A narrative review of animal health interventions for designing herd health interventions for Ethiopia

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Table of Contents

Executive summary

Livestock production in Ethiopia, with 60.4 million cattle, 31.3 million sheep and 32.74 million goats (CSA, 2018), is an important source of livelihood for the smallholder farmers in the highlands and a mainstay of the livelihoods of pastoralists in the lowlands. However, the productivity level is low and thus the contribution of livestock to the livelihoods of their keepers and the national economy is highly limited. Livestock disease, limitations in genetic potential of the indigenous animal resources and the marginal production environment have been implicated as the major limiting factors for improving livestock productivity in Ethiopia. Diseases have impacted food security and livelihoods of smallholder farmers and pastoralists and the national economy at large by limiting export earnings due to stringent animal health requirements. Efforts to prevent and control diseases have been stepped up recently with improved veterinary and para-veterinary training, use of CAHWs, production of 16 livestock vaccines by the National Veterinary Institute (NVI), disease surveillance and diagnostics supported by 14 regional and one national laboratories, and grassroots health service delivery through health posts in most kebeles (LMP, 2015). However, the service delivered is still far from satisfactory, especially for small ruminants. For instance, the proportion of animals vaccinated in 2017/18 were 64.1% of cattle, 25.9% of sheep and 28.5% of goats (Gebremedhin et al., 2017), and likely these animals were vaccinated for a single disease instead of all diseases needed, and the proportion of animals treated out of those inflicted/diseased were 71.0% for cattle, 49.9% for sheep and 38.4% for goats (CSA, 2018).

The objective of the current review was to collect and synthesize available information on general and multiple animal health interventions and herd health intervention packages from Ethiopia and elsewhere with similar production systems that could be synthesized into herd health intervention packages for Ethiopia. The review document is organized accordingly. This literature review was prepared following a narrative review method as described by Ferrari (2015). A narrative review method was chosen because of the heterogeneity of the selected studies which arose from the aim of the review which was to collect and synthesize available information on general and multiple animal health interventions that could be synthesized into herd health intervention packages for Ethiopia.

We have reviewed available animal health interventions from the literature with emphasis from developing livestock systems including Ethiopia. The review also assessed the impacts and cost-benefits of interventions. The reviewed interventions were structured into health service delivery schemes, vaccination interventions, deworming interventions, ectoparasite control, and capacity development interventions to enhance effectiveness of health interventions. A section is devoted to a review of actual herd health interventions and evaluation of herd health interventions. The following are the key conclusions drawn from the review:

- The common animal health interventions are vaccination, deworming and health service delivery schemes, often involving Community Animal Health Workers (CAHW). However, coverage is often patchy and CAHWs are not institutionalised.
- Integrated herd health intervention packages are virtually absent, even though they have a huge potential to improve productivity with highly favourable cost-benefit ratios.

- Interventions, particularly vaccinations, are introduced as emergency measures against outbreaks and droughts, even though there is a need for their use in systematic prevention.
- Most of the reports reviewed indicate a significant impact of animal health interventions on animal productivity and they are cost-effective.
- Cost-benefit analysis may not be the sole tool for appraising the suitability of interventions. A farmer participatory approach needs to be adopted.

Literature in this review and priority diseases in Ethiopia (Wieland et al., 2016; Alemu et al, unpublished; unpublished data), recommended herd health interventions for Ethiopia would include the following.

- Strategic community-based deworming intervention

- Vaccination schemes for important diseases

- Community-based ectoparasite control (particularly in the lowlands)

- Assess animal welfare status and introduce animal welfare interventions

- Husbandry management intervention (Feeding, sanitation, housing, etc)

- Record keeping at community/village level (performance and health records)

- Set targets for growth, reproduction and mortality rates

- Setting up of monitoring and evaluation framework

I. Introduction

Livestock production in Ethiopia, with 60.4 million cattle, 31.3 million sheep and 32.74 million goats (CSA, 2018), is an important source of livelihood for the smallholder farmers in the highlands and a mainstay of the livelihoods of pastoralists in the lowlands. However, the productivity level is low and thus the contribution of livestock to the livelihoods of their keepers and the national economy is highly limited. Estimated based on data from the 2017 livestock sample survey (CSA, 2018), the offtake rates due to sale in 2017 can be calculated to be 12.2%, 22.1% and 20.5% for cattle, sheep and goats, whereas the mortality rates were 7.7%, 15.9% and 15.8%, respectively. These data show that the number of ruminant animals died (13.1%) were very close to the number of animals sold (18.2%). Livestock mortality is generally high. Calf mortality ranges from 11% in Somali to 52% in Afar region, lamb mortality from 11% in SNNPR to 41% in Afar, kid mortality from 13% in SNNPR to 35% in Afar, and poultry mortality 23% in Somali to 35% in Oromia (Gebremedhin et al., 2017).

Livestock disease, limitations in genetic potential of the indigenous animal resources and the marginal production environment have been implicated as the major limiting factors for improving livestock productivity in Ethiopia. Diseases have impacted food security and livelihoods of smallholder farmers and pastoralists and the national economy at large by limiting export earnings due to stringent animal health requirements. Efforts to prevent and control diseases have been stepped up recently with improved veterinary and para-veterinary training, use of CAHWs, production of 16 livestock vaccines by the National Veterinary Institute (NVI), disease surveillance and diagnostics supported by 14 regional and one national laboratories, and grassroots health service delivery through health posts in most kebeles (LMP, 2015). However, the service delivered is still far from satisfactory, especially for small ruminants. For instance, the proportion of animals vaccinated in 2017/18 were 64.1% of cattle, 25.9% of sheep and 28.5% of goats, and likely these animals were vaccinated for a single disease instead of all diseases needed, and the proportion of animals treated out of those inflicted/diseased were 71.0% for cattle, 49.9% for sheep and 38.4% for goats (CSA, 2018).

The Ethiopian Livestock Master Plan lists 17 livestock health interventions, among which interventions number 16 and 17 (LMP, 2015) directly address the health issue at grassroot levels, namely (1) strengthening grassroots animal health extension services through the preparation of an animal health knowledge kits, and sharing of good practices and (2) strengthening veterinary services in lowland pastoral areas through CAWHs. Yet, it is not clear whether the approach for these interventions meets the objectives of herd health interventions. So far, there is very little to none herd health practice in place in Ethiopia, apart from selected large-scale poultry or dairy farms. Herd health is not a new concept and is based on a planned animal-health and production-management program that uses a combination of regularly scheduled veterinary activities and good herd management designed to optimize animal health and productivity (Blood, 1979). It is therefore important to design and package farm or community specific herd health interventions based on individual health innovations and proven interventions by reviewing best practices from Ethiopia and elsewhere with similar conditions. Individual health interventions may include curative treatments, preventive services and regulatory bans, improved husbandry practices, syndromic surveillance, efficient delivery of health services, and capacity development.

The objective of the current review was to collect and synthesize available information on general and multiple animal health interventions and herd health intervention packages from Ethiopia and elsewhere with similar production systems that could be synthesized into herd health intervention packages for Ethiopia.

