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Influence of human activity patterns on epidemiology of plague in Western Usambara Mountains, Tanzania

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Abstract: Human plague has been a recurring public health threat in some villages in the Western Usambara Mountains, Tanzania, in the period between 1980 and 2004. Despite intensive past biological and medical research, the reasons for the plague outbreaks in the same set of villages remain unknown. Plague research needs to broaden its scope and formulate new hypotheses. This study was carried out to establish relationships between the nature and the spatial extent of selected human activities on one hand, and the reported plague cases on the other hand. Three outdoor activities namely, fetching water, collecting firewood and going to the market, were selected. Through enquiries the activity patterns related to these activities were mapped in 14 villages. Standard deviation ellipses represent the extent of action spaces. Over 130 activity types were identified and listed. Of these, fetching water, collecting firewood and going to the market were used for further analysis. The results indicate a significant correlation between the plague frequency and the size of these action spaces. Different characteristics of land use and related human activities were correlated with the plague frequency at village and hamlet levels. Significant relationships were found between plague frequency and specific sources of firewood and water, and specific market places.

Keywords: plague, epidemiology, land use, human activities, Tanzania

Introduction

Plague is a zoonosis caused by the bacillus *Yersinia pestis*, which circulates in rodent hosts, and is transmitted to other mammals via a bite by adult fleas. At the event of a local outbreak, plague is a rapidly progressing disease that is likely to be fatal if not treated or if treatment is delayed (Dennis *et al*., 1999; Gage & Kosoy, 2005; Drancourt *et al*., 2006). Plague remains a public health concern in many parts of the world, but most particularly in eastern and central Africa and Madagascar, with over 10,000 cases reported in the last decade (Laudisoit *et al*., 2007; Stenseth *et al*., 2008; Neerinckx *et al*., 2010a). The disease is endemic in some parts of Tanzania including Lushoto District in the Western Usambara Mountains, Mbulu (Kilonzo & Mhina, 1982) and Karatu districts (Makundi *et al*., 2008; Haule *et al*., 2013; Ziwa *et al*., 2013). In the Western Usambara Mountains, the first documented outbreak dates from 1980 (Kilonzo & Mhina, 1982). It has been reoccurring almost every year until 2003. Between 2003 and 2008, no single case of plague was recorded in the area. However, in 2008 a total of 133 cases were reported (WHO, 2010). In the Mbulu district, located 350 km west of the Western Usambara Mountains, a new plague outbreak occurred in 2008, after a quiescent period of about 30 years (Makundi *et al.,* 2008).

Researches on the plague disease and on the ecology of the rodents as potential hosts have been carried out in Lushoto District during the last three decades. However, the precise rodent and flea species involved in plague transmission have not been identified yet and questions remain on why the plague emerges in the same suite of villages (Kilonzo *et al*., 1997; Njunwa *et al*., 1989; Makundi *et al*., 2003; Davis *et al*., 2006; Kamugisha *et al*., 2007; Laudisoit *et al*., 2009a; Neerinckx *et al.,* 2010b). Studies comparing distributions of rodent and flea populations in plague-positive and plague-negative villages could not explain the details of the spatio-temporal distribution of the disease in the region (Kilonzo *et al*., 1997; Makundi *et al*., 2003; Davis *et al*., 2006; Laudisoit *et al*., 2009b). Following this, a number of studies were initiated in the area to

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explore the eventual role of environmental and biological factors in the epidemiology of plague in the Western Usambara Mountains (Laudisoit, 2009). Neerinckx *et al*. (2008) used ecological niche modelling at the scale of south-eastern Africa and at the scale of the Western Usambara Mountains (Neerinckx *et al*., 2010b), to explore on the importance of elevation and vegetation cover as general predictors of plague occurrence and to derive predictive maps at sub-continental to regional levels. Later, in the same area, Debien *et al*. (2011) demonstrated the relationship between yearly rainfall fluctuations and the temporal pattern of plague outbreak.

The roles of land use, anthropogenic disturbance, and specifically of household activity patterns and flows, on the recurrence and the spreading of plague in different regions in the world have been described (Liu *et al*., 2000; Gubler *et al*., 2001; Kilonzo *et al.*, 2003; Gage & Kosoy, 2005; Foley *et al*., 2005; Friggens & Beier, 2010; Ari *et al*. 2011). So far these factors have not been studied in the Western Usambara Mountains of Tanzania. In this region, the scarcity of life resources including water and firewood, and the lack of access to social services, forces people to engage long and daily travel patterns through different landscape settings. These travel patterns and the specific associated activities cause physical contact with soil, vegetation, water and organisms, and possibly conditions for increased risk of contact with the plague vectors.

This study was conceived from two specific socio-environmental hypotheses: (i) the occurrence of the outdoor human activities is correlated with the human plague frequency cases; and (ii) the spatial patterns of the outdoor human activities are correlated with the reported human plague frequency cases. The specific objectives of the study were therefore: (i) to map the selected activities and their targeted land uses, (ii) to define the agents for these activities and register their timings, frequencies, origins, journeys and destinations, and (iii) to establish spatial relationships between the activities and the reported plague cases in Western Usambara Mountains of Tanzania.

