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Agricultural Impact of Porcine Cysticercosis in Africa: A Review

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1. Introduction

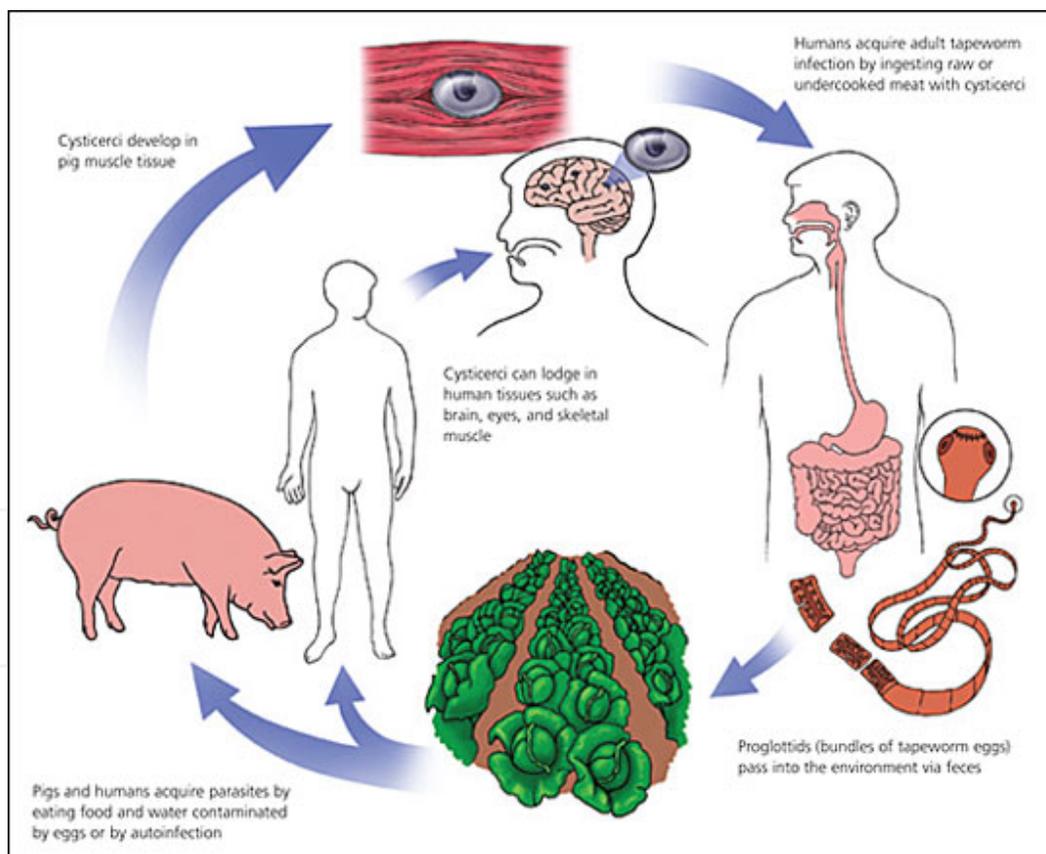
This chapter reviews the status of pig production and porcine cysticercosis caused by *Taenia solium* in Africa. First, it provides background information regarding pig production and porcine cysticercosis in the region. The chapter then reviews in some more details the current status of porcine cysticercosis in each of the countries based on available scientific literature. Furthermore, this chapter analyses extensively the economic impact of porcine cysticercosis, especially to the agricultural sector in Africa. Finally, the chapter provides conclusions and recommendations to guide future work in relation to porcine cysticercosis in the African continent. To simplify the reporting, the African continent has been divided into five regions based on the United Nations classification system. The regions are northern Africa, southern Africa, western Africa, central Africa, and eastern Africa.

