

Original Article

Risk mapping of bovine hypodermosis using geographical information system (GIS) in cattle of subtropical region, Pakistan

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Abstract

Introduction: Hypodermosis is an ectoparasitic disease of cattle caused by *Hypoderma lineatum* and *Hypoderma bovis*. It is an important health problem of cattle, leading to considerable economic losses. There are various factors that are involved in the spread of this disease such as herd size, location, temperature, humidity, and precipitation.

Methodology: Blood samples from 112 herds were collected to determine the presence of *Hypoderma* spp. infestation. For these herds, size and location were determined; temperature, humidity, and precipitation data were obtained from meteorological stations; and topographic features were obtained from existing maps and through field work. A regression analysis was then used to generate a risk factor analysis profile for hypodermosis and geographic information system (GIS) was used to map the risks.

Results: The GIS map developed showed the degree of infestation in different geographical locations at district and village levels. Cluster analysis demonstrated that hypodermosis prevalence varied within zones and across zones. The regression analysis showed that the temperature in the months of January, February, March, August, and November, and the precipitation in September and October had significant results ($p < 0.05$) when all the risks factors were analyzed.

Conclusions: It is concluded that different ecological factors have an important impact on the intensity and infestation rate of hypodermosis across the globe. The present study might be used to control and eradicate the hypodermosis across the globe.

Key words: Hypodermosis; GIS; prevalence; risk mapping; Subtropical Region.

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Introduction

Warble flies (*Hypoderma* spp.) are common parasites of cattle in the northern hemisphere. In Pakistan, warble fly infestation (WFI; hypodermosis) is a notorious and common disease of cattle, buffalo, sheep, and goats, and is considered an especially important menace in cattle and buffalo of different areas of northern Punjab [1-3]. Infestations of cattle with the larvae of this fly cause serious damage to hides and cause occasional deaths due to anaphylactic

shock, toxemia, or damage to the central nervous system or esophagus. The adult flies are a nuisance, causing reductions in milk yield and/or subnormal weight gain [4].

Warbles of the genus *Hypoderma* are parasites with a complex life cycle, including endoparasitic (L₁ larvae), ectoparasitic (L₂ and L₃ larvae), and free-living (pupae and imagoes) stages. The presence of free-living stages, strictly dependent on climatic conditions, makes bovine hypodermosis an invasion of

marked seasonal character. Many authors have reported that the adult fly requires windless weather and temperature higher than 18°C for the nuptial flight and oviposition. Such weather conditions are necessary for the beginning of oviposition and they influence the occurrence of successive developmental stages of these parasites. In Pakistan, the fly's egg-laying season varies in location and ranges from February to June. The warbles on the backs of infested animals are generally recorded from November to January. Larvae fall to the ground by mid-January [5]. The seroconversion of *Hypoderma bovis* antibodies in infested animals strictly depends on the time of infection [6].

The ecology of the vector or the parasite and the environmental determinants of their distribution are of primary importance in the transmission, surveillance, and control of vector-borne and parasitic diseases [7]. However, the relationship between the development of warble flies and climatic risk factors has been studied only *in vitro* [8-11]. The factors found to be of interest were a high temperature during the pupal period, moisture, age, and type of dairy cattle breed [12].

In recent years, the application of geographical information system (GIS), a computerized system that combines spatial and descriptive data for mapping and analysis, has been increasingly used to map and collate available epidemiological information. It is also used to relate climatic and environmental factors to the distribution of diseases together with time, people, and other dimensions of interest [13]. This advanced analytical tool has been widely used in monitoring, identification, and disease surveillance to prioritize high-risk areas. These mitigation and surveillance plans provide an effective tool for visualization and spatial analysis of epidemiological and environmental data [14-17].