Materials and Methods

Study area

This study was carried out in Lushoto District of north-eastern Tanzania. The district is about 3,500 km^2 in size and located in the Western Usambara Mountains. In the district 2,000 km^2 is used for agricultural land and settlements, often in mixed patterns, and about 340 km^2 is forest reserve. Lushoto district is one the most densely populated areas in Tanzania with a population of 492,441 (National Bureau of Statistics, 2013). Agriculture is the main economic activity of over 90% of the population. The remainder consists of plantations, nucleated settlements, fallow land, marshland and bare rocks. The study area is a rectangular section of the Lushoto District (04°30'-04°45'S and 38°00'- 38°45'E) (Figure 1). Three major physiographic units are the plain, the escarpment and the plateau. There are 14 villages within the plague endemic part of the selected area, but all are located essentially on the plateau.

Human plague data

Data on human plague occurrences was obtained from the Lushoto District Hospital, covering the period between October 1986 and December 2003. These data were made available through the intermediation of researchers who have used, checked and supplemented these data in the frame of other studies (Davis *et al*., 2006; Neerinckx, 2010). A study by Davis *et al.* (2006) reported a plague frequency (PF) of 49 villages in Lushoto District. Five villages were classified as high, five villages as medium and four villages as low plague frequency villages. To this dataset Neerinckx (2010) linked the most recent hamlet names to the patients' home place, in order to calculate the plague frequency not only at village but also at hamlet level. The plague frequency (PF) is defined as the proportion of years during which at least one plague case occurred (Figure 2). A plague year is defined as the 12 month period beginning in July of one year and ending in June the following year. Of over 6,000 plague cases reported by the hospital, about 3,000 were used in this study to calculate the plague frequency of the 14 villages and the 79 hamlets in the study area.

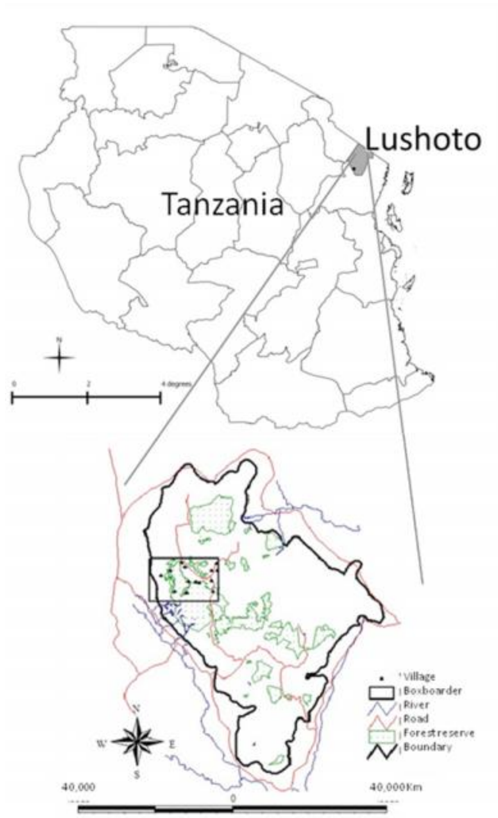

Figure 1: The study area in Lushoto District, Tanzania

Land use mapping

To define the land use categories and develop a land use map of the study area different sources of information were used. A base map of the study area was derived from satellite images, aerial photographs and existing maps. The topographic maps of 1985 (scale 1:50,000) and two series of aerial photographs of 1996 (scale 1:54,000) and 1976 (scale 1:30,000) were used to locate the different villages, the agriculture fields, the plantations and the roads. Landsat-TM satellite images of 2003 and 2008 with resolution 30 m were used to derive information on land cover, supported by systematic ground survey to verify remote sensing information.

