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*The monetary impact of  
zoonotic diseases on society*

# EGYPT

Evidence from two zoonoses



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# **EGYPT: the monetary impact of zoonotic diseases on society**

## **Evidence from two zoonoses**

### **1. Introduction**

In Egypt, population growth, urbanization and gains in real per capita income will result in increased consumption of animal source foods. This will provide incentives for livestock producers and other actors along the value chain to rapidly expand and improve their businesses to satisfy the growing consumer demand (ASL2050, 2017a). In a rapidly changing environment, returns on investments are often uncertain: competitive, economic, operational, legal, financial, fiscal, reputational and other risks will affect the profitability of livestock farming. Some livestock farmers and enterprises will succeed, expand and thrive; while others will fail and exit the livestock business altogether.

As livestock is a private business, the key role for the government of Egypt is to ensure that policies – largely implemented through public investments, laws and regulations – support a smooth and socially desirable transformation of the sector in the coming years. This is easier said than done because livestock farming, though a private business, also has broader, often negative, impacts on society. For example, grasslands degradation, microbiological water pollution, excess greenhouse gas emissions, animal epidemics and zoonotic diseases, are all consequences of inappropriate livestock farming practices, and reduce societal welfare.

Zoonotic diseases, which jump the animal-human species barrier, are a major threat for society – they can affect entire sectors of the livestock industry and reduce human capital. For example, it is estimated that avian influenza, at its peak, reduced chicken meat production by over one third in China (Huang *et al.*, 2017), and that the 2009 swine flu pandemic, which originated in Mexico, infected over 100 million people with a death toll of about 20 000 (Nathason, 2016).

The government of Egypt is taking steps to prevent, manage and control zoonotic diseases. However, given the current zoonotic disease information system, it may be challenging to generate accurate estimates of the incidence and prevalence of zoonoses, assess their impact on society, and measure the benefits of programmes and investments for their prevention, management and control (ASL2050, 2017b). In brief, the Ministries may have major difficulties in allocating public resources to tackle zoonotic diseases efficiently.

The Africa Sustainable Livestock 2050 initiative (ASL2050), under the guidance of a National Steering Committee comprising representatives of the Ministry of Agriculture and Land Reclamation, the Ministry of Health and the Ministry of environment, has tried to gather the data needed to measure the impact of zoonoses on society in monetary terms, thereby providing the government with a key piece of information for allocating country budget efficiently.

Because three quarters of new emerging infectious diseases in humans have a zoonotic origin, and because the anticipated growth of Egypt will modify the drivers influencing the emergence and re-emergence of zoonotic pathogens, the value of accessing information for measuring the costs and benefits of preventing, managing and controlling zoonoses cannot be overstated.

This brief presents the results of the ASL2050 compiled information on zoonotic diseases and their impact, as validated by stakeholders.

What matters, however, is that stakeholders have used a One Health approach to experiment with a new methodology to look at zoonotic diseases – a methodology that they may or may not scale up or replicate – to provide decision-makers with information on how to best allocate admittedly scarce public resources.

**Box 1. The willingness to pay for a disability-adjusted life year**

To estimate the social cost of the disease, we estimate the Disability-Adjusted Life Years (DALY), a method used by the World Health Organization (WHO) to quantify the burden of disease from mortality and morbidity<sup>1</sup>.

One DALY can be interpreted as one year of healthy life lost. It is a health gap measure that combines both time lost due to premature mortality and the time spent in sickness. For each disease, a disability weight is attached to the DALY, which measures the severity of a disease during sickness.

We calculate the willingness to pay off a DALY to arrive at its value in monetary terms. We multiply the estimates of DALY by the annual minimum wage of Egypt.

**2. Livestock and public health monetary impact calculation: methodology**

The monetary impact of the priority zoonotic diseases on society is determined as the sum of the losses in value (USD) due to morbidity and mortality in infected animals and humans over the period of one year:

$$\begin{aligned}
 &\text{Livestock and Public Health USD Impact} \\
 &= \\
 &\quad \text{Value of animals lost} \\
 &\quad + \\
 &\quad \text{Value of production decrease in infected animals} \\
 &\quad + \\
 &\quad \text{Social cost of mortality in humans} \\
 &\quad + \\
 &\quad \text{Social cost of morbidity in humans}
 \end{aligned}$$

The methodology used to calculate the value of the different variables in the equations is briefly discussed below both for animals and humans. Detailed explanation and data sources are described in the Annexes.

**3.1 Cattle**

In cattle systems an infected animal will either die, be culled, be salvage slaughtered, or survive but suffer from reduced productivity during the disease. Both the value of the animals lost as well as the decreased production should be estimated to calculate the total loss due to occurrence of a disease in animals. Figure 1 depicts a flowchart that highlights the different cattle-related variables the protocol data estimates, including the value of animals lost due to the disease (in red) and the value of production lost in survivors (in dark orange).

<sup>1</sup> [http://www.who.int/healthinfo/global\\_burden\\_disease/metrics\\_daly/en/](http://www.who.int/healthinfo/global_burden_disease/metrics_daly/en/)

