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## Title

Lifestyle, habitat and farmers' risk of exposure to tick bites in an endemic area of tick-borne diseases in Hungary

## Running head

Lifestyle, habitat and exposure to tick bites

## Authors and affiliations

Sen Li<sup>a,†</sup>, Linda Juhász-Horváth<sup>b</sup>, Attila Trájer<sup>c</sup>, László Pintér<sup>b,d</sup>, Mark D.A. Rounsevell<sup>e,f</sup>, Paula A. Harrison<sup>g</sup>

- a. Environmental Change Institute, University of Oxford, South Parks Road, Oxford, UK.
- b. Department of Environmental Sciences and Policy, Central European University, Nádor u. 9, Budapest, Hungary.
- c. MTA-PE Limnoecology Research Group, József Attila utca 10, Veszprém, Hungary.
- d. International Institute for Sustainable Development, 325-111 Lombard Avenue, Winnipeg MB, Canada.
- e. IMK-IFU, Karlsruhe Institute of Technology, Kreuzeckbahnstrasse 19, Garmisch-Partenkirchen, Germany
- f. School of GeoSciences, University of Edinburgh, Drummond Street, Edinburgh, UK.
- g. Centre for Ecology & Hydrology, Library Avenue, Lancaster, UK.

† Author for correspondence: S. Li ([sen.li@ouce.ox.ac.uk](mailto:sen.li@ouce.ox.ac.uk))

## Summary

Controlling tick bites on farmers is important to the management of tick-borne diseases and occupational health risks in agriculture. Based on an extensive household survey conducted between June and August 2015 with 219 farmers from western Hungary where tick-borne diseases are endemic, we analysed the pattern of farmers' self-reported contacts with ticks, and investigated the potential interactions between farmers, landscape and the risk of exposure to tick bites. We developed a lifestyle typology based on farmers' socioeconomic profiles, farming objectives and time use patterns, and a habitat typology describing different configurations of tick habitats and agricultural areas in place of farming. We found no relationship between tick exposure risk and self-prevention. The lifestyle typology could be used to classify the risk of tick bites and the adoption of prevention measures into different levels, the difference between which could further be modified by the habitat typology. Our results suggest that (i) farmers who are frequently engaged in outdoor recreations and (ii) part-time and inexperienced farmers who have lower rate of preventive actions are likely to experience greater exposure to tick bites either in less cultivated, semi-natural habitats or in agricultural landscape with highly diverse land uses. Future disease prevention practices should take into consideration the interaction of lifestyle and habitat and the need to associate different farmer groups with different landscape configurations.

## Keywords

Exposure risk, tick bites, farmer, lifestyle, habitat, typology

## Impacts

- Farmers experienced a spatially heterogeneous pattern of tick bites in the endemic areas of western Hungary.
- No relationship between exposure to tick bites and self-prevention was found and this called for improved translation of knowledge into preventive action.
- Future disease preventative actions should take into consideration the interactions between lifestyle and habitat configuration in the risk of exposure.

## Introduction

Ixodid ticks (e.g., *Ixodes ricinus* L.) are important disease vectors widely distributed in Europe. Via biting, they can transmit zoonotic pathogens causing severe health issues in humans and animals, such as Lyme borreliosis (the most prevalent vector-borne zoonoses in Europe), tick-borne encephalitis and louping ill (Dantas-Torres et al., 2012). It is of increasing public health interest to understand the determinants of the risks of tick-borne diseases (TBD), in order to facilitate adaptive disease management in a changing environment. Previous studies on TBD dynamics place a major focus on the influence of climate, habitat, and wildlife host composition on the geographical distribution of ticks and pathogens (Medlock et al., 2013). However, little is known about the exposure risk of TBD associated with human-tick contact (i.e., tick bites).

Farmers are regarded as a major occupational group at risk of TBD, as most of their activities are undertaken in rural areas that are also suitable as tick habitats (Piacentino and Schwartz, 2002). In order to understand farmers' risk behaviour in the field, it is necessary to understand the heterogeneity of farmer lifestyles, which have previously been explored through typological approaches (Guillem et al., 2012; Karali et al., 2013). In the agricultural sector, typologies, or classifications, have commonly been produced for better representing the heterogeneity of farmers' land use and behavioural drivers, and for enhancing the relevance and effectiveness of policy development (Acosta-Michlik and Espaldon, 2008; Valbuena et al., 2008). They have also been increasingly used to categorise different decision-making procedures in agent-based modelling of environmental change (Rounsevell et al., 2012; Arneth et al., 2014). A behavioural typology can be used to establish links between the exposure risks of TBD and a wide range of external and internal land use decision drivers e.g., socio-economic profiles, objectives, time management etc. This further supports integrated risk assessments and cross-sectorial communication between occupational health management and land use management.