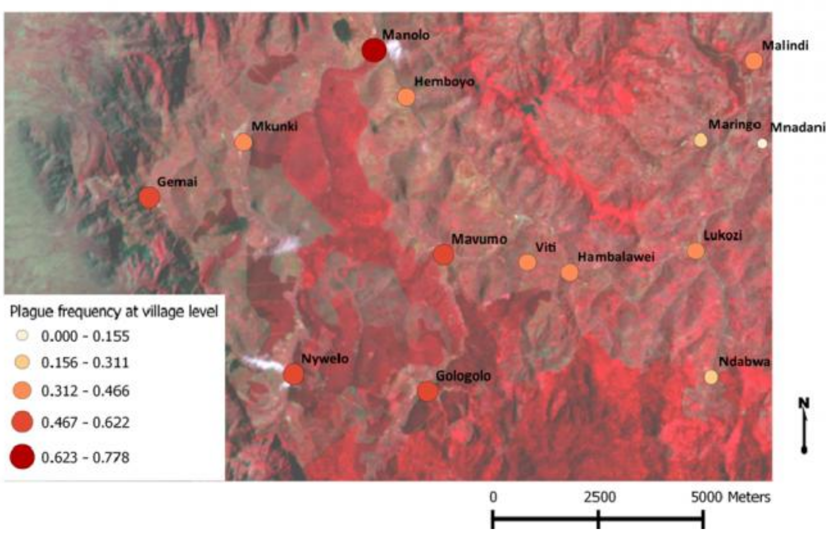

Figure 2: Plague frequency at village level projected on a LANDSAT image of 2003

The classification codes in this study used the terminology of the guidelines for soil description of Food and Agriculture Organization (FAO, 2006) and the description of the different land use categorizations was based on Anderson *et al*. (1976). ArcGIS 9.2 was used as technical platform to create the land use map at a scale of 1:80,000. Global Positioning System (GPS) was used to record village and hamlet coordinates, water sources, firewood collection places, marketplaces and different settlement infrastructures including dispensaries, churches, mosques, and timber factories.

Human activities and flows data set

Field observations and focused Participatory Rural Appraisal (PRA) methods were used during the fieldwork to define categories of human activity in the outdoor environment. Key informants, including the village executive officers, agricultural managers, villagers, and district officers were interviewed and group discussions were held to generate a joint categorisation of land use and human activities. A field survey of predetermined categories of key sites, such as hamlets, water wells, and markets was done.

A human participating to any of the activities is called an "agent". Out of the list of outdoor activities, a selection was made based on the result of group discussions. The selection of these activities was inspired by the importance of the activity concerning the livelihood, the time consumption and the contact frequency with specific landscape objects and other people. The spatial location of the activities was, where possible, georeferenced using a GPS to extend the land use map to a more detailed scale of 1:20,000 including the human activities. A questionnaire was composed and corrected prior to its use by a multidisciplinary team. The questionnaire was tested and modified several times until a satisfactory state was reached. The actual fieldwork covered 240 semi-structured interviews and 30 group discussions. The first part of the questionnaire investigated the purpose of the activity and the specific resource location; the second part the duration and the frequency, and the third part the involvement of other people.

The different variables retrieved from the questionnaire used in the statistical analysis were the duration, the frequency and the type of activity place. The duration is the time necessary to complete an activity including the trip. The duration is a useful parameter to interpret the accessibility of the type of source because waiting time was included. The frequency was the amount of times the activity was done in a certain time interval, e.g. x times per day or x times per week.

Table 1: Categories of ordinal data (columns 'code') derived from questionnaires

Frequency WF		**Duration WF**		**Frequency FC**		**Duration FC**		**Frequency M**	
Code	Description	Code	Description	Code	Description	Code	Description	Code	Description
0	<1/day	1	<30min	1	<1/week	1	<1h	1	Every week
1	1/day	2	30min-1h	2	1/week	2	1h	2	>1/month
2	2/day	3	1h	3	2/week	3	2h	3	1/month
3	3/day	4	2h	4	3/week	4	3h	4	<1/month
4	4/day	5	3h	5	4/week	5	4h		
5	5/day	6	4h	6	5/week	6	5h		
6	6/day	7	5h	7	6/week	7	6h		
7	7/day	8	6h	8	7/week	8	>6h		
		9	>6h	9	>7/week				
Type of water body						**Type of FC place**			
Code	Description					Code	Description		
1	River					1	Natural forest		
2	Spring					2	On the field		
3	Water well					3	Plantation		
4	Tap					4	Timber factory		

Key: WF=water fetching; FC=firewood collection; M=going to the market; h = hours

The measurement scale of the questionnaire is categorical with qualitative and discrete variables. Therefore, all the variables are treated as ordinal because the variables can be ranked in different levels. The type of destination place is also treated as ordinal variable. For water fetching, the ranking is based on the technical level of the water delivery system (from natural wells to taps) and on the water quality. For firewood collection, the levels are based on the accessibility and the human energy needed to obtain firewood.

Table 1 represents an overview of the ordinal data categories derived from the semi-structured interviews. A representative sample of people was interviewed concerning the three selected activities and the places and distances involved. The data collection of the questionnaires was done in three different modes: a first one was at different destination places (for example a water source), the second mode was at origin places (for example different households at hamlet level), and the third mode was during transect walks with local informants. The problems, the opportunities and the different living and working conditions of the villages and in the village grounds were observed during the transect walks. The targeted agents were mostly women as women are mainly responsible for domestic activities such as fetching water and collecting firewood in this area.

Data analysis and synthesis

The spatial synthesis of the distribution of the overall activities of households and individuals - their activity spaces - was done using the methodology of the Standard Deviational Ellipses (SDE) (Lefever, 1929; Yuill, 1971; Levine, 1996; Eryando *et al*., 2012). SDE provides a visualization of a trend of sample points (Schönfelder & Axhausen, 2003; Sherman *et al*., 2005) and models how activities are concentrated around a geographic mean, and provide information about dispersion and orientation. In this study, the activity spaces were drawn at village level to find interrelationships between different villages. This scale level matches well with the scale at which the overall land cover and land use have been defined in this study, as well as the resolution of the plague database.

