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Participative modelling of a micro insurance scheme for African swine fever (ASF) in a peri-urban pig farming (PF) in Kinshasa, democratic republic of Congo (DRC)

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Abstract
A study was conducted using the active / accelerated participatory research method (APRM) on the public model of ASF risk management from the colonial era to the present day, with a view to identify their limits and propose a model for the future in Kinshasa, DRC. Fishery and livestock experts stated that the ASF was propagated using the SIR (Susceptible-Infested-Retired) model. The appearance of ASF presents a serious health risk in terms of PF productivities. This study identified two models. The first model, the colonial state one, supported the insurance premium ASF 100% while the second or current model from 1960 to the present day, the Congolese state supports the insurance premium ASF 0%. Small and large pig farmers use 100% self-insurance in case of ASF. At the provincial level in Kinshasa, an average pig people of 24% is swept away annually by the ASF and represents nearly 16,093 pigs or $ 4,224,237.50. Whereas at the level of a PF, the pig farmer loses all of his pigs. The 3 months growing pig premium is calculated taking into account its target point which is estimated at 75 kg. The parent premium is calculated over 5 years. Compensation for losses due to ASF is essential to eradicate ASF and allow the collaboration of pig farmers and communal health police. We recommend the model (90.10) for small pig farmers and (60.40) for large pig farmers. Small pig farmers are 84% of all pig production in Kinshasa, DRC. The National Insurance Company (NIC) is ready to create a micro insurance department to support small pig farmers.

Keywords: Pig breeding, ASF, Micro insurance

1. Introduction
Agricultural production is surrounded by many uncertainty. Any agricultural production plan has many potential outcomes associated with it. Whatever the generating event and how it is triggered, the risk will have an impact on the farmer's income (pig farmer). In these conditions, risk in agriculture is today one of the essential elements to take into account in the overall management of its operations. The risk in agriculture therefore represents a nested system in which markets and government measures interact with the risks and strategies of the farmers (Mathieu, 2011) [22]. In agricultural activity, which is inherently dependent on climatic and health conditions, the risk is particularly present. Risk is the harmful consequence of a random event. Agricultural risk management is primarily the responsibility of the farm business. Its general approach begins with a phase of prevention, followed by a phase of risk treatment (Cordier *et al.*, 2013a) [10]. Risk management in agriculture is a strategic issue for governments as old as agriculture. Indeed, the food security of a society is the prerequisite for social and economic stability. When the state intervenes heavily in risk management, as in the case of Spain, Canada and the United States, the question of risk sharing between companies (farmers, insurers) and governments inevitably arises. The balance between the respective contributions of each is unstable because it results from more or less fragile political compromises (Cordier *et al.*, 2013) [10]. In the context of the DR Congo, two periods stand out clearly: (i) the period before independence (before 1960) where the pig farmer was obliged to collaborate with the health police of his commune in the execution these hog farming activities

to avail themselves of compensation in case of passage of the ASF (Piron and Devos, 1959) [25]. (ii) After independence, from 1960 to today, the code Piron, Volume III, updated to March 31, 1959 being placed in the drawer. Some texts of this document have been modified and completed to date without this can provide a qualitative leap from the current requirements of the World Trade Organization (WTO), the International Organization of Epizootics (IOE) and the Codex Alimentary Commission (World Animal Health, 2002). (Bakajika law December 2004, Agricultural Code December 2011) [22]. The ASF is considered a scourge by the code Piron and Devos (1959) [25] and as a fire risk with compulsory insurance by the National Insurance Company. The insurable pig will have to be 3 months to 5 years old (NIC, 2001 and CNAAS, 2010) although no pig farmer knows it and does not contract it. The probability of ASF being abused in a pig breeding is respectively 0.8 and 0.5 for large and small pork producers and limits pig production (Tona-Tona *et al.*, 2019) [27]. Sorin, 2006 quoted by Yandia, 2011 estimates the parts due to ASF between 0.24 ± 0.14% in Cameroon, Benin, Gambia and Togo. From these contributions, the expression model of the phenotypes can be written in "current" terms as follows, assuming that the phenotypes (P) are expressed in a homogeneous environment and that they are the sum of the effects of the genotype (G) and environment (E) and what escapes model α: Additivity of genotype and environment:
$P = G + E + \alpha$ is the model of quantitative genetics (Laloe, 2011). The present study aims to propose a model of the future for public risk management ASF in Kinshasa, DRC.