The aim of the present study was to investigate the seroprevalence of *H. lineatum* and to develop a risk model predicting infestation risk in Pakistani cattle herds based on local climatic conditions. In Asian countries, it is the first study on the risk mapping of *Hypoderma* spp. However, a similar type of study was done in Belgian cattle herds based on ecological conditions [12]. In the present study, our aim was to develop a spatial model to predict the prevalence risks in cattle herds using local climatologic, geographic, and demographic risk factors. To accomplish this, GIS was applied for risk mapping of bovine hypodermosis to facilitate the development of effective control strategies. This was the first study of this type about

warble fly ever conducted at a national level both in Pakistan and the subcontinent of South Asia.

Methodology

Location, survey design, and sample size

Data were collected between October 2009 and March 2011 from northern Punjab, Pakistan. The survey used a stratified one-stage cluster sampling design, with villages as the stratification variable and with proportional allocation of the number of herds among villages based on the total number of herds [18]. The total number of herds to be sampled was set at 112. The sampling frame consisted of all cattle-keeping holdings in the study area, which were present in the various villages. The geographic coordinates of the main building of the farm were also recorded at the time of sampling.

A total of 1,000 animals were examined on a monthly basis for the incidence of hypodermosis. Blood samples were taken, and serum samples were tested for antibodies against *Hypoderma* spp. using the enzyme-linked immunosorbent assay (ELISA) method [19]. During the village visit, herd type (dairy, mixed, or beef herd) and size (number of cattle on the premises) were also recorded. Only data from October 2009 to March 2011 were used. In Pakistan, the warble fly is active only from February to April because the larval stages are present inside the body of an infested animal from May to January. Weather data from the actual fly season (2010) and also from the previous year (2009), because 2010 flies were the result of the fly generation in 2009, were obtained from ground stations. Data from the ground stations included minimum and maximum daily temperatures, daily rainfall, and daily relative air humidity. The mean daily minimum, maximum, average, and range of temperature, and the mean daily rainfall and mean daily relative air humidity from October to March were calculated for each station.

Factors considered in risk analysis

A risk mapping model was developed using different ecological parameters that affect the lifecycle and developmental stages of the warble fly. Environmental conditions have a deep influence on the biology and developmental stages of *Hypoderma* spp. Minimum temperature, maximum temperature, average temperature range, rainfall, and relative air humidity were used as predictors of the bovine hypodermosis in a GIS environment

All of these variables were used because they play an important role in the prevalence of bovine

hypodermosis. The incubation of an egg requires a suitable temperature, which is provided by the body of infected animals. Hatching requires three to seven days [20]. Heavy rainfall increases the odds of infection, as reported by Haine, contrary to the literature [21-23,9]. In Pakistan, there are different land cover types. Statistical results have shown that pastures are a major risk factor for WFI [24]. Minimum temperature, maximum temperature, average temperature, rainfall, and relative humidity were used as predictors (independent variables), and the prevalence of hypodermosis was used as the dependent variable.

The cluster analysis was done using ArcGIS’s spatial statistical tool of cluster analysis using the points of different herds and the disease prevalence. This tool identifies statistically significant spatial clusters of high values (hot spots) and low values (cold spots). It groups features based on feature attributes (in this case, prevalence) and optional spatial constraints (occurrence). Cluster analysis, when combined with mapping, is useful because the clusters that emerge may form geographic patterns that lead to insights about connections between patterns in attribute data and the spatial context within which those patterns are formed.

Statistical analysis

Statistical analyses were performed using Statistical Package for Social Studies (SPSS) software. A final regression model was used to produce a GIS-based raster surface. These raster surfaces show the probability of hypodermosis based on local ecological conditions using ArcView. The regression-based model was developed:

$$Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X + \beta_5X_5\beta_6X_6 + u_i$$

The regression equation was developed using the stepwise multiple regression method in SPSS.

Results

Prevalence of hypodermosis

Out of 1,000 cattle, 184 (18.4%; 95% confidence interval [CI] 2.2–4.5) were found to be infested with *Hypoderma* (Table 1). First warbles appeared by the end of September, and skin perforation started from the end of October to December. All larvae collected from infested cattle were identified as *Hypoderma lineatum* based on Zumpt *et al.*’s definition [25].

