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Remote sensing recognition of Ixodes ricinus habitats using LANDSAT MSS imagery

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Introduction

To forecast the incidence of the tick *Ixodes ricinus,* the most important vector of indigenous infectious diseases in Central Europe, we used the observation that certain types of vegetation may indicate the presence of this tick species. A detailed study of *I. ricinus* ecology, together with the studies of the phenomenon of natural foci of tick-borne encephalitis (TBE), revealed the importance of the character of plant communities as an indicator of the occurrence of ticks. The vegetation types were shown to be also useful indicators of the ecosystem suitable for TBE circulation and, consequently, for the existence of natural foci of this disease.

In those cases where the occurrence of *I. ricinus* in a certain vegetation type has been shown to be characteristic, a simple botanical map may seem to be sufficient for the evaluation of certain territories as appropriate tick habitats. In such a simplified concept, maps of large areas predicting the probable distribution of this tick have already been made. However, such maps are unsuitable for epidemiological analysis of infection circulation and effective prevention. The scales of these maps cannot reflect either details of the landscape or other factors important for *I. ricinus* distribution and its epidemiological significance, e. g. actual changes in the landscape caused by human activities. Neither the social factor is clearly considered — density and proximity of human dwellings determining the contact density between man and tick.

The method of remote sensing (RS) seems to be the most suitable solution of such a problem since it makes it possible to determine exactly the distribution of the respective plant communities and, with the knowledge of the tick relation to them, shows the places of potencial *I. ricinus* occurrence and the epidemiologically important density of ticks. Therefore we tried to make a predictive map of *I. ricinus* occurrence in Central Europe on the basis of remote sensing satellite data.

Material and methods

The forest locality of Poteplý (Central Bohemia) was chosen as model area. It is situated about 40 km southwest from Prague city being an intensively visited recreational area. It is known for regularly occurring high tick numbers and it was repeatedly virologically proved as a TBE natural focus and now also a focus of Lyme borreliasis. Over 25 years (1953 - 1972) a regular all-season investigation was conducted in this area aimed at evaluating changes in *I. ricinus* numbers in different types of vegetation.

Remote sensing data were obtained by means of a Multispectral Scanner (MSS) operating aboard the LANDSAT 5 satellite. Data were recorded in a digital form on magnetic tape, the values ranging between 0 to 255. The value of each number corresponded to the intensity of sun light reflected from the surface of a square 80 × 80 m (i. e. about 0.64 ha) and to the results of the spectral analysis of this light. The scanned areas are linked forming "lines" perpendi-

cular to the direction of the satellite orbit. The frequency of measurement in the line is synchronized in such a way that it enables the linkage of neighbouring areas in the adjoining lines. Thus the scanned data can be referred to a certain area and be reproduced in a graphic form. In this case, numeric values are expressed as points with respective degrees of shade located in the same order they had been scanned in the landscape.

The data in question were obtained on August the 3rd 1984 and comprised the territory of north-west Bohemia measuring approximately 185 × 170 km. The coordinates of the central point of the scene are 50.2° northern latitude and 13.66° eastern longitude. A data file was selected for evaluation from the entire recording. The file comprised 512 by 512 point measurements which corresponded to an area of approximately 41 by 41 km. The territory covered by the file included the study site of Poteplý as well as a sufficient zone of surrounding areas. This enabled a comparison with a reference area which had different numbers of tick. Areas for identical testing were selected in each zone measuring roughly 1,600 ha.

The data were processed by supervised classification using the Bayes' decision rule of maximum likelihood (DANIEL and KOLÁŘ [2]). Data processing was carried out using the PERICOLOR 2001 system at the Institute for the Theory of Information and Automation, Czechoslovak Academy of Sciences, Prague.

Results

Six landscape categories were examined:

1. Coniferous forest,
2. deciduous forest,
3. mixed forest,
4. water basins,
5. glades and
6. housing developments.

Categories one to three are crucial for the evaluation of the probability of tick presence, whereas the sixth category is significant in assessing the man exposure to ticks. The findings were obtained both in a graphic form and in the form of statistical reviews as regards the presence of appropriate landscape categories (Fig. 1 – 3, Tab. 1).

