EpiMAN-TB, a decision support system using spatial information for the management of tuberculosis in cattle and deer in New Zealand

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Abstract

EpiMAN-TB is a decision support system that is being developed as a tool to assist the development and evaluation of TB control strategies, and the management of the TB control program in New Zealand. It takes the form of an epidemiological workbench of tools to support TB control decisions made by field veterinarians and farmers. These tools include: the prediction of possum TB hot spots, classification of farms according to TB risk, evaluation of possum TB control strategies at the level of individual farms and at regional level. EpiMAN-TB comprises a database, map display tools, simulation models of the spread of TB between possums at farm and at regional levels, and decision aids based on expert systems. It utilises spatial information relating to vegetation cover, topography and farm boundaries, plus TB history and management information for individual farms.

1. Introduction

Tuberculosis (TB) in cattle and deer is a problem of national concern to the New Zealand pastoral industries due principally to its negative impact on export markets. A national TB control program has been in place since the 1970s. However, efforts to control the disease in farmed animals are hampered by the presence of TB in the brushtail possum (*Trichosurus vulpecula*). Infected possum populations are the major source of TB infection for cattle and deer in New Zealand. Thus control of the disease in farmed animals involves controlling the disease in infected possum populations.

TB control strategies used to date have successfully reduced the total number of infected possums and consequently the total number of infected cattle and deer. However, they have not been successful in eradicating TB from possum populations, hence continued control of these populations is required to maintain the incidence of TB in farmed animals at a low level. We believe that more effective control strategies can be developed through an integrated approach involving the use of scientific information and field data on the epidemiology and spatial distribution of the disease in possums and the use of models to compare the effects of different strategies.

The spatial distribution of TB in possums is clustered at three scales. It is present in possum populations only in certain regions of New Zealand, and within these affected regions certain farms or groups of farms have a TB problem while others have no (or very infrequent) infection. The smallest unit of clustering is possum denning areas occupying as little as 0.25-0.5 hectares (Hickling, 1995). Field research indicates that TB clusters in possums fall into two categories: endemic and sporadic. At the site of endemic clusters, TB spreads well between possums and remains in the same location for many years. These are colloquially known as 'hot spots'. Sporadic clusters remain

for only short periods of time as TB does not spread so well between possums and has not become firmly established at the site. It is highly likely that TB is maintained in possum populations at the sites of endemic clusters even after the population density has been reduced to a low level by control measures. It is the perpetuation of TB at such locations that means possum populations must continually be kept at a low level to reduce the risk of TB spreading from possums to farmed cattle and deer. This is a major expense to the industry, and the ability to target control measures at areas where the effect is likely to be greatest would improve the efficiency with which possum control resources are used.

Research has identified features of habitat that can be used to predict the potential location of endemic, sporadic and negative TB sites. Endemic clusters are more likely to occur on flat or gently sloping land with large-diameter trees that provide well-enclosed den sites. Sporadic clusters are more likely to occur on flat or gently sloping land with taller trees, but which do not have multiple enclosed den sites available. Negative TB sites are more likely to occur on steeper slopes covered in scrub. This information can be used at the scale of an individual farm to predict high risk areas within the farm, or at the scale of a region to predict farms within the region that have vegetation patterns which increase the likelihood of possums on the farm being infected with TB. Such information can then be used to assist with the formulation of TB management strategies at either farm or regional level. This paper describes a decision support system, EpiMAN-TB, which is being developed as a tool to use this spatial information in the development and evaluation of TB control strategies and in the management of the TB control program in New Zealand.

EpiMAN-TB

2.1 Description

EpiMAN-TB is a decision support system designed for the use of TB managers, mostly at the field level. It will assist in the formulation of TB control programs for farms and larger areas, and will allow evaluation of alternative control programs. It will make possible comprehensive forms of assessment of progress in TB control at district, regional or national level, and it will permit policy assessments to be made for potential new control methods. This decision support system provides a way of integrating the current state of knowledge on TB and possums into disease management decisions, with the assumption that better decisions will be made. It also provides a way of incorporating sophisticated information processing technology into the day-to-day decision making process in a form that is simple to use.

It is a stand alone system that will be used on PCs by TB management field staff throughout the country. Emphasis has been placed on it being a generic tool that can be put into any office, and a deliberate effort has been made to not be dependent on any particular commercial GIS or database management software. GIS functionality and other essential features are provided within a range of standard SQL compliant database programs. The generic nature of the software also allows it to be adapted to manage other endemic diseases that have a strong spatial component in their epidemiology.