ArcGIS 9.2 was used to draw the activity spaces. The data used for this spatial analysis was the combination of data of the different questionnaires summarized at village level, and the GPS measured coordinates of the activity locations. Most people have no motorised transportation facility, so the range of the activity space was defined as the distance over which agents are able to walk in a certain time interval with the goal to make use of a service or obtain goods. Since the observed activities in this study are necessary for the livelihood, the observed activity spaces correspond with nearly the maximal area over which an agent engages in his or her normal activities (Newsome *et al.,* 1998; Schönfelder & Axhausen, 2003).

The plague frequency was correlated with the travel and activity data from the questionnaires. The frequency, duration and type of activity place were correlated with the two parameters to investigate to what extent they predict the occurrence of the plague, and to find relationships between the activities and human flows. The statistical analyses were executed with the software package SPSS 18 (IBM, 2009). The village was defined as the basic spatial unit.

Ethical considerations

This study received approval from Directorate of Research and Post-Graduate Studies of Sokoine University of Agriculture, Tanzania and Flemish Inter-University Council (VLIR-UOS) of Belgium.

Results

Ten major land use types were identified. The dominant types on the map are Irrigated Agriculture (AI), Rainfed Agriculture (AR), Plantation Forestry (FP), Natural Forest (FN), Forest Reserve (FR), Mixed Forestry (MF), Extensive animal Husbandry (HE), Recreational use (SRe), Residential use 1 (SR1), and Residential use 2 (SR2) (Figure 3). Over 130 activity types were identified and listed. From these three were retained after group discussions: fetching water, collecting firewood and going to the market. Table 2 provides a contrasting picture between the villages, concerning the source of domestic water. For instance Mnadani and Ndabwa exclusively rely on spring water, whereas Malindi, Manolo and Maringo rely on water wells. The type of destination place “stream” was located between the agricultural fields in the valley of the village.

This is the least preferred source of water because of the low quality of the water compared to the tap. However, the plague frequency (PF) was not significantly correlated with the type of water source.

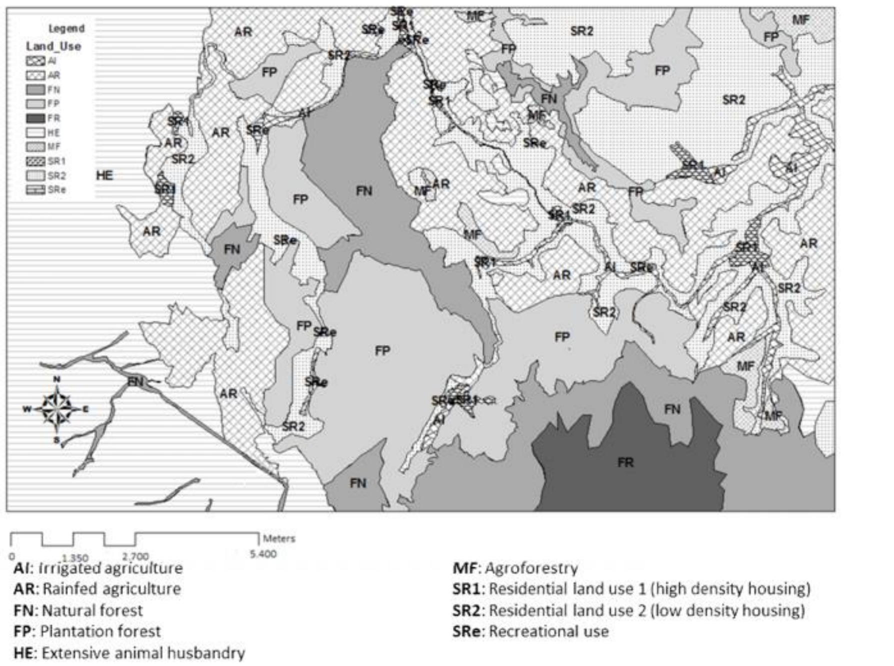

Figure 3: Identified and classified land use types in the study area

Table 3 gives insight in the collection places for firewood. Compared to water, the villages tend to use more diversified sources of firewood, but still there is a pattern of certain villages relying more on plantation, on wood growing in the agricultural parts, on natural forest, or on the presence of a timber factory. The correlation between firewood collection and plague frequency (PF) differs according to the type of firewood site. We found a strong positive correlation $\rho=0.608$ ($p<0.05$) for "plantation" and a strong negative correlation $\rho=-0.714$ ($p<0.01$) for "timber factory". This result shows that the plague frequency was higher in villages with agents collecting firewood from "plantation" as opposed to "timber factory".