The section featuring the area of Poteplý (Fig. 1), which was proved to be a focus of TBE is characterized by prevailing mixed forests. Also typical is the substancial scattering over the territory of different vegetation categories. Comparison with long-term monitoring of the ticks indicates that in this area the most implicated zones are shown as leaved forest and mixed forest. The markedly mosaic pattern of different vegetation types suggests extremely favorable conditions for the emergence and existence of ecotones, which is extremely important for the presence of *I. ricinus* and existence of natural TBE foci. The reference area is situated somewhat less than 5 km to the west and the numbers of the ticks there reach levels which are not epidemiologically significant. Visually, this area is characterized by a distinctly greater and more homogenous distribution of zones of conferous forests (Fig. 2).

Since the evaluation data also comprise non-forest classes, it is possible to determine the extent of human exposure to epidemiologically hazardous portions of the tested territory. For this purpose, data can be used on housing development as well as on non-classified points which largely correspond to agricultural soils. In this way, high-priority sites can be earmarked for protection of the human population against the exposure to tick bites and for tick control programs.

Graphic results should be made available using a computer printer on a scale corresponding to conventional maps, preferably 1 : 100,000, to enable direct comparison of these materials and supplement them with reference points not shown on satellite images but essential

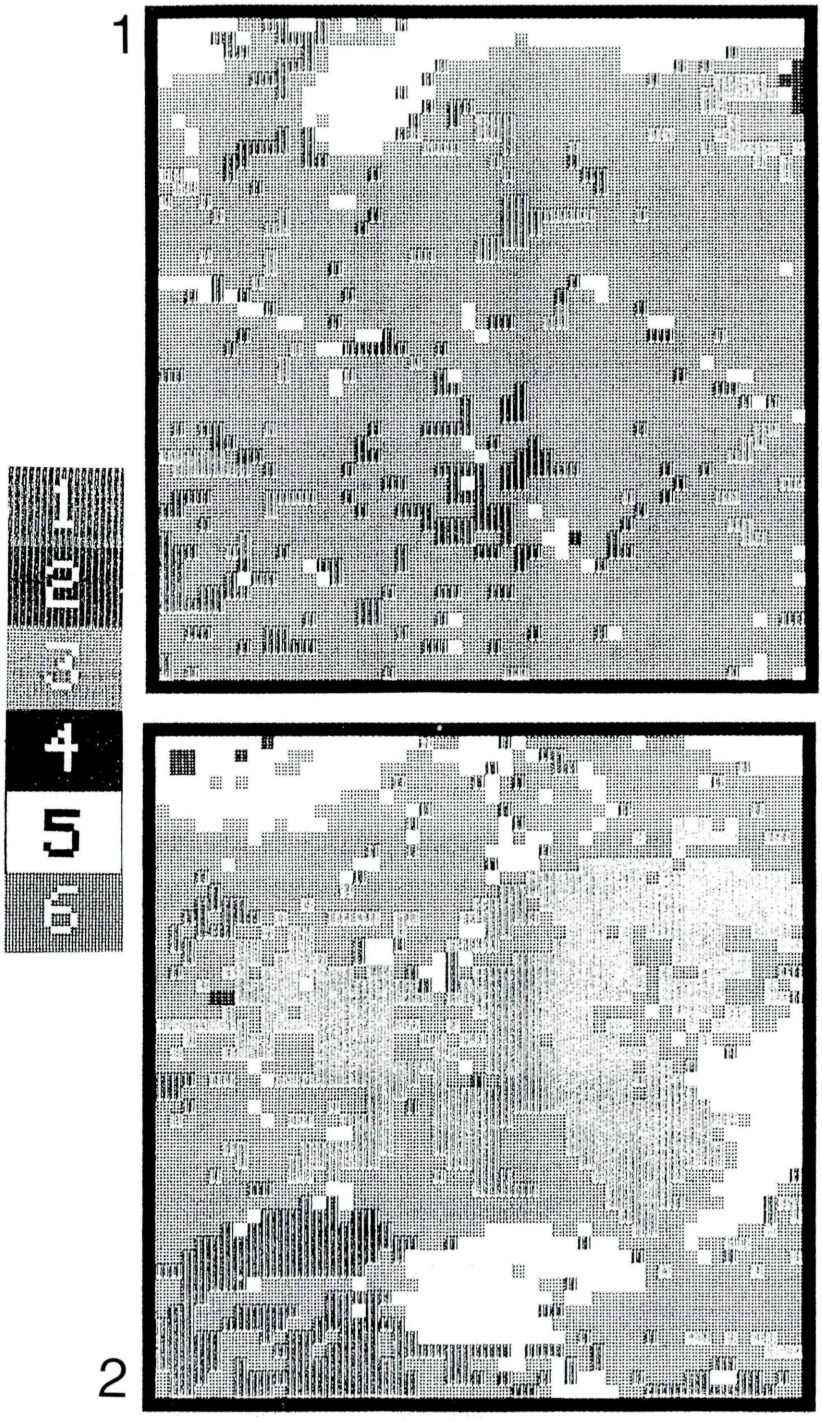

Figure 1:

Locality Poteply. An example of countryside proved to be a natural focus of tick-borne encephalitis with high numbers of the ticks observed for long periods of time. The presence of *I. ricinus* is primarily associated with areas covered by mixed and leaved forest, but also coniferous forest scattered in numerous islands in a complex with two former categories. This mosaic-like pattern with many ecotones contributes substantially to the high numbers of the ticks and the existence of a natural focus of tick-borne encephalitis.
The shown surface is about 1600 ha.

The symbols used:

1 = coniferous forest
1 = leaved forest
3 = mixed forest
4 = water basins
5 = glades (lawns when outside)
6 = housing developments

Figure 2:

Locality Lany. An example of countryside where coniferous forest forms a continuous complex unsuitable for the ticks. The island of mixed forest inside this complex are so limited in surface that the possible occurrence of occasional ticks therein is not significant from the epidemiological point of view. Only marginal areas of the section deserve attention. The shown surface is about 1600 ha. The symbols used are the same as in fig. 1.

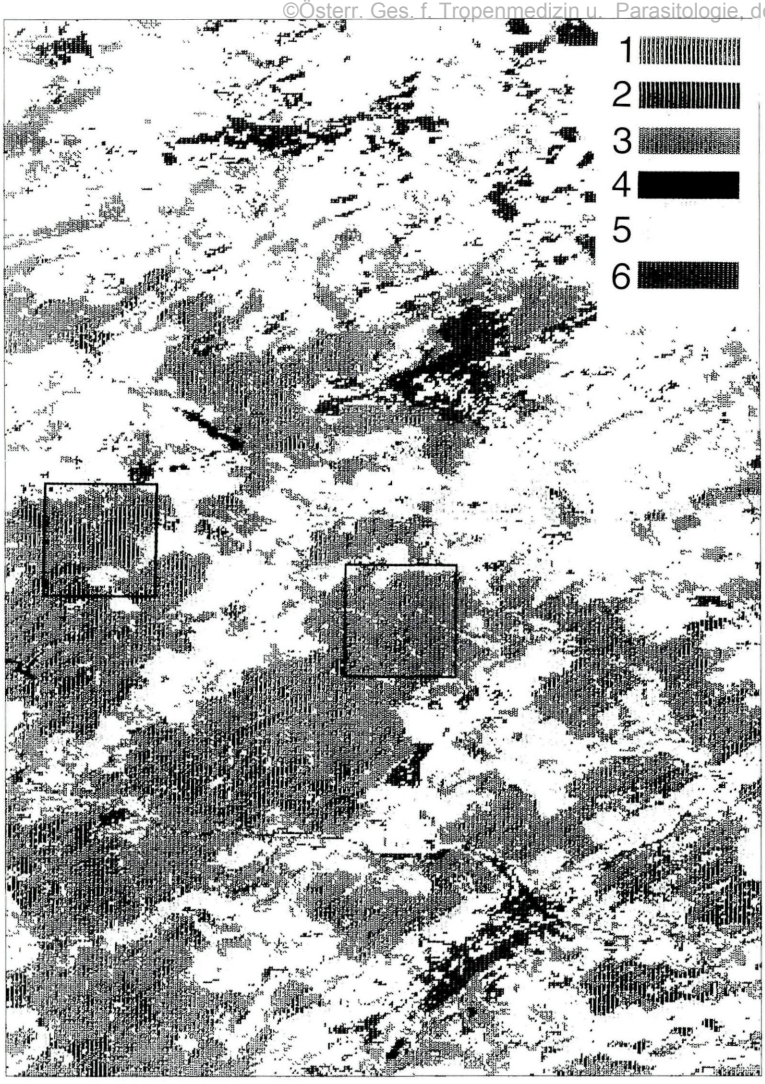

Figure 3:

PERICOLOR 2001
(Scale 1 : 100,000, originally printed in colours.)
This map documents the distribution of the evaluated plant communities and landscape categories in the area between towns Kladno (North) and Beroun (South). Square on the right depicts studied locality Poteply (see fig. 1), square on the left depicts reference locality Lany (see fig. 2). The symbols used are the same as in fig. 1.

for their use in field, the pattern of local communications networks being of special importance. Another pattern of graphic result presentation is the classified file modified using a post-classification filter to suppress individual non-homogeneities in the picture, yielding generalized information on the epidemiological situation over greater areas. In this form the material is suitable for the large-scale assessment of the epidemiological situation in great regions.

