (0.66, 5.84)	4.5 (2.12, 6.96)	na	2.9 (1.69, 4.08)
Pasteurellosis	2.3 (1.19, 3.31)	2.8 (1.52, 4.12)	5.5 (0.06, 11.05)	2.2 (1.05, 3.36)
Somali herds				
Cattle (n=59)				
Pasteurellosis	na	1.1 (0.54, 1.69)	0.8 (0.37, 1.31)	1.3 (0, 2.78)
Sheep and goats (n=71)				
CCPP	na	3.5 (2.44, 4.57)	na	1.4 (0.83, 1.93)
Pasteurellosis	na	0.7 (0.22, 1.13)	0.7 (0.32, 1.13)	0.9 (0, 2.24)
Afar herds				
Cattle (n=60)				
Anthrax	1.7 (0, 3.39)	1.7 (1.09, 2.38)	0.9 (0, 2.13)	2.5 (1.17, 3.89)
Blackleg	0.6 (0, 1.50)	0.9 (0, 2.07)	1.3 (0, 2.76)	0.2 (0, 0.47)
Pasteurellosis	1.4 (0.19, 2.64)	0.5 (0.23, 0.86)	4.3 (1.55, 7.13)	2.2 (0.73, 3.60)
CBPP	3.4 (1.13, 5.71)	2.4 (1.59, 3.15)	na	3.8 (2.88, 4.79)
Sheep and goats (n=60)				
Anthrax	na	0.4 (0.01, 0.729)	0 (0, 0)	0.8 (0, 1.66)
Pasteurellosis	na	1.1 (0.61, 1.66)	5.2 (2.05, 8.33)	2.4 (1.11, 3.71)
CCPP	na	2.5 (1.36, 3.64)	na	4.1 (3.06, 5.17)

Notes:
CI = confidence interval; na = not applicable, no vaccination conducted; CCPP = contagious caprine pleuropneumonia; PPR = peste des petits ruminants; CBPP = contagious bovine pleuropneumonia.

Source: authors.

or absent during the normal years but increased during the drought years; increases in coverage were most evident in the Somali area.

In the three study locations, different types of vaccine had been used (Table 2), although in drought years pasteurellosis vaccine had been used in all three locations in cattle, sheep and goats.

In the normal years, there was no significant difference in mortality in vaccinated and non-vaccinated herds for any of the diseases covered by vaccination (Table 2). In non-vaccinated cattle the disease causing highest mortality was contagious bovine pleuropneumonia (CBPP) in Afar herds with an annual mortality of 2.4 per cent. For all other diseases of cattle in all three locations, annual mortality was less than 2.0 per cent in unvaccinated herds in the normal years. Mortality in sheep and goats in the normal years was generally higher than in cattle, with the highest mortality due to contagious caprine pleuropneumonia (CCPP) in Borana herds (mortality 6.7 per cent) and Somali herds (mortality 3.5 per cent), and peste des petits ruminants (PPR) in Borana herds (mortality 4.5 per cent).

In the drought years there was likewise no significant difference in mortality in vaccinated and non-vaccinated herds for any of the diseases covered by vaccination (Table 2). In non-vaccinated cattle the disease causing highest mortality was CBBP in Afar herds (mortality of 3.8 per cent), followed by anthrax in Borana (mortality 2.5 per cent) and Afar herds (mortality 2.5 per cent), and pasteurellosis in Afar herds (mortality 2.2 per cent). In non-vaccinated cattle there were no significant differences in mortality for any disease between normal years and drought years. In non-vaccinated sheep and goats CCPP caused high mortality in Borana herds (4.4 per cent) and Afar herds (4.1 per cent); PPR caused the next highest mortality with 2.9 per cent in Borana herds. No vaccination for CCPP or PPR was conducted during the drought year. In non-vaccinated sheep and goats there was a significantly lower mortality due to CCPP in Somali herds in the drought year compared with the normal year. For all other diseases there were no significant differences in mortality in drought years compared with normal years.