2. Material and methods

2.1 Study environnement

This study was carried out in Kinshasa from September 2015 to June 2018. It involved two peri-urban communes, Mont-Ngafula and Maluku, whose populations are estimated at 261,000 and 180,000 people respectively. Three sites were chosen because they are representative of the organizational dynamics of the peri-urban PF in Kinshasa as well as because of the high concentration of pig farmers and their accessibility.

Source: Osfac, October, 2016

Fig 1: Location of peri-urban pig breeding sites studied in Kinshasa

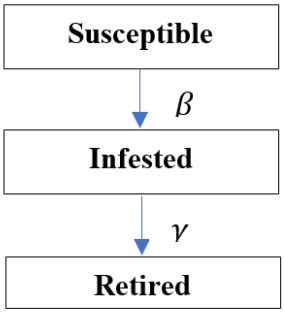
2.2 Data collection methods and statistical analysis

The approach revolves around five complementary approaches: the historical method, the survey method, the participative research: semi-structured interview (simple ranking checklist), proportional stacking, scoring matrix, seasonal calendar, participatory cartography, chronogram and transversal walk), observation and mathematical modeling. The collection of socio-economic data was carried out using the active / accelerated method of participatory research (AMPR). The collected data was saved in a database in Excel. The Scilab-6.0.2 software was used to model the ASF while the Matlab R2018b software (9.5.0.944444) was used to model the insurance premium or ASF micro insurance.

3. Results

3.1 Opinions of fisheries and livestock experts

Experts from the Ministry of Fisheries and Livestock said that the ASF spreads in Kinshasa according to the model SIR (Susceptible-Infested-Withdrawn). The incubation phase can last 3-15 days. The SIR model is due to Kermack and McKendrick in 1927. The ASF is not a zoonotic disease, the consumption of meat promotes the spread of the virus. There is a high morbidity and mortality which is above normal within 15 days. We consider the case of an open pig people due to birth rate and entry into the borders.



$$\frac{dS}{dt} = -\beta SI$$

$$\frac{dI}{dt} = \beta SI - \gamma I$$

$$\frac{dR}{dt} = \gamma I$$

The expressions found after the resolution of the differential system above, are given by

$$S(t) = \exp\left(-\beta \int I(t)\,dt\right);$$

$$I(t) = \exp\left(\beta \int S(t)\,dt - \gamma t\right);$$

$$R(t) = \gamma \int I(t)\,dt.$$

3.2 Propagation of ASF in a breeding without intervention

At the level of a pig breeding, when ASF is rampant, in addition to the action of the disease, the pig farmer eliminates his pig herd and leaves with a healthy nucleus.

3.3 Opinion of the pig farmers of Maluku and Mont Ngafula in Kinshasa

The pig farmers confirm the presence of ASF. The cutaneous signs observed are mainly redness in the extremities (ears, paws) and hyperthermia. The presence of anorexia, diarrhea, sometimes hemorrhagic vomiting is also noticed. High mortality appears in a record time (ie in one month). The losses are total at the level of a PF reported the pig farmers.

3.4 Evolution of the ASF epidemic

Provincial level in Kinshasa: the differential equation system provided by the SIR model is not linear, so it is mathematically hard to find the exact solutions. To find approximate solutions, we use a software. The SciLab-6.0.2 software allowed us to solve the SIR system and its variants in a relatively easy way. It works by writing command lines, but it also gives the possibility to execute scripts that implement a calculation and display the procedure quite easily.