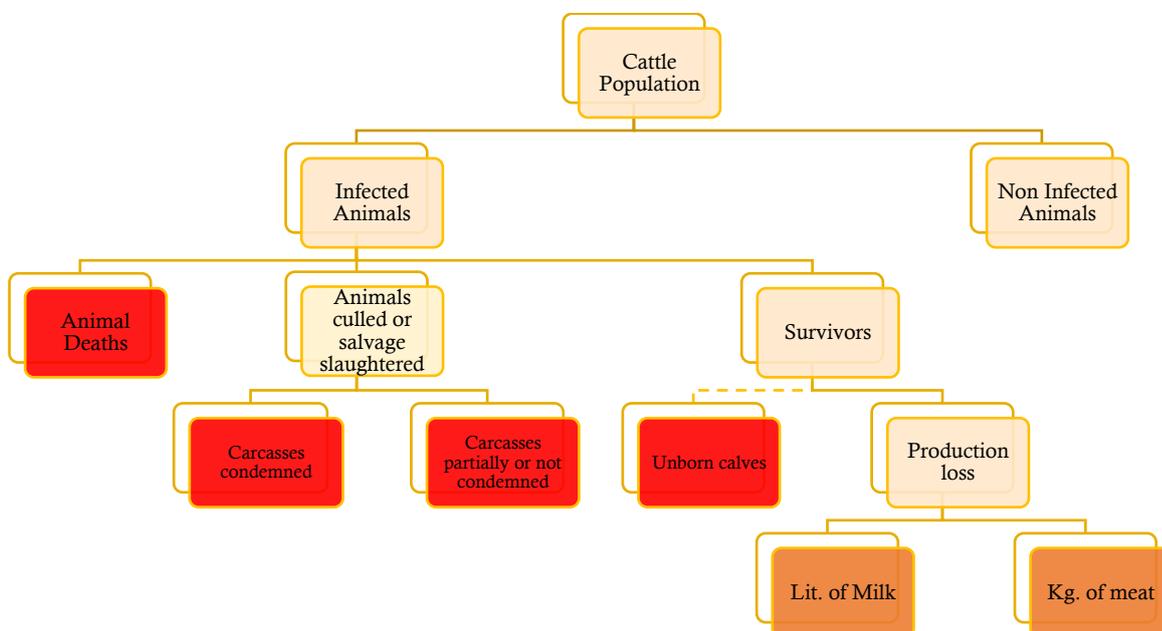
The cost of treating sick animals is not accounted for as data on farmers' expenses on veterinary goods and services by disease are not available, because the share of farmers with access to animal health services is usually small, and because their spending on veterinary services is typically negligible (CAHI, 2015). The value of animals lost is calculated as the sum of:

- the number of animal deaths multiplied by the farm-gate price of an adult animal;
- the number of carcasses fully condemned multiplied by the farm-gate price of an adult animal;
- the number of carcasses partially or not condemned animals multiplied by the farm-gate price of an adult animal discounted by 30 percent;
- the number of unborn calves, due to fertility reduction in survivors, multiplied by the farm-gate price of a young animal.

The value of production decrease in survivors is calculated as the sum of:

- The number of lost lactation periods – which is equal to the number of unborn calves, or the number of female infected by the disease and affected by fertility loss – multiplied by the average litre per lactation and by the market price of one lit. of milk;
- The number of females infected by the disease and not affected by fertility loss, multiplied by the average reduction in milk production in litres and by the market price of one litre of milk;
- The number of survivors multiplied by the average dressed weight lost and by the market price of one kg of beef.

**Figure 1 - Cattle-related variables in the USD loss calculation**



### 3.2 Poultry

In poultry systems, birds affected by a disease may die, be culled or salvage slaughtered, or suffer from a decrease in egg production. For some diseases the whole flock might be slaughtered as a precaution, therefore salvage slaughtered also includes non-infected birds. In addition, while no

sale happens after culling, in the case of salvage slaughter the birds can still be consumed, though they presumably have not reached their full slaughter weight.

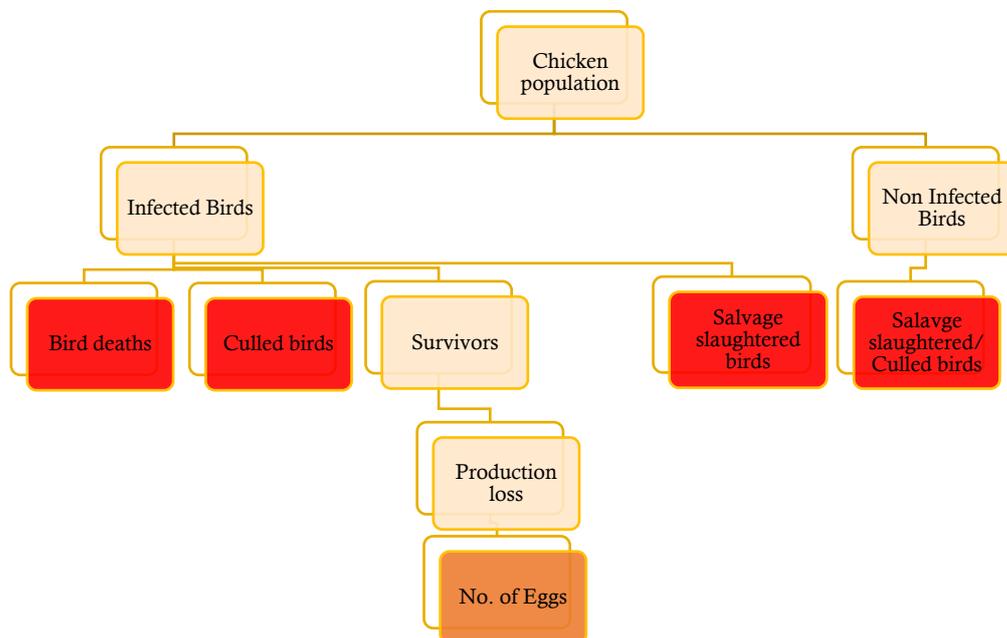
Figure 2 depicts a flowchart that highlights the different poultry-related variables the protocol data estimates, including the value of animals lost due to the disease (in red) and the value of production decrease in survivors (in dark orange). The cost of treating sick birds is not accounted for as data on farmers' expenses on veterinary goods and services by disease are not available, because the share of farmers with access to animal health services is usually small, and because their spending on veterinary services is typically negligible. The value of birds lost is calculated as the sum of:

- the number of birds killed by the disease multiplied by the farm-gate price for a live chicken;
- the number of culled birds multiplied by the farm-gate price of a live chicken;
- the number of salvage slaughtered birds multiplied by the farm-gate price for a live chicken.;

The value of production decrease in surviving hens is calculated as:

- the number of surviving hens multiplied by the average reduction in the number of eggs produced and by the egg market price.