2. Background

Porcine cysticercosis refers to as an infection of pigs with the larval form of *Taenia species*. *Taenia solium*, *T. saginata asiatica*, and *T. hydatigena* are the *Taenia species* that can infect pigs. While *T. saginata asiatica* is currently known to be limited to Asia, *T. solium* and *T. hydatigena* have a worldwide distribution. On the African continent, however, *T. solium* ('pork tapeworm') is the most important species of *Taenia* economically and for public health. The larval form of this parasite is capable of infecting humans leading to life-threatening neurological disorders, including epilepsy. In addition, *T. solium* cysticercosis in humans and pigs causes serious economic losses in affected countries because of condemnation of infected pigs and disability in neurocysticercotic patients. The human is the only natural definitive host of *T. solium*. An adult tapeworm is harboured in the small intestine of

humans, a condition referred to as taeniasis. *Taenia solium* taeniasis is acquired through ingestion of infective larvae of the parasite from infected meat. Raw or inadequately cooked pork provides the route for taeniasis transmission. On the other hand, the larval form of *T. solium*, cysticercosis, can infect both humans and pigs if the hosts ingest infective eggs of the parasite. The life cycle of *T. solium* is presented in Figure 1. Water and foodstuffs contaminated with faecal material from a human carrier of the adult tapeworm are the major sources of cysticercosis transmission. Several factors have been found to facilitate the occurrence of cysticercosis. These include open defaecation, poor personal hygiene, free ranging pigs, and lack of safe drinking water. These factors facilitate both human and animal host access to human faecal materials, which at times may contain *T. solium* eggs.

Although a number of animal species including dogs [1] can be infected with *T. solium* cysticercosis, domesticated pigs play the major role in the transmission cycle of the parasite because of their close proximity to humans, especially in rural areas, and the increasing popularity of pig keeping and pork consumption in many developing countries [2]. Therefore, most of the literature on *T. solium* has focused on the human-pig transmission cycle. This is also the focus in this chapter.



Source [3]

Figure 1. The life cycle of *Taenia solium*.

Taenia solium is prevalent in several countries of Africa, Asia and Latin America, providing the full life cycle of the parasite. Poverty has facilitated the parasite's

endemicity by inhibiting adequate sanitation and good pig husbandry, which are primary in the control of *T. solium* transmission. The currently emergence and re-emergence of cysticercosis in some industrialised countries of the USA and Europe resulting from international migration have been limited to human-human transmission leading to human cysticercosis (including neurocysticercosis). However, because of improved sanitation and intensive pig rearing, porcine cysticercosis can rarely be (re)introduced in these countries, and hence, a full cycle of the parasite is virtually impossible. In such countries, the major impact of the parasite is related to human morbidity and associated economic losses.

In response to the WHO's effort to estimate the global burden of neurocysticercosis, four comprehensive studies have reported estimates of burdens of *T. solium* cysticercosis [4-7]. While three of the studies estimated the economic burden of cysticercosis, each focusing on a specific country [4,5,7], a global extensive systematic review of literature found that the frequency of neurocysticercosis in people with epilepsy was consistent across endemic countries. The pooled estimate was 29.0% (95%CI: 22.9%–35.5%) [6]. Knowledge on the proportion of epilepsy caused by neurocysticercosis is primary to enable estimation of the economic impact of neurocysticercosis in endemic countries. For the studies that have estimated the economic burden of cysticercosis in both human and pigs, the infected pigs have been found to contribute 4.7-26.9% of the overall costs of the infections [4,5]. The cost estimates in the pig industry have been entirely based on the prevalence of porcine cysticercosis and the economic loss of the pig's value due to the infection. Thus the observed variation between countries has been primarily due to the differences in porcine cysticercosis prevalence and reduced values of the infected pigs in the different country settings. A study in the Eastern Cape Province of South Africa also reported different values due to different data analytical methods [4]. Generally, the price of a finished pig was estimated to be reduced by 20-60% because of infection with cysticercosis [4,5].