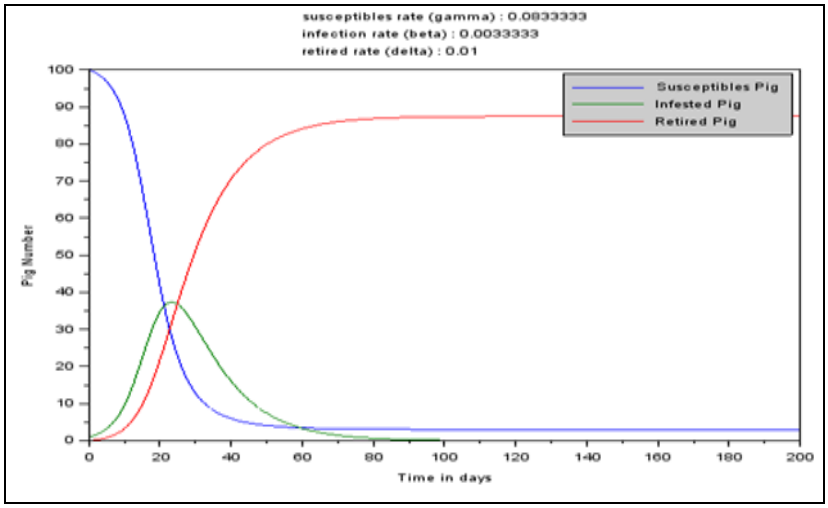


Fig 2*:* Evolution of the ASF at the provincial level in Kinshasa, DRC.

The ASF carries a maximum of 38% of the provincial pig people in Kinshasa. The epidemiological unit is at least one infested pig, two infested pigs, one infested pig herd, one District or one commune. At the level of a pig breeding, when the ASF is rife, the pig farmer loses all of his pigs. He uses self-insurance to revive his pig breeding.

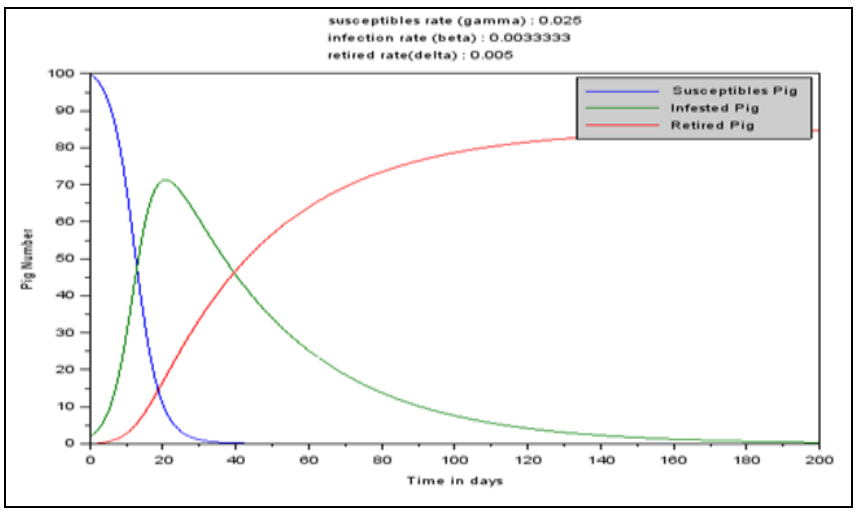
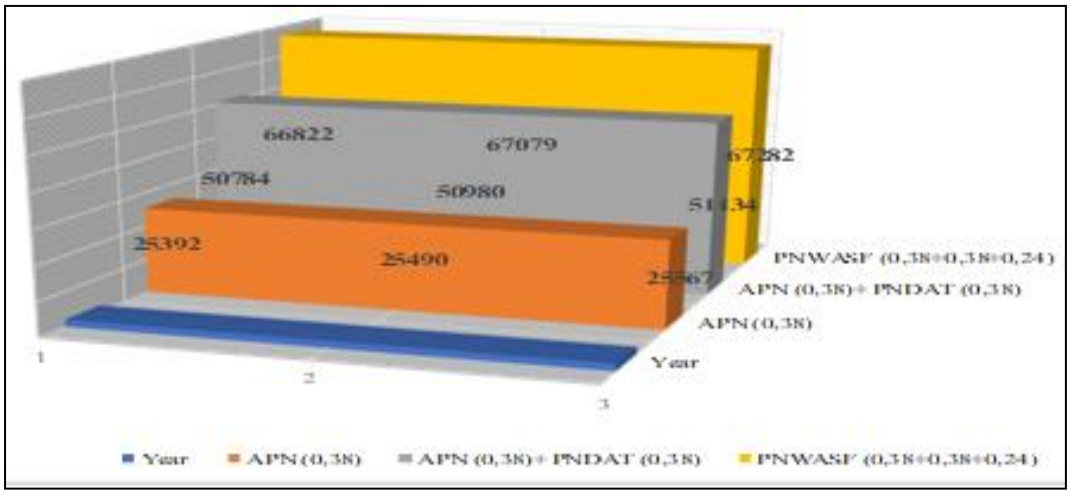


Fig 3: Evolution of the ASF in a pig breeding in Kinshasa, DRC.