**Figure 2 - Poultry-related variables in the USD loss calculation**



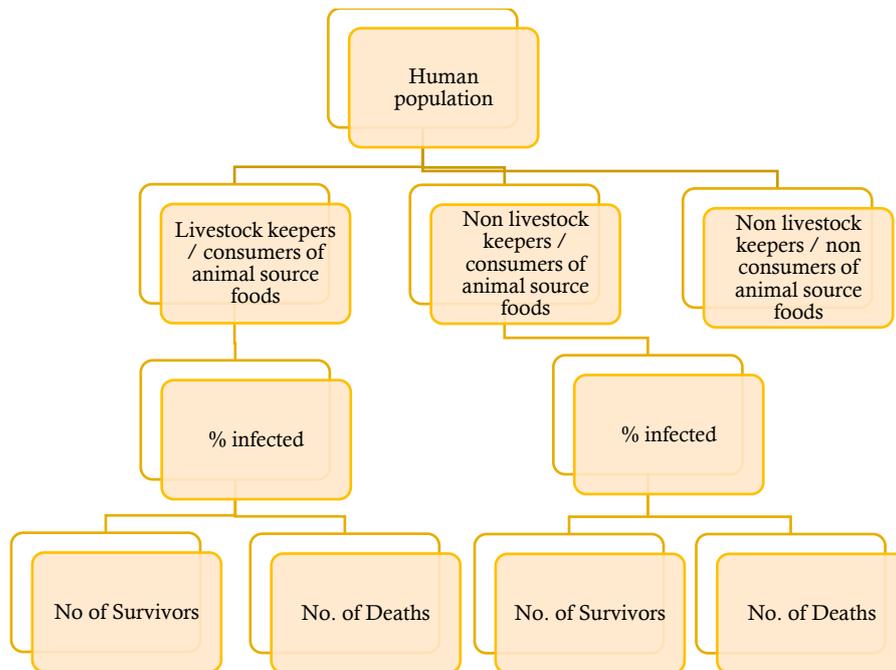
### 3.3. Humans

Zoonoses are transmitted from animals to humans through direct and indirect contact, vectors and food consumption. Different categories of people, therefore, face different risks of contracting zoonotic diseases. To estimate the impact of morbidity and mortality of zoonoses in humans, we have split the population at risk in three broad groups: (i) non-livestock keepers &

non consumers of animal source foods; (ii) non-livestock keepers & consumers of animal source foods; (iii) livestock keepers & consumers of animal source foods<sup>2</sup>.

Figure 3 depicts a flowchart that highlights the different human-related variables the protocol data estimates, including the number of infected people, as well as survivors and deaths, by category of people. We assume there are no infections among the non-livestock keepers & non consumers of animal source foods.

**Figure 3 - Human related variables in the USD loss calculation**



The economic cost of the zoonotic disease is calculated as the sum of:

- the total number of survivors multiplied by the average number of working days lost (proxy for duration of the disease) and the DALY weight measuring the severity of the disease<sup>3</sup> and by minimum wage per person per year
- the total number of deaths multiplied by the average number of years of life lost – given by the difference between healthy life expectancy and average age at infection – and minimum wage per person per year.

#### **4.1. Data validation**

Our reference year is 2016. Accordingly, all the data, analyse done and results obtained refer to yearly values and 2016 available statistics. We validated the collected data through a two-step

<sup>2</sup> Occupations at higher risk of infection include also veterinarians, culling personnel, slaughterhouse workers and all that are in direct contact with live animals and animal material. However it is not possible to obtain good information on the number of such workers, let alone to know how many of them are already included in the other two categories. We assume that the majority are already living in a livestock keeping household or are consumers of animal source foods.

<sup>3</sup> A DALY weight measures the severity of a disease and can take values from 0 to 1, zero meaning completely healthy and 1 meaning death. DALY weights by disease are provided by the WHO Global Burden of Disease

process. First, we generated summary statistics for the key variables. Second, for those variables whose values were implausible, we consulted relevant literature

Finally, we presented the summary statistics and literature review during a meeting involving key persons from both the Ministry of Health and the Ministry of Agriculture to reach a consensus on data and results.

Table 1 presents the reference population, prevalence and fatality rate data that were used to calculate the monetary impact of the selected zoonoses on society.

**Table 1 - Key variables (reference population, prevalence and fatality rate) underpinning the USD loss calculation - 2016**

Brucellosis in Animals (2016)	Bovine Production system		
	Intensive	Extensive	Total
Total population	568 057	7 547 045	8 115 102
Number of cases	183	830	1 013
Number of deaths	0	0	0
Number of slaughtered	183	830	1 013
<i>prevalence (cases/pop) %</i>	<i>0.03%</i>	<i>0.01%</i>	<i>0.01%</i>
<i>mortality (deaths/pop) %</i>	<i>00%</i>	<i>00%</i>	<i>00%</i>
<i>fatality (deaths/cases) %</i>	<i>00%</i>	<i>00%</i>	<i>00%</i>
Brucellosis in Humans (2016)	Human category		
	Livestock keepers	Consumers	Total
Population at risk	10 525 755	84 206 039	94 731 794
Number of cases	1 683	2 991	4 674
Number of deaths	0	0	0
<i>prevalence (cases/pop) %</i>	<i>0.016%</i>	<i>0.004%</i>	<i>0.005%</i>
<i>mortality (deaths/pop) %</i>	<i>00%</i>	<i>00%</i>	<i>00%</i>
<i>fatality (deaths/cases) %</i>	<i>00%</i>	<i>00%</i>	<i>00%</i>
HPAI in Animals (2016)	Poultry Production system		
	Intensive	Extensive	Total
Total population	669 935 135	151 063 805	820 998 940
Number of cases	173 615	48 102	221 717
Number of deaths	7 920	11 485	19 405
Number of culled	279 400	2 603	282 003
<i>prevalence (cases/pop) %</i>	<i>0.03%</i>	<i>0.03%</i>	<i>0.03%</i>
<i>mortality (deaths/pop) %</i>	<i>0.00%</i>	<i>0.01%</i>	<i>0.00%</i>
<i>fatality (deaths/cases) %</i>	<i>4.56%</i>	<i>23.88%</i>	<i>8.75%</i>
HPAI in Humans (2016)	Human category		
	Livestock keepers	Consumers	Total
Population at risk	19 137 736	75 594 058	94 731 794
Number of cases	8	2	10
Number of deaths	4	0	4
<i>prevalence (cases/pop) %</i>	<i>0.0004%</i>	<i>0.000003%</i>	<i>0.00001%</i>
<i>mortality (deaths/pop) %</i>	<i>0%</i>	<i>0%</i>	<i>0.000004%</i>
<i>fatality (deaths/cases) %</i>	<i>50%</i>	<i>0%</i>	<i>40%</i>