Descriptive statistics

A total of 112 herds were studied for risk mapping of bovine hypodermosis. The epidemiological information of these herds was recorded in the form of a questionnaire. The risk mapping analysis was done using SPSS software based on prevalence data and environmental data.

Cluster analysis

From the four regions of Pakistan, the herd-based seroprevalence in Rawalpindi was 25.92%, and in Attock was 25.34%. Moreover, in Jhelum and Chakwal, herds were mainly negative, but the seroprevalence was higher in Rawalpindi and Attock provinces. The dark pigmented clusters in some regions of Rawalpindi district represent those areas where disease distribution was higher, while the yellow area shows where the probability of disease was lower as compared to other clusters in the study area.

The cluster analysis showed the most likely occurrence of disease based on the statistical data of cattle herds in provinces of Jhelum and Rawalpindi. Three secondary clusters were established (Figure 1).

Risk factor analysis

A regression-based model was developed for risk factor analysis. This model was based on rainfall; minimum, maximum, and average temperature; air humidity; and land cover (intensive or extensive grazing). These variables were used as predictors of bovine hypodermosis. The results show that ecological

Table 1. The different parameters influencing the distribution pattern of bovine hypodermosis in a subtropical region, Pakistan

No.	Area	No. of villages	No. of cattle	No. of herds	No. of positive herds
1	Rawalpindi	5	354	21	10
2	Attock	17	172	61	36
3	Jhelum	4	249	20	8
4	Chakwal	2	225	8	8

factors have an important influence on seroprevalence. The results of the regression model indicate the different risks factors (Table 2). The regression analysis showed that the temperature in the months of January, February, March, August, and November, and the precipitation in September and October had significant results ($p < 0.05$) when all the risks factors were analyzed.

Regression equation

$$\text{Prev} = (533.7 * \text{Jan Temp}) - (768 * \text{Feb Temp}) + (1049 * \text{March Temp}) - (356.84 * \text{Aug Temp}) + (38.19 * \text{Sep ppt}) - (41.505 * \text{Oct ppt}) + u_i$$

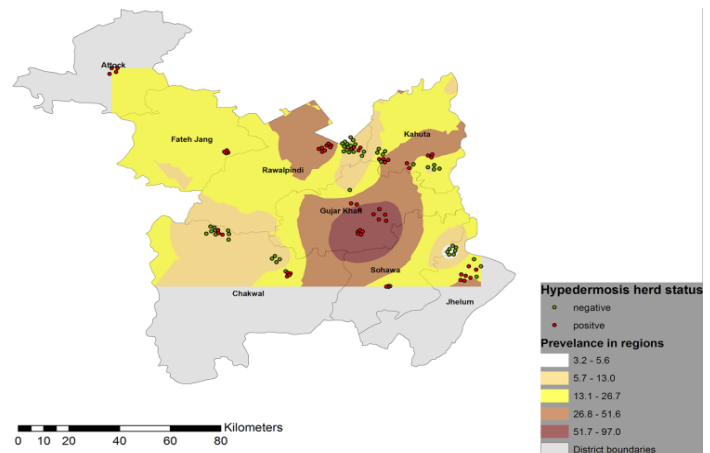
The present study is very novel because there is a lack of such studies, especially in Asian countries, where livestock is a major component of the economy.

Discussion

In the present study, a total of 112 herds were studied for the risk mapping of bovine hypodermosis. The risk mapping analysis was done using SPSS software based on prevalence data and environmental data. Similarly, in a previously study, 362 herds were examined for risk mapping of WFI in a Belgian cattle herd with epidemiological data [12].