3.5 Evolution of the pig people in Kinshasa in the presence of ASF in the 2013-2015 period.



Legend: APN: Annual Pig Number; PNDAT: Pig Number Dead and Traitor; PNE: Pig Number Estimated et PNWASF: Pig Number Without African Swine Fever

Fig 4: Evolution of the pig people in Kinshasa in the presence of the ASF in the 2013-2015 period.

The average pig people lost by the ASF in Kinshasa in 2013, 2014 and 2015 was respectively 16,038; 16,099 and 16,140 and represents a considerable shortfall.

3.6 Dynamic economic model of ASF management in Kinshasa, DRC

3.6.1. Payment of insurance premium or micro insurance ASF

Central and provincial fisheries and livestock experts support the subsidy of insurance and micro insurance premiums by the Congolese state. The NIC has issued a favorable opinion for the creation of a micro insurance department and supports the subsidy of insurance premiums by the Congolese state. The NIC and private insurers such as the insurance financial company (IFC), RAWSUR SA DRC and ACTIVA INSURANCE DRC require reliable data production for a consecutive period up to 5 years and at least 3 years before to launch the product to have indicators of actuarial calculations.

3.6.1.1. Analysis of the existing mathematical models

Let's denote by *x* the part of the pig farmer, *y* the part of the Colonial / Congolese State and *z* the premium insurance or micro insurance.

We have the following equation: $z = x + y$

Before independence, we have: $z_1 = 0 + 100 = 100$ ***(1)***

From 1960 until now: $z_2 = 100 + 0 = 100$ ***(2)***

3.6.1.2. Model of the future

Two models are proposed: one for small pig farmers and one for large pig farmers as economically characterized by Tona Tona *et al.*, 2019a:

1. Small pig farmers: $z_3 = x_3 + y_{3 \Rightarrow} z_3 = 10 + 90 = 100$ ***(3)***
2. Large pig farmers : $z_4 = x_4 + y_{4 \Rightarrow} z_4 = 40 + 60 = 100$ ***(4)***

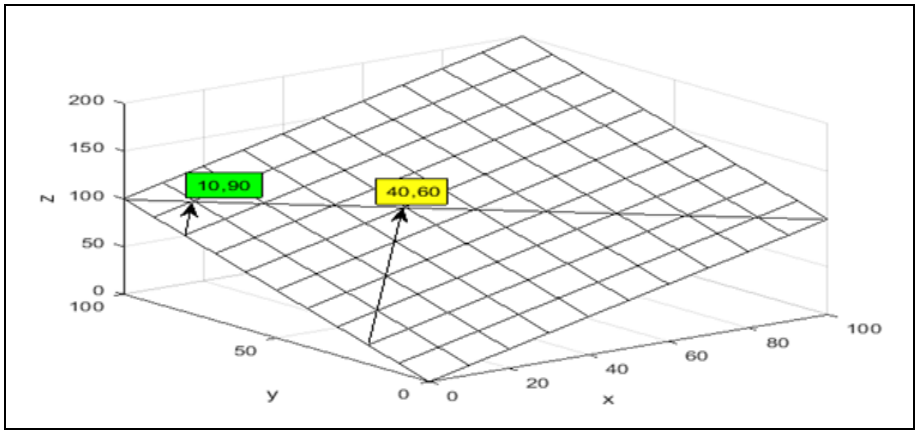


Fig 5: Contribution of x and y in ASF micro insurance premium.