The data used are the official data from both Ministry of Agriculture and the Ministry of Health.

In regards to HPAI, data on deaths in animals shall be integrated with the number of birds culled either due to the disease or salvage slaughtered. However, the official data has no information on salvage slaughter, only dealing with deaths recorded on site when a case is reported.

For brucellosis, the results of the losses should be taken carefully as the official data for brucellosis in animals are not representing the country situation since the way the data is collected through surveillance is not statistically representing the total bovine population in Egypt. This is due to the fact that the testing samples for bovine diseases are only taken from the female of selected sites and a limited number of samples are collected every year. So, the prevalence of the disease in the country is not accurately known.

The data on brucellosis for Humans, categorised by livestock keepers and consumers, are estimated based on the statement of MOH that around 36% of the cases were livestock keepers or person dealing with animals like veterinarians.

## **4.2. Results**

For each disease, we present the results in terms of i) the value of the livestock-related losses; ii) the estimated annual social costs in humans; and iii) the total cost of the disease expressed as the relative shares of livestock and human costs. The value of the livestock-related losses includes the value of animals lost and the value of foregone production.

Results are presented by different production system, compared to the yearly added value of the sector, and also estimated by case (i.e. total cost is divided by the number of animals affected by the disease at hand) and compared with the farm-gate price of a healthy animal.

Social costs in humans are expressed in Disability Adjusted Life Years (DALYs), i.e. the number of years of life lost due to mortality (YLL) and number of years lost due to morbidity (YLD), which we both value with the the minimum wage per person. According to the World Bank, healthy life expectancy in Egypt is about 71 years, which is thus the reference we use to calculate the number of years of life lost due to mortality.

We estimate the social cost of the diseases for two sub-groups of people: cattle keepers, who can be infected either through contact with animals/infected material or the consumption of animal source foods; and for non livestock keepers but consumers of potentially contaminated animal source foods.

The social cost of the diseases in humans is expressed as percentage of national GDP. This comparison should be regarded with caution: the GDP is an annual value, whereas mortality costs include the individual's future years remaining up to the expected end of his/her life.

Finally, we look at the total cost the disease expressed as the relative shares of livestock-related costs and human-related costs, which helps us appreciate the value of the One Health concept. As above, it is important to note that the livestock-related costs express an annual value while social costs in humans include the value of "loss" of future years of healthy life.

### **4.2.1 Brucellosis**

#### **Brucellosis in Cattle and Buffalo**

**Table 2** shows the economic impact of brucellosis measured as value of animals lost and value of production lost by production system. Brucellosis causes an estimated economic loss of 3.5

million USD per annum (expressed as PPP) that is mostly attributed to the extensive systems, recording the larger number of animal cases.

**Table 2 - Value of losses due to brucellosis by different production systems - 2016**

<b>Variables for Brucellosis in Animals</b>	<b>Intensive</b>	<b>Extensive</b>	<b>Total</b>
Number of cases	183	830	1 013
<i>Estimated prevalence</i>	<i>0.03%</i>	<i>0.01%</i>	<i>0.01%</i>
Value of animals lost due to the disease (USD PPP)	427 235	1 572 109	1 999 344
<i>per case (USD PPP)</i>	<i>2 335</i>	<i>1 894</i>	<i>1974</i>
Value of production lost due to the disease (USD PPP)	557 399	957 374	1 514 772
<i>per case (USD PPP)</i>	<i>3 046</i>	<i>1 153</i>	<i>1 495</i>
TOTAL (USD PPP)	984 634	2 529 483	3 514 117
<i>per case (USD PPP)</i>	<i>5381</i>	<i>3 048</i>	<i>3 469</i>
Total loss as a percentage of bovine added value (i.e. “bovine GDP”)	0.01%	0.03%	0.04%
<i>Loss per case as a percentage of the farm-gate price of a healthy animal</i>	<i>83%</i>	<i>60%</i>	<i>60%</i>

The table shows that in 2016, about 0.04 percent of the bovine value added in Egypt is lost due to brucellosis infections. As already mentioned, the official data for brucellosis in animals are not representing the country situation since the way the data is collected is not statistically representative. In terms of losses per case, each case of brucellosis was estimated to an average cost of 3 469 USD for animal.

The losses per case can be also compared to the farm-gate prices of animals. In this respect, the cost of the disease averagely impact on 60% of farm-gate price, with a peak of 83 percent in the intensive system.

The value of animal lost per case is lower in intensive due to high animal density and lower disease incidence, which can be related to better care, treatment and veterinary control (lower mortality).

#### Brucellosis in Human Beings

The official data estimated 1 683 cases of brucellosis in cattle keepers (with 0 deaths) and 2 991 cases in consumers (with 0 deaths) for 2016. Consumers – mainly through milk consumption – are thus the category of people most affected by the disease.