2.2 Structure

EpiMAN-TB comprises a database, map display tools, a simulation model of TB in possums, and decision aids based on expert systems, as illustrated in figure 1. Database information required to run EpiMAN-TB relates to farm ownership, animal numbers and TB status of cattle and deer on the farms. This information is currently available in databases which are either owned or managed by MAF Quality Management (MQM). Farm information is obtained from Agribase which is a national database of farms in which each farm is uniquely identified. Agribase contains basic property ownership and land use information plus locational information that facilitates the production of farm maps. TB status information is obtained from the National Livestock Database (NLDB). This database contains a history of TB testing results for most farms in New Zealand. Farms are identified by the Agribase farm identification

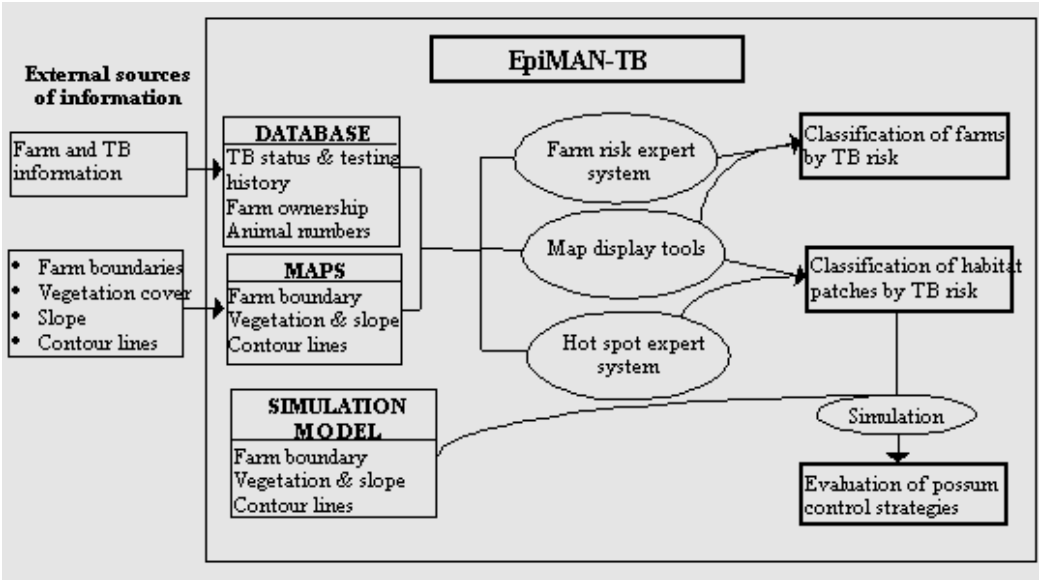

Figure 1. An overall view of the structure of EpiMAN-TB

number so that information in the two databases can be linked.

At present, the database information is extracted from the original two databases and is maintained separately within EpiMAN-TB. As MQM staff are likely to be the major users of this system, the establishment of a live link between EpiMAN-TB and the original databases will be explored. This will provide for more efficient use of computer space, and ensure that the information in EpiMAN-TB is as current as that in the original databases.

EpiMAN-TB does not include sophisticated spatial manipulation tools. Users require access to map data that has already been processed with a GIS into the form required by EpiMAN-TB. Such processes include creation of digital elevation models, overlay analyses, map generalisation, and others. The geographic tools programmed into EpiMAN-TB are predominantly to display map information in different ways customised to the users' needs, and to undertake various analytical procedures. The map information required by EpiMAN-TB is: farm boundaries, rivers, roads, vegetation cover, slope of the land and contour lines. Details of information in each of these maps follows.

Farm boundary maps are vector maps outlining the boundaries of individual farms, each with an associated farm identification number from Agribase. Vegetation and slope maps are both raster images with 40 meter pixels. Vegetation classes were derived from a SPOT multi-spectral satellite image. The classes of vegetation are: podocarp-broadleaved forest, beech forest, pine forest, scrub, willows, shelter belts, swamps and pasture. A SPOT multi-spectral image was chosen as this provided an appropriate spatial resolution of 20 meters with adequate, though somewhat limited, spectral resolution. SPOT MS imagery is the best currently available in New Zealand with good spatial resolution. As information with higher spatial and spectral resolution becomes available in the future, enabling more detailed vegetation maps to be produced, these can be incorporated into EpiMAN-TB, if it is found that the greater differentiation of vegetation improves the accuracy with which possum TB hot spots can be predicted.

