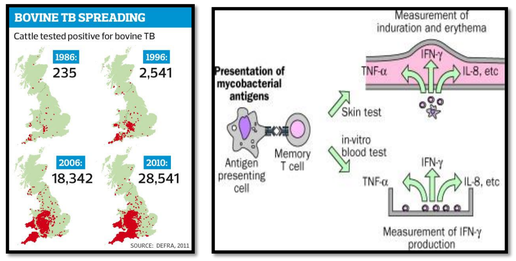
Using Dynamic Bayesian Network for Decision-Making and Evaluation of Polices in Nexus despite their Incredible Complexity

introduction:

In this poster, an extended form of Bayesian networks (BN) is presented for policy evaluations and decision making in complex systems, specially the energy, environment, water and food (Nexus). A policy structure is represented as a process flow diagram system which is transformed into a dynamic (hybrid) BN representation. The dynamic (hybrid) BN is a graphical structure which provides a simple technique to define the dependencies and, therefore, to implement a compact representation of the complex Nexus. We demonstrate the effectiveness of the technique with a case study which explains the growth and persistence of infection.



Bovine tuberculosis (bTB):

The bTB is considered an ongoing problem in cattle farms in England despite current policy including cattle herd testing and slaughter. Besides badgers acting as an important wildlife reservoir, cattle husbandry and farm management practices play a role to heighten the risk of spreading the disease. The following definitions are essential:

Failed test

Where at least one animal tests positive during any test herd level (routine, whole-herd, follow up)

Breakdown

A failed test on officially bTB free herd, not currently subject to movement restriction.

Bayesian Network (BN) :

BNs are used generally to explore and display causal relationships, between key factors and outcomes in a complex system, in a straight-forward and understandable manner. Moreover, BNs can also be used to calculate the effectiveness of interventions, such as alternative management decisions or policies where the associated uncertainties with these causal relationships are explored at the same time.

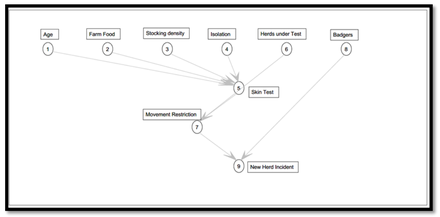


Figure 1: Static Bayesian Network Model

Dynamic Bayesian Network(DBN):

A DBN is an extension of BNs to model dynamic processes consists of a series of time slices to represent the state of all the variables at a certain time, t. Additionally, there are edges between variables from different slices, with their directions following the direction of time, defining the transition network (Figure 2)

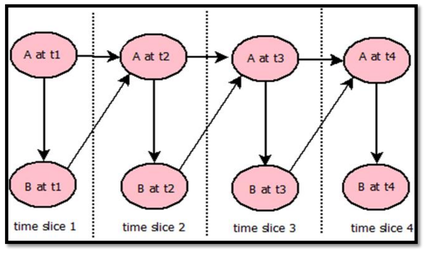


Figure 2: Bayesian diagram of a simple 4 time-step dynamic Bayesian network.

Method:

Farm's risk factors:

There are a number of risk factors related to the bTB disease including (i) environmental biosecurity, (ii) herd, (iii) contact between cattle and badgers, and (iv) animal. Among all of these key factors, the following are considered in our model:.

Farm's risk factors					
Farm food: there are different types of food and storage methods and storage periods	Badgers: active badger sett density showed significant associations with herd incidents.	Age of the cattle: based on available information age of purchased animals were categorized as: • Calves: stores or replacement breeding animal less than 12 months, • Yearlings: stores or replacement breeding animal between 12 and 24 months, • Cows: female breeding animals over 24 months.	Stock density: based on available data, farms with relatively high stocking densities (≥ 3 head of cattle/ha) were more protected from breakdown versus the farms with low densities (< 3 head of cattle/ha).	Purchased cattle: in control farms the main reason of increasing the risk of infection is cattle movement onto farms from market or other farms.	Isolation: based on available data there are five categories which farmers decide to isolate their newly purchased animals or milking equipment.

Data and statistical procedures:

Data are available publicly as secondary for high risk, edge risk and low risk areas of England. Data are mostly presented as monthly data. Our model is a herd-level model that does not distinguish between individual cattle on a farm.

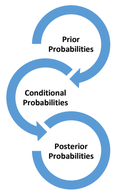
Dynamic Bayesian network model:

Probabilities:

Conditional Probability Formula

- The conditional probability of A given B is expressed as P(A | B)

$$P(A \mid B) = \frac{P(A \text{ and } B)}{P(B)}$$



Network:

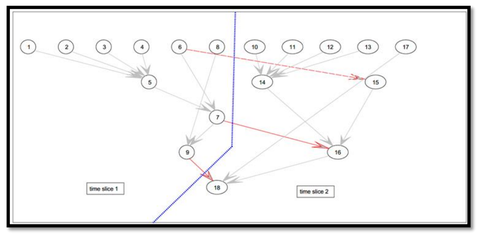
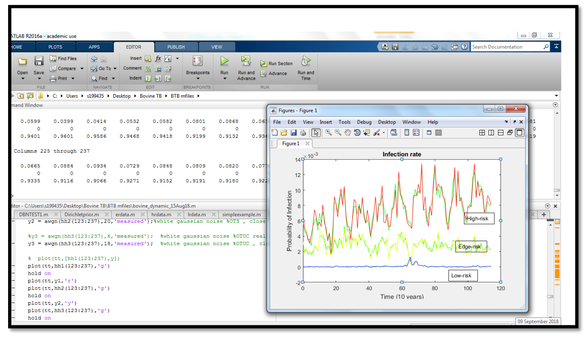


Figure 3: Dynamic Bayesian Network Model.



Conclusions:

The model shows the influence of particular risk factors upon the risk of breakdown in cattle farms. The model shows the importance of risk factors already considered under current management recommendations which are part of BTB policy aimed to reduce bTB and number of breakdown and new herd incidents in the England cattle farms. The model is able to replicate corresponding new herd incidents from 2008 until 2018 thus evaluating the effect of bTB policy in this period.

References:
[1] A. J. Pope and R. Gimblett, Frontiers in Environmental Science, (2015) 1-9.
[2] J. L. Ticehurst, A. Curtis and W. S. X. Merritt, Environmental Modelling and Software, 26 (2011) 52-56.

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