**Table 3 - Estimates of the annual social costs of brucellosis - 2016**

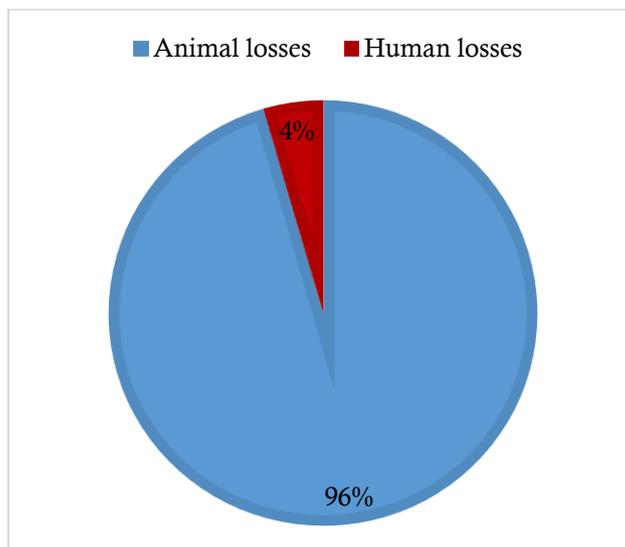
<b>Variables for Brucellosis in Humans</b>	<b>Bovine keepers</b>	<b>Consumers</b>	<b>Total</b>
Years of life lost due to mortality (YLL)	-	-	-
Years lost due to morbidity (YLD)	10	19	29
DALYs (YLL + YLD)	10	19	29
Minimum Wage per person per year	5 663	5 663	5 663
Total social cost (USD PPP)	59 205	105 253	164 458

In 2016, Brucellosis has a total cost of about 164 458 USD on Egyptian society. The social cost per Human case is 35.2 USD which represent 0.6% of the minimum yearly wage.

#### Cost of Brucellosis in animals and humans in 2016

The total burden of brucellosis in Egypt amounted to about USD PPP 3 678 575 USD in 2016, largely (96 percent) due to losses in animals.

**Figure 4: The monetary (USD) impact of brucellosis on society in livestock and humans - 2016**



This split is very important for policy implications. Indeed, this result proves that the control and management of brucellosis should be mainly directed to the veterinary services which will limit the negative externalities in humans. Consequently, other Ministries or national bodies may be involved in dealing with the disease.

#### 4.2.3 HPAI

##### HPAI in poultry

The following table shows the value of losses by production systems for HPAI outbreaks in 2016. HPAI in poultry caused an estimated economic loss of 2 216 616 USD in 2016 (expressed as PPP), mainly concentrated in the intensive system.

**Table 4 - Value of losses due to HPAI by different production systems - 2016**

Variables for HPAI in Animals	Intensive	Extensive	Total
Number of cases	173 615	48 102	221 717
<i>Estimated prevalence</i>	<i>0.03%</i>	<i>0.03%</i>	<i>0.03%</i>
Value of animals lost due to the disease (USD PPP)	2 123 295	93 122	2 216 416
<i>per case (USD PPP)</i>	12.23	1.94	10.00
Value of production lost due to the disease (USD PPP)	na	na	na
<i>per case (USD PPP)</i>	NA	NA	NA
TOTAL (USD PPP)	2 123 295	93 122	2 216 416
<i>per case (USD PPP)</i>	12.23	1.94	10.00
Total loss as a percentage of poultry added value (i.e. "poultry GDP")	0.06%	0.00%	0.06%

<i>Loss per case as a percentage of the farm-gate price of a healthy animal</i>	165%	29%	143%
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The share in losses in the intensive systems due to HPAI infection is higher than the extensive systems' share, which could be related to larger poultry number in this sector (82 percent of the poultry population is raised in intensive systems).

The total losses from HPAI in poultry represent only 0.06 percent of the total poultry added value per year. Losses only refer to animal deaths, since HPAI is a killer disease, with no losses in production. It is worth to note that there is a strong under estimation in number of deaths due to data unavailability.

In terms of estimates by case as a percentage of the price of a live chicken, the losses per case are higher than the average farm-gate price of a healthy chicken (which is around 7 USD) because of the value of losses due to culled birds which are much more than the number of cases.

#### HPAI in humans

As described above, the social cost of the disease is estimated as the sum of the cost of mortality and cost of morbidity. As previously explained, we estimate the impact of the disease for two sub-groups: poultry keepers who are in contact with birds, and individuals who are not livestock keepers but might be infected through direct or indirect contact.

Since 2006, 359 cases of HPAI has been confirmed in Egypt out of these 122 people have died, on average age of 20. The experts agreed that the large majority of human cases and deaths are related to poultry keepers. In 2016, there have been 10 cases of human HPAI infection, with 4 deaths.

**Table 5 - Estimates of the social costs of HPAI - 2016**

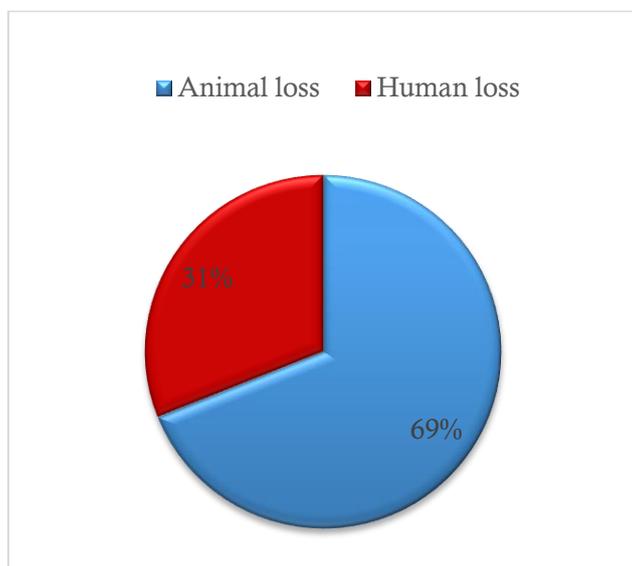
<b>Variables for HPAI in Humans</b>	<b>Poultry keepers</b>	<b>Consumers</b>	<b>Total</b>
Years of life lost due to mortality (YLL)	214	0	214
Years lost due to morbidity (YLD)	0.052	0.026	0.08
DALYs (YLL + YLD)	214	0	214
Willingness to pay for one year of healthy life (USD PPP)	34 300	34 300	34 300
Total social cost (USD PPP)	1 209 828	148	1 209 976
Total social cost as percent of GDP (USD PPP)	0.0001%	0%	0.0001%

According to the estimates performed, the social cost of HPAI on public health is about 1.2 million USD in 2016, corresponding to about 0.0001 percent of national GDP. Livestock keepers are the human category most affected by the disease.

