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Simulating the risk of Liver Fluke infection using a mechanistic hydro-epidemiological model

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(1) MOTIVATION

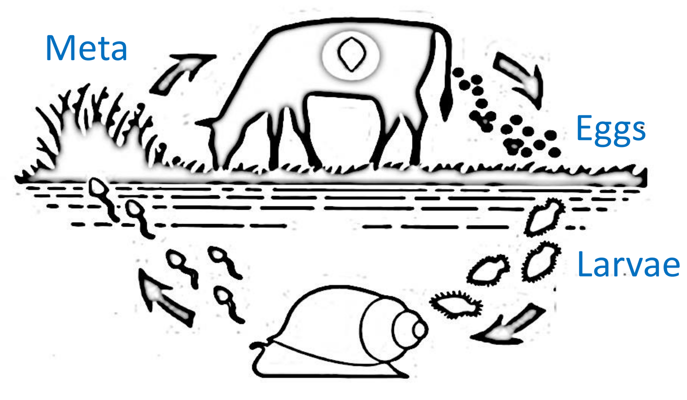
Our environment is increasingly non-stationary due to climate change and direct human activities, such as land use change, with implications for hydrological and connected processes [1].

Significant effects are expected on parasitic diseases, as many parasites complete a large part of their life-cycle outside of the host, and, thus, are directly affected by changes in the environment. Evidence of climate-driven changes in the phenology of parasites and timing of infection already exists, with consequences for human and animal health [2].

Therefore, **it is crucial to have mechanistic models capable of reliably simulating the impacts of potential future environmental conditions on risk of transmission** [1,2,3].

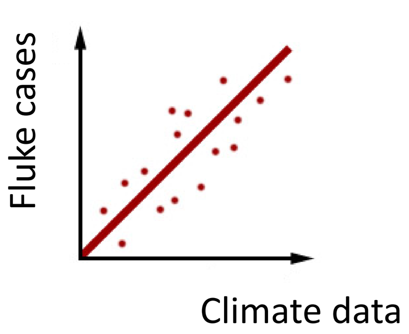
(2) LIVER FLUKE

- Parasitic flatworm which can be found worldwide
- In the UK infects sheep and cattle
- Reduces growth rates and milk yields → costs £300M per year
- No vaccine and evidence of resistance to existing treatment
- Prevalence expected to increase with climate change



Its life-cycle is strongly controlled by temperature and soil moisture conditions [4].

(3) EXISTING EMPIRICAL FLUKE RISK MODELS

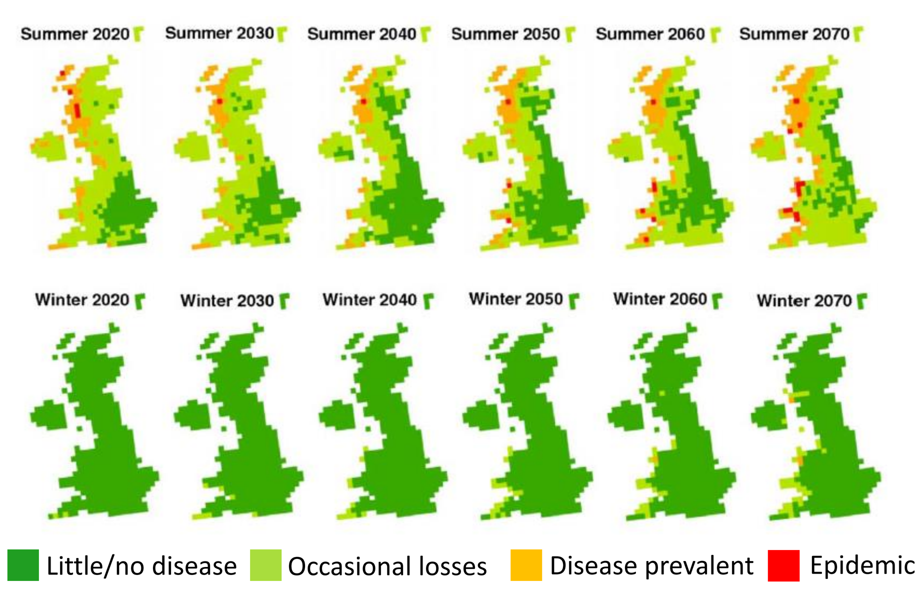


Existing and currently used Fluke risk models are based on **empirical** relationships derived between historic climate and incidence data and, thus, are **unlikely to be robust for simulating risk under changing conditions.**