Table 2: The different type of water sources determined by the percentage of the agents of the 14 villages

Villages	Tap (%)	Water well (%)	Spring (%)	Stream (%)
Gemai	6	0	59	35
Gologolo	100	0	0	0
Hambalawei	100	0	0	0
Hemboyo	27	55	0	18
Lukozi	95	0	5	0
Malindi	0	100	0	0
Manolo	20	80	0	0
Maringo	0	100	0	0
Mavumo	60	40	0	0
Mkunki	86	8	6	0
Mnadani	0	0	100	0
Ndabwa	0	0	100	0
Nywelo	60	0	40	0
Viti	100	0	0	0

The five marketplaces in the study area were ordered based on their sizes and trade from high to low as follows: Lukozi, Manolo, Viti, Gologolo, and Nywelo (Table 4). Marketplaces are gathering places, and so might facilitate contagion from one person to other persons. The majority of agents travelled to Lukozi (57%) and to Manolo (20%). Also, the market of Viti received 19% while Gologolo and Nywelo attracted only 2% each of market agents. These results show that Lukozi, Manolo and Viti have an important sphere of influence while in contrast Gologolo and Nywelo were more local markets with a small sphere of influence. The results also reveal a strong negative correlation between the visits to the two largest markets at Lukozi and Manolo $\rho=-0.932$ ($p<0.01$), which means the agents in the study used to visit either Lukozi or Manolo. There was also a positive correlation between the plague frequency (PF) and visiting Manolo market ($\rho=0.538$ ($p<0.05$) and a negative correlation between the PF and visiting Lukozi market ($\rho=-0.663$ ($p<0.01$). Note that, Manolo was a village with a high plague frequency during the period 1980-2003 (Table 5).

Table 3: Type of firewood collection places determined by the percentage of the agents of the 14 villages

Villages	Natural forest (%)	On the field (%)	Plantation (%)	Timber factory (%)
Gemai	0	100	0	0
Gologolo	0	0	100	0
Hambalawei	0	12	50	38
Hemboyo	7	14	79	0
Lukozi	11	56	0	33
Malindi	29	14	0	57
Manolo	25	62	13	0
Maringo	0	0	0	100
Mavumo	0	0	100	0
Mkunki	0	0	100	0
Mnadani	0	43	0	57
Ndabwa	100	0	0	0
Nywelo	3	17	80	0
Viti	24	8	20	48

Based on the data of Tables 2, 3 and 4, the human flows are represented in Figures 4, 5 and 6 for water fetching, firewood collection and market visiting, respectively. The land use map in the background is used as geographical reference. The thickness of the linking lines represents the percentage of agents of a certain village going to a specific destination. The human flows are represented by straight lines because detailed information on the route network was lacking. The human flow maps show the dispersion of the activities of agents from a certain village and give an indication of the overall connection between the villages. Moreover, the visual comparison of the flow maps indicates the interrelationships of the selected activities summarized at village level in terms of dispersion, distance and self-sufficiency. Table 5 present the plague frequency (PF) of villages represented in Figures 4, 5 and 6.

Table 4: The different marketplaces determined by the percentage of the agents of the 14 villages

Villages	Gologolo	Lukozi	Manolo	Nywelo	Viti
Gemai	0	7	86	0	7
Gologolo	31	43	3	0	23
Hambalawei	0	55	3	0	41
Hemboyo	0	33	37	0	30
Lukozi	0	100	0	0	0
Malindi	0	100	0	0	0
Manolo	0	33	33	0	33
Maringo	0	93	0	0	7
Mavumo	0	50	0	0	50
Mkunki	0	27	46	5	22
Mnadani	0	91	0	0	9
Ndabwa	0	86	0	0	14
Nywelo	0	41	36	16	7
Viti	1	43	13	0	42

Most agents from villages had adequate access to natural or artificial water sources in the village; hence the villages were self-sufficient except for the villages of Mkunki and Mavumo. Agents from Mkunki had to travel to other villages (mainly Nywelo and Manolo) to fetch water. The explanation of the long distance the agents travelled to fetch water in Nywelo and Manolo is the presence of a continuous working water tap in Nywelo and several water wells in Manolo.

Table 5: Plague frequency (PF) of the villages representing the studied human activities and flows

Village	PF	Village	PF	Village	PF
Gemai	0.556	Malindi	0.333	Mnadani	0.000
Gologolo	0.556	Manolo	0.778	Ndabwa	0.278
Hambalawei	0.389	Maringo	0.278	Nywelo	0.556
Hemboyo	0.389	Mavumo	0.611	Viti	0.389
Lukozi	0.389	Mkunki	0.444		