#### Cost of HPAI in birds and humans in 2016

The total burden of HPAI in Egypt amounted to about 3.9 million USD PPP in 2016. The livestock sector contributed about 69 percent to the total cost, with the social cost in humans accounting for the remaining 31 percent.

**Figure 5: The monetary (USD) impact of HPAI on society in livestock and humans - 2016**



### **3. Discussion and conclusions**

This brief presents a methodology to assess the monetary impact of zoonoses on society, including value livestock-related losses as well as the cost of morbidity and mortality in humans.

Results indicate that both zoonotic diseases analysed – brucellosis in bovine and HPAI in poultry – represent a considerable economic burden for the Egyptian economy.

As for literature, many studies confirmed higher incidence levels in targeted diseases in different parts of the country for human and animal cases. For example, a study testing samples from feverish humans has resulted in higher incidence level of positive human cases in brucellosis 3% (Afifi S. et al, 2005).

The results from a controlled serological cohort study, related to people exposed and not exposed to poultry, estimated the seroprevalence of antibodies against H5N1 (titers >80) at 2 percent. If this seroprevalence were to be extrapolated to the entire poultry-exposed population in Egypt, the true number of infections would amount to several hundred thousand (R Gomaa et al, 2015).

Similar examples exist for the brucella spp. infection in large ruminants in an endemic area of Egypt, where the estimated seroprevalence of brucellosis in cattle and buffalo ranges from 11 percent to 15.5 percent (Hannah R Holt et al, 2011).

All these estimates provided by the literature, with respect to the official data, are more in line with the estimates of the burden of zoonotic diseases assessed by international organisations<sup>4</sup>

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<sup>4</sup> For instance, a study by OIE on the economic impact on Brucellosis in the world concluded that, the burden of brucellosis is greatest in low-income countries J. McDermott *et al.* 2013. It was also revealed that the average of prevalence has been 13 percent in cattle and buffalo. However, it was clear that the degree of under-reporting of brucellosis is enormous. The report also concluded that studies on the economic production losses of bovine

and highlight the necessity for different way of surveillance for estimation of prevalence of diseases especially for Brucellosis in animals..

### Impact on society

The two zoonotic diseases analysed have consequences on society causing economic global losses. The split of losses between animal losses and social costs for human morbidity and mortality shows that, for brucellosis, 4 percent of the losses are related to humans, while 96 percent to animals. For HPAI, human losses are 31%, while animal losses are 69% of the total.

In terms of animal losses, the comparison of the monetary impacts between the two diseases shows that the losses due to brucellosis in bovine are higher than HPAI's losses – despite the lower incidence of brucellosis vis-à-vis HPAI - because of the high price for animals and the loss in production. The losses of HPAI in poultry is underestimated due to data unavailability.

In terms of human losses Avian Influenza in poultry appears to create higher negative externalities on society, with HPAI impacting about USD PPP 1.2 million USD in 2016. This is mainly do to the human mortality embedded in the computation.

In terms of animal losses, the comparison of the monetary impacts between the two diseases in referring to their total annual production value shows that the losses due to HPAI, 0.06% of the poultry added value are higher than brucellosis losses in bovine, 0.04% of the bovine added value. However, we need to consider also that the losses in both diseases is underestimated due to data unavailability or inaccuracy.

For HPAI intensive production systems have a greater impact on national GDP due to high productivity and higher animal density. The animal losses in the intensive system from HPAI were indeed estimated as 99 percent of the total animal losses. In brucellosis, the major impact was related to the extensive system as the animal losses due to extensive represented 72 percent of the total animal losses

### Policy implications

This survey has revealed the importance of neglected zoonotic diseases, such as brucellosis, that may have a strong impact on animals and on society. The impact of brucellosis in extensive production systems has higher value due to a higher number of animals and higher production, which affect the livelihood of household keepers and is more vulnerable for Human due to less control of the production system.

HPAI were proven to affect poultry production very hard leading to significant losses in bird population (HPAI). The diseases have a strong impact on Human due to presence of deaths.

The results suggest that the benefit of tackling the diseases would be very high, possibly justifying the related cost of intervention.

Results also suggest that tackling zoonotic diseases would require a One Health approach involving both the ministries in charge of livestock and public health. The benefits of tackling zoonoses in animals, in fact, reduces the public health costs.

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brucellosis are reasonably consistent across a range of production systems in Africa, with losses estimated at 6 percent to 10 percent of the income per animal.

Indeed, the results prove that the control and management of brucellosis, generally funded by the General Organization for Veterinary Services, causes much bigger negative externalities in humans. Consequently, the other Ministries or national bodies may be involved in dealing with the disease.

Full assessment of the livestock and social impacts of zoonotic diseases is challenging and the results of this brief should be considered as preliminary. However, the importance of both collecting with regularity information on zoonoses in animals and humans and valuing their total cost cannot be neglected.

It is only when generating information on the returns of investment in tackling zoonotic diseases in animals in terms of both improved livestock production and productivity and reduced public health costs, that a true One Health approach can be implemented, which leads to the formulation and implementation of policies towards a sustainable livestock sector.

