Evaluation of the risk of the spread and the economic impact of Classical Swine Fever and Foot-and-Mouth Disease by using the epidemiological model Be-FAST.

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4. *Mathematical formulation and validation of the Be-FAST model for CSF Virus spread between and within farms.* **Annals of Operations Research**. *Online First. 2013*

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Classical Swine Fever description

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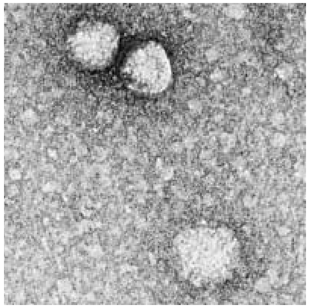
- Classical Swine Fever (CSF) is a non-zoonotic highly contagious viral disease of domestic and wild pigs caused by a *Flaviviridae Pestivirus*.



- Infected animals present various symptoms (fever, lesions, hemorrhages...) provoking a disease mortality of $\approx$ 30% up to 100% (depending of the strain).

Foot-and-Mouth Disease description

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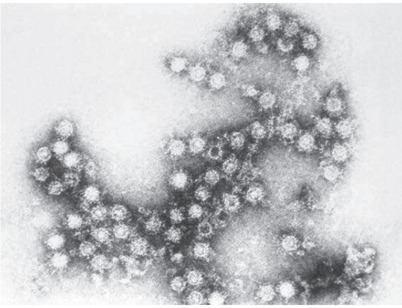
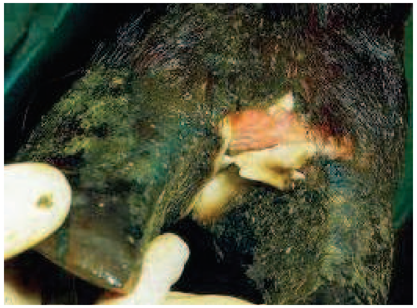
- Foot-and-Mouth Disease (FMD) is a highly contagious viral disease of cloven-hoofed animals (bovine, sheep, swine, camelid etc.) caused by a *Picornaviridae virus* which can rarely contaminate humans.



- Infected animals present various symptoms (blisters, severe weight loss, myocarditis ...) provoking a disease mortality of $\approx$ 20%-50% for adults and 25%-90% for juveniles