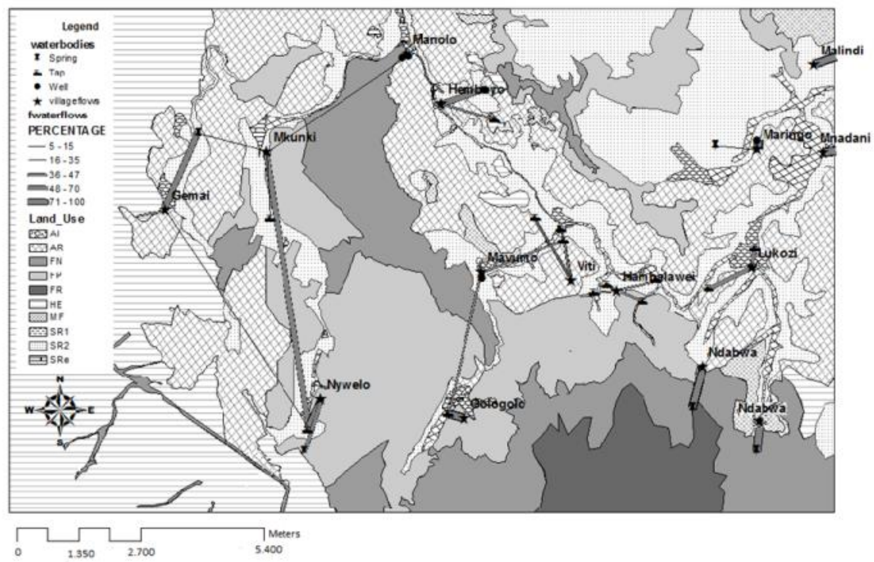

Figure 4: Human flows to fetch water at village level

The activity patterns of firewood collection (Figure 5) were more widely spread than the human flows of water fetching. The self-sufficiency of the villages for firewood was less than that for the activity of water fetching as water was being collected closer to home in comparison to firewood. In addition, the collection of firewood from the natural forest was predominantly done by agents from neighbouring villages, such as Ndabwa and Manolo.

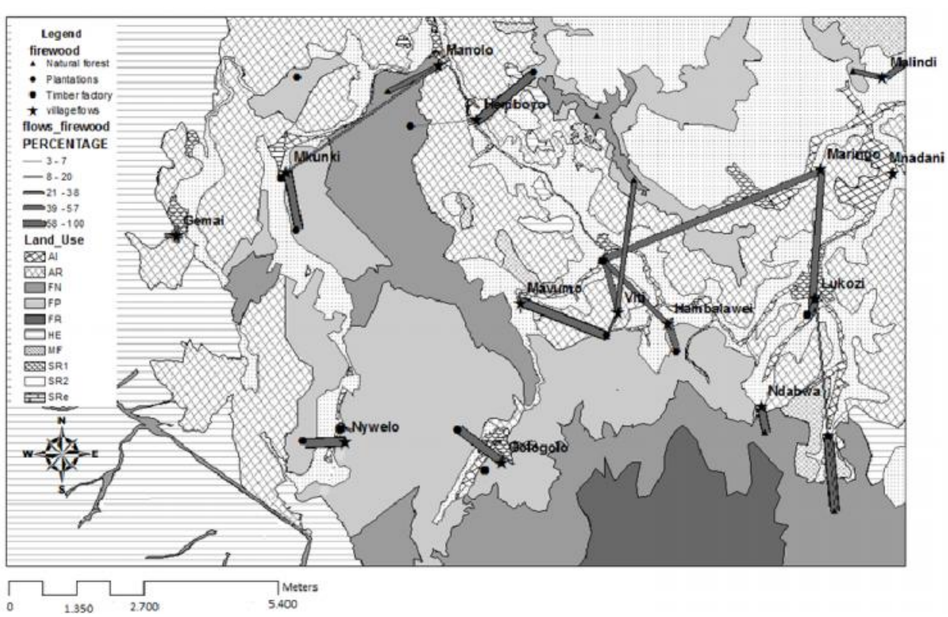

Figure 5: Human flows to collect firewood at village level

Nywelo and Gologolo were local markets, for which a small sphere of influence was found. Viti had a medium sphere of influence and Manolo and Lukozi had the largest sphere of influence. The sphere of influence of Manolo was to be found on the western side of the study area (represented by a higher percentage of agents going to Manolo instead of Lukozi) and the sphere of influence of Lukozi was located essentially in the eastern part of the study area. People from further distant villages, such as Mkomazi, Lushoto, Mlalo, Mkumbara and Emao, also visited the markets but information on their flows was not available.

