REVIEW ARTICLE

A Systematic Scoping Study of the Socio-Economic Impact of Rift Valley Fever: Research Gaps and Needs

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Impacts

- Overview of the different types of socio-economic impact induced by Rift Valley fever disease is presented with a description of their broad characteristics.
- Studies on the socio-economic impact of RVF are scarce and mostly based only on partial cost-analysis, however the figures provided point out clearly significant impact.
- Recommendations on the needs for research on the socio-economic impact of RVF are discussed, along with potential tools to apply and outputs of such studies in terms of improvement of RVF disease management.

Keywords:
Arabic Peninsula; economic impact; Horn of Africa; rift valley fever; zoonotic disease

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Summary

Rift Valley fever (RVF) is a severe mosquito-borne disease affecting humans and domestic ruminants. RVF virus has been reported in most African countries, as well as in the Arabic Peninsula. This paper reviews the different types of socio-economic impact induced by RVF disease and the attempts to evaluate them. Of the 52 papers selected for this review, 13 types of socio-economic impact were identified according to the sector impacted, the level and temporal scale of the impact. RVF has a dramatic impact on producers and livestock industries, affecting public and animal health, food security and the livelihood of the pastoralist communities. RVF also has an impact on international trade and other agro-industries. The risk of introducing RVF into disease-free countries via the importation of an infected animal or mosquito is real, and the consequent restriction of access to export markets may induce dramatic economic consequences for national and local economies. Despite the important threat of RVF, few studies have been conducted to assess the socio-economic impact of the disease. The 17 studies identified for quantitative analysis in this review relied only on partial cost analysis, with limited reference to mid- and long-term impact, public health or risk mitigation measures. However, the estimated impacts were high (ranging from $5 to $470 million USD losses). To reduce the impact of RVF, early detection and rapid response should be implemented. Comprehensive disease impact studies are required to provide decision-makers with science-based information on the best intervention measure to implement ensuring efficient resource allocation. Through the analysis of RVF socio-economic impact, this scoping study proposes insights into the mechanisms underpinning its often-underestimated importance. This study highlights the need for comparative socio-economic studies to help decision-makers with their choices related to RVF disease management.

Introduction

Animal diseases are a major threat to farming-based economies. Recently, zoonotic diseases such as the highly pathogenic avian influenza (HPAI) H5N1 have affected the world's economy. For HPAI H5N1, the losses were estimated in billions of US$ worldwide. The economic impact was equivalent to 2% of the East Asian gross domestic product (GDP) (McLeod et al., 2008).

Rift Valley fever (RVF) is a zoonotic disease of domestic ruminants and humans due to infection by an arbovirus belonging to the *Phlebovirus* genus (Bunyaviridae family). The RVF virus (RVFV) is transmitted between ruminants by mosquitoes, mainly from the *Aedes* and *Culex* genera, or by direct contact with viremic fluids such as blood, foetal membranes or amniotic fluids. The viremic incubation period following infection ranges from a few hours to a few days (Pepin et al., 2010). Fresh and raw meat of viremic animals can also be a source of infection for humans, but the virus is rapidly destroyed by meat maturation (Gerdes, 2004). The virus can be present in fresh milk but at a very low level. Infection in faeces and urine of infected animals has never been demonstrated (Pepin et al., 2010). Other potential sources of virus such as nasal and lachrymal secretions have never been experimentally confirmed (Walker et al., 1970). RVFV causes abortion storms and high mortality among newborns and offspring of domestic ruminants due to severe hepatic damage (Swanepoel and Coetzer, 1994; Bird et al., 2009). The mortality rate in newborns is 95–100% (Pepin et al., 2010). As experimentally demonstrated, the mortality of adult sheep may be as high as 20% (Easterday, 1965). However, it may also cause subclinical infections (Davies, 2006). In humans, the infection can also result from mosquito bites from ruminant-to-human transmission following an exposure to body fluids (such as blood) of viremic animals during slaughtering, butchering or necropsy (Chevalier et al., 2010).

In humans, most infections cause moderate to severe non-fatal, influenza-like acute illness. A few patients, however, may develop ocular lesions, encephalitis or severe hepatic disease with haemorrhagic manifestation which can be fatal (Hoogstraal et al., 1979; Meegan and Bailey, 1989). During an outbreak in Saudi Arabia in 2000, 7.1% of infected people developed haemorrhagic symptoms, 1.5% ocular complications and 17.1% neurological complications. The overall case fatality rate is estimated to be between 0.5% and 2% (Madani et al., 2003).

Since the first declared outbreak in Kenya in 1930 (Daubney et al., 1931), RVF has been encountered in an enzootic or epizootic form in most African countries including Madagascar (Pepin et al., 2010) (Fig. 1). The first recorded RVF outbreak outside the African continent was in September 2000, when Yemen and Saudi Arabia were affected simultaneously (Ahmad, 2000; Madani et al., 2003). In 2006–2007, an epidemic in Kenya and Tanzania resulted in more than thirty thousand animal cases and one thousand human cases (Lichoti, 2009). In May 2007, RVF was diagnosed in the French island of Mayotte (Sissoko et al., 2009). The importation of infected live ruminants from Kenya and Tanzania was likely responsible for the introduction of the virus, leading to the epidemics of 2006–2007 (Chevalier et al., 2010). Countrywide outbreaks occurred in Madagascar in 2008 (Andriamandimby et al., 2010) and South Africa in 2010 (ProMED-mail, 2010). Sporadic animal cases were also reported in Botswana and Namibia in 2010 (ProMED-mail, 2010). The last large outbreak occurred in 2010 in Mauritania with human and animal (camels) cases (El Mamy et al., 2011).

Due to its tropism for domestic ruminants, RVF may be expected to impact pastoral livelihoods first. In pastoral societies, livestock is the basis of human subsistence and prosperity, as well as of cultural life and social organization (Davies, 2010). It represents the main repository of household wealth and serves an important livelihood function, providing valuable goods and services such as milk, meat, blood, manure, transport, draught power and financial services. Livestock is a tool for risk management at the household level, through its basic function of savings and also as a means for mobility in a highly variable environment. It is also a source of risk through its own vulnerability to environmental conditions and infectious diseases (animal diseases and zoonoses). Risk around livestock keeping is thus the fundamental driver of food security, health and overall vulnerability of pastoral populations.

In the Horn of Africa, pastoralism plays an important role in national economies. In particular, the export of livestock from the pastoral communities to the Middle East is of vital economic importance as millions of animals are imported each year, particularly during the religious festival periods. Export incomes can represent up to $300 million USD (Holleman, 2002; Cagnolati et al., 2006; Soumaré et al., 2006). Export orientation allowed for and was spurred by the turning of a subsistence transhumant system into a market-integrated ranch activity (Holleman, 2002; Solomon et al., 2003; Cagnolati et al., 2006; Soumaré et al., 2006). Thus, pastoral wealth became the main national wealth. The livestock sector as a whole appears in these pastoralist countries as a major driver of macroeconomic variables, a source of considerable employment and foreign currency.