While *T. solium* is progressively being recognized as an important parasite at the global level, to date scientists in several developing countries endemic for the parasite are struggling to bring the disease to the national attention. Failure of *T. solium* endemic countries to recognize the importance of the parasite is attributed partly to lack of knowledge by stakeholders on the presence, magnitude and impacts of the parasite. While understanding both the human health and agricultural impacts of the parasite is necessary in order to establish the overall societal burden of the parasite to countries, for endemic diseases such as cysticercosis, political decisions in most developing countries are often based on economic impacts of the diseases. This is because most long-term, persisting endemic diseases are difficult to quickly appreciate their impact, especially to non-professional policy makers. This is different from epidemic diseases, which draw significant attention when they occur, and hence, favourable measures are usually taken urgently to control such diseases. Political will is important for countries to allocate necessary resources to solve community related problems such as diseases. Specific

knowledge on the contribution of the various sectors in the overall societal burden of *T. solium* is of particular importance to promote inter-sectoral collaboration towards control of the parasite [8].

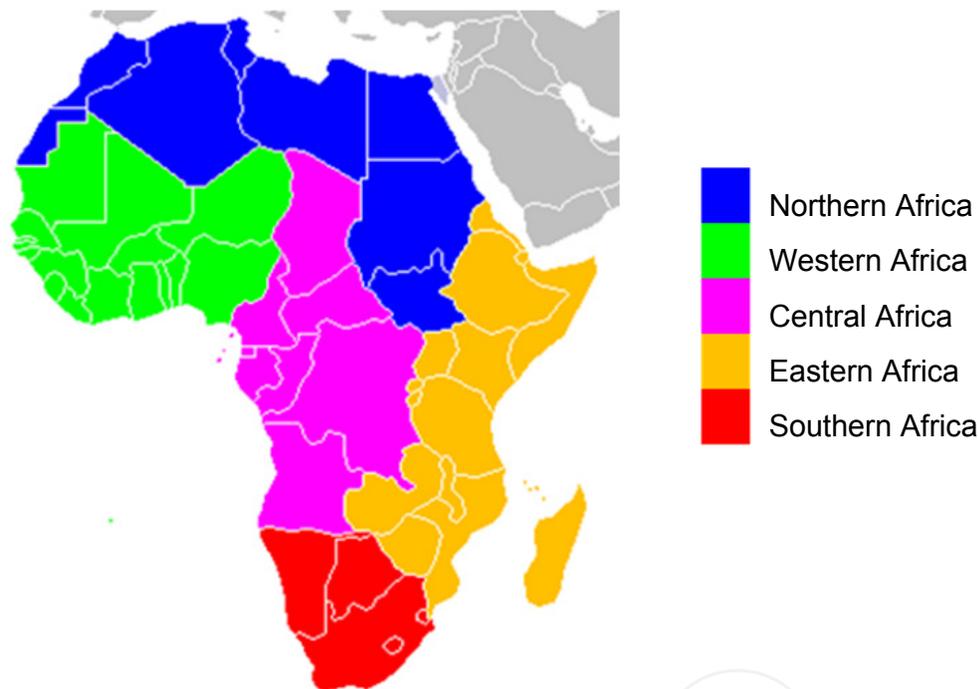
In Africa, pig keeping is popular in many countries. However, there has been no study that has clearly described the pattern of pig production and the overall status of porcine cysticercosis on the continent. This is important in order to understand the importance of the pig enterprise in the region as well as the potential for porcine cysticercosis to constrain the industry. Africa is one of the regions where the full cycle of *T. solium* is occurring because of the favourable environmental conditions and poverty, which inhibit application of effective control measures for the parasite. Thus Africa provides a suitable ecology for *T. solium* endemicity. While information on human taeniasis and cysticercosis status in Africa is still scant, inhibiting a full appraisal of the parasite's burden to the affected countries, a number of scientific publications are presumed to be available with regard to the magnitude and impact of porcine cysticercosis to the agricultural sector in the affected African countries. The emergence of *T. solium* cysticercosis in eastern and southern Africa as a serious agricultural problem and public health risk was described earlier by the Cysticercosis Working Group in Eastern and Southern Africa (CWGESA) [2]. Other authors have described the taeniasis-cysticercosis complex in West and Central Africa [9]. These provide some of the evidence on the importance of cysticercosis caused by *T. solium* in Africa. Synthesizing the information on the burden of porcine cysticercosis to the agricultural sector in Africa would inform on the regional status and guide future efforts towards control and ultimately elimination of the parasite