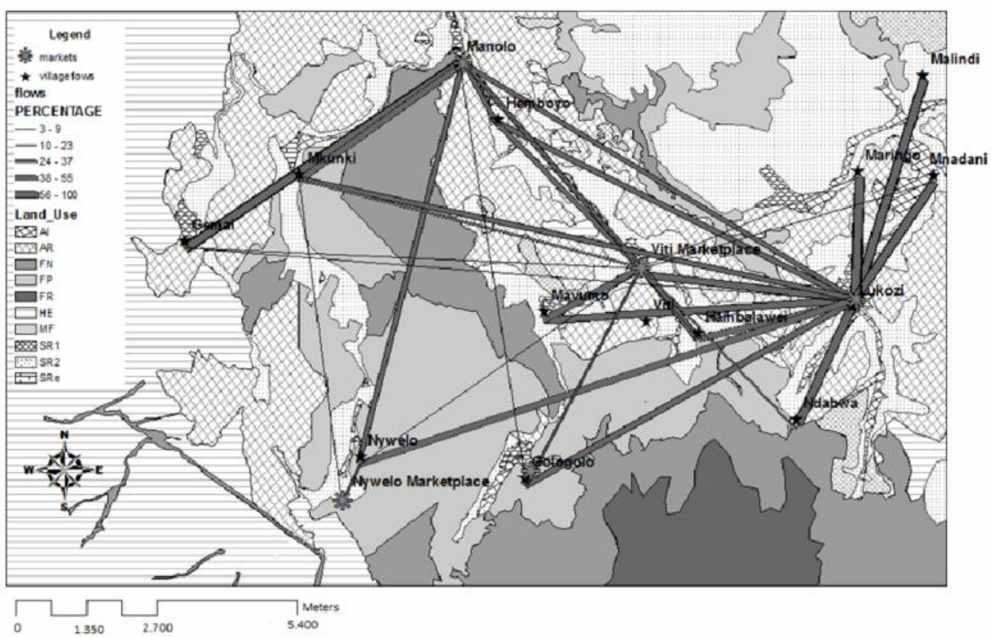

Figure 6: Human flows to go to the market at village level

The activity spaces of the villages are shown in Figures 7 and 8. The villages of Malindi and Mnadani were not used in this analysis because they are situated on the border of the study area and not all the activity sites and facilities were mapped which gives a scattered visualization. An illustration of the example of drawing the standard deviational ellipses (SDE) as activity spaces for the villages Gemai, Gologolo and Lukozi is represented in Figure 7. The plague frequency (PF) was positively correlated $\rho=0.600$ ($p<0.05$) with the area of the activity spaces. The villages with a high PF had a larger area of activity space, or in other words agents from villages with a high PF had a higher dispersion of activities. The results suggest that agents from a village with higher PF have to travel over larger distances to complete the overall activities.

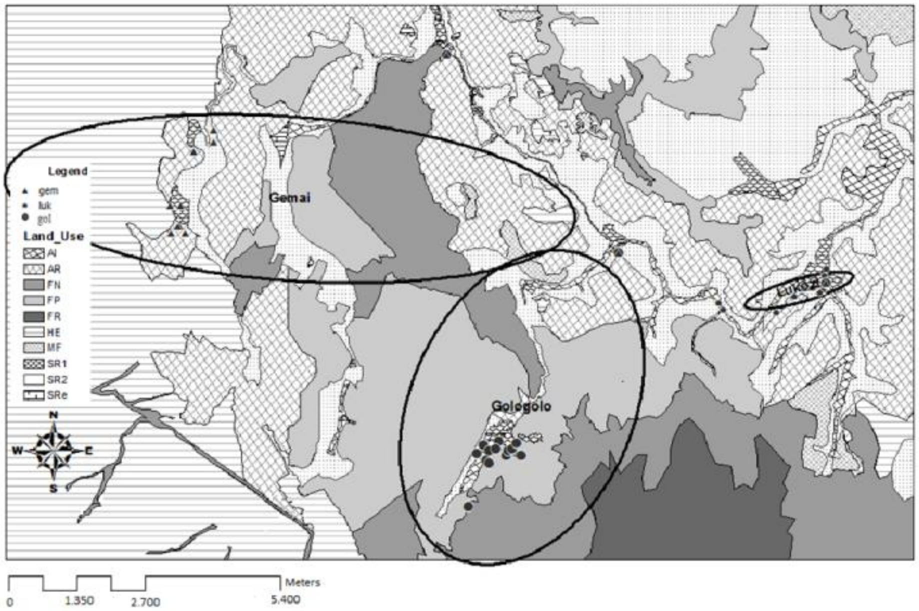

Figure 7: Ellipses representing the activity spaces for Gemai, Gologolo and Lukozi villages