2.3 Functions

Users are able to select from a number of different tasks available within the software, depending upon their specific need. Tasks are outlined in figure 2 and each task is described in more detail below.

2.3.1 Hot spot prediction

Having the ability to predict hot spots, or the location of habitats where TB is likely to be endemic in possums on a farm, helps develop a TB management plan for the farm. These high risk areas can be targeted for more intensive possum control efforts, and/or can be avoided in a cattle or deer grazing program.

Prediction of possum TB hot spots utilises farm boundary, vegetation and slope information. This task can be run for an individual farm or for a small area including a number of farms. Farms are identified by entering the farm identification number which brings up the farm plus a buffer of 100 meters around the boundary. An alternative area can be selected interactively by the user. This defines the geographic boundaries for the vegetation and slope map which is used in the prediciton process. Vegetation cover is represented in 40 meter pixels and the hot spot expert system is then run for all cells in the selected area, assigning one of three TB risk categories to each cell. Risk categories are high, medium and low. EpiMAN-TB outputs a map shading each cell according to its risk category. Contour lines are drawn on the map to provide some contextual information to help users identify landmarks. Hard copy of this map can be given to a farmer to take away and use to develop a TB management program.

2.3.2 Possum control strategy evaluation

i) Farm or small area control

Having identified areas of habitat where the risk of a TB hot spot is high, alternative possum control strategies can be compared for their influence on reducing the prevalence of TB in the possum population. This can be done in EpiMAN-TB by means of a simulation model of TB in possums, PossPOP, which can be run for a single farm or a small group of contiguous farms. PossPOP is a geographic model representing the ecology and infection dynamics of wild possum populations, which includes natural stochastic variation, spatial (spatial heterogeneity and autocorrelation) and temporal (seasonal and cyclical effects) effects (Pfeiffer et al, 1994). PossPOP uses a real vegetation map for the area of interest in the simulation to better represent real-

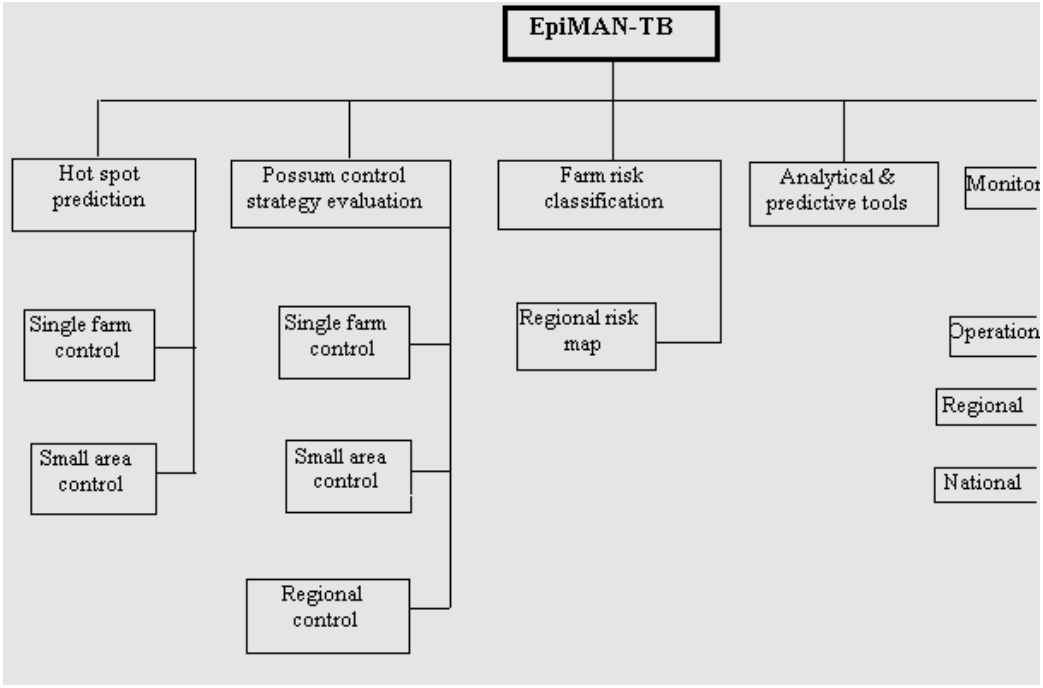

Figure 2. An outline of the tasks available within EpiMAN-TB

ity. Currently vegetation is divided into four main habitat categories: forest, scrub, bush/pasture margin, and pasture. These categories may be modified as research results identify different habitat types that are associated with the density of possums and/or the transmission of TB between possums. Vegetation maps are currently in IDRISI raster format with 20-meter pixels. However, maps with different pixel sizes and map formats can be incorporated into the model.