Global Situation

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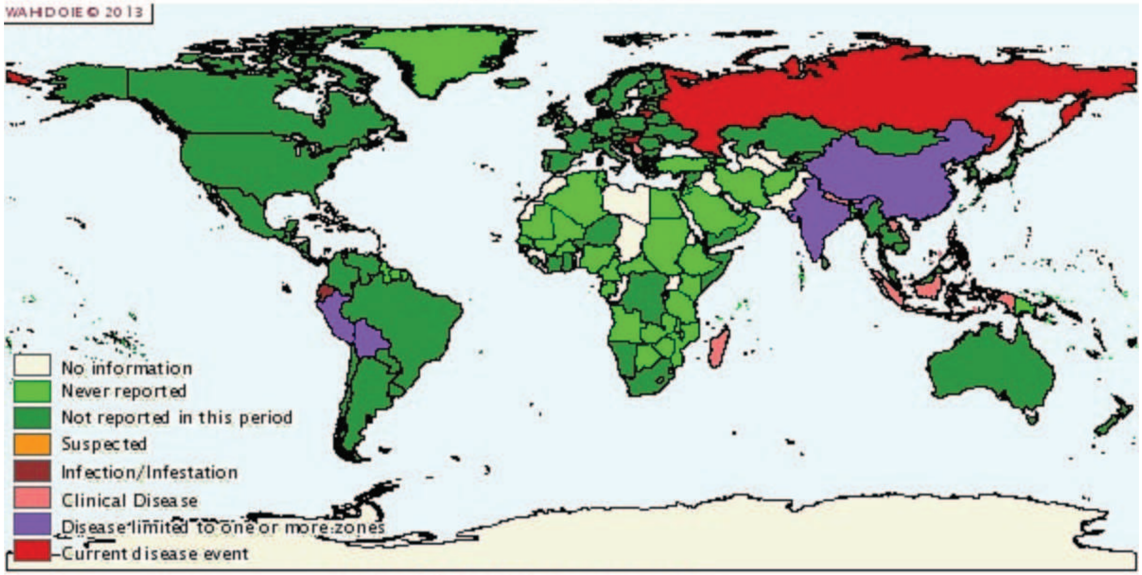
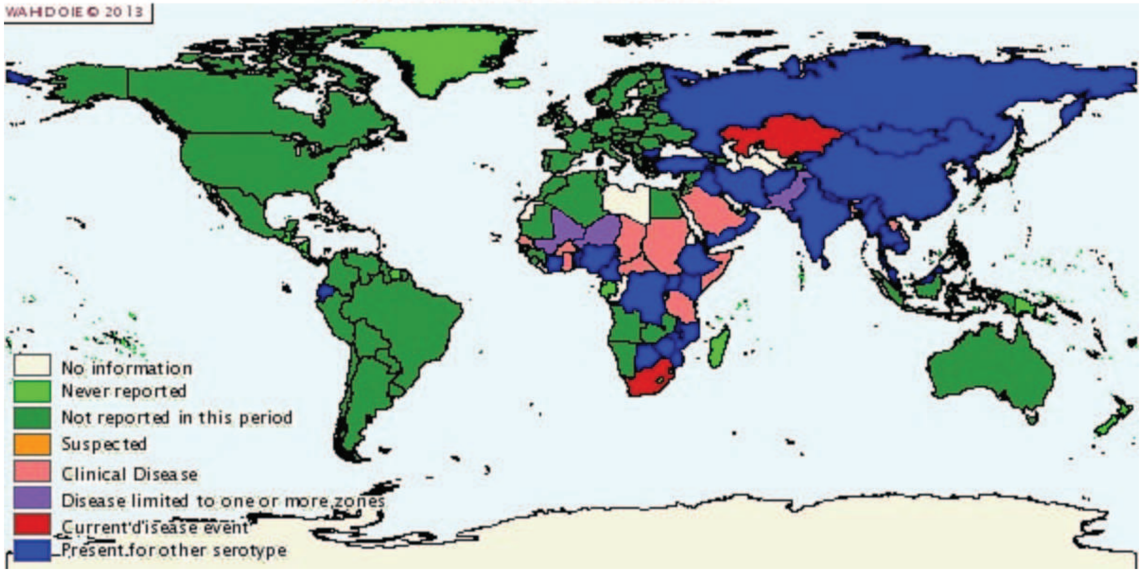
CSF (2011) - Source OIE



FMD (2011) - Source OIE



Routes of transmission

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The main known routes for farm to farm transmission of the considered livestock diseases are (proportion depending of the disease):

- Airborne spread.
- Movement of infected domestic animals.
- Movement of people: yatrogenic, farmers, etc.
- Contaminated fomites: vehicles, semen, material, etc.
- Infected food: meat, milk, cereals, etc.
- Infected wild animals : boar, deer, etc..
- Parasites: ticks, etc.

Control measures

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Depending on the Country legislation, the measures to control and eradicate CSF or FMD epidemics are based on:

- Culling.
- Zoning.
- Movement restrictions.
- Increase of active surveillance: diagnostic tests, media campaigns, etc.
- Tracing.
- Vaccination.