The most widely used type of vaccine in normal and drought years was pasteurellosis vaccine (Table 2), and so further analysis was conducted using the combined

Table 3 Cross-tabulation of pasteurellosis outbreaks and vaccination for pasteurellosis in pastoral herds

Pasteurellosis outbreaks		Vaccinated herds		McNemar test
		–	+	
Normal year				
Cattle (n=179)	–	94	20	Chi-square = 5.5, p=0.019; the proportion of outbreaks was significantly higher in vaccinated herds.
	+	39	26	
Sheep and goats (n=191)	–	122	4	Chi-square = 44.3, p=0.000; the proportion of outbreaks was significantly higher in vaccinated herds.
	+	57	8	
Drought year				
Cattle (n=179)	–	55	64	Chi-square = 17.3, p=0.000; the proportion of outbreaks was significantly higher in vaccinated herds.
	+	25	35	
Sheep and goats (n=188)	–	61	54	Chi-square = 2.4, p=0.118; no significant difference in the proportion of outbreaks in non-vaccinated and vaccinated herds.
	+	38	35	

Source: authors.

data from all three regions. A comparison of the number of outbreaks in vaccinated and non-vaccinated herds is shown in Table 3 and indicated that vaccination did not prevent outbreaks of pasteurellosis in either normal years or drought years.

Pastoralists' preferences for different types of veterinary treatment or vaccination during drought are shown in Table 4. In general, treatments with curative or prophylactic

Table 4 Ranking of veterinary interventions during drought by pastoralists

Intervention	Mean rank (summary rank)		
	Sheep and goats	Cattle	Camels
Afar informants (n=60)			
Vaccines			
Pasteurellosis	5.6 (7th)	5.6 (7th)	nr
Anthrax	4.9 (6th)	4.9 (6th)	3.6 (4th)
Blackleg	4.8 (5th)	4.8 (5th)	nr
CBPP	na	3.8 (3rd)	nr
CCPP	3.8 (3rd)	na	na
Treatments			
Anthelmintic	4.5 (4th)	4.5 (4th)	2.4 (2nd)
Acaricide	6.9 (8th)	6.9 (8th)	2.7 (3rd)
Antibiotic	1.9 (1st)	1.9 (1st)	1.4 (1st)
Antiprotozoal	3.6 (2nd)	3.6 (2nd)	nr
Trypanocide	na	nr	4.5 (5th)
Borana informants (n=60)			
Vaccines			
Pasteurellosis	5.1 (6th)	5.3 (7th)	nr
Anthrax	6.7 (7th)	5.2 (6th)	nr
Blackleg	na	6.3 (8th)	na
CBPP	na	7.1 (9th)	na
FMD	na	3.7 (5th)	nr
CCPP	2.8 (3rd)	na	na
PPR	3.4 (5th)	na	nr
Treatments			
Anthelmintic	2.4 (1st)	3.3 (3rd)	3.6 (4th)
Acaricide	3.3 (4th)	3.1 (=1st)	2.6 (3rd)
Antibiotic	2.7 (2nd)	3.4 (4th)	2.3 (2nd)
Trypanocide	na	3.1 (=1st)	1.7 (1st)
Somali informants (n=75)			
Vaccines			
Pasteurellosis	4.6 (4th)	4.5 (5th)	5.7 (6th)
Anthrax	nr	nr	5.0 (5th)
CCPP	5.8 (5th)	na	na
Treatments			
Anthelmintic	1.6 (1st)	2.2 (=1st)	2.4 (3rd)
Acaricide	3.1 (3rd)	3.9 (4th)	3.9 (4th)
Antibiotic	2.1 (2nd)	2.4 (3rd)	2.0 (2nd)
Trypanocide	na	2.2 (=1st)	1.9 (1st)

Notes:
The lower the mean rank, the greater the preference.
na = not applicable; nr = not ranked; CBPP = contagious bovine pleuropneumonia; CCPP = contagious caprine pleuropneumonia; FMD = foot and mouth disease; PPR = peste des petits ruminants.

Source: authors.

medicines were preferred over vaccinations. The most widely-used type of vaccine was pasteurellosis vaccine. This was often ranked sixth or seventh in preference when compared to other vaccines or medicines.