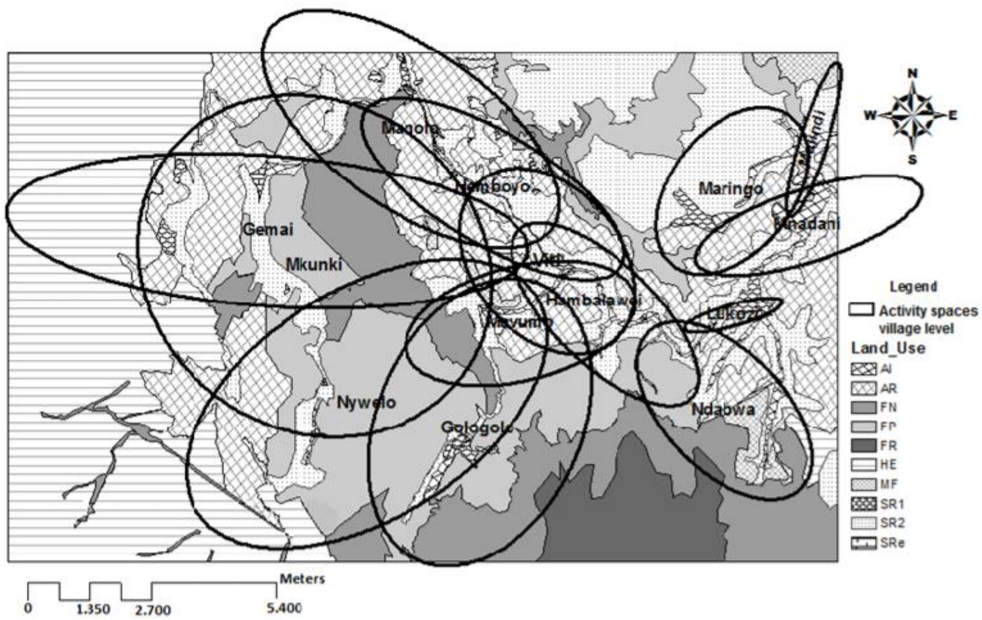

Figure 8: Activity spaces at village level

Discussion

The purpose of this paper was to introduce land use and more particularly the associated human flows as hypothetical factors to help explain the presence or absence of plague in villages in the Western Usambara Mountains. The results show a remarkable positive correlation of plague risk with the extent of activity spaces linked to household related activities and uses of the territory. Each of the selected activity types taken separately, fetching water, collecting firewood and visiting markets adds to the statistical relations with the registered plague incidences and frequencies at village level. However, land use has many forms, and it would have been difficult to investigate in depth 130 human activities related to the identified land use types in this region. The selection made was not haphazard but based on intensive discussions with a wide range of stakeholders. The three selected human activities (market visiting, fetching water and collecting firewood) stand out in the sense that they all have their spatial origin in households, which in turn are key elements in villages. Also they generate spatial activities on a very regular basis, year round. Furthermore, their destinations stand out as potentially hazardous places.

Two of the activities (firewood and water fetching) are strongly linked to the spatial distribution of natural factors, and a third (visiting markets) generates direct social contacts across the region. So with these three activity types it was certain to cover an important fraction of activity spaces in the study area. It turns out that these important land uses or activities are essentially performed by women and partly also by children. There is certainly no ground to exclude men, eventually also tourists or other parties from this kind of research. This gives clues to launch complementary anthropological and sociological research in order to obtain a stronger picture of the landscape of human activities and the contribution of different population categories. An important advantage of this selection of activities carried out by women was the efficiency with which distinct activities could be probed in a same major sociological category.

The importance of ecological and biological factors and their relationship with the plague occurrence is highlighted by the positive correlation between the plague frequency and the plantations and the negative correlation between the plague frequency and the timber factories. A possible explanation for the correlation could be the increase in contact frequency between humans and the plantation forest, which was reported in earlier studies to be suitable habitat for plague hosts and vectors (Kilonzo *et al*., 1997). The timber factories may not be suitable habitats for hosts and vectors because these are temporarily erected in sites close to areas where timber harvests are being carried out. Agents who visited the market of Manolo came typically from a village with a higher plague frequency while in contrast agents who visited Lukozi predominantly came from villages with a lower plague frequency. This study found no relationship of frequency of plague and the type of water source uses. One would expect some positive correlation with the use of water from streams, as these can match the habitats of rodents or other carriers of the plague bacterium.

The plague frequency was positively correlated with the area of activity spaces. This result is consistent with studies by Morse (1995) and McMichael (2004) who reported the consequence of travel for emergence of infectious diseases. Moreover, the finding that the home location is an important determinant for the size of the activity spaces is consistent with what was observed in other studies (Newsome *et al*., 1998; Builing & Kanaroglou, 2006).

The details of the information on both the plague frequency and the origin of the land use actors was not precise enough to execute this spatial analysis at hamlet level, let alone at the level of household. The connectivity between origins (villages) and destinations (market places etc.) was also modelled in a coarse way, assuming straight lines. Inserting information of the concrete pathways people take during their activities in the landscape may enhance substantially not only the estimation of distances travelled, but also give more subtle clues on features encountered, and eventually physical contact to these features. Also the spatial activity relations between villages and between other land use categories should be studied in a more refined way. Monitoring activities over time might reveal how for instance the alteration of water quality at specific source points, or the closure of forests for collecting fuel wood, may alter the spatial behaviour of people. This study did not consider travel over longer distance and outside the study area. Moreover, this study did not investigate the causation of the correlations. Future plague research should continue this analysis and take into consideration a broader range of agents, land uses, and associated territorial activities. Also, much would be gained by refining the resolution of both the data on plague incidence and on the details of landscape features and land use. This will allow to model village-specific data on risk factors against the human activity space variables to study the causal relationships of the observed correlations in this study.

In conclusion, this study demonstrated the possibility to relate outdoor human activities to the spatial distribution of the plague in the Western Usambara Mountains in Tanzania. Different characteristics of land use and related human activities were correlated with the plague frequency at village and hamlet levels. The extent of action spaces centred around villages is an interesting metric to clarify the complex interactions of land use, activities, and plague distribution. The results of this case study indicate the importance to investigate environmental and land use factors in research on diseases like plague.

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