3. Scope

In this chapter, we review the pig production and agricultural impact of porcine cysticercosis on the African continent based on available literature. Data on the pig population in Africa is based on the most current global pig population estimates [10]. For the prevalence of porcine cysticercosis, the most recent information is included, with a priority for prevalence estimated using antigen ELISA, where available, in order to reflect active infections. However, prevalence based on a less accurate diagnostic method is used if that is the only information available. Note that, the purpose of the review is to describe the current status of porcine cysticercosis in the African region rather than presenting all that has been done in the region with regard to porcine cysticercosis. For simplicity, the African continent is divided into five major regions as classified by the United Nations. That is northern Africa, southern Africa, western Africa, central Africa, and eastern Africa [Figure 2]. Only the 54 countries fully recognised by the United Nations are included. These consists of seven, five, 16, nine and 17 countries of the northern, southern, western, central and eastern Africa, respectively.

It is possible that porcine cysticercosis poses more economic losses than those only related to condemnation or reduced value of infected pigs. For example, studies have established possible reduced fertility of pigs naturally infected with cysticercosis, which would reduce

the productive performance of the pigs [12]. Similar findings have been reported in human infected with neurocysticercosis [13]. In both the pig and human studies, cysticercosis was found to significantly reduce serum level of testosterone while increasing significantly the level of follicle stimulating hormones in males [12,13]. On the other hand, cysticercosis significantly reduced the level of progesterone in females [13]. These endocrinological changes are thought to exert significant inhibitory action in the reproduction function of the infected individuals. However, it has been observed that the effect is more intense in male than female hosts. Although the study of pigs included males only, there is strong evidence from laboratory trials, which suggests that the effect of the parasite in female pigs will most likely resemble that observed in female humans [12,13].



Source: [11]

Figure 2. Regions of Africa based on the United Nations system of classification.

Disability in persons infected with neurocysticercosis is another potential factor that is likely to contribute to further economic losses in the agricultural sector through reduced manpower, some of which would be used in pig production in the countries. This can be supported by studies in Eastern Cape Province of South Africa and Cameroon, which show that the majority of people in Africa are not employed in salaried jobs [4,5]. This significant proportion of the population is likely to engage in small-scale businesses, including pig farming. Those suffering from neurocysticercosis in this category of the population are likely to contribute significantly to agricultural losses in the pig industry.

Because of the current lack of information on the actual reduction of pigs' reproductivity as a result of cysticercosis and specific contribution of unemployed populations to pig production in endemic countries, the analysis of the agricultural impact of *T. solium* in this study is mostly based on the costs related to the partial or total condemnation of infected pigs. However, we observe possible gross underestimation of the impact.

4. Methodology

4.1. Study area and duration

This study was carried out between April and June, 2012 and included the 54 African countries that were fully recognised by the United Nations as of 2012 [14]

Collection of data on country pig populations and status of porcine cysticercosis

Pig population data for each of the 54 countries were downloaded from the FAO statistical database [10]. The most recent pig population estimates (those of 2010) were used. Thereafter, several Google searches were performed for each country name and key English phrases and words such as "porcine cysticercosis", "*Taenia solium*", "*T. solium*", and "cysticercosis" to gather scientific publications related to porcine cysticercosis in each country. When a relevant article was encountered, necessary information such as disease magnitude, sample size and diagnostic method was recorded as available. If more than one article was found to be relevant, a range of values was given and authors for all the articles used were cited. The most current literature was preferred.