## References

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## APPENDIX

### A1. DATA SOURCES

- **Protocol data:** After a thorough review of available literature and data, the ASL2050 team designed an Expert Elicitation Protocol to gather the information needed to calculate the economic and public health impact of the priority diseases in project countries. More than 250 experts were interviewed in the six countries. The questions were asked in relative terms (i.e. per 1,000 cattle, per 100,000 consumers etc.) and were converted to national numbers using information from the production system briefs (animal population), number of livestock keepers (household surveys) and number of consumers (World Bank Consumption Database).
- **Household survey data:** Nationally representative household survey data implemented by the countries' National Statistical Offices allow the number of households keeping livestock to be determined.
- **World Bank Consumption Database:** The World Bank Consumption Database provides information on the share of households consuming cattle and poultry products.
- **Global Livestock Environmental Assessment Model (GLEAM):** GLEAM is a GIS<sup>5</sup> framework that simulates the bio-physical processes and activities along livestock supply chains under a life cycle assessment approach. The aim of GLEAM is to quantify production and use of natural resources in the livestock sector and to identify environmental impacts of livestock in order to contribute to the assessment of adaptation and mitigation scenarios to move towards a more sustainable livestock sector.

### A2. EQUATIONS

We determine the economic and public health impact in monetary terms, as a sum of the value of animals lost due to the diseases, the loss from salvage slaughtering and culling, the loss from production decrease and the social cost of human mortality and morbidity. The following sections describe the calculations and the sources of data for these components.

#### **Economic and Public Health impact (USD)**

$$\begin{aligned} &= \\ &\text{Value of animals lost (I)} \\ &+ \\ &\text{Loss from salvage slaughter and culling (II)} \\ &+ \\ &\text{Loss from production decrease (III)} \\ &+ \\ &\text{Social cost of human mortality (IV.1)} \\ &+ \\ &\text{Social cost of human morbidity (IV.2)} \end{aligned}$$

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<sup>5</sup> Geographic Information System

## (I) Value of animals lost

The value of animals lost comprises three main components: the value of the animals that died due to the disease, the value of animals whose carcass had to be condemned and the value of calves who were not born due to fertility decrease caused by the disease:

$$\begin{aligned} &\text{Value of animals lost} \\ &= \\ &\text{Number of animals that died due to disease (I.1)} \\ &\quad * \\ &\text{Animal farmgate price (I.2)} \\ &\quad + \end{aligned}$$

Only for cattle:

$$\begin{aligned} &\text{Number of carcasses condemned (I.3)} \\ &\quad * \\ &\text{Animal farmgate price (I.2)} \\ &\quad + \\ &\text{Number of unborn calves (I.5)} \\ &\quad * \\ &\text{Calf farmgate price (I.6)} \end{aligned}$$

**I.1 Number of animals that died due to the disease:** The number of animals that died due to the disease was asked in the protocol per 1,000 animals for Brucellosis, Bovine TB, Anthrax and Salmonellosis and per 1,000,000 birds for HPAI.

**I.2 Adult animal farmgate price:** To attach a monetary value to the number of animals lost, country data on the adult animal farmgate price was used.

**I.3 Number of carcasses condemned:** The number of carcasses condemned was asked in relative terms (see I.1) for cattle related diseases.

**I.4 Number of unborn calves:** The protocol gathered information on the fertility loss in percentages due to cattle related diseases. To estimate the number of unborn calves, we determined the number of calves that were likely to be born among the infected animals in the given year by calculating the number of survivors as the difference between cases and deaths available from the protocol and multiplying this with the share of adult cows and the calving rate that is available by production system in GLEAM. Then we applied the fertility loss in percentages to the number of calves that were to be born among survivors:

$$\begin{aligned} &\text{Number of unborn calves (I.4)} \\ &= \\ &\text{Number of survivors (Protocol: cases-deaths)} \\ &\quad * \\ &\text{Share of adult cows (GLEAM)} \\ &\quad * \\ &\text{Calving rate (GLEAM)} \\ &\quad * \\ &\text{Fertility loss (Protocol)} \end{aligned}$$

## **(II) Salvage slaughter and culling**

### **a) Cattle**

Carcasses (or parts thereof) may be condemned after culling (or salvage slaughter), therefore we must subtract the number of carcasses condemned to avoid double counting. The loss due to culling or salvage slaughtering one animal is determined as the difference in the sales value of a healthy adult and the salvage value. The salvage value of an animal has been calculated using a discount rate on the full price, given by experts consulted during the validation of the protocol data.

$$\begin{aligned} & \text{Loss from salvage slaughter and culling (cattle)} \\ & = \\ & (\text{Number of salvage slaughter} + \text{Number of animals culled} - \text{Number of carcasses condemned}) \\ & \quad (\text{II.1}) \\ & \quad * \\ & (\text{Animal farm gate price (I.2)} - \text{Salvage value (II.2)}) \end{aligned}$$

**II.1 Number of salvage slaughter, animals culled and carcasses condemned:** available from protocol data, in relative terms (per 1,000 cattle) and converted to absolute numbers using cattle population data from the countries' Production Systems Spotlights.

**II.2 'Salvage value' of culls/salvage slaughter:** A discounted price of an animal culled (or salvage slaughtered), estimated using the discount rate given by experts consulted at the validation of Protocol results.

### **b) Poultry:**

For poultry, some producers decide to slaughter and consume the animal a disease is suspected. The animal will likely have a lower weight and therefore we suggest using a discount rate of 50 percent when calculating the total value. The producer may cull the entire flock, such that the number of deaths + salvage slaughters + culls may be more than cases. Where the number of deaths + salvage slaughters + culls surpass the number of cases, we assume total loss of all the cases plus the additional animals that were slaughtered/culled but not sick. Where there the number of survivors is obtainable, then we calculate the productivity loss. There is no production from poultry being culled, therefore there we account the total value of the animals as a loss.

$$\begin{aligned} & \text{Loss from salvage slaughter and culling (poultry)} \\ & = \\ & (\text{Number of salvage slaughter (Protocol)} \\ & \quad * \\ & \quad \text{Price of live animal (Country data, FAOSTAT)} \\ & \quad * \\ & \quad (1 - \text{Discount rate due to disease (50\%))) \\ & \quad + \\ & \quad (\text{Number of culls (Protocol)} \\ & \quad * \\ & \quad \text{Price of live animal (of same age as culls) (Country data, FAOSTAT)}) \end{aligned}$$