From the four regions of Pakistan, the herd-based seroprevalence was found to be higher in Rawalpindi and Attock provinces. The dark pigmented cluster in some regions of the Rawalpindi district represents those areas where disease probability and distribution was higher, while the yellow pigmented area shows

Figure 1. Potential risks areas of occurrence of hypodermosis of Subtropical Region, Pakistan



where the probability of the disease was lower as compared to other clusters in the study area. Our results correlate, as the seroprevalence of hypodermosis was 48.7% in the two federal regions of Belgium. It was 85% and 29% in Wallonia and Flanders regions, respectively [12] and was 31.9% in Kars province of Turkey [26].

The cluster analysis shows the most likely areas where disease occurs in the study area. The clusters were based on the statistic-represented negative cattle herds in the provinces of Jhelum and Rawalpindi. There were three secondary clusters (Figure 1) in Rawalpindi, Jhelum Chakwal, and Attock. Similarly, clusters in different regions were previously reported by Hainea *et al.* [12].

A regression-based model was developed. This

Table 2. Risks factor analysis model showing influence of factors on the prevalence of bovine hypodermosis in a subtropical region, Pakistan

	R	R²	Adjusted R²	SE		
	0.943	0.890	0.614	16.116		
ANOVA						
	Model	Sum of squares	df	Mean square	F	Sig.
1	Regression	16,782.850	20	839.142	3.231	.047
	Residual	2,077.783	8	259.723		
	Total	18,860.632	28			
Model	Unstandardized coefficients	Standardized coefficients		T	Sig.	Model (p value)
	Jan temperature	532.702	204.847	9.042	2.600	.032
	Feb temperature	-768.632	228.527	-13.652	-3.363	.010
	Mar temperature	1,049.962	301.287	23.155	3.485	.008
	Aug temperature	-356.847	145.111	-5.069	-2.459	.039
	Sep precipitation	38.192	16.141	13.364	2.366	.046
	Oct precipitation	-41.505	16.110	-5.275	-2.576	.033
	Dec precipitation	5.897	1.962	1.297	3.006	.017

ANOVA= Analysis of Variance; d.f= Degree of Freedom; Sig= Significance; S.E= Standard Error; T= Time

model was not dependent on data, but rather on rainfall; minimum, maximum, and average temperature; air humidity; and land cover. Both mean and median of the X variable show where the center of the data is located, and show the average value of the X variable. The largest value in the data was 147.97, and the smallest value was 20.660. Skewness was -1.535054, which is < 0 , so it is a left-skewed distribution. Most values were concentrated on the right of the mean, with extreme values to the left. Similarly, the value of kurtosis was 8.082955, which is > 3 ; it was, therefore, leptokurtic distribution, which is sharper than a normal distribution, with values concentrated around the mean and with thicker tails. Here, the mean is slightly larger than the median, so it is slightly skewed in a positive direction.

GIS, which combines spatial and descriptive data for mapping and analysis, is widely used to map and assemble the available epidemiological information, and its correlation with climate and environmental factors known to influence the distribution of vector-borne diseases. This tool has been used in many areas such as surveillance and monitoring of vector-borne and water-borne diseases, in environmental health management, analysis of disease for optimal policy and planning, identification of high-risk health groups, and planning and programming of activities to improve animal health. Spatial data analysis involves describing data related to a process operating in space, the exploration of patterns and relationships in such data, and the search for explanations of such patterns and relationships.

GIS for disease surveillance plays a major role in public health and epidemiology. GIS-based risk mapping is widely used to map and predict the status of disease in a particular region. It is very important to explore the potential risk area on a map rather than in tabular form to assist policy makers, livestock officers, farmers, and other stakeholders.

Conclusions

The temperature in the months of January, February, March, and August, and precipitation in September and October had significant results when all the risks factors were analyzed. These factors have an important influence on the biology and developmental stages of *Hypoderma* in field conditions. Similarly, the relationship between the development of warble flies and climatic risk factors has been studied only *in vitro* [8-11]. The factors found to be of interest were a high temperature during the pupal period, moisture, age, and type of dairy

cattle breed. The present study predicted the importance of different ecological factors that have an important influence on the prevalence of hypodermosis, and it is very useful in providing a right direction to explore other factors in the rest of the world.

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