Depending upon the importance of the livestock sector, the socio-economic impacts of RVF can be considerable. One could expect these impacts to involve actors far beyond the strict livestock production sector (Cagnolati et al., 2006; Rich and Wanyoike, 2010). Due to the multiplicity of actors and the intricacy of the cultural, social and economic importance of the livestock sector, these impacts

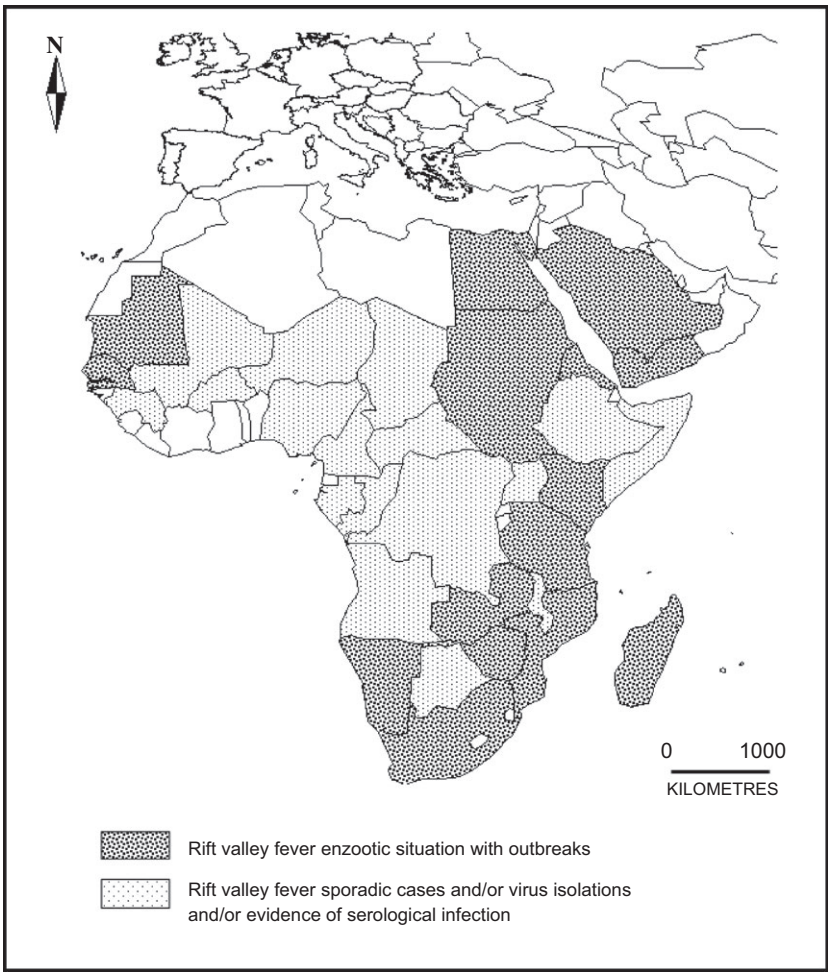

Fig. 1. Geographical distribution of enzootic and epizootic Rift Valley fever in the Middle East and the African continent. Adapted from Chevalier et al. (2010) available online: http://www.eurosurveillance.org/ViewArticle.aspx?ArticleId=19506.

are also expected to be multidimensional in nature (Zinsstag et al., 2007; Sindato et al., 2012). Nevertheless, public policy tends to concentrate primarily on financial losses incurred by livestock producers and neglects downstream impacts and redistributive effects (e.g. overall loss of activity for butchers and slaughterhouses, especially for actors inside quarantine areas) (Rich and Wanyoike, 2010; Rich and Perry, 2011).

Socio-economic impacts of a disease may include impacts of disease occurrence and of its management (control, prevention, surveillance). Such impacts can be related either to health resource mobilization (e.g. animal morbidity and/or mortality, disposal of carcasses, healthcare costs) or to non-health resources (e.g. reduction in butchers' activity due to reduction in meat market volumes) observed at different time scales and horizons as well as on different economic scales (Drummond et al., 1998). The term 'impact' is used here as it relates to a broader concept than costs. It also includes redistributive and structural effects on socio-economics, which may not be considered as costs (e.g. when players are forced out of the business by the disease or its control (or forced to diversify) and the market is later taken up by competitors) (Holleman, 2002). The term 'socio-economic' is preferred here to explicitly account for the multiple natures of these additional consequences. The array of impacts of a disease such as RVF is determined by its pathological and epidemiological characteristics (including its zoonotic potential), by the characteristics of the economic sector it primarily affects and by the insertion of this sector in the national and international economy. Many impacts will be determined by the way actors react to the disrupting event this represents. Political, psychological or social drivers can underpin these reactions (Sindato et al., 2012).

Considering the current zoonotic threat of RVF and the increasing risk of spread to a disease-free continent, there is a need for better understanding of the socio-economic impact of RVF to integrate it within the disease management and policy decision process (Arzt et al., 2010; Chevalier et al., 2010; Pike et al., 2010).

This scoping study presents an overview of the types and estimates of the socio-economic impacts of RVF, at different economic levels (micro, meso, macro) and temporal scales. The main objectives of this study were 1) to identify and provide estimates if available of the different types of RVF socio-economic impact that have been described in the literature and 2) to provide elements on the needs and gaps for further research on the socio-economic impact of RVF.

Material and Methods

Search strategy

Standard search terminology was developed based on the review objectives to collect information on the following research questions: (a) What are the different types of RVF socio-economic impact? (b) How and where has the RVF socio-economic impact been estimated? (c) What are the limits of the current estimations and the needs for further research? The search was conducted up to 1 September 2013 in the PubMed, CAB abstract, Web of Science, Science Direct and Scopus databases. The search was restricted to articles in English and French and with available abstracts. The search terms used were ('rift valley fever') AND ('impact*' OR 'financ*' OR 'economic*') using corresponding keywords extracted from the MeSH database (presented in Supporting Information).

All records retrieved from these scientific databases were imported into Reference Manager® version 11 bibliographic package (Thomson Reuters, New York, NY, USA), and duplicate articles were removed.

An additional search was performed using Google Scholar to identify any relevant documents not published in peer-reviewed journals using the following terms: ('rift valley fever' AND ['impact'OR'economic'OR'financial'OR'outbreak'] NOT 'laboratory' NOT 'genetic' NOT 'biological' NOT 'vaccine' NOT 'climate' NOT 'environment'). Exclusion criteria were directly included in the Google Scholar search because of the technical limitations of this approach to limit the number of records and allow for exhaustive screening of the retrieved references (manual import of the references into bibliographic package and no option to sort out the list of references by first author names). Moreover, the removal of duplicates between the scientific databases and Google Scholar searches was performed during the screening step to ease the process because of the technical limitations of the Google Scholar search. Grey literature retrieved from personal contacts was also included in this analysis.