Discussion

The suitability of satellite data for forecasting the occurrence ticks was analyzed by HUGH-JONES (3). In his opinion it is the microclimate, extrapolated into a habitat, that we hope to recognize by the remote sensing of its different physical characteristics. HUGH-JONES (4, 5) also described the distribution of *Amblyomma variegatum* in the Caribbean region. On Guadeloupe Isle the analysis of LANDSAT-TM imagery consistently identified a series of habitats, using data on plant composition and environmental characteristics, which appeared to have different tick-carrying capacities.

PERRY et al. (6) discussed the role of the satellite-derived normalised difference vegetation index (NDVI) in studies of *Rhipicephalus appendiculatus* habitats in Africa. This spectral vegetation index quantifies the level of photosynthetic activity of vegetation and is calculated from the advanced very high resolution radiometer (AVHRR) data provided by the National Oceanic and Atmospheric Administration's (NOAA) meterological satellites. COOPER and HOULE (1) used the data of LANDSAT-TM imagery to develop a map of expected tick densities of *Dermacentor variabilis,* based on the dominant vegetation type and ecotones in North Carolina (USA).

Summary

To make a predictive map of *Ixodes ricinus* occurrence in Central Europe, the authors used the observation that some types of vegetation may indicate the presence of the tick. To obtain the necessary information remote sensing data were utilized from the Multispectral Scanner (MSS) operating aboard LANDSAT 5 satellite. A file was selected representing a territory of TBE natural focus at which high numbers of ticks were consistently present (forest Poteplý, 40 km SW from Prague, Central Bohemia). Six landscape categories were examined. The first *Ixodes ricinus* predictive map obtained in this way determines not only the extent of individually suitable tick habitats (mixed forest, deciduous forest), but also their dispersion into smaller areas together with coniferous forest (mosaic character). The ecotone range can be established from these data, too. In this way sites with high tick density and risk of tick bites can be marked.

Key words

Remote sensing, tick habitats, *Ixodes ricinus.*

Table 1:

Comparison of the proportion of vegetation types and landscape categories on the examined areas Poteply and Lany

Landscape categories	Surface covered (%)	
	Poteply (Fig. 1)	Lany (Fig. 2)
Coniferous forest	5.0	26.4
Leaved forest	9.9	12.6
Mixed forest	75.5	43.7
Glades (lawns)	1.1	43.7
Housing developments	0.2	0.3
Non-classified	8.2	13.4

Zusammenfassung

Verwendung von Satellitenaufnahmen (LANDSAT 5-MSS) zur Abschätzung der Dichte von Ixodes ricinus

Zur Abschätzung der Dichte von *Ixodes ricinus* wurden Beobachtungen verwendet, daß ein bestimmter Pflanzentyp als Indikator des Vorkommens dieser Zeckenart dienen kann. Um praktisch verwertbare Informationen für den Schutz der Bevölkerung vor dem Kontakt mit Zecken zu erhalten, wurden Meßdaten des Satelliten LANDSAT 5, die mit Hilfe des Multispectral Scanners gesammelt wurden, ausgewertet. Zur weiteren Erforschung wurden Ergebnisse von Messungen auf einem Territorium im Maßstab von annähernd 41 × 41 km ausgesucht, wo sich ein Gebiet mit hoher Zeckendichte befindet, das einen natürlichen Herd der Zeckenenzephalitis darstellt. Angaben aus diesem Gebiet (Poteplý) wurden mit Ergebnissen der Umgebung verglichen. Insgesamt wurden sechs Landschaftstypen untersucht. Die Datenanalyse wurde nach der Methode der kontrollierten Klassifikation mit Ausnützung der maximalen Wahrscheinlichkeit nach BAYES durchgeführt. Auf diese Weise konnten Gebiete mit einer hohen Zeckendichte und der Gefahr von Zeckenbissen lokalisiert werden.

Schlüsselwörter *Ixodes ricinus,* Abschätzung der Dichte, Satellit LANDSAT 5-MSS.

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