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Possible effect on border fencing and animal corridors blocking on African Swine Fever (ASF) Virus propagation in Poland

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Epidemiology: African swine fever (ASF) – viral infection of domestic pigs and wild boar (WB) – causes massive economic losses (directly at least 100M EUR yearly) in Poland mainly due to trade restrictions (indirectly more than 300M EUR yearly). The disease is characterized by very complex transmission dynamics (multiple routes, hosts and vectors). We analyze 3487 ASF notification in Poland from February 2014 to April 2019 (50 out of 380 poviats have been affected and due to restrictions, almost 90% of farms in affected area stopped pig production) comprising event time, longitude and latitude (within the administrative unit of poviat), where at least one house swine or wild boar case was reported. The disease propagates from East to West of Poland with the following velocity of spatial expansion: subepidemic regime ~0.28 County per month; preepidemic ~0.8 County per month; epidemic ~0.75 County per month [Fig. 2].

Model: We choose a pseudo gravity propagation model for the future projection of the disease spread taking into account: pig abundance (pork production chain), disease vectors (wild boar density), and human failures to restrictions. Thus we propose a heuristic multilayer network approach related to disease propagation considering counties (poviats) as nodes of a network. We run a set of simulations for selected subspace of parameters of significance a- swine amount, b- biological vectors (wild boars), c- pork products and animal movement, d- mechanical vectors (humans) [Fig. 3].

$$p_{ij} \sim \frac{a(P_i * P_j)}{1+d_{ij}} + \frac{b(F_i * F_j)}{1+d_{ij}^2} + \frac{d(H_i * H_j)}{1+d_{ij}}, \quad g_{ij} \sim p_{ij} * c$$

Where: a, b, c, d – simulation parameters; i, j – poviats; P – normalized amount of pigs; F – coverage of forests; H – normalized human population; p_{ij} -probability of infection from a neighbor; g_{ij} -probability of infection from a whole networks; d_{ij} -angular distance between centroids of poviats (counties)