Screening of the articles and data extraction

All the titles and abstracts of the articles were screened, and 'irrelevant' documents were removed based on the following exclusion criteria: studies not providing any information on the economic impact of the disease (e.g. studies on RVF virus laboratory analysis, genetics, experimental or field testing of vaccine efficacy, environmental studies and predictive models on the impact of climate change on RVF virus vectors). All the studies providing qualitative or qualitative information on impact (e.g. number of outbreaks; socio-economic impact data) were included in the study. Articles were selected for review and data extraction if their abstract provided information on economic assessment, financial data on RVF impact and figures on RVF outbreaks. Additional articles not captured in this search were retrieved, based on the references contained in the selected articles. A flow chart diagram of the inclusion selection process for publication in this study was developed based on the PRISMA approach (Fig. 2). A template was developed in Microsoft Excel® version 2007 to organize relevant information extracted from each article: study objectives, location, year, study type, type of impact considered, assessment method, assessment outputs and limits of the study.

Data analysis

The links between the different types of impact extracted from the reviewed literature were assessed, and a diagram of these links was developed using Microsoft Power Point® 2007 (Fig. 3). Quantitative data were analysed using Microsoft Excel® 2007. The estimates of the socio-economic impact of RVF provided in the retrieved literature were expressed as a percentage of each country's gross domestic product at purchasing power parity (GDP, PPP) to allow for comparison (Budke et al., 2006; McLeod et al., 2008). The GDP, PPP values were retrieved from the online World Bank database (The World Bank, 2014). The relative importance of each impact was assessed for each case study country by measuring the proportion of each type of impact against the total estimate of RVF impact within each country.

Results

Search strategy

A total of 1055 articles were retrieved from the searches in the scientific databases and additional citation search, and 541 duplicate articles were removed. A total of 512 documents were retrieved from the Google Scholar search and personal contacts (Fig. 2). Of these 1026 documents (514 from scientific database search and 512 from other sources), 947 were excluded through title and/or abstract screening based on the exclusion criteria, and a further 11 articles from the Google Scholar search were removed because of duplication with the scientific database searches.

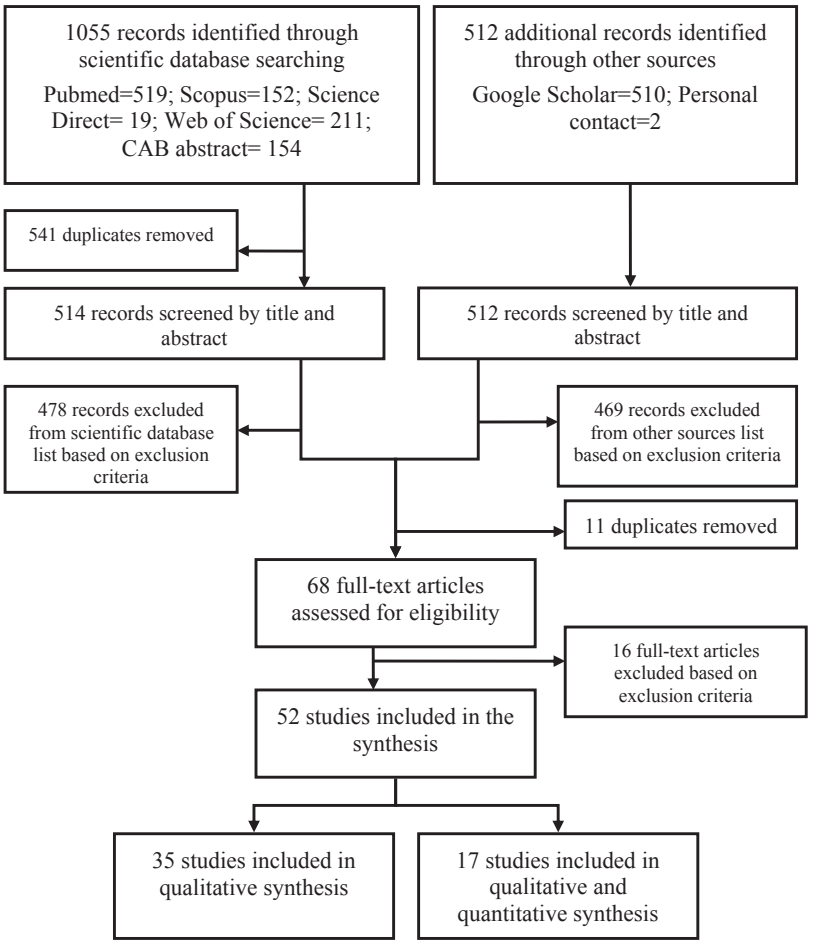

Fig. 2. Flow chart diagram of the study selection process for inclusion in this scoping study.

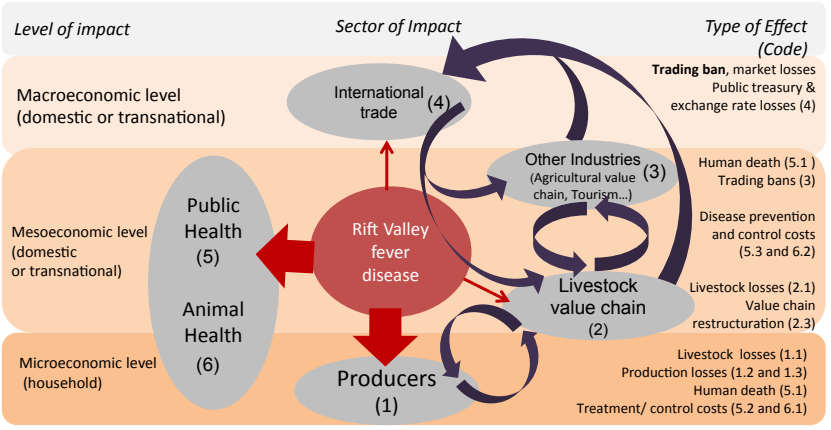

Fig. 3. Socio-economic impacts of Rift Valley fever per sector, level and type of effects induced. The links between the disease and the different sectors and level impacted (health related costs) are represented by straight (red) arrows; the links between the different sectors and level impacted (non-health-related costs) are represented by the bent (blue) arrows.

The remaining 68 articles or documents were fully reviewed. Of the 68 selected articles, 16 were excluded based on exclusion criteria (Fig. 2).

Of the remaining 52 articles, 35 provided only qualitative information on RVF impact (outbreak description and general type of impact) and 17 provided qualitative and quantitative information on the socio-economic impact of RVF (seven reports, five conference abstracts and five articles) (Tables S1; Tables 1 and 2). Information on RVF outbreak figures and related financial data along with qualitative information on RVF socio-economic impacts was extracted from the 52 documents selected for qualitative

analysis. The 17 references included in the quantitative analysis provided case study information from the Horn of Africa in general ($n = 3$) (Bonnet et al., 2001; Walter et al., 2007; Kimani et al., 2012), Kenya and Tanzania ($n = 6$) (USAID, 2008; Lichoti, 2009; Rich et al., 2009; Rich and Wanyoike, 2010; Orinde et al., 2012; Sindato et al., 2012), Somalia ($n = 5$) (Ahrens, 1998; Holleman, 2002; Nin Pratt et al., 2005; Cagnolati et al., 2006; Soumaré et al., 2006), Yemen and Saudi Arabia ($n = 1$) (Handlos, 2009); USA ($n = 1$) (Hughes-Fraire et al., 2011) and Sudan ($n = 1$) (Hassan et al., 2011). As only five of the 17 records providing quantitative data on RVF socio-economic impact assessment were retrieved from peer-reviewed literature search, it was decided to analyse the data extracted from both grey and scientific literature searches in a similar way but to focus the review on highlighting research needs and gaps rather than on estimates of the RVF socio-economic impact. Moreover, the choice of focusing the review on the Horn of Africa and Arabic Peninsula was also based on the available data retrieved (15 of 17 records).