II. Review method

Review approach

This literature review was prepared following a narrative review method as described by Ferrari (2015). A narrative review method was chosen because of the heterogeneity of the selected studies which arose from the aim of the review to collect and synthesize available information on general and multiple animal health interventions that could be synthesized into herd health intervention packages for Ethiopia. Narrative reviews aim at identifying and summarizing what has been previously published, avoiding duplications, and seeking new study areas not yet addressed (Grant and Booth, 2009). This contrasts with systematic reviews, which involve formulation of a well-defined question focusing on a unique query (Bastian et al., 2010) and review of relevant studies on a specific topic which are synthesized according to a predetermined and explicit method (Klassen et al., 1998). The aim and nature of the current study also was not suitable for meta-analysis which involves the statistical combination of at least two studies to produce a single estimate of the effect of a specific intervention. The review used a qualitative approach supported with quantitative evidence where such data are available. Although narrative reviews have their own limitations, (Klassen et al., 1998), their number per year in MEDLINE significantly surpassed that of systematic reviews (Bastian et al., 2010).

Literature search and selection criteria

The source of information for this review included both consultation meetings with livestock development organizations in Ethiopia and literature review. Literature search for the review was based on the key concept of the review, which was herd health interventions. Since the literature search based on this concept yielded very few publications or studies, the search was expanded to general animal health interventions which may not conform to the concept of herd health interventions as defined, for instance, by Blood (1979). The concepts of herd health interventions and animal health interventions were transformed into key words for electronic literature search. The key words included the key terms in the concepts and four livestock species (cattle, sheep, goat, chicken/poultry). The electronic search was not limited to specific databases, but specific websites of development institutions working on livestock and animal health interventions in developing countries were targeted. These included FAO, Farm Africa, VSF, Mercy Corps, Brooke, Tufts University project, ILRI, Ministry of Agriculture (Ethiopia), and VetAid.

The review included mainly development interventions, but research findings were also included where reports on relevant development interventions are not available for some of the topics. All types of publications were used for the review, including project reports, booklets and peer-reviewed journal articles and unpublished information. The review was restricted to interventions introduced in Ethiopia and other countries with similar livestock production systems.

III. Interventions and impacts

1. Health service delivery schemes

1.1. Community animal health workers (CAHWs)

Provision of animal health service through CAHWs could be considered one of the major animal health interventions in Ethiopia in the last 2-3 decades. A CAHW is defined (VSF, 2018) as a farmer/field agent selected by his/her community with the collaboration of veterinary doctors, the veterinary public service and supporting bodies (projects and NGOs). He/she provides basic animal health services and animal husbandry advice to livestock keepers in order to optimize animal health and production. As a relay agent, the CAHW can also play an important role in epidemiological surveillance.

A major challenge in the prevention and control of animal diseases both in the lowland pastoral and highland mixed crop-livestock smallholder systems has been the absence of efficient schemes for delivery of animal health services in Ethiopia. There are several reasons for the inefficient delivery of services, which may vary over the years. Berhanu (2002) and Hooper 92016) in their assessments identified that the staffing of clinics in district towns (by veterinarians, animal health assistances and animal health technicians) and animal health posts in *kebeles* (by animal health technicians) is far from adequate, the number of clinics being twice as many as the number of veterinarians and the shortage of AHA and AHT being equally severe. Despite the high turnout of veterinary graduates since Berhanu's (2002) report, CAHWs are still considered essential for improving delivery of services, especially in remote areas and in the pastoral system, the justification being provision of high-quality proximity animal health services (VSF, 2017).

Community health service interventions started as early as 1970's and have been known by different designation, including Vet Scouts, Paravets, Community Veterinary Agents (CVAs), Farmers Animal Health Representatives (FAHR), and recently Community Animal Health Workers (CAHWs) (Berhanu, 2002). The intervention has been introduced by both governmental and non-governmental institutions and with various modalities and success rates. Based on Berhanu's (2002) historical review, the characteristics of the intervention is summarized in Table 1. The different variants of CAHWs service are presented below in Sections 1.1.1 to 1.1.3.

Impact of CAHWs

CAHWs were a critical element in the eradication of rinderpest, such as in the case for the Afar region through the PARC-Ethiopia project (Catley et al., 2005). A participatory assessment of the impact of CAHWs in Ethiopia (Admassu et al., 2005) showed significant reductions in the impact of diseases handled by CAHWs compared with diseases not handled by CAHWs, which included mange, trypanosomiasis, helminthosis, anthrax and non-specific respiratory disease in camels; blackleg, anthrax and helminthosis in cattle; and mange, helminthosis, CCPP, ORF and non-specific diarrhoea in small ruminants. The CAHWs contributions were attributed mainly to increased use of modern veterinary services and vaccination campaigns involving CAHWs. CAHWs were highly accessible, available, affordable and trustworthy relative to other service providers. In a review of the impact of CAHWs in the Horn of Africa including Kenya, South Sudan, and Ethiopia (Leyland et al., 2014), CAHWs were also seen as very accessible, available to meet needs, trusted, and affordable by pastoralists. In Ethiopia, CAHWS also play a huge role in the fight against the Peste des Petit Ruminants (PPR) in Afar and Somali regions and against Anthrax in South Omo (VSF, 2018).

Quantitative evidence on the impact of CAHWs is rare in the literature. CAHWs are important health service providers in Ethiopia, particularly in the pastoral and agro-pastoral systems. For instance, CAHWs are the second most accessible service providers for Afar, Somali and Oromia pastoralists/agro-pastoralists with percent of households reporting access being 29.2%, only next to veterinary drug stores with access reported by 31.6% of the interviewed households. CAHWs also provided the second most satisfactory service, only next to service provided by livestock extension agents (Gebremedhin et al., 2017). Elsewhere, Bartels et al (2017) presented a positive impact of CAHWs on animal health and production. Their results indicated mortality (expressed as Incidence Rate Ratios) in partial-users and full-users of paravets was respectively 0.80 and 0.73 times the mortality observed in the partial non-users. The offtake rates were 1.24 and 1.21 times higher in partial-users and full-users.

1.1.1. CAHWs network model

Although CAHWs are recognized as effective providers of localized animal health services in many cases, there are several challenges facing the adoption of CAHWs as appropriate intervention. A study in 19 countries (Galière, 2017; cited in VSF, 2018),) identified four categories of challenges: lack of standardized training, lack of common nomenclature, problem of proper and ongoing supervision related to the legal relationship between CAHWs and the other bodies of animal health professionals, and problem of the formalization or legal recognition of CAHWs. In some cases, CAHWs rarely have stocks of veterinary drugs and, commonly, they do not receive adequate ongoing support and supervision (Leyland et al., 2014). Most CAHWs interventions are funded by international development projects and failed when these projects were phased out (e.g. Vet scouts were employed and paid salaries by the TLDP project; vet scouts stopped service when the TLDP project phased out; Table 1).

To overcome the challenges facing CAHWs (Galière, 2017), Farm Africa (Kithuka et al., 2007) introduced a CAHWs system in Kenya. The system consists of CAHWs (referred to in Kenya as disease reporters), animal health assistants and veterinarians. These are organized in a network within a district. The system provides for supervision of CAHWs by health assistants and veterinarians. It also addresses the challenges of efficient delivery of supplies at village level by supporting health assistants and veterinarians to access loans to establish rural drug shops in local market centres and district towns, respectively.