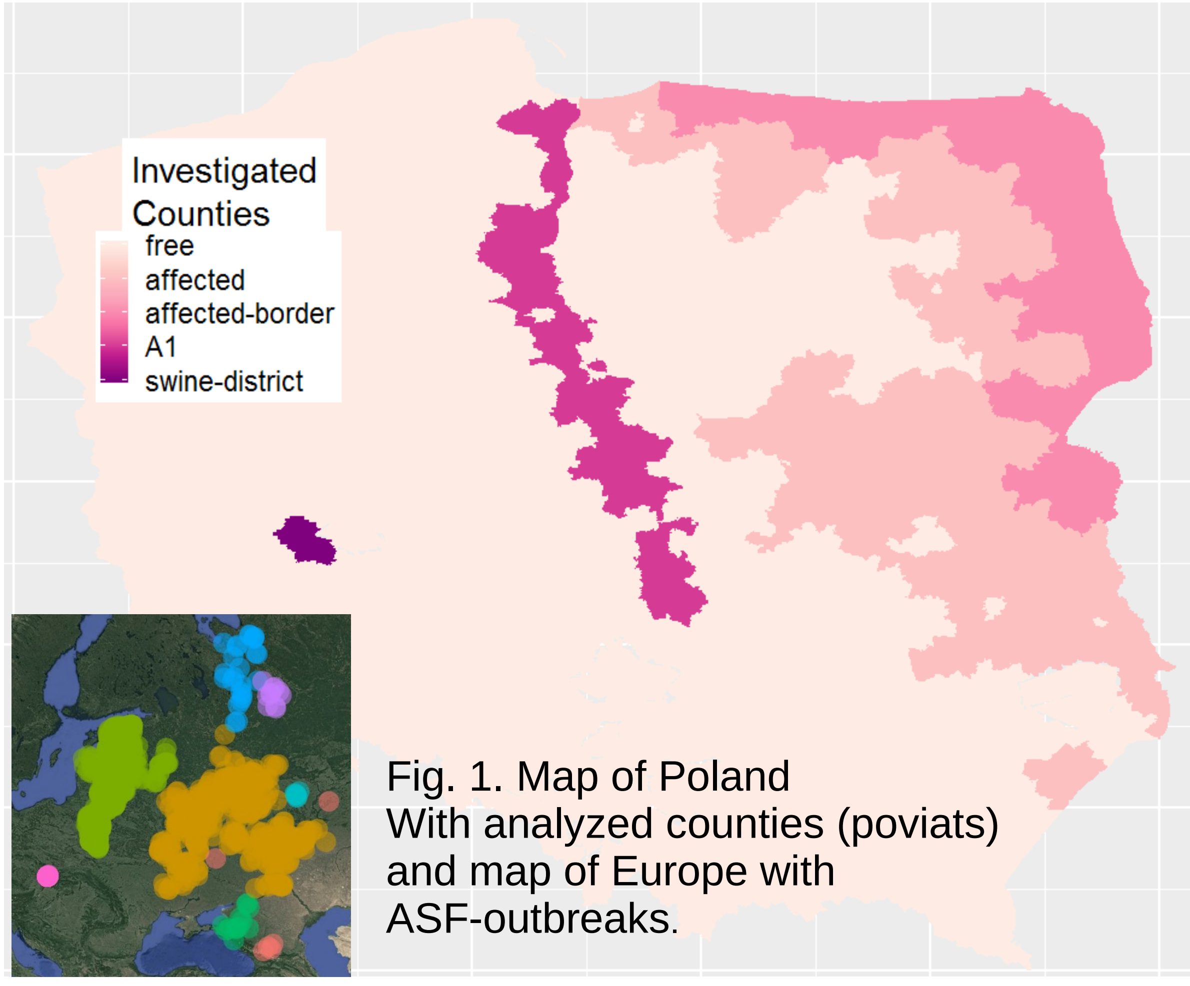


Fig. 1. Map of Poland With analyzed counties (poviats) and map of Europe with ASF-outbreaks.

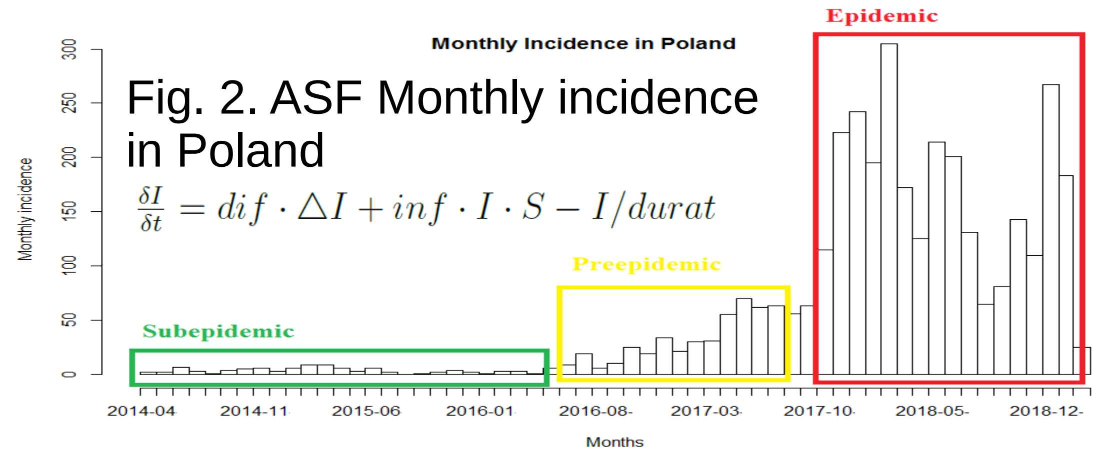


Fig. 2. ASF Monthly incidence in Poland

Research Question: We verify theoretically a barrier effect of building a fence on the part of the Polish EU-border and blocking animals corridors on the A1 motorway by comparison of the disease arrival times to Polish "swine hot spot" (poviat gostyński and surroundings) [Fig. 1] in Greater Poland to the baseline (no barrier interventions) scenario (most likely to be affected in **33.5 months** according to our model: http://interdisciplinaryresearch.eu/index.php/asf/).

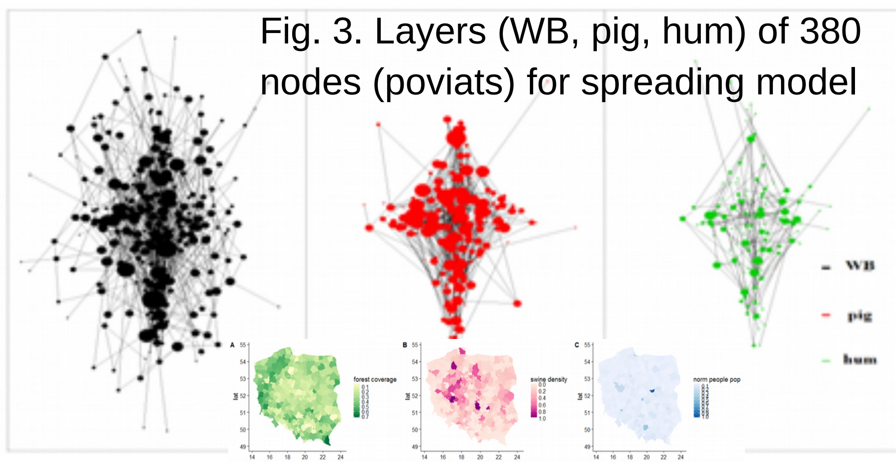


Fig. 3. Layers (WB, pig, hum) of 380 nodes (poviats) for spreading model

Testing A1 blocking:

To verify a possible effect of blocking animal corridors, we test a scenario in which all poviats on A1 motorway are disconnected on the outgoing wild boars layer [Fig. 3].

