THE ROLE OF GEOGRAPHIC INFORMATION SYSTEMS IN PEST RISK ANALYSIS

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ABSTRACT

Pest risk analyses (PRAs) are conducted to assess and manage the risks posed by alien pests. Many of the datasets used in PRA contain data with a spatial reference. This makes it possible to place the data on a map to assist analysis. For example, when assessing whether a pest can enter and establish in a new area, the current distribution of the pest is taken into account and the extent to which the new area contains suitable host plants, climate and the other key factors for successful colonisation is also considered. When evaluating the impacts that might be caused to crops and the environment if establishment occurs, the location and value of vulnerable crops need to be estimated, in order to highlight the areas at greatest risk. If outbreaks occur, mapping crop location and the other key factors which may influence the spread of the pest and its management may greatly enhance the prospects for eradication.
This presentation will show how mapping and analysing these datasets with computer mapping software, Geographic Information Systems (GIS), can assist throughout the pest risk analysis process and help communicate the results to those who take decisions.
Key words: geographic information systems, pest risk analysis

IZVLEČEK

VLOGA GEOGRAFSKEGA INFORMACIJSKEGA SISTEMA (GIS) PRI ANALIZAH TVEGANJA ZARADI VNOSA IN ŠIRJENJA ŠKODLJIVIH ORGANIZMOV

Analize tveganja zaradi vnosa in širjenja škodljivih organizmov (PRA) izvajamo za vrednotenje in nadzor tveganja, ki ga predstavljajo tuji škodljivi organizmi. Številne podatkovne baze, ki se uporabljajo pri tovrstnih analizah, vsebujejo podatke o nahajališču. Omogočeno je vmeščanje tovrstnih podatkov na zemljevide, s čimer je neka analiza (PRA) olajšana. Na primer, ko ocenjujemo ali je nek škodljivi organizem lahko zanesen v neko novo območje in ali se na tem območju lahko obdrži, moramo upoštevati njegovo trenutno geografsko razširjenost ustreznih gostiteljskih rastlin na novem območju, podnebne razmere in druge ključne dejavnike, ki so potrebni za uspešno naselitev obravnavanega škodljivega organizma v novo območje. Ko ocenjujemo morebitne vplive škodljivih organizmov, ki se v novem okolju lahko obdržijo, na gojene rastline in samo okolje, je potrebno v smislu določitve območja, kjer je tvegan-

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je največje, opredeliti rastišča in vrednost občutljivih vrst, za katere delamo analizo tveganja. Ob morebitnem izbruhu nekega škodljivega organizma, lahko kartiranje rastišč gojenih rastlin in drugih ključnih dejavnikov, ki vplivajo na širjenje škodljivega organizma in njegovo prilagodljivost, vpliva na povečanje možnosti za njegovo izkoreninjenje (eradikacijo).
V prispevku bo prikazano kako si lahko s kartiranjem in analiziranjem podatkov s pomočjo ustreznega računalniškega orodja, geografsko informacijskega sistema (GIS), pomagamo pri analizah tveganja zaradi vnosa in širjenja škodljivih organizmov (PRA) in posredovanju
Ključne besede: geografski informacijski sistemi, ocena tveganja zaradi škodljivih organizmov

Pest risk analyses (PRAs) are conducted to assess and manage the risks posed by alien pests to a defined area (Baker & MacLeod, 1999, EPPO, 1998, IPPC 2001). Many of the datasets used in each component of the PRA contain data with a spatial reference. This makes it possible to place the data on a map to assist analysis. For example, when assessing whether a pest can enter and establish in a new area, the current distribution of the pest is taken into account and the extent to which the new area contains suitable host plants, climate and the other key factors for successful colonisation are also considered. When evaluating the impacts that might be caused to crops and the environment if establishment occurs, the location and value of vulnerable crops need to be estimated in order to highlight the areas at greatest risk. If outbreaks occur, mapping crop location and the other key factors which may influence the spread of the pest and its management may greatly enhance the prospects for successful eradication. To generate maps of the spatially referenced datasets and to summarise conclusions, computer mapping systems, known as geographical information systems (GIS), can be used to assist throughout the pest risk analysis process and help communicate the results to those who take decisions. This paper illustrates some of the ways in which this can be done by considering two aspects of the PRA for the *Leptinotarsa decemlineata* (Colorado beetle) as an example.