1.1.2. Women vaccinators

CAHWs service intervention could be designed following herd health concepts and engendered. For instance, Farm Africa introduced a complete poultry package delivered by women poultry vaccinators in Tigray region of Ethiopia. The project, which benefitted 1,312 households each receiving 15 pullets, managed to improve the benefits of the beneficiaries by reducing chicken mortality through supplementary feeding, proper housing and vaccination and treatment services provided by 10 voluntary women per kebele trained on poultry care.

1.1.3. Voucher based CAHW service

A public-private sector partnership voucher based CAHW service was designed by VSF Germany in Ethiopia (Bekele et al., 2014). VSF Germany implemented a new voucher-based treatment intervention for livestock. The service was delivered through CAHWs and a public veterinary service. Herders were responsible for purchasing drugs administered as prophylactic and curative treatments with vouchers received from the program. The vouchers were distributed once to individual recipients at the beginning of the program. Each

recipient secured nine vouchers with a total value of Birr 240. VSF was responsible for supplying veterinary stock used for the voucher program to the district veterinary unit. The district veterinary unit supplied CAHWs with initial veterinary drugs and then treatment in exchange for vouchers submitted. CAHWs received 20% of the cost of the submitted voucher in the form of cash from VSF Germany as a mark-up. Both VSF Germany and district veterinary units were responsible for monitoring the implementation process.

Table 1. Historical development of community health service delivery [1]

Start year	Designation	Institution	Modality †
1970's	Para vets	RRC (DPPC) [2]	- >= 3rd grade farmers trained. - No clear objective, paravets ended as illegal drug dealers
1975-1987	FAHR[3]	APTC[4]	- Trained for 6 months. - Follow-up of disease outbreak and reporting outbreaks to vet stations
1986-1995	FAHR	FLDP[5]	- Mainly in the highlands, linked with co-operatives, assist AHTs to sell acaricides & anthelmintics only - Drug shops opened within service co-operatives. - Not successful, top-down approach
1974 – 1989	Vet scouts	TLDP	- Integrated approach (3-month training including animal husbandry). - employed by the TLDP project and paid salaries; vet scouts stopped service when the TLDP project phased out
1989 – 2001	Vet scouts	Farm Africa[6]	- women as vet scouts/CAHWs - Involved in private drug supplies through cooperative groups
1989 – 1995	Para vets	SORDU[9]	- Para vets operated without supervision and refresher training
1991 – 2000	Para vets	SERP[7]	- Paravets as part of a pilot community development program.
1994 – 1996	Vet scouts	FAO	- Not successful: drug supply based on revolving funds failed, no post-training monitoring
1994-1997	CAHWs	APDP[8]	Provided with initial kit, sell drugs at market price plus a 10% service mark-up, drugs replenished by either private drug vendors or the public woreda clinics
1994 – 2000	CAHWs	PARC	Contribution of CAHWs "critical" element in PARC-Ethiopia in eradicating rinderpest from the Afar region.

1996 – 1999	CAHWs	SCF (UK) / SERP	Established by SCF (UK) provision of drugs as seed money for revolving fund. The system for drug supply was not sustainable, though 74 Community-based Animal Health Workers were providing service to their community.
NGOs ‡			
1995	CAHWs	LVIA [10]	- Based on a vaccine cost sharing system, CAHWs provided vaccines for CBPP, PPR, Blackleg and Pasteurellosis
1996	CAHWs	Save the Children UK	- In the highlands; CAHWs are limited to de-worming and spraying (regulations of the regional government)
1997	CAHWs	BLPDP[11] /GTZ	- Supported by refresher training
1998	CAHWs	PCAE/COOPI	- consistent annual 7-days refresher training
1999	CAHWs	Farm Africa	-An integrated project using the mobile outreach camp approach.
1999	CAHWs	IPDP	- Well Linked with woreda agriculture office: drug supply and supervision
1999	CAHWs	ACF	- in remote pastoral areas where there were no health professionals
2000	CAHWs	HCS	
2001	CAHWs	CCM	

[1] Based on Berhanu (2002). [2]Relief and rehabilitation Commission (Disaster Prevention and Preparedness Commission). [3] Farmer animal health representatives. [4]Agarfa Peasant Training Centre. [5] Fourth Livestock Development Project. [6] Third Livestock Development Project. [6] FARM Africa Dairy Goat Development Project. [7] The Southeast Rangelands Project. [8]Afar Pastoralists Development Pilot Project. [9] Southern Development Unit. [10] Lay Volunteers International Association. [11] Borana Lowland Pastoral Development Program. [12] Pastoralists Concern Association Ethiopia and Co-operazione Internationale. [13]Integrated Pastoral Development Project. [14] Action Contre la Fiem. 15 Hararghe Catholic Secretariat. Comitato Collaborazione Medica. † All service providers were trained. ‡All the NGO-supported services operated at least until 2002

1.2 Collective action for disease control

Gastrointestinal parasite infections are the second most important health problems next to respiratory diseases under smallholder systems in Ethiopia. Although technical/technological solutions to control GIT parasites exist, it has been a challenge to effectively and sustainably introduce technological solutions under the smallholder small ruminant production systems in developing countries due to several factors. GIT parasite control interventions implemented by individual farmers will have limited impact due to the uncontrolled and communal animal management system (communal grazing, herding and watering points) which will dilute the efforts of individual progressive farmers as communal grazing lands are contaminated by untreated flocks. Access to veterinary inputs and services by individual smallholders often is also difficult or uneconomical. It is thus imperative for smallholders to act as a collective entity.

It can be hypothesized that community engagement and collective action in strategic anthelmintic treatment enables control of internal parasite in a more sustainable way under smallholder systems. The CGIAR research program on Livestock launched a project with the objectives of introducing and assessing the performance and feasibility of participatory/community-based strategic helminth control programs in three regions (SNNPR, Oromia, Amhara) of Ethiopia. The design involved organizing cooperative small ruminant breeding groups which share common communal grazing resources and watering points and are separated from other village flocks in the *kebele* to plan collective deworming action by all members of the cooperative. The intervention also included capacity building of farmers and livestock extension workers and multi-stakeholder platforms for the cooperative control of diseases.

Impact of collective action

Monitoring showed that collective action by villagers in worm control is effective (Table 2) and farmers expressed positive opinion towards the intervention (Fig 1).

Table 2. The odds of GIT intervention increasing the number of animals testing negative for GIT parasite eggs in reference to the number of positive animals

Strongyle [a]					Fasciola [a]				
Parameter	B	Std. Error	Sig.	Exp(B)	Parameter	B	Std. Error	Sig.	Exp(B)
Intercept	-0.27	0.11	0.01		Intercept	0.83	0.13	0.00	
Post-intervention	2.29	0.20	0.00	9.83	Post-intervention	2.17	0.32	0.00	8.77
Pre-intervention	0[b]	.	.	.	Pre-intervention	0[b]	.	.	.

[a] The reference category is Positive for Strongyle and fasciola eggs. [b] This parameter is set to zero as it is redundant.