Ollerenshaw Index Model

$$Risk = n\left(\frac{rain}{25.4} - \frac{pet}{25.4} + 5\right)$$

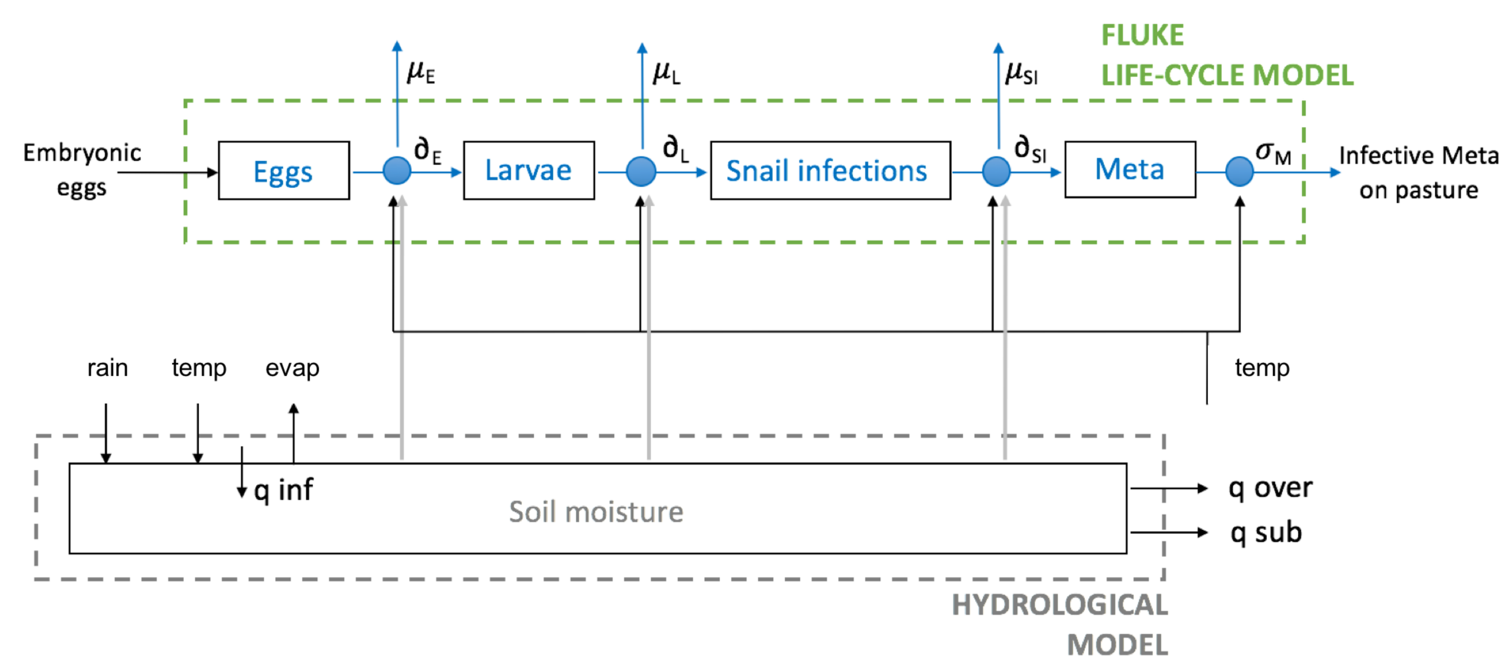
- Developed in the 1950s [5]
- No representation of soil moisture
- No temporal dynamics
- Spatial resolution not valuable for decision support



Projected change in Fluke risk for the UK up to the 2070s at 25 km^2 resolution. Figure from [4].