The study presented here was based on an extensive, multi-purpose household survey conducted in the TBD endemic regions of western Hungary. The objectives of this study were: (i) to report farmers' self-reported tick bite frequency between 2014 and 2015, the rate of adopting prevention measures and the land cover types where they encountered ticks; (ii) to develop a "lifestyle" typology (based on socio-economic profiles, farming objectives and time management patterns) to understand farmers' behavioural risks, and a "habitat" typology (based on the composition of tick habitats and agricultural areas) to characterise the differences in tick exposure in place of farming, and; (iii) to explore the relationships between lifestyles, habitat and risk of exposure to tick bites.

## **Materials and Methods**

### *Study area and household survey*

In Hungary, Lyme borreliosis (LB) and tick-borne encephalitis (TBE) have been notifiable for more than 20 years, with an average yearly incidence rate (1998 – 2008) of 12.37 (LB) and 0.64 (TBE) per 100,000 inhabitants, and with endemic areas in the country's western and northern regions (Zöldi et al., 2013). The two diseases represent 98% of vector-borne zoonoses in Hungary in the last two decades. A household survey was conducted between June and August 2015 in collaboration with the Hungarian Central Statistical Office to investigate farmers' land use decision-making procedures and tick exposure patterns. The design and methodology of the survey is explained in detail in Li et al. (2017). In total 219 farmers were interviewed from 65 settlements in the parts of western Hungary where TBD risk is high (Figure 1A). The tick exposure part of the survey involved three key questions: (i) "How many tick bites have you had in the past year?" (ii) "Have you adopted any preventative measures against ticks (e.g. wearing long pants/long-sleeved shirts, wearing tick repellent, avoiding wooded and bushy areas with high grass and leaf litter)?" and (iii) "If you have had any tick bites, please identify the land cover types in which you have encountered ticks." A descriptive analysis was applied to report these results.

### *Developing lifestyle and habitat typologies*

Farmer lifestyles were characterised by three sets of variables, following Ziegenspeck et al. (2004): (i) social situation (age, gender, income, experience of farming, and access to social networks and information); (ii) mental level (the objective of farming); and (iii) expressive behaviour (time use pattern for professional and leisure activities). All lifestyle variables were collected from the household survey. Their definitions are provided in Table S1, Supporting Information 1. Habitat typology considered the character of tick habitats (e.g., forests, semi-natural areas and pastures) and agricultural areas (e.g., arable, permanent crops, and heterogeneous agricultural areas) and was used to approximate the level of co-presences of tick and farmers within a settlement where farming activities take place. Data on these habitat types were extracted from the CORINE 2012 land cover dataset, provided by the Hungarian Institute of Geodesy, Cartography and Remote Sensing (FÖMI). Descriptive statistics of the habitat variables are provided in Table S2, Supporting Information 1. Data were explored following the two-step approach adopted in recent typological studies (Guillem et al., 2012; Karali et al., 2013). First, a principle components analysis (PCA) was performed to extract a number of key components. A Kaiser-Meyer-Olkin (KMO) value of >0.5 is desirable to suggest acceptable sampling adequacy and a reliable PCA result. Second, data items were classified based on the principle components using a hierarchical cluster analysis (i.e., a K-means cluster analysis using Ward's method). The same approach was applied to develop both the farmer lifestyle typology and the habitat typology.

### *Exploring the associations of lifestyle type and habitat with tick exposure*

We first analysed whether the rate of prevention and risks of exposure to tick bites could be distinguished by the lifestyle types and habitat types respectively. The risks of exposure to tick bites were represented by two variables: the self-reported tick bites and a binary variable expressing whether a farmer had reported tick bites or not. A Kruskal-Wallis H test (or "one-way ANOVA on ranks") was used to determine if the differences (in prevention rate and exposure risks) between the lifestyle and habitat types were statistically significant. Since the validity of the number of

self-reported tick bites was uncertain, and the effect of prevention was not feasible to determine, the binary variable of tick exposure risk was used as the only dependent variable for the next steps. A Mann-Whitney U Test was performed to check if the prevention rate was significantly greater among farmers who had reported tick bites. Then, the interactions of lifestyle and habitat on the risk of exposure were explored with a two-way ANOVA. Once the interaction was found to be significant, a “simple main effects” analysis was performed to determine the mean difference in tick exposure risk between the lifestyle types in each habitat type. All analytical steps were conducted in IBM SPSS Statistics 22.