Discussion

Assessment methodology

According to Hofmann et al. (2004) there is no standard, accepted way for measuring human mortality in humanitarian crises. Similarly, there appears to be no generally accepted method of measuring livestock mortality during drought assessments or for the impact assessment of interventions based on possible changes in livestock mortality. Our field experience suggests that livestock mortality estimates during drought are commonly based on rapid observation by government or aid agency staff and a limited number of interviews on the ground, whereas impact assessment using mortality measurements is very rarely performed; we could find no examples of such assessments in the veterinary literature in relation to drought-related livestock vaccination programmes.

The two broad options for assessing the impact of vaccination on mortality in pastoralist herds are to collect retrospective information from livestock keepers, or conduct prospective (real-time) longitudinal monitoring of herds by placing a trained data recorder in each herd or in groups of herds. To our knowledge, the second option has never been used during a humanitarian crisis in a pastoralist area and this is probably due to the practical difficulties and high cost of this approach. The data recorders would need to be either physically based with each herd or supported by vehicles to enable regular monitoring of groups of herds. There is also the possibility that herds would be split during the monitoring process, with camels, cattle, sheep and goats all being managed in different ways and moved to different grazing areas. In more settled communities with fewer livestock, seasonal monitoring of livestock mortality is possible, and useful information of the impact of veterinary programmes can be obtained. This approach has been used successfully in Afghanistan (Schreuder et al., 1996), but the context was protracted crisis rather than drought and a two-year study period was possible. Although the Afghanistan study used control groups, it did not disaggregate specific causes of mortality and therefore did not describe the impact of vaccination by disease, relative to other types of veterinary intervention.

The assessment methodology described in this paper is unusual from the perspective of the impact assessment of humanitarian drought intervention, because it used control groups. It was assumed that not all livestock had been vaccinated in the selected districts during the drought and it was also assumed that both vaccinated and non-vaccinated herds could be identified retrospectively. In this case, the control groups were unvaccinated livestock herds, but in other interventions it is possible that control groups within target areas might be non-users of a particular service, such as human health, water, sanitation or veterinary services. In an assessment of community-based animal health workers in southern Ethiopia, service users compared the livelihoods impact of diseases 'handled' and 'not handled' by the project, and the researchers used the latter category as the control (Admassu et al., 2005).

Despite our assumption that non-intervention households (herds) could be identified, when designing the study the proportion or absolute number of vaccinated and non-vaccinated herds was not known. Although the number of vaccinated livestock by species was known in each district, estimates of total livestock population by district were considered to be unreliable and therefore vaccination coverage could not be calculated. Similarly, data such as average livestock holdings by household was not available for all three areas where the study was conducted, and nor were lists of households with vaccinated livestock. These deficits in baseline data made the calculation of sample size problematic and meant that there was no guarantee that equal numbers of livestock keepers in intervention and control groups would be interviewed. Also, when calculating sample size there was very limited baseline information available of livestock disease mortality in the study districts. Although we assumed that mortality in non-vaccinated herds for each disease would be five per cent and that mortality in vaccinated herds for each disease would be one per cent, the results indicated that for many diseases of cattle in non-vaccinated herds in normal and drought years, mortality did not exceed 2.5 per cent (Table 2). This indicates that a larger sample size should have been used, but also raises the question of the need to prevent diseases causing such low mortality. When calculating sample size we also used the assumption that the least numerous species was camels and that in mixed pastoralist herds the numbers of sheep, goats and cattle would usually exceed the number of camels. However, as the study progressed it became evident that no vaccination had been conducted in camels. At field level we did not attempt to count the actual numbers of animals in each herd, partly because herds can be split and managed in different locations. Also, the vaccination coverage figures in Table 1 are only indicative as we did not ask informants to describe vaccination coverage for each type of vaccine used.

These various methodological and study design issues illustrate the problems of working in pastoralist areas where baseline data is often absent and where post-drought communities and households can be dispersed over wide areas. These problems contrast with the design of assessments in settled or camp situations where households are accessible and can be counted relatively easily.