1. COLORADO BEETLE

This beetle, one of the most destructive insect potato pests in the world, has now spread to most of the northern, temperate areas of the world from its origins in central USA. In the UK, the *L. decemlineata* has been a continuous threat to UK agriculture since it was first found in a US grain shipment at Liverpool Docks in 1877. One hundred and sixty three outbreaks have been discovered and eradicated since 1901 (Bartlett, 1979). To combat this threat, the UK plant health service maintains regular inspections, updates the PRA and revises its contingency plans to eradicate any outbreaks. Over the last ten years an average of 129 live beetles per annum have been found so the threat of invasion remains very high and measures need to remain in place and be constantly updated to combat this threat.

2. ESTABLISHMENT POTENTIAL

While *L. decemlineata* has already exhibited the potential to enter, establish and cause a significant economic impact in the UK, further research on its establishment potential continues to be carried out to highlight endangered areas, to explore the spatial and temporal aspects of establishment and to investigate the impact of climate change on its potential distribution. This research has focused on the application of climatic mapping techniques to PRA. Two methods have been employed: CLIMEX and phenology models.

CLIMEX is a generic inductive model which predicts potential pest distribution according to climate (Sutherst & Maywald, 1985). It generates an annual growth index, which "describes the overall potential for population growth", and this is combined with four stress indices (representing hot, cold, dry and wet weather) to produce an ecoclimatic index (EI), which "describes the overall suitability of the location for the propagation and persistence of the species" (Sutherst *et al.*, 1995). Maps of EI provide an indication of the potential distribution of a species as determined by climate. The CLIMEX program contains world meteorological data for 1931-1960 and predictions are based on locations represented by the weather stations themselves. Many weather stations are situated in flat terrain, e.g. at airports, in urban areas or on sea coasts, and do not provide an accurate guide to climatic conditions in the fields, orchards and nurseries where crops are grown. To overcome these difficulties, meteorological data, which have been interpolated onto a 0.5 latitude x 0.5 longitude grid according to geographical coordinates and elevation (New *et al.*, 1999), were imported into CLIMEX and used with a GIS to generate maps of EIs for *L. decemlineata* under current (1961-1990) (Baker, 1996) and future (2050) conditions with Europe warming on average by 2.3`C (Baker *et al.*, 1996; 1998; 2000). For Great Britain, it was found that, with global climate change, *L. decemlineata* could expand its range by 120% with a mean northerly increase of 3.5° latitude (400 km) (Baker *et al.*, 1998).

Phenology models, which predict the timing of key events in a pest's life cycle, can also be used to find out if conditions are suitable for an organism to establish in a new environment by determining whether the organism can develop to reach the particular stage in its life cycle which is able to survive periods of climatic stress, such as winter. Phenology models are normally run on weather station data which, as noted above, are likely to be unrepresentative of the areas where crops are grown. In order to map phenologies over the landscape, either the model outputs, usually the Julian dates at which a pest is expected to reach a particular stage, can be interpolated over the landscape (e.g., Schaub *et al.*, 1995) or the phenology model is run on weather data which have already been interpolated over the landscape (Jarvis & Baker, 2001a). Jarvis & Baker (2001a) found that predicting *L. decemlineata* establishment using nearest weather station produced significant over-estimates in the area at risk.

Maps generated by climatic mapping techniques give strong visual representations of risk which can be misleading. They must therefore be balanced by stressing the fact that many other factors apart from climate influence pest establishment and the functioning and interpretation of both CLIMEX and the phenology models. The temporal and spatial scale at which the data are available and at which the studies are made remains of key importance. Predictions based on thirty year monthly averaged climatic data over a 0.5 latitude x 0.5 longitude grid can clearly lead to error if, for example, a sequence of very warm years occurs at locations which are poorly represented in the grid (Jarvis & Baker, 2001b).

3. MANAGEMENT OF OUTBREAKS

To explore the potential of GIS in eradicating outbreaks, a hypothetical outbreak scenario for *L. decemlineata* at a location in south-eastern England was constructed. Datasets and mapping tools were evaluated to determine their importance in outbreak management. A succession of maps was produced in the GIS to show inspectors searching for the pest the structure of the natural landscape and man-made environment surrounding the infested field and to provide key information required to optimise and target the search, e.g. field ownership and the location of potato fields in the current and previous years. Maps were also produced using the GIS for spray contractors to highlight important natural features, such as watercourses, which they must take into account when spraying the crop. GIS functionality was further exploited by mapping the 6 metre buffer around watercourses to show the areas within which treatments of certain pesticides are not permitted.