Overview of the socio-economic impact of RVF

A list of 13 socio-economic impacts induced by RVF along with their general characteristics (level of impact, sector impacted, temporality and type of effect induced) was defined, based on the data extracted from the selected studies (Table 1). The links and organization of the different types of effect are presented in Fig. 3. The reported impacts related to microeconomic (effects of choices made by individual actors in the economy), mesoeconomic (intermediate scale effects) or macroeconomic (effects linked to large-scale market systems) levels.

Impact of RVF on producers' livelihoods (microeconomic level, household economy)

The first reported direct socio-economic impact of RVF was on livestock producers due to high levels of mortality (between 50% and 100%) and morbidity (e.g. abortions in 90–100% of cases) in animals. This represents an important loss of stock, especially in young ruminants (Daubney et al., 1931; Bird et al., 2009) (Table 1, effect 1.1; Fig. 3).

In addition, the disturbance on herd dynamics could result in production losses lasting several years or even several animal generations (long-term effects) (Table 1, effect 1.2). These effects are perceived over the long term and are subject to the combined influence of other economic mechanisms besides the strict herd dynamics (Table 1, effect 1.3) (Anonymous, 2007). The long-term effects are fundamentally dependent on the response of households coping with the sanitary and economic context. Besides destocking, these adjustment responses may include recourse to credit, changes in their production mode (species, herd size, diversification in agricultural production, diminishing use of inputs), in their livelihood basis (seeking off-farm employment), in their consumption modes and levels (shifts to cheaper food) and in reliance on social network (sending children to wealthier relatives, financial help) (Holleman, 2002). The sustainability of such adjustments is nevertheless questionable and might not be considered as true coping strategies but rather signs of distress. (Holleman, 2002). Furthermore, households do not all share the same ability to implement such strategies, potentially leading to redistributive effects in favour of those with higher resilience (i.e. those who have the higher ability to cope with changes in their household economy).

If the household economy is diversified enough, that is, if there are other activities or opportunities to generate income, the direct impact of RVF on livestock losses can be partly mitigated (Holleman, 2002; Rich and Wanyoike, 2010). This can be the case of agro-pastoral households or of commercial producers who also have non-agricultural activities. Otherwise, the household is vulnerable and food security can be threatened. Resilience is then highly dependent on the endowment (meaning the herd size) and the ability to downsize their expenses (adjustment strategies) and to create new small income-generating activities (Holleman, 2002).

Pastoral communities relying on a livestock economy are highly vulnerable to the threat of disease to their livestock such as RVF (Davies and Martin, 2006). Moreover, in the context of the Horn of Africa, pastoralists who represent 15–20 million people in Djibouti, Eritrea, Ethiopia, Kenya, Somalia and Sudan (USAID, 2005) have turned to a market-integration and international trade orientation. This has led to new development opportunities but also to new economic threats, by increasing interdependence with the international economy.

Impact of RVF on livestock industry (mesoeconomic level, domestic or transnational value chains)

The impact of RVF on producers will have repercussions along the livestock value chain (production and market activities) and its ancillary services (Table 1, effects 2.1, 2.2 and 2.3). Cumulatively, the impact on other service providers within the livestock supply chain and other parts of the larger economy can be greater than the impact of RVF at the farm level (Bonnet et al., 2001; Murithi et al., 2011; Rich and Perry, 2011). The impacts may be short (<1 year) or long term (over 1 year) and qualitative (value chain restructuring) and/or quantitative (performances and socio-economic values). These impacts are partially due to changes in the value and quantity of animals on the market (Nin Pratt et al., 2005).

Table 1. Overview of the different types of socio-economic impact induced by Rift Valley fever, their broad characteristics and their estimation from field case studies

Impacted sector (code)	Level[a]	Category	Type of Effect (code) (*timescale*[b])	Financial estimate per country (Reference)
Producers (1)	Microeconomic Household economy	Food security and livelihood economy	Livestock losses (1.1) (*short term*)	Kenya: $9.3 million USD (Lichoti, 2009; Rich et al., 2009; Rich and Wanyoike, 2010; Sindato et al., 2012) Somalia: $47–55 million USD (Ahrens, 1998; Soumaré et al., 2006) Yemen: $0.6 million USD (Handlos, 2009) Saudi Arabia: no estimates
			Losses in production (1.2) (*short term*)	Kenya, Milk ($2 million USD) (Lichoti, 2009) Somalia, Yemen, Saudi Arabia: no estimates
			Abortion; destocking; redistribution effects (inequalities) (1.3) (*long term*)	No estimates
Livestock industry (2)	Mesoeconomic Domestic or transnational	National economy Food security Livelihood economy	Livestock losses (2.1) (*short term*)	Kenya ($32 million USD) (Rich et al., 2009; Rich and Wanyoike, 2010; Orinde et al., 2012) Yemen ($15 million USD) (Handlos, 2009) Saudi Arabia ($5.3 million USD) (Mohammed, 2007) Somalia, no estimates
			Trading bans impact on local value chain (local market losses) (2.2) (*short term*)	Kenya ($10 million USD) (Rich and Wanyoike, 2010; Orinde et al., 2012) Somalia ($29–45 million USD) (Ahrens, 1998; Holleman, 2002; Nin Pratt et al., 2005; Cagnolati et al., 2006; Soumaré et al., 2006) Yemen, Saudi Arabia: no estimates
			Value chain restructuration, consumer perception (2.3) (*long term*)	No estimates
Other agro-industries (3)	Mesoeconomic Domestic or transnational	National economy	Transport; tourism; trading bans (3) (*short and long term*)	Yemen, tourism ($30 million USD) (Handlos, 2009) Kenya, Somalia, Saudi Arabia: no estimates
International trade (4)	Macroeconomic	National economy	Trading bans impact on import/export; public treasury and exchange rate losses (4) (*short and long term*)	Kenya ($ 10 million USD) (USAID, 2008; Rich and Wanyoike, 2010; Orinde et al., 2012; Sindato et al., 2012) Somalia ($330 million USD) (Ahrens, 1998; Holleman, 2002; Nin Pratt et al., 2005; Soumaré et al., 2006)Yemen ($50 million USD) (Handlos, 2009) Saudi Arabia: no estimates
Public health (5)	Microeconomic household and Mesoeconomic Domestic	Livelihood and national economies	Human death (5.1) Private treatment (5.2) (*short and long term*) Prevention and control (human infections) (5.3) (*short and long term*)	Kenya 1% of total DALY (household costs: $82 000 USD) (Orinde et al., 2012) Yemen ($12 million USD, human death) (Handlos, 2009) Somalia and Saudi Arabia: no estimates