The transition from the first model to the second constitutes an institutional / legal (systemic) risk that Congolese pig farmers had experienced losing the advantage of the full coverage of the insurance premium by the colonial state. This study proposes a subsidy of ASF microinsurance premiums of about 90% for small pig farmers and 60% for large pig farmers. The NIC offers a 40% subsidy for all pig farmers. Out of a total of 12,828 pigs produced annually, small pig farmers produce 10,788 pigs, ie 84.1% compared to 2,040 pigs or 15.9% for large pigs. In case of loss of pork confirmed by the health police that it is due to the ASF, the insured pig farmer is compensated by the insurer and this goes through the recent pig farmers, their pigs, the porcine traceability, serological monitoring of pig breeding by experts in production and animal health. The application of these economic models should have an impact on the reduction of losses and even the eradication of ASF.

Table 1: Actuarial calculations of premium, deductible and indemnity according to NIC

Pig	Sex	LW kg	VM $	LW kg	VM $	Premium (6,5%) $	Franchise (20%) $	Indemnification (80%) $
First year breeder	♀	80-100	300	---	---	19,5	60	240
		80-100	600	---	---	39	120	480
	♂	80-100	500	---	---	32,5	100	400
		80-100	1000	---	---	65	200	800
Gowing piglet	♀	15-25	70	80	280	18,2	56	224
	♂ castré	15-25	70	75	262,5	17,06	52,5	210

Legend: ♂: male; ♀: female; LW: Live Weight; kg: kilogramme; Monetary VM: Monetary Value et $: American dollar and%: percentage

The genetic value of a pig spawner decreases with age, however it retains its commercial value as consumable meat. The actuarial calculations of the premium of a piglet in growth is made with respect to its target live weight (75 kg) and its payment is annual.

Table 2: Actuarial calculations of losses, total premium (commercial), indemnification and tax in US dollar from 2013 to 2015

Year	Pig Number	LW/pig kg	Price $/ kg of LW	Loss $	Total premium (commercial) $	Indemnification $	*Tax $
Minimum (0,10)							
2013	6383	75	3,5	1.754.287,50	114.028,69	1.403.430,00	16.707,50
2014	6708	75	3,5	1.760.850,00	114.455,25	1.408.680,00	16.770,00
2015	6725	75	3,5	1.765.312,50	114.745,31	1.412.250,00	16.812,50
	Average (0,24)						
2013	16.038	75	3,5	4.209.975,00	273.648,38	3.367.980,00	40.095,00
2014	16.099	75	3,5	4.225.987,50	274.689,19	3.380.790,00	40.247,50
2015	16.140	75	3,5	4.236.750,00	275.388,75	3.389.400,00	40.350,00
	Maximum (0,38)						
2013	25.394	75	3,5	6.665.925,00	433.285,13	5.332.740,00	63.485,00
2014	25.490	75	3,5	6.691.125,00	434.923,13	5.352.900,00	63.725,00
2015	25.555	75	3,5	6.708.187,50	436.032,19	5.366.550,00	63.887,50
	Kinshasa provincial pigmeat Pure Premium						
2013	66822	75	3,5		1.140.150,38	752.499,25	
2014	67079	75	3,5		1.144.535,44	755.393,39	
2015	67282	75	3,5		1.147.999,13	757.679,42	

* The tax on pig is $ 2.5 per pig

In terms of evaluating the economic impact of an animal epidemic such as ASF, the most widely used and used tool is Cost Benefit Analysis (CBA). Table 2 shows that it is better to cushion the shock of ASF with an ASF micro insurance program. According to Simonet (1994) [30] the pure premium is 66% of the commercial premium. Pure premiums collected cover allowances for a minimum of 53.63%; average of 22.34% and a maximum of 14.11%. There is an exponential law relationship between premium and indemnity. For NIC, the Congolese state should also support the compensation of 46.35 to 85.99% as appropriate and insurance or micro insurance ASF should be mandatory. For the minima, it is an operating loss while the average and maximum losses lead to the ruin of the insurer.