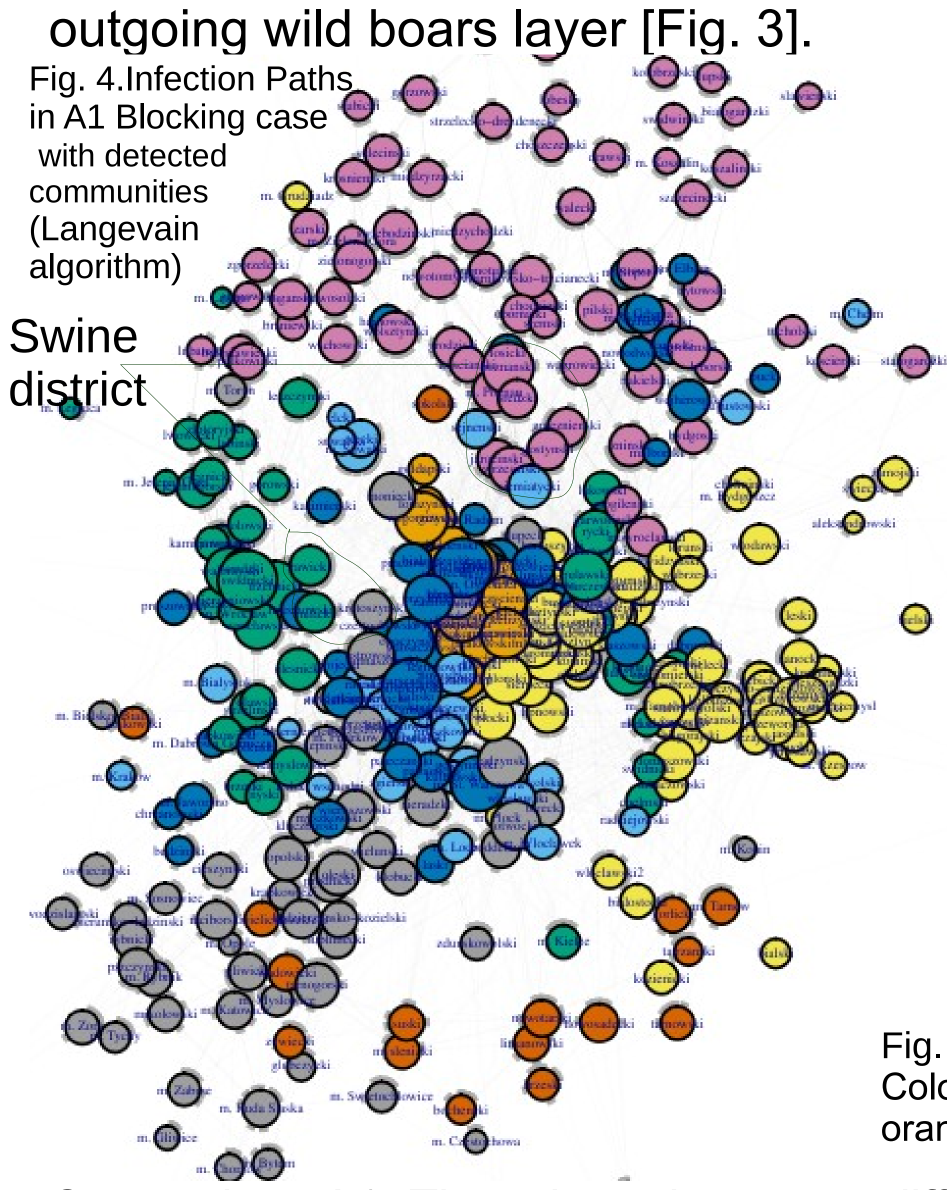


Fig. 4.Infection Paths in A1 Blocking case with detected communities (Langevain algorithm)