#### 4. (III.) Loss from production decrease

**a) Cattle:** The animals infected but not dead suffer a decrease in productivity, notably weight loss, milk production decrease and fertility loss. To evaluate the economic impact of a disease we estimate the value of total decrease in production:

$$\begin{aligned} & \text{Loss of production decrease (cattle)} \\ & = \\ & \text{Loss of meat production (III.1)} \\ & + \\ & \text{Loss of milk production (III.2)} \end{aligned}$$

##### (III.1) Loss of meat production

$$\begin{aligned} & \text{Loss of meat production} \\ & = \\ & \text{Number of survivors (cases-deaths, Protocol)} \\ & * \\ & \text{Weight loss in kilograms per head (Protocol)} \\ & * \\ & \text{Dressing percentage (GLEAM)} \\ & * \\ & \text{Price of beef per kg (Country data, FAOSTAT)} \end{aligned}$$

##### (III.2) Loss of milk production

$$\begin{aligned} & \text{Loss of milk production} \\ & = \\ & \text{Loss from foregone lactation period (III.2.1)} \\ & + \\ & \text{Loss from milk productivity decrease (III.2.2)} \end{aligned}$$

##### **III.2.1 Loss from forgone lactation period:**

$$\begin{aligned} & \text{Loss from foregone lactation period} \\ & = \\ & \text{Number of unborn calves (see I.5 above)} \\ & * \\ & \text{Average litres per lactation (Country data by production system)} \end{aligned}$$

##### **III.2.2 Loss from milk productivity decrease:**

$$\begin{aligned} & \text{Loss from productivity decrease} \\ & = \\ & \text{Number of cows affected by productivity decrease (II.2.1)} \\ & * \\ & \text{Milk loss in litres per lactation period (Protocol)} \end{aligned}$$

*II.2.1 Number of cows affected by productivity decrease:* The number of cows affected by productivity loss are those survivors who were likely to have a calf and were not affected by the fertility loss (i.e. they had a calf):

$$\begin{aligned} & \text{Number of survivors (cases-deaths from Protocol)} \\ & \quad * \\ & \quad \text{Share of adult cows (GLEAM)} \\ & \quad \quad * \\ & \quad \quad \text{Calving rate (GLEAM)} \\ & \quad \quad \quad * \\ & \quad \quad \quad (1-\text{Fertility loss}) (\text{Protocol}) \end{aligned}$$

**b) Poultry**

(III.3) Loss from eggs lost in survivors:

$$\begin{aligned} & \text{Loss from eggs lost in survivors} \\ & \quad = \\ & \quad \text{Number of survivors (cases-deaths from Protocol)} \\ & \quad \quad * \\ & \quad \quad \text{Percentage of eggs lost in survivors (Protocol)} \\ & \quad \quad \quad * \\ & \quad \quad \quad \text{Number of eggs per hen in one year (Country data)} \\ & \quad \quad \quad \quad * \\ & \quad \quad \quad \quad \text{Farm gate price of eggs (Country data, FAOSTAT)} \end{aligned}$$

**5.**

IV. Social cost of disease

$$\begin{aligned} & \text{Social cost of disease} \\ & \quad = \\ & \quad \text{DALY (IV.1)} \\ & \quad \quad * \\ & \quad \quad \text{Willingness to pay for a DALY (IV.2)} \end{aligned}$$

Variables:

**Number of livestock keepers by production system:** We estimate the number of people at risk of contracting one of the zoonotic diseases through direct contact with animals. We use household survey data (LSMS and DHS) to estimate the number of people living in households keeping cattle and poultry. We assume that the distribution of livestock keepers among production systems is the same as the distribution of the number of farms among production systems. We use the animal population per production system and the average herd size to estimate the number of farms per production system.

**Number of consumers who are not livestock keepers:** In cases where people can be affected by the disease through consumption, we need to calculate the number of consumers but to avoid double-counting, we do not include livestock keepers. We determine the number of non-livestock keepers using household survey information described above. We use the share of

households reporting consumption of cattle and poultry products using the Global Consumption Database of the World Bank.<sup>6</sup>

## VI.1 DALY

Disability adjusted life years (DALYs) are calculated as the sum of the years of life lost due to premature mortality in the population and the equivalent “healthy” years lost due to disability during the sickness of survivors.

$$\begin{aligned}
 & \text{DALY} \\
 & = \\
 & \text{Number of deaths (Protocol)} \\
 & * \\
 & (\text{Average life expectancy (World Bank)} - \text{Average age of infection (Protocol)}) \\
 & + \\
 & \text{Number of survivors (Protocol)} \\
 & * \\
 & \text{Duration of disease (Protocol)} \\
 & * \\
 & \text{DALY weight (WHO)}
 \end{aligned}$$

## IV.2 Willingness to pay for a DALY

To attach a monetary value to a DALY, we need to determine the willingness to pay for a healthy year of life, i.e. the WTP to avoid a DALY. We use the value of statistical life calculated by the US Department of Transport, and translate it into a yearly value using the expected life span and a discount rate, following the methodology of the OECD. Then we translate this value into country context using a benefit transfer methodology. This methodology takes into account the differences in GDP per capita and the elasticity of the willingness to pay for a healthy life (i.e. how WTP changes as income grows).

$$\begin{aligned}
 & \text{Willingness to pay for a healthy life year} \\
 & = \\
 & \text{Willingness to pay for a healthy life year in the United States (PPP) (see below)} \\
 & * \\
 & (\text{GDP per capita in PPP of country} / \text{GDP per capita in PPP of US})^{\text{elasticity}} \\
 & \text{Willingness to pay for a healthy life in the United States (PPP)} \\
 & = \\
 & \text{Value of Statistical Life (US Department of Transport)} \\
 & / \\
 & \sum_{t=0..T} (1 + \text{discount rate})^t
 \end{aligned}$$

<sup>6</sup> <http://datatopics.worldbank.org/consumption/detail>



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