The study used the PE method of proportional piling, which has been widely applied to estimate livestock disease incidence and mortality in pastoralist areas of the Horn of Africa. The method draws heavily on pastoralists' strong indigenous knowledge of livestock diseases, including elaborate disease terminology and knowledge of the clinical signs and observable pathological and epidemiological features of diseases. In terms of clinical diagnosis, pastoralists' ability to diagnose disease compares well with the diagnostic skills of veterinarians (Catley, 2006), and in these areas laboratory facilities that might be used for confirming disease diagnosis are usually unavailable. For disease outbreaks at a herd level, high positive predictive values for pastoralists' observations have been reported in Tanzania (Catley et al., 2004) and Ethiopia (Rufael et al., 2008). In addition to these quantitative assessments of herder diagnoses there is a substantial body of qualitative literature on indigenous veterinary knowledge dating back to the colonial period in east Africa (for example, Mares, 1954).

For some diseases, mortality was higher in vaccinated compared with non-vaccinated herds. This might be explained by the behaviour of herd owners with a history of disease in their herds, who sought vaccination more actively than other owners. In the event that vaccination was ineffective, a highly mortality in so-called 'vaccinated' herds would be recorded.

Actual impact of vaccination on mortality

Objectives of vaccination and vaccination coverage

The results showing livestock mortality in vaccinated and non-vaccinated herds (Table 2) were a cause for concern as there was no evidence of significant impact of vaccination on mortality. This finding should be viewed relative to the objectives of vaccination and, as explained in the methodology, these objectives were not well documented by the agencies concerned. The common objective, albeit expressed in different ways, seemed to be to vaccinate as many livestock as possible with the resources available. When vaccination coverage targets were mentioned, these targets were not disaggregated by disease. As a result, there was limited understanding that different diseases with different epidemiological characteristics and impact would require different levels and type of coverage. Looking more specifically at the diseases in question, anthrax outbreaks are associated with contact between livestock and contaminated soil or water (Edelsten et al., 1990). Outbreaks tend to be location-specific and herders often know the high-risk areas and will avoid such areas unless other grazing is unavailable or inaccessible. During drought, the strategic vaccination of livestock residing in, or likely to move to, anthrax areas might be preferable to mass vaccination (vaccinating as many animals as possible) of all livestock within an administrative boundary. In the case of blackleg, outbreaks are most commonly observed in young cattle in good condition, and often grazing good pasture (Edelsten et al., 1990). These conditions do not apply in a drought situation but become more relevant post-drought, after the rains. If so, it might be more appropriate to vaccinate cattle at the onset of the rains rather than during drought.

For pasteurellosis, the review of vaccination objectives was complicated because the term 'pasteurellosis' encompasses different diseases with different epidemiology (De Alwis, 1999). Unless the specific type of pasteurellosis is defined in a vaccination objective, it is unclear which disease is being targeted. Due to this problem, we looked at the composition of the pasteurella vaccines that were used. For cattle, the vaccine contained *Pasteurella multocida* type B organisms, indicating that agencies were attempting to prevent a specific form of pasteurellosis called haemorrhagic septicaemia (HS). If so, vaccination coverage of at least 70 per cent is recommended for this disease (De Alwis, 1999). In drought years in this study, vaccination coverage reached 81.7 per cent of Somali sheep and goat herds, and 81.9 per cent of animals within these herds (Table 1), indicating that vaccination failure was not due to low vaccination coverage in these herds. In Afar and Borana herds during drought, herd vaccination coverage did not exceed 40 per cent and within herds did not exceed 66.9 per cent (Table 1).

For sheep and goats, the vaccine contained *P. multocida* type A organisms. However, the main types of pasteurellosis affecting sheep and goats are caused by *P. haemolytica,* a different species of bacteria. We could find no rationale for the use of this vaccine, other than that it was the only vaccine available at the time. Vaccination did not prevent outbreaks of pasteurellosis in cattle or in sheep and goats (Table 3). A further consideration when reviewing vaccination objectives was the focus on cattle, sheep and goats. Although camels are the most valuable type of livestock in pastoralist areas and the least susceptible to drought, we found no records of the vaccination of camels during drought.