Table 1. (Continued)

Impacted sector (code)	Level[a]	Category	Type of Effect (code) (*timescale*[b])	Financial estimate per country (Reference)
Animal health (6)	Microeconomic household and Mesoeconomic Domestic	Livelihood and national economies	Private surveillance and control in livestock (6.1) (*short and long term*) Public surveillance and control in livestock (6.2) (*short and long term*)	Kenya ($2.5 million USD, short term) (Lichoti, 2009; Rich and Wanyoike, 2010) Yemen ($ 0.1 million USD, vector control) (Handlos, 2009) Somalia, Saudi Arabia: no estimates

[a]Microeconomic focus on the choices made by individual actors in the economy; mesoeconomic focus on intermediate-scale effects; macroeconomic focused on market systems that operate on a large scale.

[b]Short term = less than 1 year; long term = more than 1 year.

Beyond the livestock value chain, there may be spillover effects on other agricultural value chains (e.g. the importation of other agricultural products may be banned from the infected countries) (Table 1, effect 3) as well as non-agricultural sectors, such as transportation or tourism (Table 1, effect 3) (Handlos, 2009). Therefore, much of the disease impact is often felt by downstream actors and outside of the sector that is first affected (Rich and Perry, 2011). Thus, attention should not only focus on the nature of value chain relations within the livestock sector itself but also on its relation with other industrial sectors (Rich and Perry, 2011).

Impact of the trading ban (macroeconomic level)

RVF outbreaks may result in the enforcement of embargoes on the exportation of live animals and animal products, as imposed by international sanitary policies. Where the banned export sector has an important economic weight in national trade balance, the ban may significantly affect the national economy (Table 1, effect 4) (Ahrens, 1998; Soumaré et al., 2006; USAID, 2008; Handlos, 2009). Hence, the successive RVF-related trade bans could impact the public treasury, the exchange rate of national currency and thus, the price of imported goods (Fig. 3, Table 1) (McDermott et al., 1999; Bonnet et al., 2001).

In some countries (e.g. Somalia, Tanzania), taxation on livestock exports is the main source of government revenue (Gaani et al., 2002; Soumaré et al., 2006). Livestock exports play a major role as a source of employment, income and foreign exchange (Sindato et al., 2012). The export bans thus lead to decreasing livestock prices and worsening terms of trade, which further undermine pastoralists' purchasing power and livelihood (Fig. 3, Table 1).

The impact on livestock marketing is more severe during the major public religious feasts. During these periods, the risk of RVF infection increases because of a high density of animals and the religious practices (Abdo-Salem et al., 2011). Within this period, the foregone income is even higher due to the increase in animal value resulting from the peak in demand. Therefore, given the zoonotic nature of RVF, the loss of confidence by an importing country can trigger a lasting embargo and have major economic and social repercussions on all the sectors (livestock and other industries) (Fig. 3) (Bonnet et al., 2001; Soumaré et al., 2006; Rich and Wanyoike, 2010; Rich and Perry, 2011).

Holleman (2002) and Cagnolati et al. (2006) described the national economic consequences of trade bans. First, the fall in exports was also associated with a fall in the exchange rate of the national currency. This resulted in an increase in the local price of imported goods (petrol, rice, sugar, etc.) and overall inflationary pressure, which affected the purchasing power of the country population. The transfer of government incomes from export taxes to import taxes

Table 2. Main Rift Valley fever outbreaks from 1930 to 2009: animal, human health and global estimated economic costs

		Human		Animal		Estimated economic impact		
Year	Country	Cases	Death	Cases	Death	US$ (x10^6)	% GDP (PPP)	References
1950–1951	South Africa	nd	nd	600 000	100 000	nd	nd	Swanepoel and Coetzer (1994)
1977–1978	Egypt	200 000	594	nd	nd	115	0.8	Imam and Darwish (1977), Meegan et al. (1979), Shimshony and Barzilai (1983), Meegan and Bailey (1989), Johnson et al. (1993), CDC (1994) Shimshony (1999)
1978	Zimbabwe	nd	nd	70 000	10 000	nd	nd	Swanepoel and Coetzer (1994)
1997–1998	East Africa[a]	89 000	478	nd[b]	Nd	>250	nd[c]	CDC (1998), Holleman (2002), Gerdes (2004)
2000–2001	Saudi Arabia	883	123	>10 000	1000	10	0.02	Ahmad (2000), Anonymous (2000a), CDC (2000a,c), Davies and Martin (2006), Al-Afaleq and Hussein (2011)
2000–2001	Yemen	1328	166	22 000	6000	107	0.8	Ahmad (2000), Anonymous (2000b), CDC (2000b), Alquadasi (2009), Handlos (2009)
2006–2007	Kenya	684	155	>4400	235	66	0.1	Woods et al. (2002), CDC (2007), USAID (2008), Lichoti (2009), Rich et al. (2009), Davies (2010), Munyua et al. (2010), Nguku et al. (2010), Rich and Wanyoike (2010)
2006–2007	Somalia	114	51	nd	Nd	471	5.5	Ahrens (1998), Holleman (2002), Nin Pratt et al. (2005), Soumaré et al. (2006)
2006–2007	Tanzania	264	109	32 000	4200	6,7	0.01	Lichoti (2009), Sindato et al. (2012)
2008–2009	Madagascar	>650	21	23	18	nd	nd	WAHID (2008)
2008	Sudan	698	222	nd	Nd	nd	nd	WAHID (2007), Hassan et al. (2011)
2010–2011	South Africa	186	18	>15 000	9000	nd	nd	Anonymous (2010), Perez et al. (2010)

This list is a non-exhaustive list, and complete information on RVF outbreaks could be found on World Animal Health Information database (WAHID) at http://www.oie.int/wahis/public.php. $USD, United States Dollar; GDP (PPP), gross domestic product at purchasing power parity; nd, not determined.

[a]Kenya, Somalia and Tanzania.

[b]Only available for Kenya: 70% of sheep population, 20–30% of camel and cattle.

[c]Available for Somalia: US$186 million, 4.3%GDP (PPP).

(presented as a decline in import subsidies) added to this rise in prices. Also, the general fall in activity in the livestock sector forced stakeholders to diversify, when possible, or forced people to move into urban centres, thereby increasing problems of urban poverty and unemployment. One would expect similar impacts for any country whose national economy relies heavily on livestock trade. Impact on rangelands and the environment (pollution, water quality, deforestation, etc.) was also reported in the case of Somalia.