Economical impact of outbreaks

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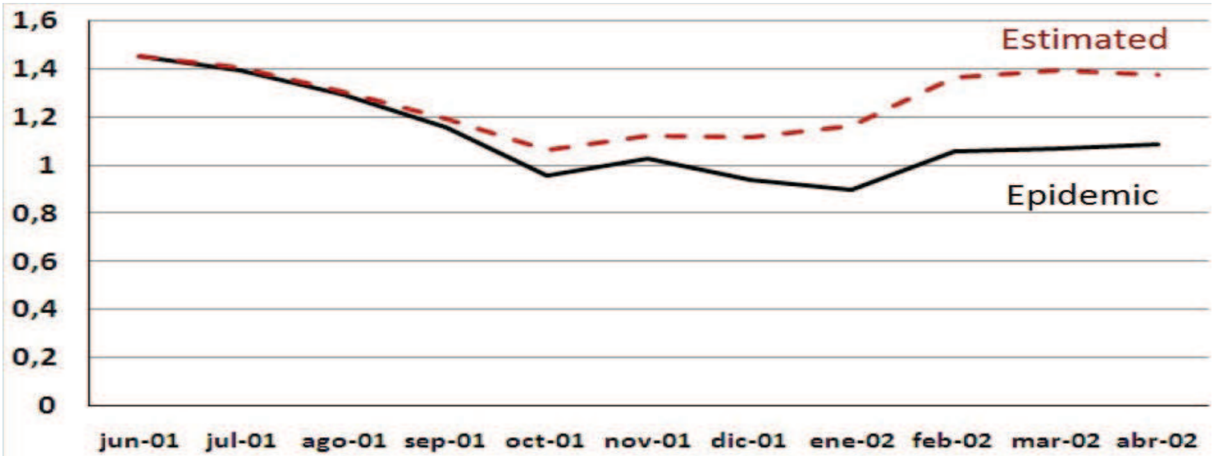
Economical costs due to FMD/CSF epidemics are classified as:

- Indirect: paid by agriculture companies due to meat price devaluation.



- Transferable: paid by authorities due to control measures.
- Payable: paid by authorities to compensate third-parties (farms, insurance companies, etc.).
- Computable: paid by third-parties until of the regularization of the situation (e.g., quarantine, culling, etc.).

Example: CSF, 2001, Spain (4rd Pig Producer, 4.500 M€/yr), duration of 1 year, 49 outbreaks, estimated total cost 48 M€.

Mathematical modeling interest

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Main objectives:

Develop a model, called Be-FAST (Between Farm Animal Spread Transmission), which can be adapted to each specific case (disease, region, ...) in order to:

- Analyze the patterns of the spread between farms.
- Characterize the risk areas for disease introduction/spread.
- Estimate the economic losses generated by the epidemics (useful for insurance companies and authorities).
- Evaluate the efficiency of control measures (existing or future).
- Optimize the control policy.