Vaccination practices

In a recent qualitative study on livestock vaccination practices in pastoralist areas of Ethiopia it was suggested that the efficacy of vaccination was compromised due to weaknesses in confirming disease diagnosis, delayed implementation of vaccination following reports of disease outbreaks, inappropriate vaccination coverage, and improper storage of vaccines at field level (Meketa and Yimenu, 2007). In pastoralist areas, reported disease outbreaks were rarely supported by basic laboratory confirmation of disease. In situations where laboratory facilities were not available locally, samples were rarely collected or forwarded to a central laboratory. The timing of vaccination campaigns in normal years was such that in most cases a period of months passed between the recognition of a disease outbreak and vaccination. For the diseases in question, this delayed response probably resulted in vaccination taking place after peak mortality had already occurred. In general, facilities for the proper cold storage of vaccines were inadequate.

In addition to these issues, we examined the protocols for vaccine administration. In the case of HS vaccine for cattle, the vaccine manufacturer advised that an initial course required the administration of two doses of vaccine, three to four weeks apart, to ensure protective immunity. However, when the vaccine was used in the field, only a single dose was administered. Although the literature on HS vaccines indicates that a single dose of vaccine may protect cattle for up to three months, we were unable to find any peer-reviewed case control studies to support this advice. Similarly, the vaccination of sheep and goats against pasteurellosis requires an initial course of two inoculations but it appeared to be standard practice to administer a single dose of inactivated pasteurellosis vaccine to sheep and goats. When reviewing the peer-reviewed literature, we could find no evidence of the efficacy of this approach.

A further issue affecting the vaccination of drought-affected livestock is the possibility of a weak immunological response to vaccines due to poor body condition of animals or concurrent disease. Although we could not find any published evidence that weakened animals develop lower levels of immunity following vaccination than healthy animals, it is feasible that debilitated livestock would respond less well. For HS vaccination, it has been suggested that pre-existing trypanosomiasis may diminish the immune response (De Alwis, 1999); trypanosomiasis has also been associated with delayed antibody response to rinderpest vaccination (Twinamasiko and Kakaire, 1994). Bovine trypanosomiasis is widespread in pastoralist areas of Ethiopia.

Potential impact of vaccination on mortality

For donors, aid coordinators and programme managers with limited technical knowledge of livestock diseases it is important to note that if weaknesses in vaccination programmes could be overcome, and assuming that a sufficiently wide range of diseases could be covered, vaccination could play a useful role in preventing livestock losses. Summating the mortality figures in Table 2 for different diseases provides an approximate measure of the total mortality that might be prevented. For example, for Afar cattle, mortality from anthrax, blackleg, pasteurellosis and CBPP totalled 5.5 per cent in the normal year and 8.7 per cent in the drought year. For Borana sheep and goats, mortality from CCPP, clostridial disease, pasteurellosis and PPR reached 15.8 per cent in the normal year and 11.0 per cent in the drought year. Using vaccines prices and administration protocols provided by the National Veterinary Institute in Ethiopia for all these diseases, it would cost, in a normal year, USD 8.30 to procure vaccine for 50 cattle and USD 6.95 to procure vaccine for 50 sheep and goats. These prices are low compared to many other countries because the institute is subsidised by the Ethiopian government. Using average market values for these types of livestock, and ignoring subsidies and delivery costs, the benefit-cost ratio for cattle vaccination is 964:1 and for sheep and goats 144:1. Even if the government subsidy on vaccine production was removed and delivery costs were calculated, we propose that the benefit-cost of vaccination would exceed 20:1.

However, the realisation of these benefits depends on correct programme design. Agencies need to think carefully about the types of vaccines to be used, vaccine storage, administration protocols, the levels of vaccination coverage required to achieve immunity, and the correct timing of vaccination to ensure herd immunity before periods of high risk. In the event that vaccination is compromised by weaknesses in one or more of these factors, programme managers need to be aware that impact will be compromised.