Estimation of agricultural impact of porcine cysticercosis

This was the main focus of the study. Therefore, more attention was given to this aspect. A total of 200 articles were retrieved following several Google searches using the following four phrases in that order: (i) Burden-of *Taenia-solium* cysticercosis, (ii) Impact-of *Taenia-solium*, (iii) Economic-impact *Taenia-solium*, and (iv) Financial-impact *Taenia-solium*. For each search phrase, 50 first articles we retrieved from which the relevant ones were downloaded from their publishers for further analysis. This first screening was based on a quick assessment of information given in the abstracts. Following the first screening, a total of 18 articles were considered relevant and different from each other, and hence, were included. Out of the 18 articles, 10 were obtained from the first search, seven new articles from the second search, one from the third, and none new from the fourth search phrase. In the second screening, only those articles that included information for Africa were sub-selected from the 18 articles. Five were obtained at this sub-sampling stage. Finally, only those articles that included information on the economic burden of porcine cysticercosis in Africa were selected. Four articles met this criterion and were included for further analysis. The four articles were all peer-reviewed journal papers [4,5,16,17]. A flow diagram to illustrate the sampling procedure described above is given in Figure 3.

The information collected was recorded as reported by the author(s) of the article. If there was different information regarding the cost of porcine cysticercosis in a country, a range of values was given and data sources cited.