Discussion

The results made it possible to highlight two public models of payment of the insurance premium or micro insurance ASF implemented from the colonial era to the present day. The first so-called colonial model (0.100) had made the PE prosper, while the second model, which is the opposite of the first (100.0) model from 1960 until now, did not ensure the development of the PF. DRC pig farmers had experienced institutional / legal (systemic) risk during independence. This finding is supported by OECD. Harwood *et al.*, (1999) and Holzmann and Jorgensen (2001) cited by Lidsky *et al.*, (2017) [18]. The PF as it is practiced without support of the Congolese state on the eradication of the ASF cannot know a notable development. This finding was also made by Fasina *et al.*, (2011) [14] and Sánchez-Vizcaíno *et al.*, (2014) [26]. ASF is considered a scourge, a fire hazard by NIC and IOE international regulations (2017) and therefore requires the support of the public authorities. FAO (2014) [15] argues that transboundary animal diseases (TADs) whose ASF must be avoided and controlled, as they cause economic losses for smallholders and pastoralists. Rault and Krebs (2010) argue that the economic consequences of epidemic health risks are potentially high and multi-sectoral. Proposals for 60% and 90% support for large and small pig farmers, respectively, are supported by Cordier *et al.*, (2008) [11] who offer 80% assistance with the payment of insurance premiums. The proposed ASF micro insurance would bring hope once initiated. It is useful to set up a pilot program to control the spread of ASF and to create pest free areas. The optimization of the compensation passes by the increase of the level of biosecurity of the PF. The low level of biosecurity in PF interviews the ASF in Kinshasa, DRC. This observation was also affirmed in Cameroon (Anonymous, 2015) [1]. Risk management by small pig farmers is a real challenge, they must be able to ensure, but also develop resilient pork production systems. This finding has already been reported by Hazell (2014) [16]. At the level of pig farmers households, the potential contribution of micro insurance to breaking the cycle of poverty plays both a production and a protective role (Collins *et al.*, 2009 and Cohen and Sebstad, 2005) [8, 9]. Micro insurance would therefore be a mechanism to stabilize the incomes of pig farmers and encourage investment. Troy (2013) [32] argues that micro insurance provides a stronger loan repayment guarantee and can therefore help to facilitate access to credit. Micro insurance promotes wealth creation. As an emergency financing system, micro insurance promotes the gradual formation of wealth in the low-income market and

prevents people who have managed to escape poverty from falling back into it. Bester *et al.*, (2010) [2] argue that micro insurance is thus a vehicle for mobilizing finance that, from a macroeconomic point of view, can fuel economic growth. For the KTVAC (2003) [6], the effectiveness of the measures is based in particular on compensation for losses and slaughtering of pigs. In the DRC, we must combine our efforts on the rigorous application of animal health measures (prevention, control and eradication) with a view to limiting and achieving the total extinction of this disease in the future. It is a fact that, apart from any suspicion, the defensive measures will essentially consist in promoting intensive pig farming. Indeed, the prevention of African swine fever in infected areas is almost impossible as long as traditional methods of pig breeding. The contribution of the public authorities should take into account the contribution of small pig producers to the quantity produced in pigmeat delivered on the kinship market, which amounts to 84%. Pure premiums from the total annual pig population are lower ($ 752,499.25) than the minimum losses ($ 1,403,430.00) due to ASF. This difference of $ 650,930.75 does not appeal to private insurers seeking economic profitability, however the public authority can invest in a social profitability project. The grouping of many of the risks allows statistical compensation to insurers by using the premiums collected for another risk whose loss is zero to pay a claim. The public authorities should pay 46.57-85.89% as some countries like Senegal do.

Conclusion

Production and animal health experts from the Ministry of Fisheries and Livestock said the ASF was spreading in Kinshasa, DRC according to the SIR model (Susceptible-Infested-Retired). The first model of payment of the so-called colonial ASF insurance premium z1 (0.100) had made the PF prosper, while the second z2 (100.0), which is the opposite of the first, did not make the PF prosper. Losses due to the ASF are of the average of 24% at the provincial level of Kinshasa. The victims used self-insurance to revive the PF. The present study shows that it is possible to secure the PF of Kinshasa, DRC via a ASF micro insurance program. We propose as model of the future of management of the ASF, for the small pig farmers (10,90) and (40,60) for the big pig farmers although the ideal would be to return to the first model of before 1960 and this is only possible through negotiations between associations of pig farmers, experts in production and animal health and Livestock and researchers. Public power has an important role to play in ensuring the development of PF in Kinshasa and throughout the DRC.

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