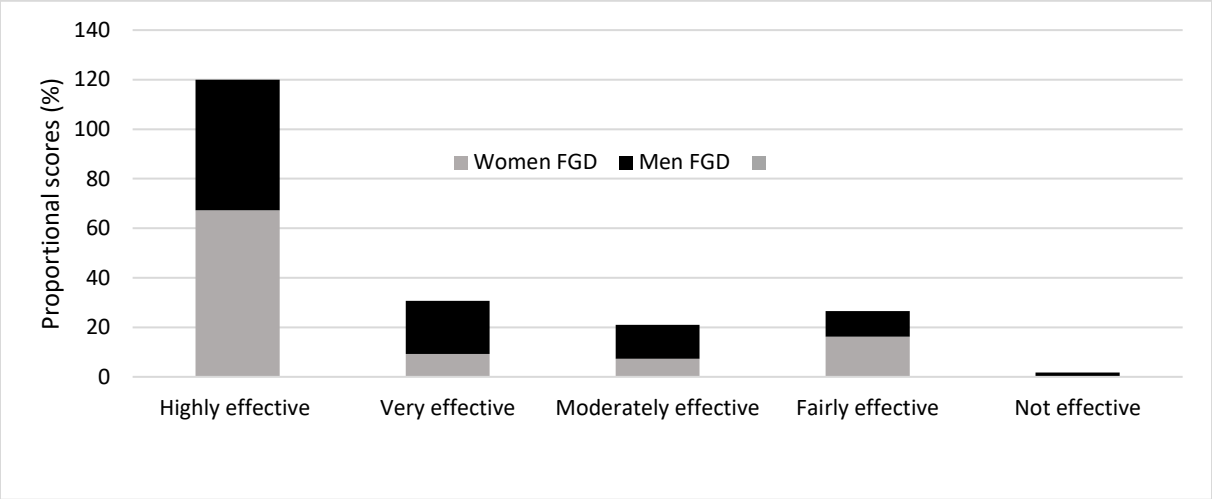

Fig. 1. Farmers opinion on the effectiveness of cooperative gastro-intestinal parasite control in three regions of Ethiopia

2. Vaccination interventions

2.1 Vaccination approaches

Disease prevention and control programmes should be planned with a high priority given to the economic welfare of smallholder farmers and pastoralists. The reality is that many animal health programmes would work much better if more attention was paid to smallholder needs (McLeod and Pinto, 2014). The major element in designing, planning and implementing a successful vaccination intervention for effective control of diseases is the vaccination approach or strategy adopted. There are different approaches that could be adopted depending on the purpose of the vaccination program and the local context. Spickler et al. (2015), in relation to vaccination against FMD, classified the various vaccination interventions into nine approaches:

Emergency Vaccination: vaccination in the face of an outbreak. This is usually conducted as reactive vaccination to a known strain of virus. This simplifies the choice of vaccine.

Protective Emergency Vaccination: conducted among animals in uninfected areas, creates a zone of animals with reduced susceptibility around the infected area.

Suppressive (or "Damping Down"): conducted in infected area where the virus is already circulating. It is intended to reduce virus transmission, aid control efforts and prevent disease from spreading beyond the infected zone.

Targeted Vaccination: attempts to protect specific groups of animals. It may be directed at uninfected animals of high value. It can also be directed at uninfected areas where there is a high density of susceptible animals.

Ring Vaccination: This is a strategy of immunizing animals within a defined area around infected premises or infected zones. Its purpose is to reduce or prevent virus transmission from a focal outbreak to surrounding uninfected areas.

Barrier Vaccination: Barrier vaccination is very similar in principle to ring vaccination; however, the vaccination zone is used to prevent the infection from spreading from a neighbouring country or region into the uninfected area. Barrier vaccination can be used in an OIE-defined protection zone, in addition to enhanced surveillance and movement controls.

Predictive Vaccination: This is based on prioritization suggested by a disease spread model. In predictive vaccination, vaccination is concentrated on farms that are predicted to have the greatest contribution to virus transmission in the future.

Blanket Vaccination: Blanket (mass) vaccination can be conducted throughout an entire country or throughout an OIE-defined zone with a separate status. Countries are most likely to consider blanket vaccination when a disease becomes widespread.

In Ethiopia for example, the vaccination approach followed against PPR involves risk-based vaccination based on active disease surveillance system, participatory disease surveillance and PPR diagnoses in the field (FAO, personal communication). However, transboundary diseases such as PPR, vaccination programs need to be implemented at a larger scale, for instance regional or continental level to be effective. One successful example is the Pan-African Rinderpest Control (PARC). PARC involved continent-wide vaccination campaigns, systematic sero-surveillance, active investigation of outbreaks and control of animal movement wherever possible (Tambi et al., 1999).

At national level, the most appropriate approach could be selected with the help of models on disease dynamics and vaccination impacts (with precaution to the reliability or accuracy of models), considering the local context, the resource limitations, including rapid, specific and sensitive methods for diagnosis. Egan et al. (2011) modelled two mass vaccination approaches (a blanket nationwide campaign vs. an approach targeted only at those geographic areas that experience smallpox cases) and found that nationwide mass vaccination is a suboptimal strategy and targeted mass vaccination is more optimal resulting in fewer deaths and less costly. One of the big problems with vaccination in Ethiopia is that frequency of vaccination is not enough (boost vaccination lacking), leading to the perception among farmers that vaccines don’t work. Also, overall there is insufficient coverage to achieve protection and interruption of disease transmission at population level.

An alternative intervention to vaccination may be the classical method of disease control, namely restricting movement of animals to and from affected areas, quarantine, elimination of contact fomites, and appropriate disposal of infected carcass (Abubeker et al., 2011). However, such strict sanitary control measures are unlikely to be feasible under smallholder farmers and pastoralists situations. Balamurugan et al. (2014) argues that control strategies may vary from country to country but in developing or under-developed countries the choices are limited, and vaccination has become a recommended tool to support control and eradication efforts.

The situation for typical production diseases that have high levels of endemicity, such as for example Pasteurellosis, requires different approaches. These diseases are often not a priority for national vaccination campaigns, and if included in national programs, coverage often is insufficient and intervals between vaccinations is too long. Community based approaches led by the livestock farmers and resulting in an increased demand would be a way forward. Instead of waiting for programs to provide vaccines, mechanisms to obtain vaccines when needed would change the situation and reduce impact of these diseases. Kebele or Woreda planning can play an important part in this, but also likely will require a cost contribution from the livestock keeper.

2.2 Thermotolerant vaccines

Although vaccination has been recommended as the most feasible disease control strategy for developing countries where other measures such as strict sanitary measures (e.g. stamping out to limit transmission of diseases), the effectiveness and/or coverage of vaccination programs has been low due mainly to poor infrastructure for maintenance of cold chain. Therefore, thermotolerant vaccines are preferred in such countries, wherein, the viability of the vaccine viruses would be ensured. Thermotolerant vaccines have been developed for some diseases, such as PPR and New Castle diseases. Although published literature on efficacy of PPR and New Castle disease thermotolerant vaccines developed in Ethiopia is not yet available, PPR vaccines developed in India (Balamurugan et al., 2014) has been tested and the thermotolerant PPR attenuated virus is innocuous, safe, immunogenic and potent or efficacious vaccine candidate alternative to the existing vaccines for the protection of goats and sheep against PPR in the tropical countries. Similarly, in Pakistan (Abubakar et al., 2011) a thermotolerant PPR vaccine was found to be stable at 45°C for 14 days with minimal loss of potency. Mariner et al. (2012) emphasized the role of Rinderpest thermostable vaccine, with a shelf life of more than eight months at 37°C, which was sufficient to recommend the vaccine for use in the field for up to 30 days without a cold chain, and the application of participatory epidemiological techniques for the eradication of Rinderpest.