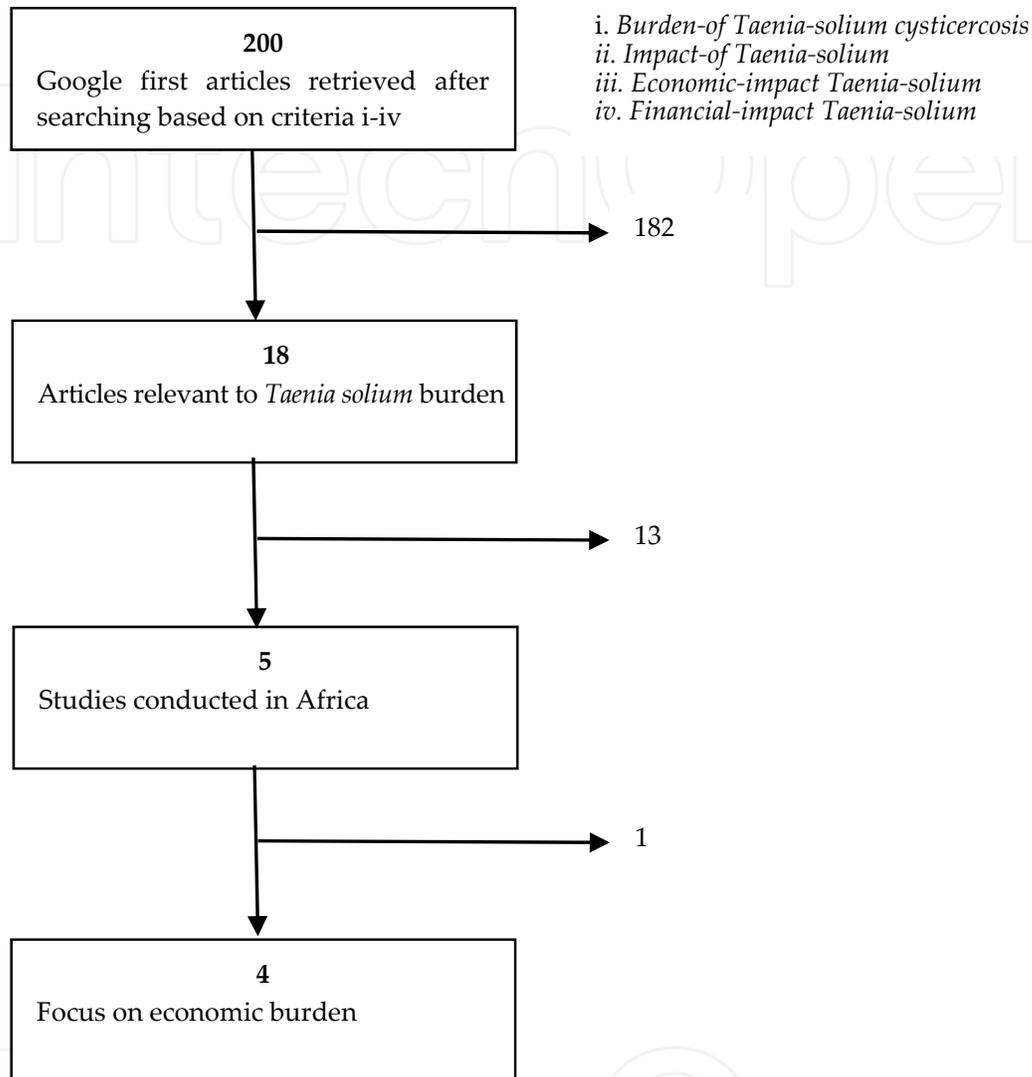


Figure 3. The flow diagram of the literature sampling procedure to analyse the economic impact of porcine cysticercosis in Africa.

5. Results

5.1. General results

The study area consisted of 54 countries. The total population of pigs estimated in the study area in 2010 amounted 29,606,438. This was approximately 3.1% of the world pig population estimate (N = 965,855,414) of 2010. Out of the Africa regional pig population, approximately 0.2% was reared in the northern countries, while 6.1%, 43.3%, 16.4%, and 34.0% were reared in the southern, western, central, and eastern Africa, respectively. Overall, 19 (35.2%) of the 54 study countries reported prevalence of cysticercosis in pigs. While no data were available

in the northern region, the remaining regions provided prevalence data, with more reporting frequency observed in the eastern followed by central Africa.

Porcine cysticercosis in northern Africa

Countries of northern Africa comprise Algeria, Egypt, Libya, Morocco, Sudan, Southern Sudan, and Tunisia. Pig rearing in this region is minimal (Table 1). While there were no pigs reported for Libya, Sudan, and Southern Sudan, indicating possibly absence of or insignificant pig rearing in the countries, pig populations in the remaining four countries ranged from 5,700-38,000 in 2010, making an overall regional pig population of 58,200 pigs. The small number of pigs reared in the northern Africa region is likely to be due to drought and the fact that most of the inhabitants in the region are Muslims. Generally, there was no report available with regard to porcine cysticercosis in the northern Africa. While there is an indication of Egypt providing the most ancient known case of *T. solium* infection in humans, there was currently no information regarding prevalence of cysticercosis in pigs in that country. Pigs in Egypt are known to be kept mainly by Coptic Christians. Before, the 2009 suspected swine flu pandemic, which nevertheless did not prove true, pigs in the country have been very valuable in cleaning the city garbage by being fed on garbage traditionally collected from cities and urban centres [15]. Although this practice might have been reduced after the 2009 suspect swine flu pandemic, generally pigs in Egypt are at a greater risk of acquiring *T. solium* cysticercosis because of feeding on the garbage. The lack of reports on porcine cysticercosis in the country can be due to lack of research, which could also be enhanced by religious conflicts towards pig keeping in that country.

Country	Pig population 2010	Prevalence of PCC
Algeria	5,700	ND
Egypt	38,000	ND
Libya	-	ND
Morocco	8,500	ND
Sudan	-	ND
Southern Sudan	-	
Tunisia	6,000	ND
Total	58,200	

Table 1. Pig population estimates of North African countries in 2010 and the current status of porcine cysticercosis (PCC) caused by *Taenia solium*. ND indicates no data

Porcine cysticercosis in southern Africa

Table 2 presents the pig population estimates and status of porcine cysticercosis in southern Africa. South Africa is the only country in the region, which has reported prevalence of porcine cysticercosis. A number of studies have been conducted in several parts of the country for various periods of time. It is apparent that porcine cysticercosis is hyperendemic in some parts of the country. The possibility of the other countries in the region being free from porcine

cysticercosis is yet to be scientifically proven. Such studies would be very valuable in guiding potential control measures for *T. solium* infections in South Africa by providing information on potential factors that may be encouraging the endemicity of the parasite in South Africa but not in the other countries if they prove to be free from the infections.