(4) NEW MECHANISTIC HYDRO-FLUKE MODEL

We develop a new **mechanistic** model, which explicitly represents the link between hydrological and epidemiological processes, instead of just exploiting correlation, and, therefore, **can be used to simulate out of sample conditions**.

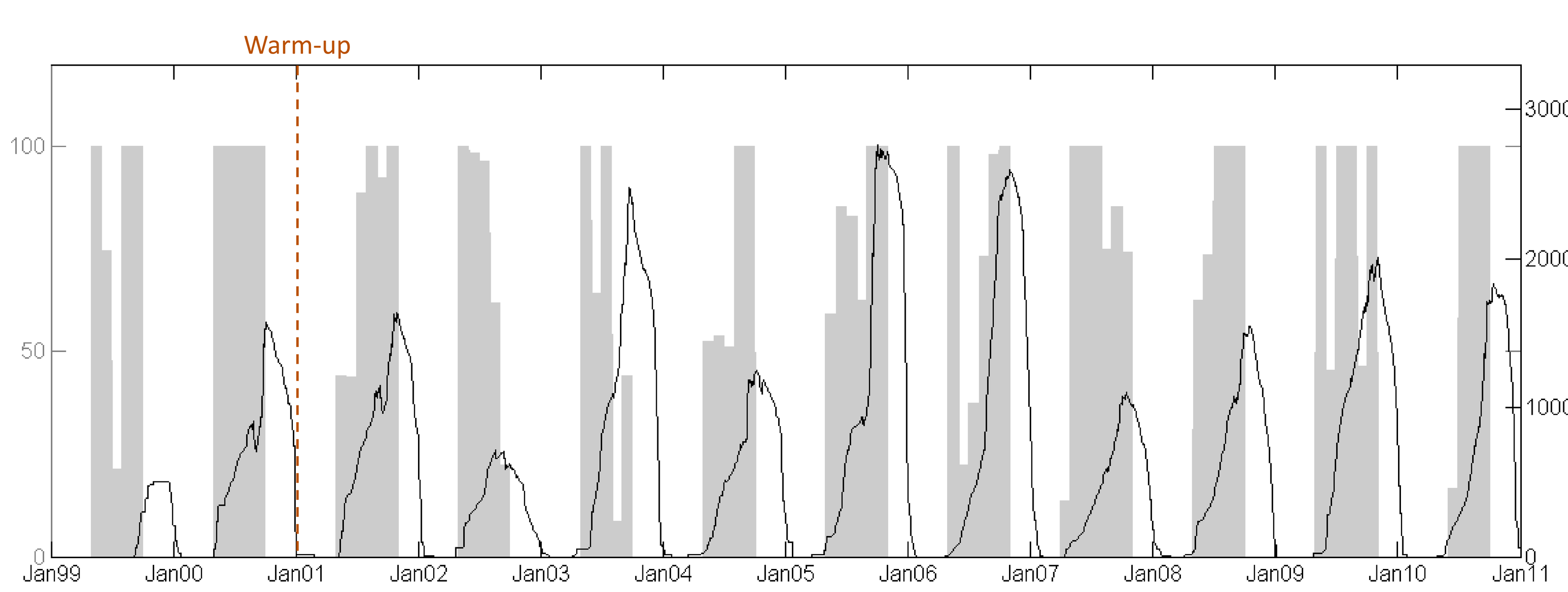


Hydrological module: based on TOPMODEL [6], simulates soil moisture dynamics.
Fluke module: based on the life-cycle stages, simulates risk of Liver Fluke infection.