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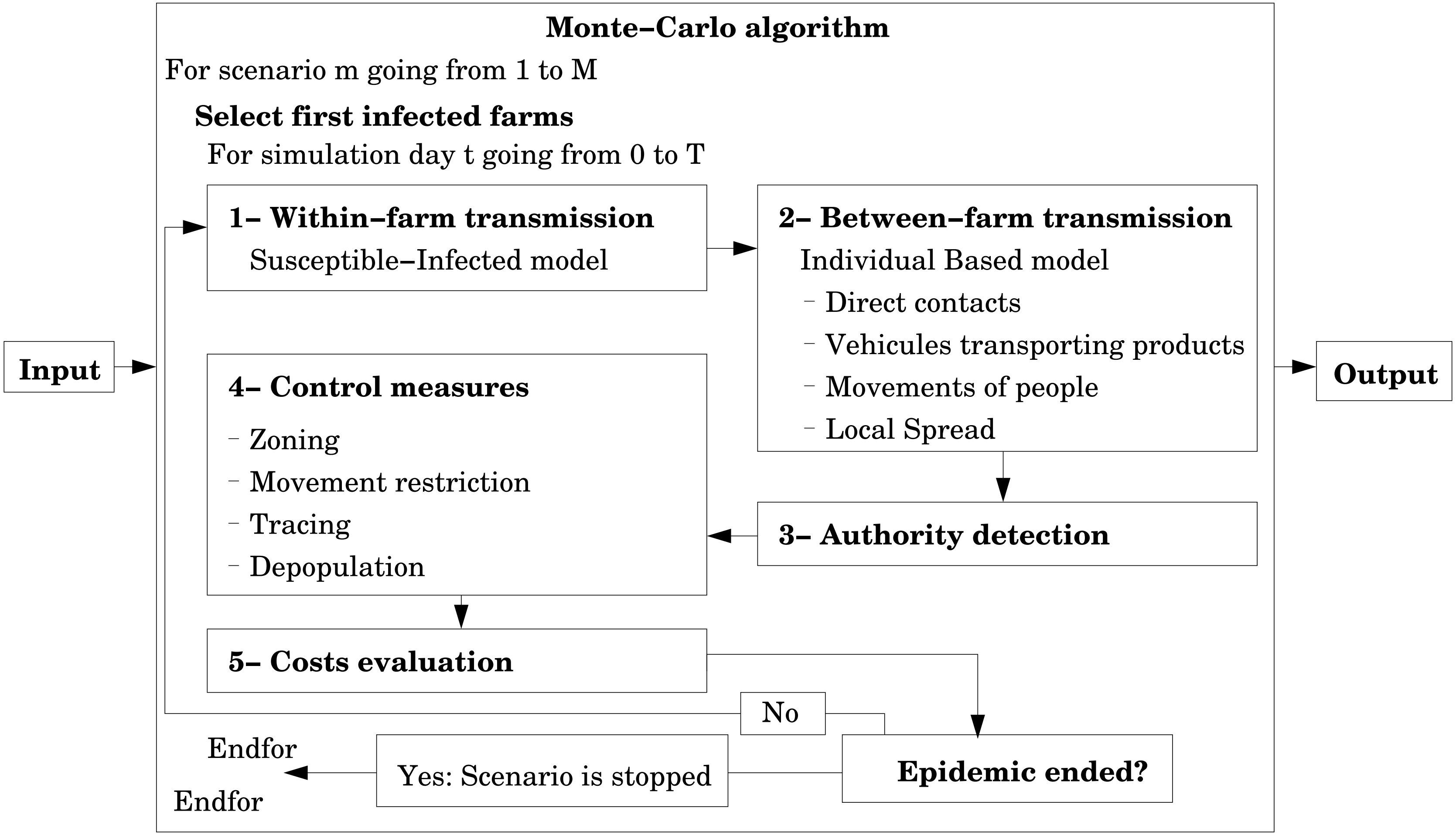
Structure

Matlab implementation of the following algorithm:



Inputs

Real Data:

Farm data: For each farm i we know:

- (X_i, Y_i): geographical location.
- $N_i(0)$: number of pigs.
- T_i: type of production.
- INT_i: Integration group.
- SDA_i: Sanitary Defense Association group.

Shipment data: For each animal shipment:

- Farm of origin and destination.
- Date of shipment.
- Number of animals shipped.

Costs data: historical data and actual prices.

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Outputs

We consider the following outputs:

- We compute statistical values (mean, min, max, 95%PI, etc.) of representative values:
  - the epidemic duration and the number of infected farms,
  - the percentages of infection due to each disease route,
  - the percentages of detection due to each control measure,
  - the different type of costs,
  - some risk values: the risk of disease introduction $RI(i)$ of each farm i (i.e., the number of times that farm i becomes contaminated).
- We build the geographical distribution of RI by considering Inverse Distance Weighted (for interpolation) and Jenks Natural Breaks (for classification) methods.

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CSF in Segovia: Case description