Country	Pig population 2010	Prevalence of PCC	Diagnostic method	Reference
Botswana	12,950	ND		
Lesotho	83,976	ND		
Namibia	65,000	ND		
South Africa	1,594,490	54.8 – 57	Ag-ELISA	[18]
Swaziland	50,000	ND		
Total	1,806,416			

Table 2. Pig population estimates of southern African countries in 2010 and the current status of porcine cysticercosis (PCC) caused by *Taenia solium*. ND indicates no data

Porcine cysticercosis in western Africa

Western Africa has the largest pig population in the region (Table 3). Six of the 16 countries of the region have reported presence of porcine cysticercosis. Burkina Faso seems to have high prevalence of porcine cysticercosis in some region, probably because of variations in pig management practices. Apart from Burkina Faso, Gambia and Senegal, data from the other countries are rather old. This suggests that research on porcine cysticercosis in these countries has been inactive for quite some time.

Country	Pig population 2010	Prevalence of PCC	Diagnostic method	Reference
Benin	354,000	ND		
Burkina Faso	1,920,200	0-39.6	Ag-ELISA	[16,19]
Cape Verde	238,600	ND		
Cote d'Ivoire	350,000	ND		
Gambia	28,500	4.8 (n = 371)	Ag-ELISA	[20]
Ghana	536,000	11.7		[16]
Guinea	95,180	ND		
Guinea Bissau	418,900	ND		
Liberia	265,300	ND		
Mali	75,015	ND		
Mauritania	-	ND		
Niger	40,000	ND		
Nigeria	7,471,730	15.3		[16]
Senegal	346,681	6.4-13.2 (n=1334)	Ag-ELISA	[20]
Sierra Leone	45,211	ND		
Togo	643,630	17		[16]
Total	12,828,947			

Table 3. Pig population estimates of West African countries in 2010 and the current status of porcine cysticercosis (PCC) caused by *Taenia solium*. ND indicates no data

Porcine cysticercosis in central Africa

Four out of the ten countries of central Africa have reported prevalence of porcine cysticercosis. Extensive studies have been conducted in Cameroon, ranging from epidemiological, intervention trials and disease burden analysis. Porcine cysticercosis prevalence in Cameroon seems to resemble that in the Democratic Republic of Congo. Central Africa also indicates high infection rates of porcine cysticercosis.

Country	Pig population 2010	Prevalence of PCC	Diagnostic method	Reference
Angola	791,000	0-6.8	Meat insp.	[16]
Cameroon	1,680,000	11-39.8	Ag-ELISA	[21]
Central Afr Rep	1,087,000	ND		
Chad	30,400	6.8-25.7	Tongue/Meat	[16]
Rep Congo	70,000	ND		
DR Congo	967,000	41.2 (n=153)	Ag-ELISA	[22]
Eq. Guinea	6,300	ND		
Gabon	215,000	ND		
Sao Tomé & Pr	2,620	ND		
Total	4,849,320			

Table 4. Pig population estimates of Central African countries in 2010 and the current status of porcine cysticercosis (PCC) caused by *Taenia solium*. ND indicates no data

Porcine cysticercosis in eastern Africa

The eastern Africa region consists of 17 countries and approximately 10 million pigs were reared in the region in 2010 (Table 5). The region includes ten out of 13 countries that belong to the CWGESA, an international non-governmental scientific organisation that was founded in 2002 with the overall objective of combating taeniasis/cysticercosis on a regional effort, considering that the disease has no border. As shown in the table below, a number of countries have reported prevalence of porcine cysticercosis, also suggesting high infection pressure in some countries. In Tanzania, an incidence rate of 69 per 100 pig-years was estimated in sentinel pigs based on antigen ELISA [23].