In the hypothetical scenario, in May a female beetle entered the UK through the Channel Tunnel in folds of a tent on a car roof rack. Warmed up by the high temperatures in the tunnel she flew out of the tent as the car travelled along the motorway and alighted in a potato field She laid over 500 eggs which developed undetected. When the adults emerged from pupae, the haulm had already been destroyed so they went into diapause with low fat reserves. In the spring, due to rotation, there were now no potato fields in the immediate vicinity and the first hot weather triggered flight over the surrounding 5-10 km. When extensive larval damage was found in one field in late June, the inspectors had to act with great urgency, prioritising the surrounding fields for intensive searches to try and find all the colonies so they could be sprayed with insecticides before the larvae pupate.

To demonstrate how GIS can assist with this prioritisation, a phenology model for *L. decemlineata* (Baker & Cohen, 1985) was run on interpolated weather data using techniques described by Jarvis & Baker (2001a) to produce seamless maps of pest development predictions over the landscape. Fig. 1 shows the percentage pupal development for 30th June in a hot summer (1976) for the polygons selected as potato fields within 5 km of the mock outbreak site. A considerable difference in the rate of development can be observed between the fields. When planning the laborious row by row searches of the potato crop, the inspectors could use this information to help prioritise the fields requiring urgent inspection. Those fields with the most rapid pest development should be targeted first because, once the larvae have pupated, they become impossible (or at least very difficult) to detect and control. In a real outbreak, a series of such maps representing the key *L. decemlineata* development stages could be generated based on actual daily synoptic weather data for the year in question together with historical data for extreme and average years.

4. CONCLUSIONS

This paper describes the use of climatic mapping techniques and GIS to help predict the establishment of alien pests and eradicate any outbreaks which occur. The procedures have been developed with particular reference to alien pests under current climatic conditions but are equally relevant to established pest problems and future climate change scenarios. Traditionally, decisions on biological systems affected by the climate have been made using data from weather stations, even though these may be located at a considerable distance from the areas where crops are grown. By using weather data interpolated over the landscape linked to biological models, maps showing the dates when key biological events are predicted to occur and the rates of development on selected dates can be produced. Indices reflecting the overall climatic suitability of areas within a country for pests can also be mapped. Maps can be created at a wide variety of scales according to needs but the availability and price of the digital datasets required may impose limitations. During eradication campaigns, GIS is an ideal method for: displaying the wide variety of relevant data, illustrating progress over time, highlighting areas for priority sampling and control and communicating key information to survey and control teams.

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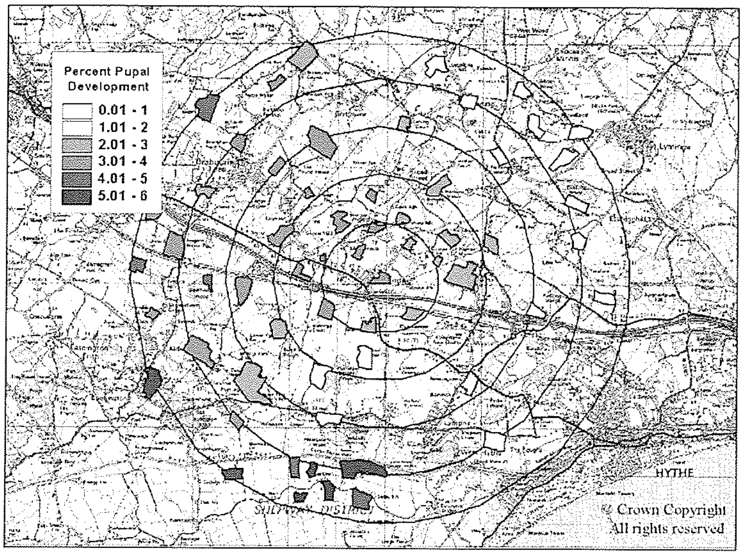
Figure 1: Predicted *L. decemlineata* pupal development on 30th June 1976 in selected fields within 5 km of an infected field chosen to represent a suitable mock outbreak location. The predictions were made by a phenology model with interpolated weather data as input.



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