Impact of RVF on Public Health (microeconomic level, household, and mesoeconomic level, domestic)

Developing and transition countries are particularly at risk of zoonoses such as RVF (Zinsstag et al., 2007). The public health infrastructure in resource-limited settings is not sufficient to support and sustain routine infectious disease surveillance, prevention and control activities, especially when outbreaks are known to occur every 5–15 years (Zinsstag et al., 2007). During a severe outbreak, a substantial number of human infections can occur inducing extensive implementation of disease treatment and control programmes (Table 1, effects 5.1, 5.2 and 5.3) (Labeaud et al., 2008).

Human deaths following RVF infection were first recorded during the epidemic of 1975 in South Africa when seven patients died of encephalitis and haemorrhagic fever associated with necrotic hepatitis (Gear, 1977). In 1977–1978, a major RVF epidemic in Egypt resulted in 200 000 human cases and 600 fatalities (Table 2) (Imam and Darwish, 1977; Meegan et al., 1979). Twenty years later, a new epidemic affected over 500 000 persons in East Africa, among which 500 people died (Davies and Martin, 2006). From December 2006 to May 2007, RVF human cases were reported in Somalia (114 cases reported, 51 deaths), Kenya (684 cases reported, 155 deaths) and Tanzania (290 cases reported, 117 deaths) (Table 2). Only one study has attempted to measure the value of 'number of healthy years lost' by measuring disability-adjusted life years (DALYs). This tool includes public health costs in the evaluation of the economic impact of a disease (valued as 120USD per household with a human case and accounting for 1% of the total DALYs during the time of RVF outbreak in Kenya) (Orinde et al., 2012) (Table 1, effect 5). Handlos (2009) used conventional techniques of insurance theory to try to evaluate economic losses linked to human lives (Table 1) (Handlos, 2009).

Cross-sectoral costs linked to disease prevention, treatment and control measures (microeconomic level, household, and mesoeconomic level, domestic)

Control costs include the value of all resources used to manage the disease at household (treatment costs) and national level (disease prevention and control costs) (Table 1, effects 6.1 and 6.2). Several control measures are described: (i) control of livestock movements with respect to trade and export, (ii) vector control with an emphasis on larvicides in vector breeding sites or (iii) vaccination of livestock (Dungu et al., 2010). The endemic status of the disease in countries with recurrent outbreaks may result in long-term financial investment and recurrent costs for disease control (e.g. animal vaccination and/or vector control) and surveillance, relying on sentinel herds, passive abortion reporting or mosquito trapping (Fig. 2, Table 1) (Gerdes, 2004; Lichoti, 2009; Al-Afaleq and Hussein, 2011; Metras et al., 2011; Bird and Nichol, 2012; Sindato et al., 2012).

Case studies of RVF socio-economic impact

Estimations of the socio-economic impact of RVF outbreaks provided in the retrieved literature relied only on partial assessment, that is, based on the estimation of 1–7 of the 13 types of impact described in the literature (Table 1). Even so, the impact estimates were high: \$66 million USD for the 2007 outbreak in Kenya and Tanzania (with 6 of the 13 impacts assessed); \$471 million USD in Somalia (with 4 of the 13 impacts assessed); \$107 million USD in Yemen (with 7 of the 13 impacts assessed); and \$5 million USD in Saudi Arabia (with 1 of the 13 impacts assessed) (Table 1). RVF impact estimates were expressed as a percentage of each country's gross domestic product at purchasing power parity (GDP, PPP) to allow for comparison: 0.1% for Kenya, 2% for Tanzania and 5.5% for Somalia for the 2006–2007 RVF outbreak; and 0.02% for Saudi Arabia and 1% for Yemen for the 2000–2001 RVF outbreak (Table 2). The relative proportion of each impact was presented for each case study (Fig. 4). The studies have concentrated so far on the short-term effects on livestock producers and livestock industries by estimating loss of livestock and its consequences on the market economy (Table 1, effects 1 and 2) (6/17 studies), along with the losses incurred by international trading bans (Table 1, effect 4) (4/17 studies). The effects of RVF on other agro-industries (Table 1, effect 3) (1/17 studies) and the transversal costs induced by public and animal health expenditures (Table 1, effects 5 and 6) (3/17 studies respectively) represented only a small fraction of the impact considered (Fig. 4). However, this might be an underestimated figure as these impacts have only been estimated in a limited number of studies (1/17 for effect 3 on other agro-industry; 2/17 for effect 5 on public health and 2/17 for effect 6 on animal health) (Fig. 4). The biggest impacts were linked to trading bans and their effects on livestock industries and the national economy (Table 1, effects 2.2 and 4) (Fig. 4) and livestock losses for producers and industries (Table 1, effects 1.1 and 2.1). Production losses,

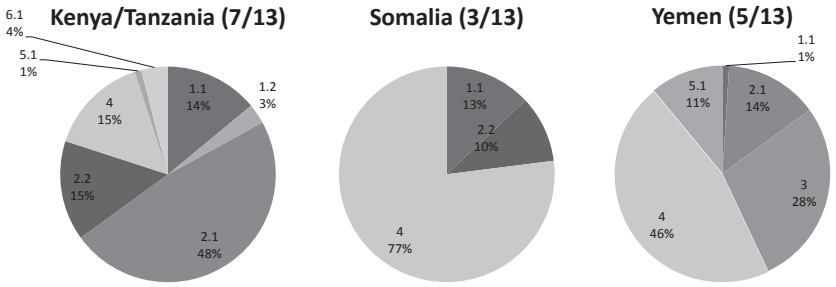

Fig. 4. Relative importance of each type of RVF socio-economic impact reported in the case studies considered in this review (*n* represents the number of studies that have assessed the impact). Shades of grey represent the different types of impact considered: livestock losses for producer (1.1) and livestock industry (2.1); losses in production (1.2); local market losses (2.2); impact on other industries (3); trading ban impact on national economy (4); cost of human losses (5.1); costs of disease surveillance and control for the producers (6.1).

impact on other agro-industries, public and animal health were not considered in all the case study countries (Table 1, effects 1.2, 3, 5.1 and 6.1). In the following section, we present a short summary of each case study's outputs and we review the research gaps and needs in terms of socio-economic assessment.

Impact of RVF in Kenya and Tanzania

In Kenya, livestock (cattle, sheep and goats) are the main source of income (employment and livelihood) mainly generated by livestock marketing (Rich and Wanyoike, 2010). The impacts of RVF outbreaks for the producers were estimated at around $10 million USD due to food insecurity and loss of income and capital (Table 1, effects 1.1 and 1.2) (Lichoti, 2009; Rich and Wanyoike, 2010). Income drop was attributed to both morbidity and mortality of livestock (including losses from stamping-out policies implemented to control the disease) (Lichoti, 2009). The long-term impact on livestock (Table 1, effect 1.3) was only described by Le Gall (2006) and Walter et al. (2007) as a reduction in herd sizes due to the high abortion rate (reduced by factor 2 in cattle, factor 8 in goat and factor 22 in sheep) but with no estimation of its cost (Le Gall, 2006; Walter et al., 2007). The impacts for the livestock industry (traders, slaughterhouse operators and butchers) and other related industries (livestock and meat transporters, livestock brokers and marking boys, or government tax collection) were considered (Table 1, effects 2.1 and 3). In many cases, these actors were unable to resume their activities even after the outbreak was contained, yet the resulting losses were not estimated (Holleman, 2002; Rich and Wanyoike, 2010).