2.3 Impact of vaccination

Vaccination has been a major animal health intervention in Ethiopia. However, its impact has rarely been evaluated and reported. According to Ashenafi's (2012) simulation of the impact of FMD vaccination on herd health in commercial dairy farms in Ethiopia, milk loss in non-vaccinated herds is 2.3 and 19.4 times higher than in herds receiving reactive and preventive vaccination, respectively. The corresponding death loss and abortion is 1.9 and 5.3 times and 33.9 and 100 times higher.

A participatory evaluation of vaccination has shown that vaccination could reduce percent of animals infected with FMD from 30–70% to 0% and with ovine rinderpest from 43–78% to 0% (Muruganandam et al., 2013). However, impact of vaccination could be limited if there are weaknesses in the design and implementation of vaccination programmes. Catley et al. (2009) attributed non-significant differences in mortality rates between vaccinated and non-vaccinated small ruminant and cattle herds in Afar, Somali and Borana communities in Ethiopia to use of inappropriate vaccines, low vaccination coverage, problems with vaccine dosing, incorrect timing of vaccination and problems with vaccine storage. Lesnoff et al. (2000), working with a

large sample size of 19 villages and 76 herds, also found no or negative effect of vaccination on offtakes.

3. Deworming interventions

3.1 Strategic anthelminthic treatment

Anthelmintic chemotherapy is widely used to control helminth infection in Ethiopia. Deworming service by the public and private sector is available throughout most of the country. Farmers and pastoralists are also applying deworming to their herds and flocks without the advice and prescription of trained veterinarians. For instance, Aga et al. (2013) reported that 95.3% of the surveyed farmers use anthelmintics as a parasite control method, but 38.7% and 25.3% of the respondents select anthelmintics based on ease of administration and color and only 21.3 based on prescription. Commonly used anthelmintics and their efficacy under research conditions in Ethiopia is shown in Table 3.

Indiscriminate and widespread use of deworming has recently led to resistance to anthelminthic drugs and effectiveness of helminth control. Deworming interventions need to be designed strategically based on epidemiology of the various nematodes and trematode species predominant in the intervention area. Furthermore, parasite control interventions need to be integrated. Sani and Gray (2004) assert that the foundation for any program on parasite control should be based on a sound knowledge of epidemiology of parasite infection in an area, use of strategic drenching, and a combination of confined and grazing systems, improved nutrition and controlled breeding.

Table 3. Fecal egg count reduction test (FECRT) under smallholder sheep farming system

Agroecology (region)	Sample size	Control	Albendazole	Tetramizole †	Ivermectin
Subalpine highland (Amhara)					
EPG count	120	300	347	323	317
% EPG reduction			98.8	99.7	99.1
Wet highland (Oromia)					
EPG count	60	176	197	187	200
% EPG reduction			98.8	99.7	99.1
Wet mid-highland (Southern region)					
EPG count	72	3072			
% EPG reduction			99.6	90.1	84.4

†Tetraclozan (Tetramisol HCL + Oxyclozanide) in Oromia

Source: Getachew et al. (2012); Seyoum et al. (2017); Aga et al. (2013)

3.2 Impact of strategic anthelminthic treatment

Although deworming is a widely used animal health intervention in Ethiopia, its impact has not been studied and quantified. A participatory evaluation of village-based deworming in India has shown that deworming could reduce per cent of animals infected with endoparasites from 67–88% to 13–16% (Muruganandam et al. 2013). Nwafor's (2004) extensive review of the impact of prophylactic anthelmintic treatment in West Africa indicates that biannual anthelmintic treatment could generate up to 40% higher weight gain and reduce mortality from 8% in control animals to 3% in treated small ruminants. Athar et al. (2012) also reported an average daily increase of 0.89 and 0.71 liters of milk along with 0.42 and 0.37% more fat per animal in oxyclozanide treated buffalo and cattle in Pakistan.

Deworming may not be expected to impact all measures of productivity in some situations. For instance, in a large-scale longitudinal study in the Gambia (Zinsstag et al., 1997), deworming has increased mortality of calves (21%) compared to the untreated control group (7.5%), whereas the treatment decreased age at first calving by 8.1 months and increased calving rate by 8.6%. Reports exist (Zinsstag et al., 1997 and references therein) that implicate and disregard the possibility of acute toxicity and embryotoxicity of fenbendazole and the whole class of benzimidazoles. Recent toxicity tests confirmed that albendazole caused stage dependent toxic effects in zebrafish embryos but was efficiently metabolized and deactivated (Matssen et al., 2012) and that metabolism of albendazole into its sulfoxide protected zebrafish embryos from toxicity (Carlsson et al., 2013).

There are factors or situations that need to be considered to expect reasonable impacts from anthelmintic treatments. In a similar set of interventions in India and Tanzania by GALVmed, while chickens treated with fenbendazole in India gained an additional 1.61 g/day, no significant change in body weight was recorded for chickens treated with a combination of piperazine citrate and levamisole. In a similar set of studies on goats, an additional significant weight gains were achieved in the treated goats in both countries' studies (25.2 g/day for goats treated with closantel in India and 9.88 g/day for goats treated with albendazole in Tanzania). It is noted that some situations that may result in insignificant impacts include low worm infection, too young chickens to have had exposure to worm infection, local pockets of resistance to anthelmintics, absence of strategic deworming interventions based on epidemiology of the parasites, and presence of other more important factors/variables determining the productivity trait measured. It is also important that accurate diagnosis of the disease is needed before applying the drugs.

4. Ectoparasite control

Ectoparasites are a major cause of loss of potential production and skin quality damages in Ethiopia. The prevalence of tick infestation could reach as high as 89.9% and 87.5% in goats and sheep, respectively (Abunna et al., 2009). A national control program against ectoparasites and skin diseases was initiated by the Ministry of Agriculture in 2005. The program has been implemented in Tigray, Amhara, Oromia and Afar regions. Evaluation of the control intervention in Tiyo and Deksis districts of Oromia region (Bedada et al., 2016) showed that effectiveness of the control campaign was minimal, with ectoparasite infestation, at 57.43%, still being among the major causes of sheep production constraints and quality deteriorations of exported skin in the districts. Similar studies in Amhara (45.5%, Zewdu et al., 2015), Oromia (61.40% in sheep

and 57.69% in goats, Shibeshi et al., 2013) and Tigray (55.5% in sheep and 58.0% in goats, Mulugeta et al., 2010) regions reported high infestation levels.

Ectoparasiticides have been found to be effective against ectoparasites and protect skin quality in sheep (Biruk et al., 2010). The limited impact of the national ectoparasite control campaign, according to Bedada et al (2016), could be due to improper formulation and application of acaricides, lack of awareness of the farmer on the transmission of ectoparasite and regulations on free animal movement. Ectoparasite treatment guidelines for the different agro-climatic zones, especially for the midlands and lowlands where the problem is severe, effective acaricides, animal movement control, sanitation, reduction of risks at breeding sites by environmental sprays, weed and vegetation controls are some of the suggestions to strengthen ectoparasite control intervention (Mulugeta et al., 2010; Bedada et al., 2016).