The basic geographic unit in PossPOP is a possum den site at a 1-meter point location. The vegetation map is used to "populate" the model with both possums and possum den sites on the farm or area of interest. The densities of each vary with the vegetation cover. For example, the density of possum dens on pasture is very low but is higher in scrub. PossPOP can also use the habitat risk map produced by the hot spot prediction model to adjust the probability of TB transmission between possums in accordance with the vegetation cover. This enables the creation of 'hot spots' within the model. It also enables habitat risk factors to be taken into consideration in the design of control programs. For example, a program with the same level of possum reduction over the entire farm can be compared with a program that has a higher and more frequent population reduction in high and medium risk patches of habitat compared to low risk areas. The relative effects of these strategies on the incidence of TB in the possum population can then be compared.

The model requires a vegetation map to run. As for the hot spot prediction model, the geographic boundaries of the vegetation map can be defined either by entering a farm identification number or by an interactive process. If the user wishes to include the habitat risk map in the model, its geographic boundaries can be defined in the same way. Parameters associated with possum control programs that can be manipulated include: percent reduction in population, frequency and duration of population reduction, location over which the population reduction is applied. The output provided by PossPOP includes possum population parameters, TB infection parameters, and location of 'infectious' den sites. An example of the TB prevalence and population size, from a run of the model for two years with a control program producing an 80% reduction in the population, implemented 6 months from the start date, is shown in figure 3. An example of the geographic output including habitat classes and the locations of dens used by TB possums at the end of the two year period is shown in figure 4.

ii) District or regional control

A further model will be included in EpiMAN-TB to model the spread of TB through possum populations distributed

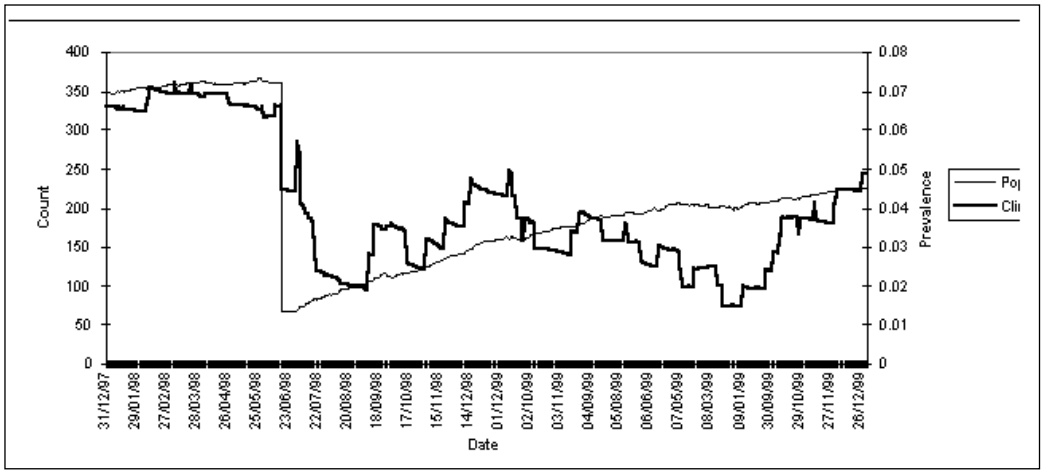

Figure 3. Graphical output from PossPOP, showing change in population size and prevalence of clinical TB over a two year period with the application of a control program in June 1998.