Overall, the results in Table 2 indicate that livestock vaccination in pastoralist areas of Ethiopia by government and aid partners, during normal and drought years, is at best a hit-and-miss affair that requires urgent revision. As a general rule, a full vaccination course for each disease needs to be completed before the period of high risk and these high-risk periods vary depending on the disease in question. According to the Office international des epizooties (World Organisation for Animal Health), for diseases of international significance such as PPR and CBPP vaccination practice should follow national disease control or eradication strategies, which, in turn, require an understanding of the epidemiology of diseases in different production systems and ecological zones. The combination of PE and simple disease modelling is feasible in pastoralist areas during normal years, thereby allowing better vaccination programmes to be designed. To date, however, this approach has been limited to only two diseases in pastoralist areas of the Horn of Africa (rinderpest and CBPP), and the application of results has been limited. Donors need to be aware that investments in relatively simple epidemiological studies are warranted for a range of endemic livestock diseases, with the objective of defining disease prevalence and mortality, improving understanding of the impact of diseases on human livelihoods, and, where necessary, the use of disease modelling to assist the design of vaccination strategies. In general, the aim should be to ensure adequate protection of livestock before drought, and, for diseases that are more of a private good than a public good, to ensure that policies are in place and enacted that enable the private sector to deliver vaccines.

Although this study focused on pastoralist areas of Ethiopia, some of the funding, programming and other issues are common to other areas of the Horn of Africa. The study indicates that donors and agencies involved in livestock vaccination programmes during drought need to evaluate critically these programmes and invest far more time and resources in baseline surveys and impact assessment. Further adaptation and improvement of the methods described in the study would assist this process.

Recommendations

1. For all the diseases covered in the study for which vaccination might be feasible, it was difficult to obtain written copies of official disease control strategies in either normal years or drought years. Considering the substantial quantity of vaccine administered to livestock in pastoralist areas during drought, a major revision and clarification of specific disease control policies and strategies is needed. Such strategies need to include epidemiological and economic analyses, and take account of the relative efficiency of the private sector in controlling diseases that are private goods. In general, preventive disease strategies should aim to ensure adequate levels of herd immunity in high-risk herds during normal years, thereby limiting the need for 'emergency campaigns' during drought. The approaches and methods of PE are particularly useful in pastoralist areas, and it may be better to invest donor funds at the level of disease control policies and related studies than to support poorly-designed vaccination programmes during drought.
2. Due to these possible problems with livestock vaccination in pastoralist areas of Ethiopia, in March 2007 the Pastoralist Livelihoods Initiative issued a briefing note (Catley et al., 2007) to implementing partners, suggesting ways to reduce risk of vaccine inefficacy. This briefing note is provided in Annexe 1 and might be used by a broader range of government actors, NGOs, international agencies and donors to ensure the effectiveness of vaccination. Even taking the advice in this briefing note into account, vaccination strategies still need to be clarified, as

indicated under recommendation 1. In Ethiopia, the Ministry of Agriculture and Rural Development is now developing a national guideline on livestock interventions during drought, and this guideline will include best-practice for vaccination programmes. At the international level a set of livestock emergency guidelines and standards are being developed as a proposed companion module to the Sphere handbook.[3]

Annexe 1

Pastoralist Livelihoods Initiative

Briefing Note: Livestock Vaccination Programmes[4]

This briefing note summarises some key technical aspects affecting the impact of vaccination and advises veterinarians and programme managers in the Pastoralist Livelihoods Initiative (PLI) to consult World Organisation of Animal Health (Office international des epizooties, OIE) and Food and Agriculture Organization (FAO) guidelines. The main OIE reference document is:

OIE (2004) *Manual of Diagnostic Tests and Vaccines for Terrestrial Animals, Volumes 1 and 2.* Fifth edition. OIE, Paris. http://www.oie.int/eng/normes/en_mmanual.htm?e1d10.