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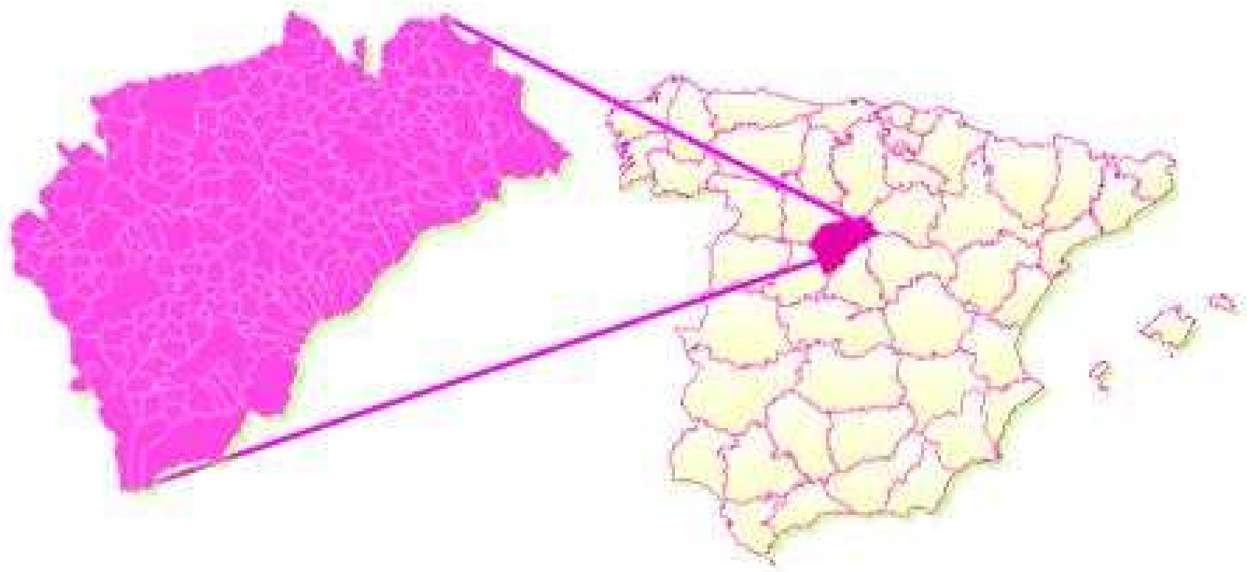
We consider the Spanish region of Segovia (important areas of pig production).



Data of the region: surface of 6796 km^2, 1400 pig farms, 1.400.000 pigs.

Data from Real Epidemic: 1997-98. 58 infected farms. epidemic duration of 60 days, cost of 36 M€.

Experiments: Model validation. Comparison with InterSpread.

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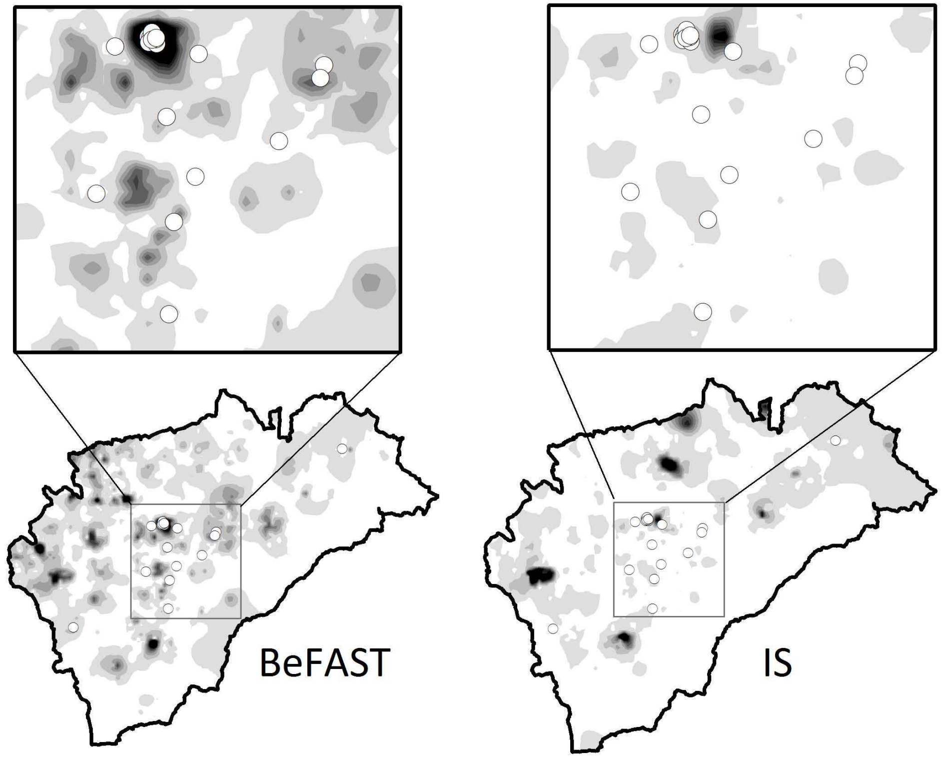
CSF in Segovia: Some results