## Results

### *Self-reported tick bites and prevention rate*

At the survey site level, farmers from 29 settlements (out of 65) reported tick bites (Figure 1A), with an averaged number of tick bites of  $3.46 \pm 9.99$  (standard deviation) in the past year (and of  $1.54 \pm 6.89$  across all sites). At the individual farmer level, in total 21% of the farmers (44 out of 219) reported tick bites during the past year, with averaged tick bites of  $4.32 \pm 8.56$  in the past year (and of  $0.89 \pm 4.23$  across all farmers). About 59% of the farmers (129 out of 219) reported adoption of preventative measures against ticks. The rate of prevention was found higher for those who reported only a few tick bites (90% for 1-2 bites; 78% for 3-5 bites, Figure 1B), and lower for those who reported no tick bites (53%) and 6 and more tick bites (50%). Only one farmer (4.6% of the total sample) reported being diagnosed with a tick-borne disease, i.e., Lyme disease. Of the land cover types in which ticks were encountered (Figure 1C), woodland (22) and garden (16) are the most frequently reported, followed by pasture (10), cropland (6), riparian areas (2), heathland (1) and others (2 responses, with one reporting park and the other reporting “I don’t know”).

### *Types of lifestyle and habitat*

Five types of farmer lifestyle and four types of habitat were identified. The lifestyle typology was classified with five principle components extracted from the variables (KMO = 0.809; results in Supporting Information 2). Differences in the means of variables between lifestyle types are compared in Table S1, Supporting Information 1. The key characteristics of these lifestyle types were:

- *Hobbyists*: mostly subsistence farmers; little time spent on farming; high level of reliance on off-farm income; low engagement in outdoor recreation; lower education; mostly males; with many years of farming experience;
- *New Starters*: mixed farming objectives; part-time farming; low engagement in outdoor recreation; well-educated; more women; less farming experience;
- *Social Activists*: commercial farmers; part-time farming; high level of reliance on farm income; frequently engaged in agricultural groups/communities; regularly engaged in outdoor recreations; mostly males; with many years of farming experience;
- *Full-time Farmers*: commercial farmers; full-time farming; high level of reliance on farm income; regularly engaged in agricultural groups/communities; low engagement in outdoor recreation;
- *Recreationist*: mixed objectives; lots of time spent on farming; high level of reliance on off-farm income; low engagement in agricultural groups/communities; outdoor recreationist; high education.

The habitat typology was constructed with three principle components (KMO = 0.542; results in Supporting Information 2). The four habitat types classified were (see Table S2, Supporting Information 1, for a comparison of the means of all variables):

- *Arable with Mixed Crops*: middle-level arable land proportion; relatively high proportion of permanent crops (e.g., vineyards and orchards) and heterogeneous agricultural areas for mixed uses;
- *Arable-dominated*: high-level arable land proportion;
- *Uncultivated and Semi-natural*: low-level arable land proportion; relatively high proportion of semi-natural areas;
- *Arable with Forests and Pastures*: middle-level arable land proportion; relatively high proportion of forests and pastures.

### *Associations of lifestyle and habitat with tick exposure*

The *Recreationists*, *Social Activists* and *Hobbyists* had relatively higher tick bites and rates of prevention (Table 1). There was a significant difference in the number of reported tick bites between the lifestyle types (Kruskal-Wallis H test),  $\chi^2(4) = 10.2, p = 0.038$ , and a significant difference in the adoption of tick prevention measures between the lifestyle types,  $\chi^2(4) = 10.7, p = 0.031$ . No significant difference between habitat types were found for prevention adoption ( $\chi^2(3) = 5.829, p = 0.12$ ), nor for the number of tick bites ( $\chi^2(3) = 7.2, p = 0.067$ ). Experience with tick bites seemed to be an important determinant in adopting tick-prevention measures, as the rate of prevention was significantly higher amongst farmers who reported tick bites than those who reported no tick bites (Mann-Whitney U Test,  $U = 4659, p < 0.001$ ). A statistically significant interaction between the effects of lifestyle and habitat types on farmers’ exposure

to tick bites was found in the two-way ANOVA,  $F(12, 199) = 2.2$ ,  $p = 0.011$ . Differences in tick exposure risk between lifestyle types were significant in the *Uncultivated and Semi-natural* (simple main effects analysis (not shown),  $p = 0.014$ ) and *Arable with Mixed Crops* habitats ( $p = 0.025$ ), but not in the other habitat types ( $p > 0.05$ ). In the *Uncultivated and Semi-natural* habitat, the *Recreationists*, *New Starters* and *Social Activists* had relative higher risks of exposure. In the *Arable with Mixed Crops* habitat, the *Recreationists*, *New Starters* and *Hobbyists* had the highest exposure risks.