The losses resulting from a trading ban (e.g. closure of Garissa market) (Table 1, effect 2.2) were estimated along with the spillover impact on the meat value chain at local and regional level (with a 25% decrease in the price of mature cattle in Garissa; Nairobi, Mombasa and other major markets in Kenya) and related activities (urban consumer populations, transporters and local authorities) (USAID, 2008). This impact was, however, transitory from March to October 2007. After this period, meat prices doubled in Garissa Market and have remained high ever since (USAID, 2008). This point highlights the importance of considering an appropriate time frame to capture all the socio-economic effects of an outbreak (Wanyoike and Rich, 2007).

The economic impact of RVF on Kenyan public health (Table 1, effect 5) was recently described by Orinde et al. (2012) by estimating the burden of the disease in DALYs and the cost of treatment. They estimated the burden of RVF during the 2006 and 2007 outbreak as 3.4 DALYs per 1000 population, representing 1% of the total DALYs, and estimated the household costs as $120 USD for every human case reported (total estimated cost of $82 000 USD for the 2006–2007 outbreak) (Orinde et al., 2012).

The socio-economic impact of RVF in Tanzania was recently reviewed by Sindato et al. (2012). The study described a qualitative analysis of the social costs related to distress in animal and human life losses (Sindato et al., 2012). The authors reviewed the impact of the disease in terms of disruption of livelihood of pastoralists and those who were depending on livestock products and related activities for labour opportunities. Livestock producers were no longer able to meet their social financial obligations (e.g. children school fees, medication, clothes, etc.). Those communities suffered stigmatization from other rural people who considered they had lost 'respect, dignity and experienced low morale' along with the economic losses due to the selling of livestock and related products (Sindato et al., 2012). Long-term illness and disability resulting from RVF infection impaired the farmers to resume their normal economic activities. Psychosocial distress was therefore important and linked to the loss of family members, livestock and crop production (Sindato et al.,

2012). No information has been provided on RVF impact on animal health (Table 1, effect 6).

Impact of RVF in Somalia

Somalia is an edifying example of the RVF impact at national level as its economy relies mainly on livestock production and trade (60–65% of Somali GDP) (Holleman, 2002). In Somalia, pastoralists represent nearly 70% of the population and 60% of this population depends on meat and milk. Livestock export to the Middle East is the main source of the country's resources (Holleman, 2002). Somalia also owns the Berbera sea port, which is the only main port exporting live animals from the Horn of Africa to the Arabian Peninsula (Soumaré et al., 2006; Pinauldt, 2009).

Following the 1997 RVF outbreak, a 16-month ban on the importation of live animals from Eastern Africa was imposed in February 1998 by Saudi Arabia (Ahrens, 1998). A second ban was imposed in September 2000, with all Arabian countries stopping the importation of live animals from the Horn of Africa, following an outbreak of RVF in Saudi Arabia and Yemen. Prior to the bans, the size of the export market from Somalia to Saudi Arabia and the United Arab Emirates varied between 1.3 and 3 million animals per year (Ahrens, 1998). Following the bans, the Somalia livestock market completely collapsed. Indeed, while 90% of its total income comes from livestock export, the ban resulted in a decline of more than 75% in exports (Ahrens, 1998) (Soumaré et al., 2006) and a loss greater than $300 millions USD (Table 1, effects 2.2 and 4). As a result of these social upheavals and the impact on government finance, the bans in this region not only affected each household, they also resulted in instability of livelihoods and food insecurity (USAID, 2000). More dramatically, it led to the collapse of the stability of the Somalia administration (Nin Pratt et al., 2005). Cagnolati et al. (2006) reported a drop of $91 million USD in nominal terms, representing a 25% reduction in national GDP compared to a normal year (Cagnolati et al., 2006). Through the use of modelling methods, Nin Pratt et al. (2005) estimated the impact of the trade bans at a 36% fall of the GDP (Nin Pratt et al., 2005).

Impact of RVF in Yemen

In Yemen, animal husbandry's contribution to employment is important with 80% of the rural population being engaged in some form of animal production (Handlos, 2009). In 2000, livestock were estimated to be around 1.35 million cattle, 4.8 million sheep, 4.2 million goats and 0.2 million camels (Handlos, 2009). Yemen is a crossroads for animal trading between Africa and the Arabian Peninsula. More than 1 000 000 animals from the Horn of Africa enter the country each year (without considering informal trade). The outbreak in 2000 led to more than 21 000 animal abortion cases, and 6000 animal deaths between September 2000 and February 2001 (Ahmad, 2000).

The impacts on producers, livestock industries and other industries and the impact of trading bans on the national economy were well described by Handlos (2009) (Table 1, effects 1.1, 2.1, 3 and 4). In this study, the cost of vector control was also included, but no attempt was made to compare the economic impact under different control strategies (Table 1, effect 6) (Handlos, 2009). Handlos also made an attempt to evaluate the public health impact and indirect long-term impact linked to the tourist industry (Table 1, effects 5 and 3). The 2000 outbreak led to a total of 1328 human cases (166 deaths). The total cost in terms of the value of the 166 human lives lost was calculated from life insurance actuarial tables to be greater than $12 million USD (Table 1, effect 5.1) (Handlos, 2009). The cost of hospital treatment for the hundreds of infected patients (household cost) (Table 1, effect 5.2), however, was not included.

Impact of RVF in Saudi Arabia

Saudi Arabia is one of the world's largest importers of sheep and goat meat (Gardner and Finan, 2013). During the pilgrimage season, around 10 million small ruminants are killed annually (Gardner and Finan, 2013). Although some of these animals come from the Arabian Peninsula itself, most are imported across the Red Sea from East African countries where RVF is endemic. The 2000 RVF outbreak in Saudi Arabia was responsible for more than 10 000 animal and 880 human cases (Anonymous, 2000b; Balkhy and Memish, 2003; Madani et al., 2003). With a high animal mortality rate, the incurred tangible losses for the cattle market in 2001 were estimated at $5.3 million USD (Table 1, effect 2.1) (Anonymous, 2001). It is not clear whether this figure accounts for the indirect impact of import trading bans on the local meat market economy (Table 1, effect 2.2).

A massive control programme was implemented to contain the RVF outbreak (Mohammed, 2007; Al-Afaleq and Hussein, 2011). It included animal movement restriction and quarantine, culling and burial of infected animals, insecticide sprayings, animal vaccination (10 million head), sero-surveillance and widespread educational campaigns (Mohammed, 2007). No documented figures of the estimated cost of control measures are available for Saudi Arabia. However, based on the global cost estimate of control measures implemented by countries importing from the Horn of Africa ($1 million USD), nearly 50% of the expenses ($0.43 million USD) were for measures implemented only by Saudi Arabia, such as quarantine and

serological monitoring of sentinel herds ($0.13 million USD) (Table 1, effect 6) (CDC, 2000c). The cost of animal vaccination was not included in this calculation.