Effective delivery of ectoparasite control services and integrating farmers'/pastoralists' traditional knowledge and practices in the control programs are key to successful parasite control programs. Mutavi et al. (2018) studied the development of tick control services in Kenya, including dip management by the public sector and its failure and eventual transfer to the communities and the private sector, the knowledge and practices of livestock keepers. The authors esteemed knowledge sharing between different stakeholder groups (livestock keeper groups and the public veterinary department) may provide opportunities for better informed decision-making based on fruitful combinations of techne (scientific knowledge) and metis (experiential knowledge) for effective and safe tick management.

5. Capacity development

5.1 Capacity development interventions

The knowledge, attitude and practices of farmers and pastoralists towards development constraints are the main determinants of the effectiveness, adoption and sustainability of interventions which are planned to solve ongoing problems. Capacity development of farmers/pastoralists and agricultural development extensionists has been the main component of agricultural extension packages in Ethiopia, small-group short training being the main form of knowledge transfer. However, not all forms of capacity development interventions are equally effective in all situations/contexts. For instance, evaluation of three knowledge-transfer interventions addressing identical learning objectives about donkey health in Ethiopia (audio program, village meeting and diagrammatic hand-out) showed that, though all interventions significantly improved the overall knowledge score of donkey keepers compared to the control group which received no knowledge transfer intervention, diagrammatic hand-out was significantly a more effective knowledge transfer intervention and was recommended as simple, low-cost intervention for communities in low-income countries (Stringer et al., 2018).

Smallholder farmers' attitudes towards modern health interventions may in some cases be marred by misconceptions, including unintended negative effects on their animals such as miscarriages, reduction in milk yield, reduction in feed consumption, and weakness. Such situations require that technical health interventions be coupled with capacity development and awareness creation interventions. Livestock farmers' widespread resistance to vaccination and

medication in a remote Indian village was overcome by delivering health interventions along with advice through different communication methods. It was found that the farmer group that received personalized training by a veterinary professional and a youth volunteer resulted in a 96% vaccination rate compared to small-group training at a central location and wall posters that advertised a distribution of free medications at a veterinary outreach event where they could also interact with animal health personnel (Muthiah et al., 2013).

Low adoption rate of health interventions by livestock keepers (e.g. low vaccination coverage in Mali; Dione et al., 2018), could also be due to limited participation of farmers, poor monitoring and evaluation of vaccination campaigns, shortage of vaccines in the field, lack of trust in veterinarians by farmers. Dione et al. (2018) found that innovation platforms have proved to be effective to increase improve linkages among livestock vaccine value chain actors, knowledge of communities about the benefit of vaccination, relations and trust between producers, veterinarians and government authorities. The above improvements led to improved accuracy of estimation of animal population to be vaccinated, which allowed better planning and helps avoiding vaccine shortage, increased participation of farmers to vaccination, especially women, and eventually increased vaccination coverage of cattle and small ruminants against CBPP and PPR by of 8% and 10% respectively compared to previous years. Participatory training of livestock keepers on disease control protocols is also very important. Dione et al. (2017) found significant impact of participatory training on biosecurity protocols on the knowledge, attitudes and practices of smallholder pig farmers in Uganda which resulted in reduced African swine fever outbreaks.

The above observations in Ethiopia, Mali and India indicate that communication methods should vary depending on general cultural settings and individual farmers situations and perceptions to increase the effectiveness of capacity development interventions. Furthermore, to overcome some of the above-mentioned challenges the CGAIR research program on livestock trialed community conversation as a gender transformative approach. The community conversation covered different topics, such as division of labor in animal health management, risk of exposure to zoonoses and more recently veterinary drug use and animal welfare. Early results provide evidence of behavior change (Lemma et al., 2018).

Livestock owners vary in several characteristics, including gender, experience of livestock farming, which is mostly related to age, education level, the mix of livestock species owned, size of livestock holdings, and primary source of livelihoods which is expressed mainly as mixed crop-livestock farming and pastoralism/agro-pastoralism. These factors determine the knowledge of livestock producers on animal diseases and need to be considered in designing capacity development interventions. This is supported by the findings of Stringer et al. (2018) where farmers differing in such characteristics had different pre-intervention knowledge of donkey diseases ($p = 0.08$).

Impacts of capacity development interventions on beneficiaries of the interventions are not commonly assessed, particularly in the regular livestock extension services provided by the public sector. Using controlled randomized trials, Stringer et al. (2018) showed that capacity development interventions could increase knowledge of farmers from pre-intervention median scores of 6.75, 7.0, 6.0 and 6.0 to 7.0, 11.0, 17.5 and 15.5 for the knowledge transfer

interventions of control group, audio, diagrammatic handout and village meeting, respectively. Muthiah et al. (2013) reported vaccination and deworming adoption rates of 84, 66 and 44% after capacity development/awareness creation interventions were introduced through three communication intervention approaches, namely personalized training, small-group training and wall posters. Other impacts of capacity development are cited in the preceding paragraphs along with the interventions.

6. Herd health interventions

6.1 Integrated herd health interventions

Herd health is a planned animal health and production management program that uses a combination of regularly scheduled veterinary activities and good herd management designed to optimize animal health and productivity (Blood, 1979). The concept of herd health implies introduction of integrated packages comprising of animal health care and management interventions (feeding, housing, reproductive management) with the object of improving overall farm performance measured in terms of reproductive and productive parameters. FAO describes the herd health and production programme (HH&PP) protocol to include five interactive steps: agree on proposed production and acceptable risk targets; define and develop the tools to collect the necessary data; interpret the data gathered from all sources; and develop and agree upon a plan of action that includes concrete steps to reach the production and acceptable risk targets set in step one; and monitor and evaluate progress and begin again at step one.

Comprehensive herd health interventions and measurement of their impacts are rarely reported from developing regions. Nonetheless, there are some model interventions with almost complete interventions based on prevailing local conditions. For instance, in Liben and Shinile Zones of Somali Region, Ethiopia, the Milk Matters project introduced supplementary feeding plus a package of vaccinations and de-worming medications for milking cows and goats at the outset of the dry season, compared the impact of the intervention with control sites based on surveillance on animal performance and child nutrition (Sadler et al., 2012). This study showed that integrated herd health intervention could increase goat milk production by 280% (early lactation) to 4775% (late lactation period) over the control villages which did not receive the intervention. The corresponding increase of cow milk production were 344% and 1870%. This increased animal performance was also translated into quantified child nutrition and growth (Sadler et al., 2012).

However, herd health intervention components could be more detailed and systematic, for instance by addressing the prevalent specific disease problems. Salisi et al. (2012) introduced anthelmintics treatment based on fecal monitoring for helminthiasis, coccidiosis, and colibacillosis; antibiotics for diarrhoea, vaccination program against pneumonic mannheimiosis, culling of goats seropositive for brucellosis, and introduction of modified feeding regime comprised of day-time grazing and feeding of cut grass and supplemented feed. Implementation of such a herd health program could significantly increase body weight gains and reduce mortality rates under tropical conditions (Salisi et al., 2012).