## Discussion

The percentage of farmers having tick bites during their life time would be high. Amongst the 219 survey responses, 21% of the farmers reported tick bites during the past year in western Hungary. In relevant studies on farmers' exposure to ticks, 87% of farmers in eastern Poland reported frequent tick bites (Cisak and Sroka, 1998), 17% of farmers in Turkey (Arikan et al., 2010) and 60% of farmworkers in Malaysia (Ghane Kisomi et al., 2016) reported tick bites. Our results are comparable to those found for other population groups in Europe, for example, 30% of adults reported having tick bites over the past 12 months (and 65.7% during a life time) in western Norway (Hjetland et al., 2013), and 18% of scouts (aged 8-16) reported having tick bites during camping in Belgium (De Keukeleire et al., 2015). Such diversity in existing findings suggests that the pattern of human exposure to TBD is a localised issue depending strongly on the population group involved.

Several implications for public health management can be drawn from our findings. The three types of farmer lifestyle associated with higher tick exposure risk should be targeted in the promotion of TBD preventative practices. Despite the fact that they had a higher rate of self-prevention, the *Recreationists* and *Social activists* who pursued more outdoor leisure activities still suffered from a higher rate of tick bites. The reasons behind this apparently contradictory finding remain unclear. Nevertheless, it is important to be able to provide key provide alerting information on the timing and location of self-prevention to improve the effectiveness of self-prevention for these farmers. This, in particular, requires integrated knowledge of the spatio-temporal dynamics of questing ticks and TBD risks in local environments (Egyed et al., 2012; Trájer et al., 2013; Trájer et al., 2014). The *Hobbyists* who tended not to engage in agricultural or recreational outdoor activities on a regular basis were also found to be highly exposed to tick bites. This is (possibly yet to be determined) due to low awareness of the disease risks, among farmers of this type, as they had a lower prevention rate (0.58) than the *Recreationists* (0.75) and *Social activists* (0.7) who are also at high exposure to tick bites. Moreover, two types of habitat were found to have significantly influenced the differences in tick exposure risks between the lifestyle types, namely, the *Uncultivated and Semi-natural* and *Arable with Mixed Crops* types. In the former habitat type, settlements were more urbanised and had a relatively greater extent of open area that could be regarded as good tick habitat. This configuration indicated more farmers were likely to be exposed to ticks near their work place. In the latter case, settlements contained highly mixed agricultural land use patterns which has commonly been thought of as an indicator of more ticks and more complex patterns of human exposure (Medlock et al., 2013). In these two habitat types, TBD preventative actions may need to further target *New Starters* who had less farming experience, lower engagement with outdoor activities and a lower self-prevention rate (0.57).

Several future research directions are suggested by this work. First, the effects of existing prevention measures need to be better assessed. The potential causal relationship between exposure and self-prevention remains poorly understood and requires further investigation on improved translation of knowledge into preventive action. Second, finer scale prevention practices may be possible with more field data or reliable model estimations, especially if these data are able to accurately depict the spatio-temporal patterns of questing ticks, the landscape factors associated with specific tick distributions, and the human-tick contact rate associated with those and other potential drivers of tick encounters as noted by De Keukeleire et al. (2015). Third, our results may contribute to the modelling of the spill-over risks of pathogens at the tick-human interface. Our findings and typologies can easily be integrated into existing land use modelling frameworks, e.g., Murray-Rust et al. (2014), to model farmer's outdoor activities, and can further be integrated with biophysical infectious tick distribution models, e.g., Li et al. (2016), to estimate the contacts between the farmers and infectious ticks.

## Conclusion

Farmers experienced a spatially heterogeneous pattern of tick bites and were potentially exposed to tick-borne disease in the endemic areas of western Hungary. The patterns of self-reported tick bite rates and prevention rates can be categorised by the lifestyle typology of farmers' socio-economic profiles, objectives and time use patterns. The differences in exposure risk between lifestyles can be modified by the habitat typology of the configuration of settlements in which their farms are situated. We found no relationship between tick exposure risk and self-prevention. The *Recreationists* and *Social activists* who are frequently engaged in farming activities and outdoor recreations, and the *New Starters* and *Hobbyists* who work on part-time basis and adopt less preventive action, were found to have greater exposure risk either in open, semi-natural area (suitable tick habitats) or in agricultural landscape with heterogeneous land use patterns. Future disease preventative actions should take into consideration the interactions

between lifestyle and habitat in the risk of exposure. Our findings add new empirical evidence to advance the modelling of human exposure risks to zoonotic diseases.