Economic impact of porcine cysticercosis in Africa

Quite a good amount of information regarding the monetary burden of porcine cysticercosis has been reported in the southern, western, central, and eastern Africa regions. Extensive and most recent studies are those conducted in South Africa and Cameroon [4,5]. These studies were also able to establish the disease burden in humans. Overall, the available information provides enough evidence of the agricultural impact of porcine cysticercosis in Africa, especially most of sub-Saharan Africa. Table 6 summarises the information on the monetary burden of porcine cysticercosis in Africa.

Country	Pig population 2010	Prevalence of PCC	Diagnostic method	Reference
Tanzania	495,000	30.7-32 (n=600)	Ag-ELISA	[24]
Kenya	347,400	4.0	Ag-ELISA	[25]
Uganda	2,300,000	8.6 (n=480)	Ag-ELISA	[26]
Rwanda	602,324	20		[16]
Burundi	244,791	2-39	Meat insp.	[16]
Djibouti	-	ND		
Eritrea	-	ND		
Ethiopia	29,000	ND		
Somalia	4,200	ND		
Mozambique	1,350,000	34.9 (n=661)	Ag-ELISA	[27]
Madagascar	1,380,250	ND		
Malawi	2,147,900	ND		
Zambia	500,000	8.2-23.3 (n=98-1691)	Ag-ELISA	[28, 29]
Zimbabwe	635,000	2.7-28.6	Meat insp.	[2]
Comoros	-	ND		
Mauritius	22,327	ND		
Seychelles	5,363	ND		
Total	10,063,555			

Table 5. Pig population estimates of East African countries in 2010 and the current status of porcine cysticercosis (PCC) caused by *Taenia solium*. ND indicates no data

Region	Country	Overall annual monetary losses	Losses due to PCC	Annual DALYs lost due to NCC	Reference
Northern Africa	-				
Southern Africa	S. Africa 04	US \$18.6 - 34.2 M	US \$5.0 M	ND	[4]
Western Africa	B/ Faso		€ 52,830		[16]
	Ghana		€ 594,945		[16]
	Nigeria		€ 17,442, 000		[16]
	Senegal		€ 57,600		[16]
	Togo		€ 2,167,500		[16]
Central Africa	Cameroon	€ 10,255,202	€ 478,844	€ 45,838.4	[5]
			€ 2,062,125		[16]
	Angola		€ 408,000		[16]
	Chad		€ 56,063		[16]
	D R Congo		€ 2,141,700		[16]
Eastern Africa	Burundi		€ 218,325		[16]
	Tanzania		*		[17]

* A community based health education intervention trial in Tanzania found out that over a period of 5 years, the health and pig management education intervention would have a significant financial benefit to a smallholder pig farmer receiving it [NPV: US \$3507 (95% CI: 3421 to 3591); IRR: 370%].

Table 6. Monetary and non-monetary costs of *Taenia solium* cysticercosis in Africa

6. Conclusion

This extensive literature survey has established the agricultural impact of porcine cysticercosis in Africa. The results indicate a high disease burden and its economic impact to affected countries due to monetary losses in the agricultural sector, human health related costs and reduced manpower as a result of disabilities in neurocysticercotic patients. Most of the previous studies have focused on financial losses due to reduced value of infected pigs. This can grossly underestimate the burden of *T. solium* to the agricultural sector since disabilities in neurocysticercotic patients (including attached stigma) and possible reduced reproductive performance of infected pigs could add further to the impact of the parasite to the agricultural sector. Only two studies in the region have in addition analysed the cost of the parasite as a result of neurocysticercotic persons. These studies found that monetary losses due to pig condemnations account only approximately 5% of the overall cost of the disease [4,5]. In addition, the studies established significant Disability Adjusted Life Years (DALYs) lost by patients suffering from neurocysticercosis. Such opportunity costs are likely to exert additional burden of the parasite to the agricultural sector as a good number of rural communities are mostly engaged in agricultural activities, including pig farming. This study recommends urgent measures to control *T. solium* in endemic countries now that adequate epidemiological data are available in several countries. In addition, studies are needed to determine the impact of porcine cysticercosis to the fertility and eventually fecundity of infected pigs.

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