(5) TEMPORAL AND SPATIAL PATTERNS OF FLUKE DISEASE FOR THE RIVER TAWE CATCHMENT (UK)

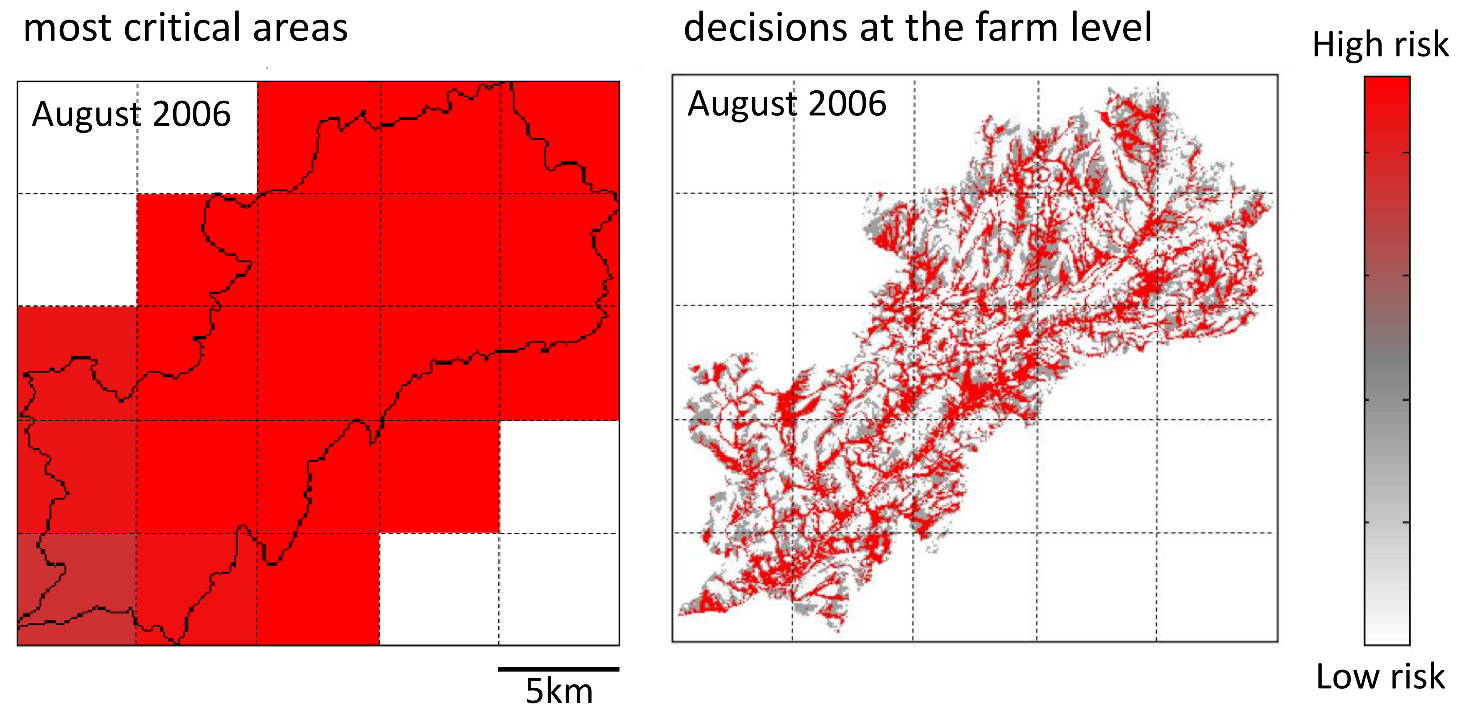
Existing empirical model: considers each month independently from every other. Would predict high risk in a wet month even if dry conditions in the previous months had eradicated any possible source of infection

New mechanistic model: actually simulates the temporal dynamics of the disease



Existing empirical model: the entire catchment is classified at high risk, no identification of the most critical areas

New mechanistic model: simulates risk at 25 m resolution, which is useful for supporting decisions at the farm level



(6) CURRENT WORK

- Testing the model against existing datasets, including data from regional veterinary laboratories.
- Forcing the model with potential future climate conditions to assess future risk.
- Driving the model with different management scenarios to investigate the sensitivity of infection rates to flukicidal treatments, environmental interventions and stock control strategies. This will be essential to support decision-making and disease management.

REFERENCES

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