Key points

Although the design of vaccination programmes varies according to the epidemiology and impact of different diseases, PLI programme managers and veterinary staff are advised that:

1. Failure to **diagnose disease(s)** according to recognised international diagnostic standards increases the risk of inappropriate vaccination, for example, through the use of the wrong vaccine.
2. For some diseases, **vaccine efficacy** is highly dependant on the identification of **local field isolates** and the inclusion of these isolates in the vaccine. This is a particular issue in the case of vaccines for haemorrhagic septicaemia and the various forms of bovine and ovine pasteurellosis. Agencies conducting vaccination should check with vaccine suppliers that the composition of vaccines is relevant to the diseases and specific pathogens in their geographical areas of operation.
3. When using vaccines, the **level and duration of immunity** varies according to the vaccine, number of doses and timing of doses:
    - for anthrax, the vaccine based on Sterne's spore vaccine is live and a single dose of vaccine provides immunity for up to 12 months;
    - for haemorrhagic septicaemia a single dose of correctly-prepared alum-precipitated (inactivated) vaccine can result in immunity of up to three to four months;
    - for correctly-prepared inactivated ovine pasteurellosis vaccine, two doses of vaccine administered four weeks apart may provide protective immunity for

up to 12 months. There is very limited evidence to indicate that a single dose of inactivated ovine pasteurellosis vaccine provides any duration of protective immunity.

Although some vaccine producers may cite results of their own laboratory-based vaccine efficacy trials, such trials require large sample sizes, relevant livestock species and a capacity to reproduce natural infection in laboratory settings. For these reasons, reference to peer-reviewed literature and/or the guidelines provided by the OIE and FAO is advised.

4. In the face of **outbreaks** of anthrax, haemorrhagic septicaemia, pasteurellosis and blackleg, vaccination of affected herds is unlikely to reduce mortality unless it is conducted before mortality peaks in a given herd. If vaccination is conducted after peak mortality has occurred, it is unlikely to affect mortality. Furthermore, delayed vaccination based on a single dose of inactivated vaccine tends to produce immunity of short duration or no immunity (depending on the vaccine—see section 3). Therefore, such vaccination may not prevent future disease outbreaks.
5. **Disease prevention**. In many areas, outbreaks of anthrax, haemorrhagic septicaemia, pasteurellosis and blackleg are predictable because the diseases are either location-specific (for example, anthrax) and/or seasonal (for example, pasteurellosis). Failure to complete a full vaccination course for these diseases before periods of high risk, and/or failure to cover a high proportion of animals in a given herd, reduces the impact of vaccination.
6. Many vaccines require **cold storage**. Failure to comply with manufacturers' recommendations for cold storage increases the risk of ineffective vaccination. In hot pastoral areas, particular care is needed to ensure correct storage of vaccines. In the event that a vaccine producer advises that vaccine efficacy is maintained even if vaccines are stored at higher temperatures than recommended in product data sheets, such advice should be treated with caution.
7. In the case of contagious bovine pleuropneumonia (CBPP), contagious caprine pleuropneumonia (CCPP) and peste des petits ruminants, the design of vaccination programmes should be the subject of national disease control programmes and strategies. In the absence of such programmes, two points are relevant:

- **sub-optimal vaccination** (low vaccination coverage) may increase the risk of these diseases developing endemic status;
- for CBPP and CCPP, the use of **antibiotics** can be considered.

These are two emerging technical issues and, in the case of antibiotic use, controversial. Feinstein International Center staff can provide more information on request.

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2 The main diseases of cattle in pastoralist areas of Ethiopia for which vaccines are currently used are anthrax, blackleg, pasteurellosis and contagious bovine pleuropneumonia. Pasteurellosis in cattle is a generic term encompassing two distinct diseases: pneumonic pasteurellosis and haemorrhagic septicaemia (HS). These two diseases are caused by different types of *Pasteurella multocida,* and each requires a different type of vaccine. The vaccine used in Ethiopia is a HS vaccine, which, if properly used, may protect cattle against HS but not against pneumonic pasteurellosis. In sheep and goats the diseases for which vaccines are currently used are anthrax, clostridial disease, pasteurellosis, contagious caprine pleuropneumonia and peste des petits ruminants. Pasteurellosis in sheep and goats is a generic term comprising pneumonic and septicaemic forms of the disease, caused by different strains of *P. haemolytica*. However, the vaccine used in sheep and goats in Ethiopia contains *P. multocida.*

3 See http://www.livestock-emergency.net.

4 See Catley et al. (2007).

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