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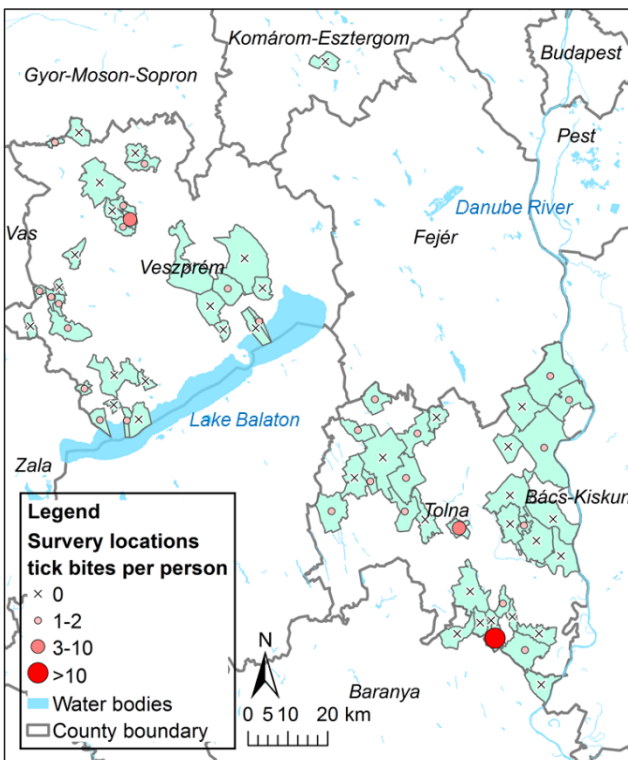
**Tables**

Table 1 Summary statistics of tick bite rate and prevention rate by farmer lifestyles and habitat types.

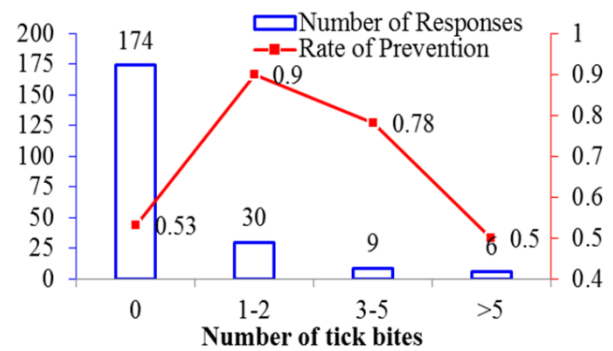
Types	N	Mean (Std. Deviation)			
		Prevention measures: 1 = Yes; 0 = No	Tick bites: Number of bites had in the past year	Tick bites (binary): 1 = Yes; 0 = No	
Lifestyle	1 Hobbyist	41	0.58 (0.49)	0.92 (3.20)	0.24 (0.43)
	2 New starter	52	0.57 (0.49)	0.25 (0.65)	0.15 (0.36)
	3 Social activist	78	0.70 (0.45)	1.19 (6.31)	0.21 (0.41)
	4 Full-time farmer	44	0.40 (0.49)	0.86 (2.79)	0.15 (0.36)
	5 Recreationist	4	0.75 (0.5)	3 (3.46)	0.75 (0.5)
Habitat	1 Arable/mixed crops	11	0.54 (0.52)	1 (2.40)	0.27 (0.46)
	2 Arable-dominated	136	0.53 (0.50)	0.5 (1.82)	0.14 (0.35)
	3 Uncultivated/semi-natural	17	0.70 (0.46)	3.70 (13.2)	0.29 (0.46)
	4 Arable/forests/pastures	55	0.70 (0.45)	0.94 (2.86)	0.30 (0.46)
Total	219	0.59 (0.49)	0.89 (4.23)	0.21 (0.40)	

**Figures**

A)



B)



C)

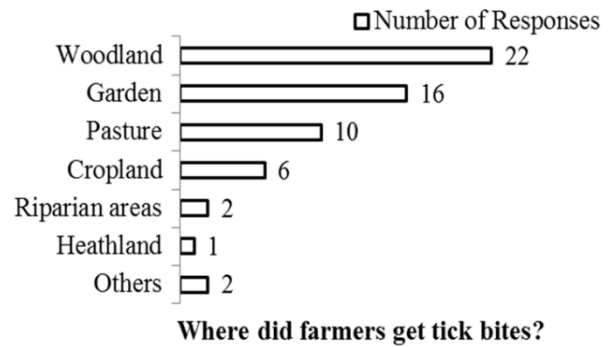


Figure 1 Survey results on (A) tick bites in the past year per person in each survey location, (B) the numbers of tick bites and rates of prevention measurements, and (C) land cover types in which the ticks were encountered.