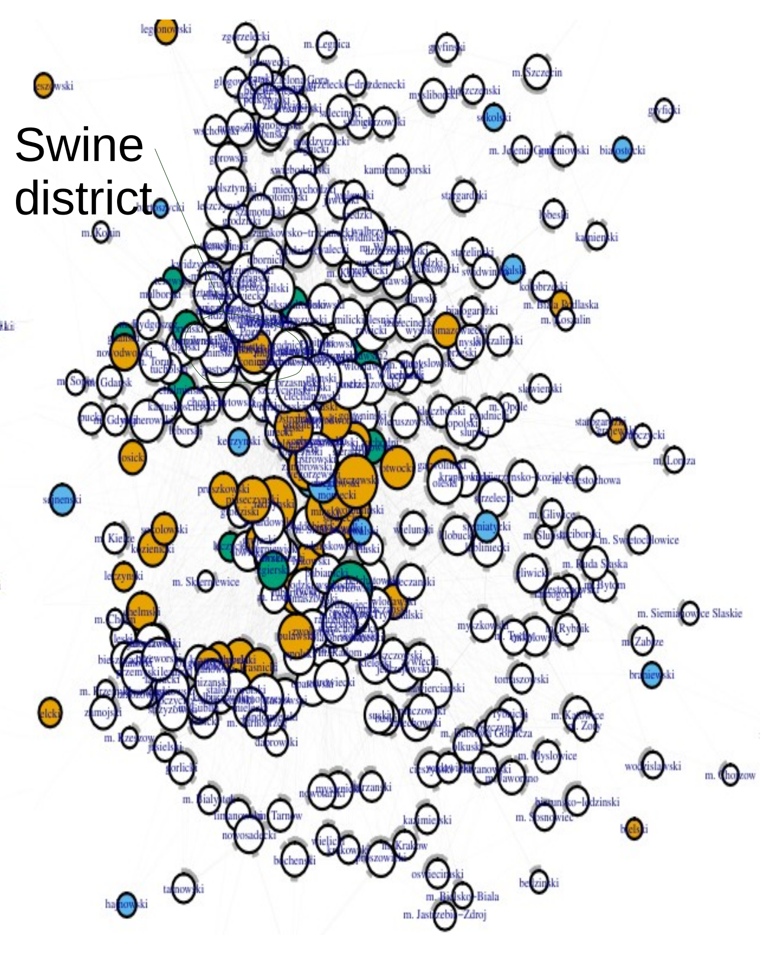


Fig. 5. Infection Paths in baseline case Colorcode: (free poviats: white, affected-interior: orange, affected-border: blue, A1:green)

Conclusions A1: There is an important difference in the arrival time to swine district (most likely to be affected in **39 months – on average half a year barrier**). A1-blocking leads to splitting of "swine district" cluster [Fig. 4, 5]. Delayed spread seems to be in agreement with observed propagation in Baltic States (e.g. via Baltica and A1 highways in Lithuania).

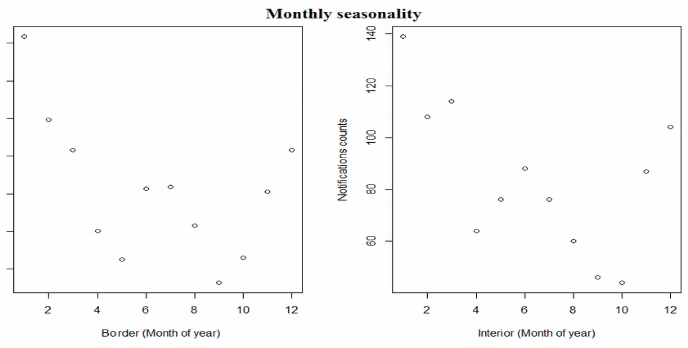
Testing in fencing

To verify a possible effect of the fence, we quantify the difference in transmission dynamics between regions at the country border -b (immigration hypothesis) and in the interior - i regions (endemicity hypothesis). We examine Seasonality and quasi-Granger causality by calculating lag correlations (pair i-b_minus higher than i-b_plus), in clear seasonal pattern with winter and summer picks.

Tab. 1. Lagged Correlations (border vs interior)

Corr.	i	b	b_plus	b_minus
i	1	0.94	0.54	0.61
b	0.94	1	0.57	0.57
b_plus	0.54	0.57	1	0.19
b_minus	0.61	0.57	0.19	1

Fig. 6. Seasality Border vs Interior



Additionally, we test a scenario in which all border poviats are disconnected on the outgoing wild boars network layer [Fig. 3].

Conclusions border: Seasonal lagged correlation suggests [Tab. 1] a phase difference (however not significant) in an epidemic wave (events in border countries are little ahead of events in interior counties). There is only a small difference in the arrival time to swine hot spot district (most likely to be affected in **34.2 months – on average less than one month barrier**), because most of the dynamics is currently happening on the West of the border counties.

Disclaimer: Our methodology capture only the upper limit of a theoretically perfect barrier in simple static model and more analysis in realistic time-dependent scenario is required.