Herd health interventions in remote areas with little access to inputs and services and drought-prone pastoralist areas need to include effective input/service delivery system and interventions mitigating effects of droughts. One such integrated intervention in Afar pastoralist region of Ethiopia included Voucher based animal healthcare (Bekele et al., 2014) together with goat supplementary feeding at the rate of 0.3 kg concentrate per adult doe. The intervention showed a significant impact: Average kid mortality decreased (15.4% in intervention and 75% in non-intervention flocks), milk offtake and children's access to milk increased. The cost benefit ratio of the intervention was 1:1.83.

Herd health interventions could also include advisory service to farmers besides technical/technological interventions, particularly to smallholder farmers and pastoralists where illiteracy is high. Here the method of delivery of capacity development determines the outcome (Muthiah et al., 2013).

To date, a herd health approach is missing from most animal health intervention packages in Ethiopia. What is also completely lacking is interventions towards improved animal welfare at farm level. Considering that poor husbandry and poor animal welfare directly impacts on productivity, it seems that there is a lot of untapped potential to improve efficiency of livestock production with low input interventions. Few incomplete herd health interventions in Ethiopia (Sadler et al., 2012; Bekele et al., 2014) show promising results. Experimental evidences to the advantages of integrated herd health interventions are also highly limited. One such experimental evidence from Ethiopia indicates a synergetic effect of supplementary feeding and deworming on helminths control (Haile et al., 2002). The CGIAR CRP program adopted a herd health approach introducing interventions to reduce the incidence of respiratory, reproductive and GIT diseases and community conversations in a community-based approach. Such interventions require monitoring of impacts through longitudinal studies. The situation regarding the concept of heard health interventions elsewhere in developing countries is the same as in Ethiopia. The few available in the literature are presented in Table 4.

Table 4. Herd health interventions and their impacts

Intervention	Species	Monitoring/indicators/impacts	Location	Reference
- Vaccination - Prophylactic treatments - Therapeutic treatments - Feed supplementation	Goat, cow	Milk production, Child milk consumption, child growth	Ethiopia	Sadler et al. (2012)
- Vaccination -Anthelmintics (multiple parasites) - Antibiotics	goat	Growth, mortality	Malaysia	Salisi et al. (2012)

- Cull brucella+ goats - Supplementary feeding				
- Vaccination - Deworming - Cleaning - Communication method	goat	Number of disease cases	India	Muthiah et al. (2013)
- Voucher-based health care - Supplementary feeding	goat	Mortality, milk offtake, child nutrition	Ethiopia	Bekele et al., 2014

Sudan/Rhodes grass supplement; - Wheat bran supplement

6.2 Herd health calendar

Herd health is an integrated program including husbandry, nutrition, parasite control and vaccination programs. Herd health interventions need to be calendared. For instance, a goat flock health calendar includes recording, measurement of performance levels, nutrition, animal management, sanitation, vaccination and parasite control calendar across age groups (Whittier et al., 2009). Herd health calendar need to be customized to the local situation. Herd health program choices are impacted by several factors (Step and Giedt) including geographic locations, climate/weather variations, housing and available facilities, animal density, resource availability and capabilities of care takers. A fact sheet needs to be developed for the local situation to monitor herd health. SNV (2017) provides vaccination calendar for the major dairy cattle diseases and fact sheet to monitor animals and premises in Ethiopia. Herd health calendars including vaccination calendars could be developed at village level (not at individual farm level) for smallholder systems like in Ethiopia. Vaccination calendar like the one presented here https://www.livestocking.net/vaccination-programme-schedule-goat-sheep-cattle could be developed considering the local situation. Similarly, herd health intervention needs to include calendars for deworming and spraying to control external parasites.

6.3 Evaluation of Herd health interventions

Evaluation of herd health intervention program entails identification of animals and record keeping on disease occurrence and animal performance. A comprehensive guideline for Integrated multipurpose animal recording systems is presented by FAO (2016). Animal health planning activities are not always providing a satisfactory positive impact on herd health and welfare. Moreover, evaluating the impact of advisory programmes is complex due to multiple interacting elements that influence its outcome. Therefore, measuring solely health outcomes is not enough: the whole process of the implementation and use of such programmes should be evaluated. In order to evaluate the impact of an intervention with a Herd Health and Production Management (HHPM) programme a process evaluation framework need to be designed (Duval et al., 2018). Cost-benefits analysis is an integral and ultimate component in evaluation of herd health intervention.

IV. Cost-Benefits of interventions

There are at least four approaches to consider for measuring the success or failure of animal health services, although no gold standard indicators or methods for assessing impact in veterinary medicine, including the International standards (i.e. OIE Terrestrial Animal Health Code), indicators of service provision (viz. accessibility, availability, affordability, acceptance and quality), production and causation involving measurement of production variables and which may also include cost-benefit analysis of disease control options, and participatory impact assessment (Catley et al., 2005).

1. Cost-benefits of CAHWs

One of the challenges for sustainability of CAWHs intervention is the low profit margin to CAHWs, which is caused by failure to ensure and maintain cost recovery principle and presence of free or subsidized service at accessible radius from any other service provider (particularly from the public service providers). Thus, the minimum requirements and indicators to ensure sustainability of a CAHW service need to include that full cost recovery service delivery principle or at least full recognition given to the CAHW service by the public service in case free or subsidized drug provision appears a must to consider it ahead (Bekele, 2003). A study in 13 districts of Ethiopia indicated the government subsidies to animal health services provided to pastoralists and farmers is on the average 55%, the 45% of the cost of service being covered by drug revenues (Moorhouse and Tolossa, 1997).

In general, health interventions are economically beneficial. A health intervention program relevant to smallholder system in developing countries can be exemplified by a cost-benefit analysis of community level health intervention in Afghanistan where the veterinary field program was carried out mainly by paravets (Schreuder et al., 1996). Comparison of each of the 22 age-species-specific district pairs showed a difference in favor of the covered district in 18 pairs in the reduction of mortality, where in 12 out of these 18 pairs this difference was significant, the overall annual mortality rates being higher in intervention districts being higher by 25%, 30%, and 22%, in calves, lambs, and kids, respectively, and by 30%, 40%, and 60% in adult cattle, sheep, and goats, respectively. The benefit cost ratio for the program was between 1.8 and 4.8.

Community-based health service has also been shown to be economically feasible in human health care. Comparison of the cost-effectiveness of adding the community-based management of severe acute malnutrition (CMAM) to a community-based health and nutrition program delivered by community health workers with the ‘standard of care’ for SAM (i.e. inpatient treatment), augmented with community surveillance by CHWs to detect cases, in a neighboring area showed that the community-based strategy costed lower (US$26 per disability adjusted life year (DALY) averted) than for inpatient treatment (US$1344 per DALY averted) (Puett et al., 2013).

2. Cost-benefits of vaccination

Benefit-cost analysis of animal health interventions is required to inform decision makers in the public sector and ensure sustainability of adopted interventions for livestock keepers. However, in some cases/situations, the concern could be ethical rather than economic in cases of humanitarian crisis (Barasa et al., 2008) and companion animals.