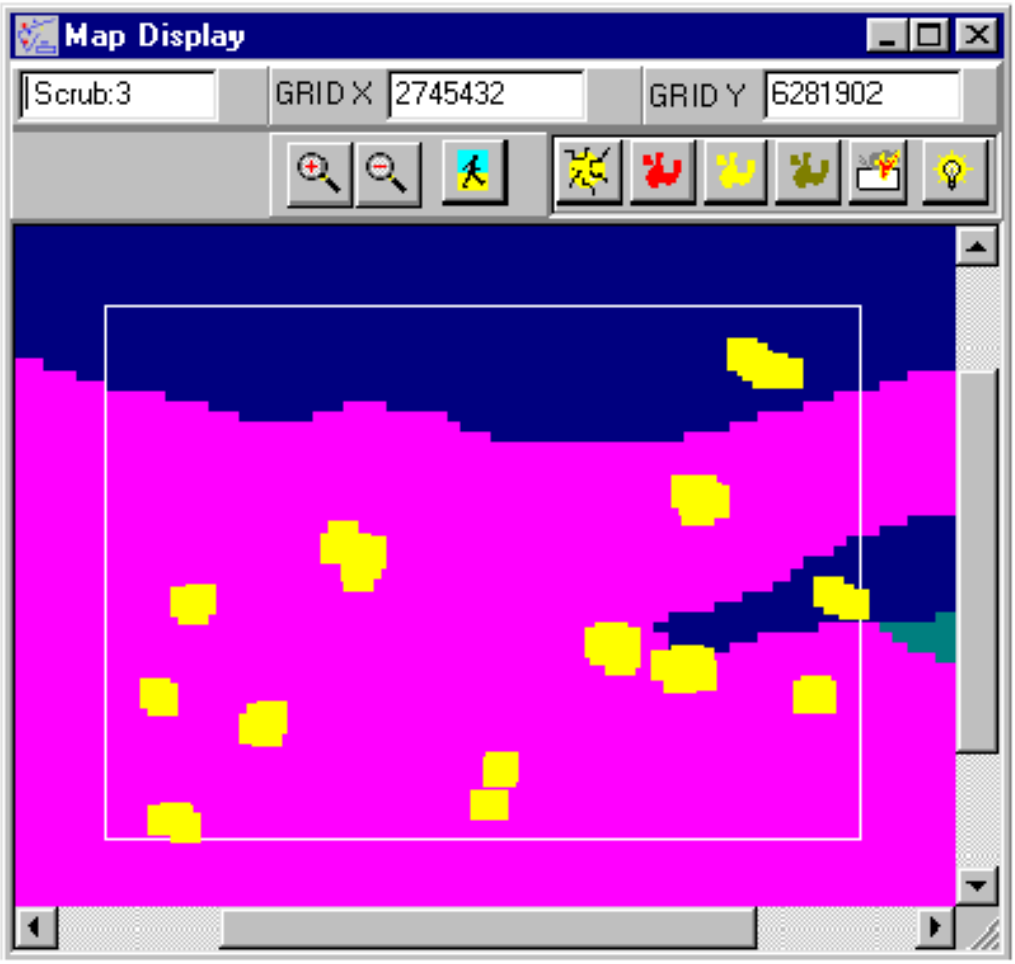

Figure 4. Snapshot of a vegetation map taken during a run of PossPOP, showing vegetation classes: forest (black) and scrub (dark grey), and the location of infectious den sites (light grey).

over a larger area at district or regional level. The basic geographic unit will be a farm, and geographic boundaries such as major rivers and mountain ranges will be treated as semi-permeable barriers to the movements of possums. This model will enable the evaluation of possum control strategies implemented over the larger area, with farm units being populated by data derived from PossPOP, adjusted to reflect the circumstances of interest on the farm.

2.3.3 Farm TB risk classification

The ability to classify farms within a region according to the risk of TB in the on-farm cattle or deer population being high, medium or low would enable TB managers to differentiate the intensity with which control measures are applied according to the risk of the farm having a TB problem. This is particularly useful in an area where the possum population has recently become infected with TB as farms at the greatest risk of having infected possums on their property could be targetted more intensively for surveillance and disease control activities.

Current research is in progress to identify a set of geographic features of farms associated with high, medium and low levels of TB infection in the on-farm cattle. As for the hot spot prediction module, these factors will be used to generate an expert system to classify farms based on their

vegetation, topography and density of TB in cattle in their surrounding area.

2.4 Other tasks

Once development of the above components is complete, the software will be expanded to include other tasks which are considered useful in managing TB.

3. Conclusion

Results of research on the spatial distribution of TB in possums are now becoming available, providing information that can be used to predict the location of TB hot spots with a useful probability. At the same time farmers are being required to take greater responsibility for controlling the spread of TB on their farms. EpiMAN-TB provides tools that will assist TB field personnel working with farmers to develop specific programs for their farms. At the regional level EpiMAN-TB provides information that will assist the development of possum control strategies that focus control measures more tightly in areas where they produce the greatest effect. At national level EpiMAN-TB assists the making of policy decisions with respect to new control methods such as biological control of TB in possums and TB vaccination of possums. It also provides tools for the monitoring of disease control progress on a geographic basis across the country.

EpiMAN-TB is a comprehensive piece of software with easy access to the information required for the major decisions that need to be made with respect to the management of possum-associated TB in an area. This decision support system provides a way of integrating the current state of knowledge on TB and possums into disease management decisions, in the expectation that better decisions will be made.

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