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Agent-based simulations to assess the vulnerability of food supply chains and increase resilience through Distributed Ledger Technologies

Research project NutriSafe (Securing of Food Production and Logistics with Distributed Ledger Technology)
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Introduction

- The binational research project NutriSafe explores the **use of Distributed Ledger Technology (DLT) to cope with incidents impacting food safety and security to increase resilience of food supply chains**.
- German research partners cover the field of food safety with two scenarios (organic cooked ham and soft cheese) and focus on **small and medium-sized incidents** that result in product contamination or loss of production capacity.
- In contrast, the Austrian consortium concentrates on food security, looking at three staple foods (table potatoes, drinking milk and pork). It focusses on **significant disaster events,** e.g., African swine fever (ASF) (Fig. 1), with the potential to disrupt the national food supply and its consequences.

Objectives

- to investigate food supply to the population and the reaction of the value chain to disturbances for industrial locations of Germany and Austria
- to provide decision support systems for the evaluation, prevention and recognition of risks, dependencies and rebound effects in the food industry.

Method

- **Business process model and notation (BPMN):** using BPMN 2.0, the processes of the food supply chains were modelled within the defined system boundaries on the basis of a well-founded data search.
- **Discrete event simulation (DES):** based on the business process models DES is used to model the supply chain in a medium degree of abstraction.
- **Agent-based modelling and simulation (ABMS):** ABMS is used to simulate many different behaviors, reactions, intentions and performances and to view these results as complex decisions in great detail as output.

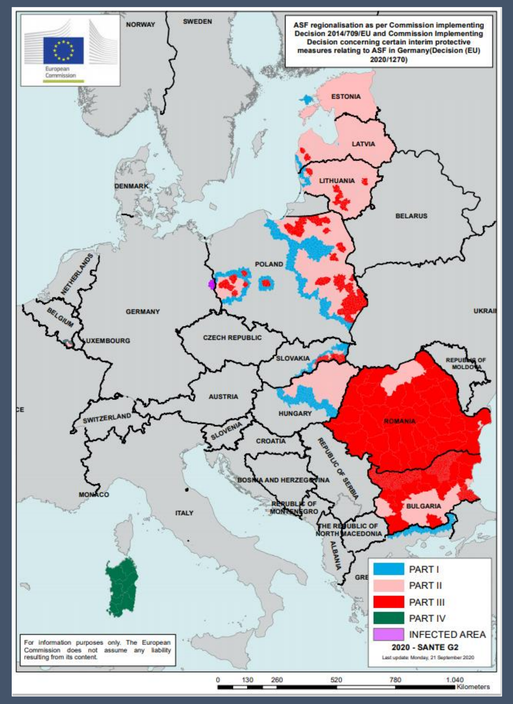

Figure 1: ASF regionalisation by the European Commission Source: https://ec.europa.eu/food/animals/animal-diseases/control-measures/asf_en

Results 1: AUT

A generic simulation model (Fig. 2) of a food supply chain was created initially. Due to the current situation in Europe with regard to the spread of ASF (Fig.1), the use case pork was examined in detail. The simulation model depicts the supply chain from the primary production to the pork half. The model includes the entities of primary production, intermediaries, processors and carriers. An outbreak of ASF can be simulated as well as its spread (Fig. 3). Based on this, capacity utilization of official veterinarians, means of transport and rendering plants as well as bottlenecks are identified. In conclusion, effects on the supply of pork in Austria can be analyzed.

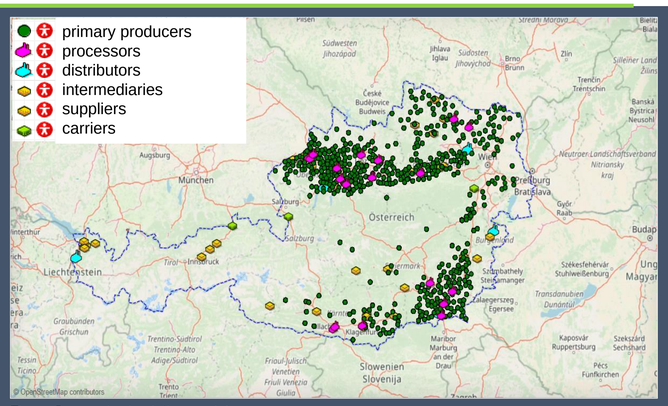

Figure 2: generic simulation model

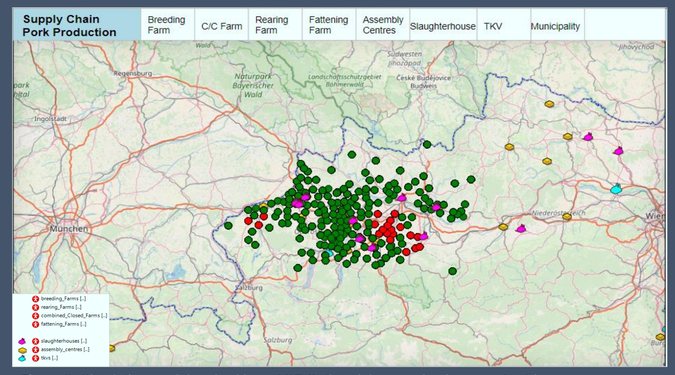

Figure 3: Simulation model pork with an ASF Outbreak in a section in upper Austria

Results 2: GER

The food supply chains of organic cooked ham and soft cheese were modeled as agent-based simulation models. Two crisis scenarios were defined and implemented in the simulation models: a cyber attack that propagates through the supply chain network and a pandemic. Figure 4 shows the interface from the cooked ham supply chain with the possibility to start such a cyber attack or pandemic at the push of a button. In the case of a cyber attack, you can select where the crisis starts, the extent of the production losses, the probability of propagation and the duration of the infection. The output is the impact on the supply chain measured in terms of production capacity in factories and the satisfaction of consumer demand.

Figure 4: Supply chain simulation with the possibility of starting a crisis

Next Steps

- The simulation of the pork supply chain will be prepared as a **serious game** and will be available for stakeholders to improve understanding and raise awareness.
- The simulations can further be used to answer the question which **effects** the **use of new technologies** such as Distributed Ledger can have on the resilience of food supply chains, i.e. it will be tested how DLT can help to track and trace ASF more accurately.
- The simulation models will be part of the **NutriSafe Toolkit** and thus open to the public for further use.

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