There has been no attempt to assess the impact of RVF on producers, other industries, international trade and public health in Saudi Arabia (Table 1, effects 1, 3, 4 and 5).

Discussion

Multidimensional nature of RVF socio-economic impacts

This review highlights the multidimensional socio-economic impact of RVF on multiple socio-economic and temporal scales and sectors (Table 1, Fig. 3). Only partial economic assessments of RVF impact have been implemented so far and reported in the literature. The values of the financial estimates provided should be considered with caution as they were mostly retrieved from grey literature, that is, the methods used to compute those estimates have not been validated by the scientific community. Nevertheless, these assessments still demonstrated a pattern of extensive economic damage through multiple economic losses. For example in Somalia, the local and/or international bans on livestock trade during the 2006/2007 RVF outbreak were responsible for most of the economic burden incurred from the disease (64%) and led to dramatic socio-economic impacts, destabilizing the livestock sector, threatening the livelihoods of pastoralist communities and strongly reducing the government revenue (Holleman, 2002; Cagnolati et al., 2006; Soumaré et al., 2006; Soumare et al., 2007). This resulted in the collapse of the Somali administration (Nin Pratt et al., 2005). The effects of RVF on other agro-industries may have been underestimated as they were only considered in a limited number of studies (Fig. 4).

The figures presented in Table 1 on public health impact are difficult to compare as they are not based on the same measurement (e.g. DALYs, insurance costs, household treatment costs). However, they highlight the economic importance of RVF disease in humans and the need to consider these costs when evaluating zoonotic risk priorities and defining strategies for efficient prevention and control. Indeed, the number of reported human cases from past outbreaks is high (e.g. 27 500 human cases during the 1997–1998 outbreak affecting Tanzania, Somalia and Kenya; 200 000 human cases during the 1977–1978 outbreak in Egypt) and, if translated into cost, could lead to further billions of US$ in treatment and human life losses (Woods et al., 2002).

No attempts have been made to assess either the long-term effects on producers and livestock industries or the long-term impact on national institutions. Long-term impacts such as the disruption in herd growth caused by animal abortions and the impact on the environment or on national economic stability should be included in the analyses (Holleman, 2002; Rich and Perry, 2011). These long-term impacts may justify the need for long-term investment and recurrent expenditure on control and surveillance.

Even though this study concentrated on the Horn of Africa and the Arabic Peninsula, these findings should be representative of any country that economy and community livelihood relies strongly on pastoralist activities (Bonnet et al., 2001).

Challenges and research needs on socio-economic assessment of RVF impact

The main objective in assessing the economic impact of RVF disease is to provide data for decision-makers to assess and improve the efficiency of different surveillance and control strategies (Tambi et al., 1999, 2004; Howe et al., 2013).

An optimal disease economic impact evaluation requires gathering sufficient knowledge for decision-making without the need to quantify everything resulting from the outbreak in detail. However, while cost analyses are a major component of the decision-making process, they cannot, as the sole indicator, capture the full and long-term impacts of the disease and the societal burden, which in developing countries plays a major role. In some areas such as those described in the case studies in this review, livestock production and trade are vital sources of livelihood for pastoralists and a potential pathway out of poverty for many smallholders. Moreover, livestock also generates other benefits that are less tangible and often overlooked in disease analysis. These benefits include the inputs to agriculture (manure, traction and transport) and to the production of complementary products (hides, fleece). Livestock further provides financial services (investment, insurance, credit and risk management) and ecosystem services (biodiversity, nutrient cycling and energy flow) and covers a range of social and cultural values (including wildlife and tourism) (Davies, 2010). The complexity of the different impacts makes precise economic assessment difficult but still needs to be considered when undergoing disease prioritization and resource allocation priorities for surveillance and control.

Moreover in the case of RVF disease alone, there has been no attempt to perform a comparative economic assessment of different prevention and control strategies. Even though some studies included a cost analysis of the surveillance and control measures implemented (Kenya and Yemen), the real impact of RVF is probably underestimated as it relies on limited local surveillance systems (in both animal and public health) to detect and report RVF cases (Tables 1 and 2) (CDC, 2000a,c). Early detection and

implementation of appropriate measures are essential to minimize direct losses. However, significant financial investment is needed to build up the capacity to implement these control measures (Berentsen et al., 1992). Rich and Perry (2011) stated that the logistics behind the control strategies further influence the disease impact. These include the technical and resource aspects of the control strategy itself (e.g. the effectiveness of animal vaccination) and recurrent costs related to control and post-control surveillance, once an outbreak is either contained or is endemic (Rich and Perry, 2011). For Somalia, it was estimated that an annual budget of $80–100 000 USD (equivalent to 0.02% of the estimated RVF disease impact) should allow the Somali veterinary authorities to continuously monitor the RVF status in the country and devise control measures closer to the production areas (Ahrens, 1998; Cagnolati et al., 2006; Soumaré et al., 2006). Predictive models of RVF disease occurrence based on environmental conditions greatly favourable to RVF vector population have been developed in the last 10 years (Abdo-Salem et al., 2006; Anyamba et al., 2009; Niu et al., 2012). However, no studies have been carried out to compare the efficiency of implementing preventive measures based on such predictive models with the cost of control actions following outbreak occurrence. There is a need to provide economic data to allow for optimum resource allocation and implementation of preventive measures rather than relying on post-outbreak corrective actions alone. Moreover, economic models and mitigation strategies are available to compare the efficiency of different control options (vector control and/or animal vaccination, etc.) and could be used to ensure better allocation of the limited resources (Tambi et al., 1999, 2004; Hughes-Fraire et al., 2011; Howe et al., 2013).

Conclusion

Despite the recognized dramatic impact of RVF on the Horn of Africa and the Arabian Peninsula, few studies have assessed the full social and economic impact of the disease. Due to the complexity of impacts and their multiple natures, part of the required assessment may need to remain qualitative. The 'cost' of national instability may remain outside the scope of economic analysis for some time. This highlights the extent to which a qualitative description of the economic, social and environmental dynamics at play can be crucial in analysing the impact of an animal disease, overshadowing the quantifiable impacts of the disease.

The geographical distribution and recent spread of RVF proves the virus' capacity to expand and adapt to new areas. RVF is now considered not only as a potential threat for Europe (Chevalier et al., 2010) but also as an important bioterror and agroterror threat to western countries including the United States (Mandell and Flick, 2010; Hartley et al., 2011; Hughes-Fraire et al., 2011).

Comparative socio-economic studies are critical in helping decision-makers to make choices related to RVF disease management. RVF threatens the livelihood and food security of small producers but also the gross domestic product of national economies relying on animal product industries. To reduce the impact of RVF and prevent it from spreading to unaffected areas, early surveillance and control should be implemented. Comprehensive disease impact studies are required to provide decision-makers with science-based information to ensure and review the efficiency of the interventions.

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Declaration of Interest

None.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Table S1. List of the 52 references included retrieved from the database searches and included in the qualitative and quantitative analysis of this scoping study.