There has not been much work on the cost-benefit analysis of vaccination programs in Ethiopia, including the national/sub-regional Rinderpest Eradication Program (except assessment at regional level, Tambi et al., 1999) and the currently ongoing PPR vaccination projects which would lay the framework for designing a national PPR eradication program. In a simulation study on the economic impact of FMD vaccination in Ethiopia, Ashenafi et al. (2012) estimated a short-term farm level direct financial loss due to outbreak of Birr45,131, but financial losses between the non-vaccinated farms and those farms that underwent reactive and preventive vaccinations prior to the outbreak were not significantly different, although treatment of sick animals during an outbreak is cost effective. However, it has been found that the benefit–cost ratio of FMD vaccination is high elsewhere. For instance, in South Sudan Basara et al. (2008) estimated benefit–cost ratio of 11.5 where losses due to the chronic form of FMD accounted for 28.2% of total losses. The authors stressed that future benefit–cost analyses for FMD control in pastoral and agropastoral areas of Africa need to consider losses caused by chronic form of the disease.

Cost-benefit analysis of vaccination interventions/programs would ideally be estimated at national level. Estimates indicate national vaccinations programs are economical and, for zoonotic diseases, it would be more cost-effective to adopt a one health approach. In Mongolia, taking a one health approach, a cross-sector economic analysis and an animal-to-human transmission model, WHO estimated mass vaccinations of cattle and small ruminants against brucellosis saved money for the public health sector, with a benefit-cost ratio for society of 3.2 (VSF-Canada, 2010). A simulation study on cost-effectiveness of different rabies-control strategies in Ghana (VSF-Canada, 2010) indicated that a single parenteral mass dog-vaccination campaign reaching 70% coverage is, on average, profitable after 6 years, and more cost-effective over a period of longer than 7 years when compared to post exposure prophylaxis for exposed humans alone. In a controlled study with 5100 sheep and 13 300 goats in treated and control flocks, Awa et al. (2000) estimated the befits from animals vaccinated against PPR (also dewormed) to be 15 million FCFA (Cameroon currency) and 11 million FCFA for sheep and goats, respectively. The benefit–cost ratio ranged from 2.26 to 3.27 in goats and 3.01 to 4.23 in sheep, depending on the project lifespan.

Tambi et al. (1999) analyzed the cost-benefits of Pan-African Rinderpest Campaign (PARC) in 10 African countries, including Ethiopia. The authors concluded that, with average returns of ECU 1.8 (European currency unit) for each EUC invested in the campaign, rinderpest control in Africa has been economically profitable. The campaign benefited both producers, who derived the greatest share of the net value gained due to avoidance of losses of production, consumers due to lowered prices from increased supplies. Vaccination programs would be more cost-effective if more than disease is targeted in any one program. OIE (2015) recommends sheep and goat pox, pasteurellosis and brucellosis as good candidates to be combined with PPR

vaccination program. However, it is warned that combining activities to control and eradicate PPR with activities against other diseases could be considered counterproductive because they could dilute the focus on PPR eradication and that regional and national analysis will be the only way to confirm the extent to which addressing several diseases together is appropriate to the local contexts.

3. Cost-benefits of deworming

The prevalence of gastro-intestinal parasites in the Ethiopian highlands is reported to be very high, ranging from 40.9% to 86.6% (Tewodros et al., 2016; Zewdu et al., 2017; Lidya and Berihun, 2015). Its impact on growth, reproduction and survival is also significant. Research in Ethiopia and elsewhere has shown strategic deworming with anthelmintics could reduce helminths burdens (Tewodros et al., 2016; Zewdu et al., 2017; Lidya and Berihun, 2015). However, no work has been reported from Ethiopia and very few from elsewhere in the tropics on the cost effectiveness of helminth controls through deworming.

In general, strategic anthelmintic application has been shown to be economically feasible. While some works indicated marginal returns, for instance with a benefit-cost ratio of 1.14 (IRR = 17%) in N'Dama cattle in the Gambia (Itty et al., 1997), most other works showed high rates of return to investment, including 246% in Djallonke sheep in the Gambia (Ankers et al., 1998), 179% in sheep and 169% in goat in the Gambia (Nwafor, 2004), and benefit-cost ratio of 3.7 (range = 1.9 - 5.4) in Senegalese sheep (Lesnoff et al., 2000).

Economic losses may result from mortality caused by helminths, but the major losses come from production losses. Athar et al. (2012) estimated the economic value of reduced production of animals infected with helminths at US$ 0.47 and US$ 0.41 per animal per day for cattle and buffaloes in Pakistan, respectively. Helminths are a major disease problem in small ruminants, resulting in higher mortality than in cattle. Thus, it is expected that deworming intervention could be more profitable in small ruminants than in cattle. Awa et al. (2000), based on large sample size of 5100 sheep and 13300 goats and reproduction and mortality parameters, estimated benefit–cost ratio of anthelmintics (although confounded with vaccination against PPR) ranging from 2.26 to 3.27 in goats and 3.01 to 4.23 in sheep, depending lifespan of intervention program in Cameroon.

There are diverse views on the cost-effectiveness of anthelmintic treatments, the appropriateness of the cost-benefit analysis tool and the adoption of anthelmintic treatment by farmers. Nwafor (2004) reviewed extensively such diverse opinions. Some authors (Martrenchar et al., 1997) do not see the cost-effectiveness of anthelmintic treatments. Tambi and Maina (1999) argue that production losses due to helminths could be in the form of unrealized production potentials which may not be noticed by farmers leading them not to commit their scarce resources. The implication of the preceding argument would be that farmer participation is always mandatory in any agricultural research and development efforts. As such, such pure economic considerations have led to the criticism of benefit-cost analysis tool for economic appraisal (Ott et al., 1995).

V. Conclusions and recommendations

1. Conclusions

- The common animal health interventions are vaccination, deworming and health service delivery schemes, especially CAHWs. However, coverage is often patchy and CAHWs are not institutionalised.
- Integrated herd health intervention packages are virtually absent, even though they have a huge potential to improve productivity with highly favourable cost-benefit ratios.
- Interventions, particularly vaccinations, are introduced as emergency measures against outbreaks and droughts, even though there is a need for systematic prevention, including an increased focus on endemic production diseases.
- Most of the reports reviewed in this paper indicate a significant impact of animal health interventions on animal productivity and they are cost-effective.
- Cost-benefit analysis may not be the sole tool for appraising the suitability of interventions. A farmer participatory approach needs to be adopted.
- Community conversation is a useful tool as a gender transformative approach in animal health interventions

2. Herd health interventions for Ethiopia

Based on the literature in this review and priority diseases in Ethiopia (Wieland et al., 2016; Alemu et al, unpublished; unpublished data), recommended herd health interventions would include the following.

- Strategic community-based deworming intervention

- Vaccination for important diseases identified

- Community-based ectoparasite control (particularly in the lowlands)

- Assess animal welfare status and introduce animal welfare interventions

- Management intervention (Feeding, sanitation, husbandry, animal welfare)

- Capacity development on herd health management and specific diseases- Record keeping at community/village level (performance and health records)

- Set targets for growth, reproduction and mortality rates

- set up monitoring and evaluation framework

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