Model	Comp. Time (s)	% cause of infection			
		LOC	*INT*	*SDA*	*TRA*
Be-FAST	9400	54	26	14	6
IS	11000	51	13	10	26
REAL	-	52	24	20	4



Estimated Simulated Cost: 35 M€(vs. 36 M€).

CSF in Bulgaria: Case description

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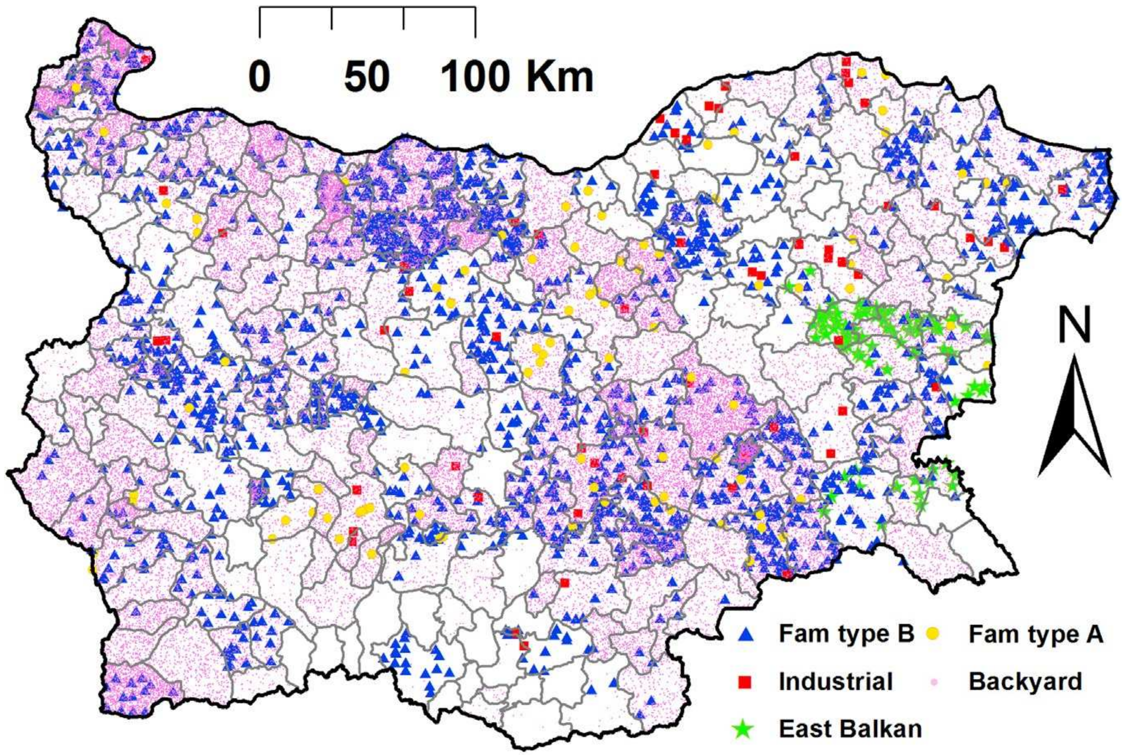
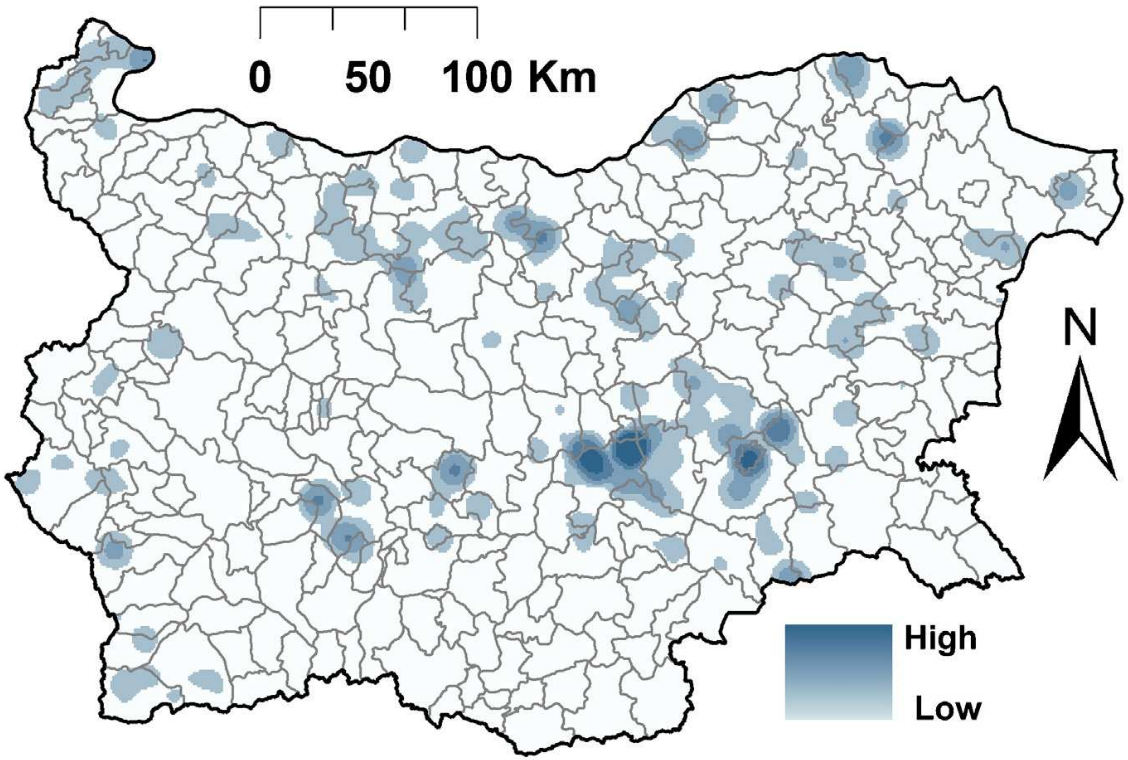
We consider Bulgaria:



Data of the region: surface of 110.994 km^2, 64.000 pig farms, 600.000 pigs.

Experiments: Study the Risk of CSF spread due to Backyard farms (assumed elevated).

CSF in Bulgaria: Some Results



Farm Type	Industrial	Family type	Backyard	East Balkan
% of inf.	56.1	20.3	13.2	10.4
Median RI	7.5	1	1	1

FMD in Peru: Case description

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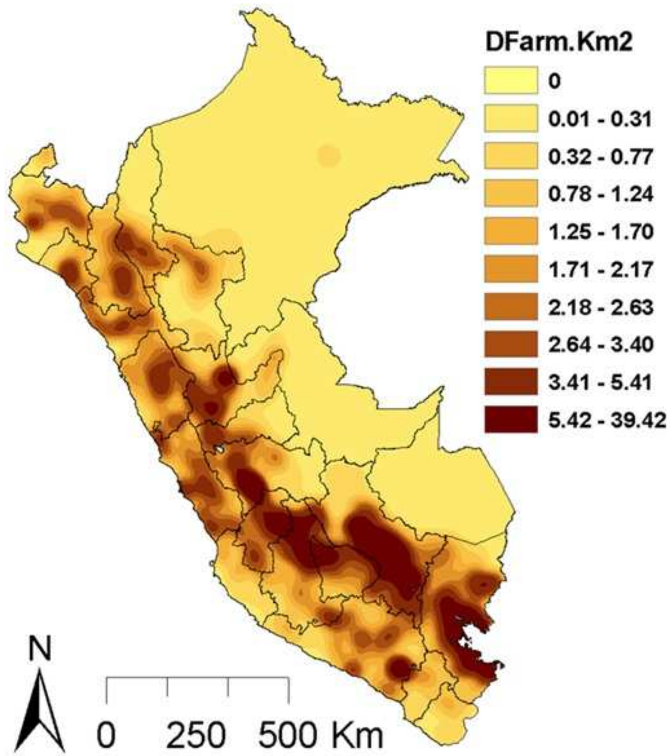
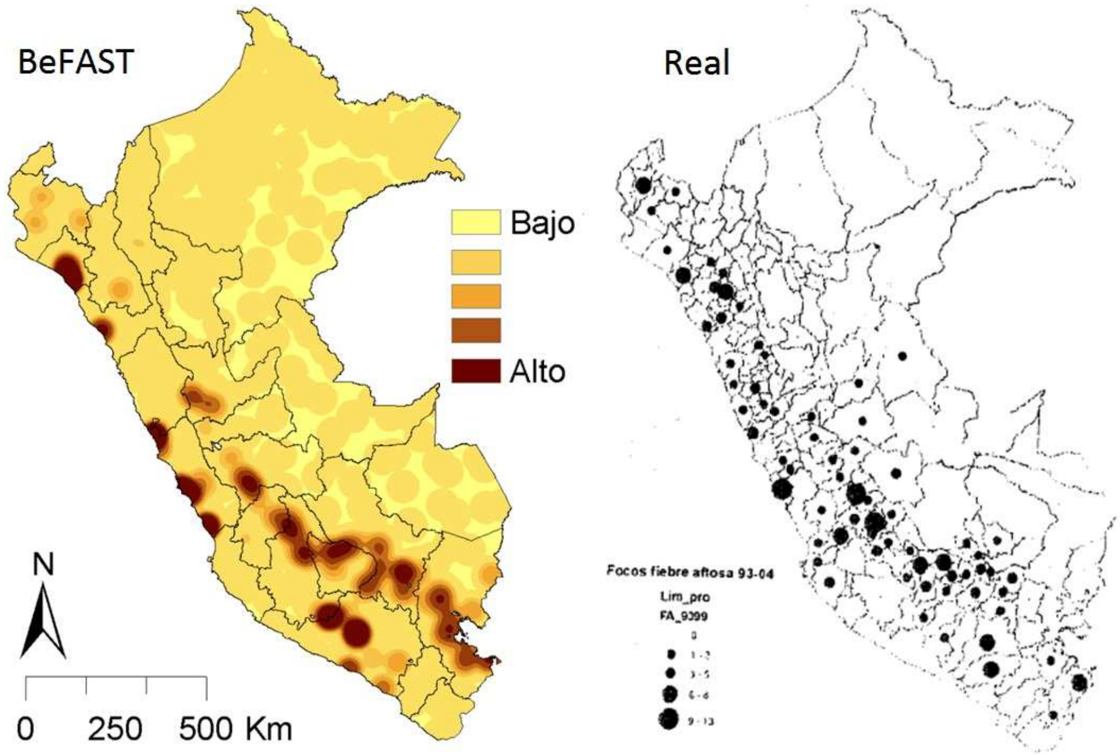
We consider Peru:



Data of the region: surface of 1.285.216 km^2, 2.000.000 farms, 15.240.348 animals. Real epidemic data (OEI).
Experiments: Study the Risk of FMD spread. Evaluate the impact of movement restriction in the worst scenarios.

FMD in Peru: Some Results



Culled farms	770
Culled animals	9.500
Restricted farms	500.000
Restricted animals	3.000.000
Epidemic length	260

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Conclusions:

We have introduced and described a new model for the study of the spread of some livestock diseases:

- Novel characteristics respecting to other models: Hybrid model, use of real database $\Rightarrow$ interest for risk maps.
- The results are consistent with real observations.
- Include the economical aspect.

Next steps:

- Applications to risk management: Optimization of control measures.
- Extension to other diseases (African Swine Fever in Bulgaria/Sardinia).

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!!! Thank you for your attention!!!