TICK SURVEY ALONG THE GRADIENT OF LAND USAGE IN SIERRA LEONE

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II. Abstract

Within the West African country of Sierra Leone there is a gap in the knowledge base of tick distribution and ecology. With a limited number of studies conducted on ticks over the past decades and no consistent surveillance programs in place, the abundance and diversity of these vectors remains unknown in the Eastern and Western Provinces where this study took place. Risk for tickborne diseases has been well established within the country, as well as its neighboring nations of Guinea and Liberia. The following study was composed of a tick survey across the Moambe, Bo, and Kenema Districts specifically looking at land usage types related to agriculture. The first of two hypotheses of this experiment was there would be a greater diversity and abundance of tick species found in land use primarily associated with livestock. The second hypothesis was there would be a significant correlation between agricultural land use types and their associated environmental factors (temperature, humidity, cloud cover, level of land cultivation, prominent plant type, leaf litter, tree cover, sun exposure, animals observed) and tick abundance. Within the three Districts, eleven transects were chosen based on the primary crop associated with the site and were sampled by flagging. Environmental data were gathered along these transects and included in the data analysis. Overall, 7,220 meters of land were sampled, and 18 ticks were found. There were 17 larval ticks of the genera *Hemoptysis's* and *Amblyomma*, and 1 adult female *Hyalomma rufipes*. The results of the data analysis indicated correlations between the land use types, environmental factors, and both the prevalence and abundance of ticks.

III. Introduction

Review of Literature

The following literature review will provide information regarding the factors surrounding hard ticks and their associated pathogens within Sierra Leone through the lens of the vector triad model. The background review will include information regarding the diseases and competent tick vectors identified in the region, environments in which they may be found, and justification for hard tick collection methodology.

Within Sierra Leone tickborne diseases pose a significant public health risk as they are under reported due to a lack of surveillance for both the diseases and vectors. Within Sierra Leone there are only a small number of tick-borne diseases that have been confirmed. The diseases that have been identified are Crimean-Congo Hemorrhagic Fever (CCHF) and a suite of rickettsial diseases. The number of identified diseases and cases have continued to grow since studies in the mid 2010's uncovered the presence of CCHF, prompting more studies to turn their attention to ticks (Zhang et al., 2019). Due to these factors, the following literature review will include studies that focus on the tickborne diseases and their associated vectors of the two neighboring countries Guinea and Liberia. Beyond the greater level of clarity for potential specimens found and assessment of risk there are a number of factors to support the inclusion of these sources. These factors include the similar environmental conditions, agricultural practices, and consistent exchange of viable hosts across borders.

Rickettsial Diseases.

Of tick-borne pathogens, rickettsial pathogens are among the most widely prevalent and diverse within this area of West Africa (Parola et al., 2013). The first of these diseases in Sierra Leone is African Tick-Bite Fever. The causative agent of African tick bite fever is *Rickettsia* *africae*, a bacterial pathogen. African tick bite fever is a mild to moderate disease whose incubation period typically lasts five to seven days. This disease is not a fatal one, but it is notably the most commonly diagnosed rickettsial disease amongst American travelers returning to the United States from sub-Saharan Africa (CDC, 2023a). African Tick-Bite Fever is also the only tick-borne disease that the CDC currently issues a travel health warning for regarding Sierra Leone (CDC, 2023b). Within Sierra Leone the cases have only been confirmed through serological testing, so the exact vector species within this region is not confirmed. Within sub-Saharan Africa, *Amblyomma variegatum* is a recognized competent vector for African Tick Bite Fever and is also a species whose presence has been confirmed within the country (Gargili et al., 2017). Within Liberia, both *Amblyomma compressum* and *Rhipicephalus geigyi* ticks were found to carry the causative agent, and in Guinea the bacteria were found within *Rhipicephalus annulatus* (Parola et al., 2013). In both Guinea and Liberia, *Amblyomma variegatum* was shown to be a common carrier of *Rickettsia africae*. Another rickettsial disease associated with ticks in guinea is *Rickettsia massiliae*, which causes spotted fever in humans. This disease was associated with *Rhipicephalus senegalensis* and *Haemaphysalis paraleachi* ticks, being transmitted at low frequencies. In 1986 a serosurvey was conducted in tropical rainforest areas of the Bo, Moyamba, Bonthe, and Pujehun Districts of Sierra Leone. This survey found that 5.3% of all sampled individuals from the communities were seropositive for exposure to a rickettsial pathogen. The Rickettsial diseases were not identified to species, and the demographic differences within the seropositive group were significant. Collectively, 73.8% of the 80 positive tests were in individuals over the age of 15, and 62.5% of this group was male (Redus et al., 1986).

Crimean-Congo Hemorrhagic Fever Virus.

Sierra Leone stands out from its neighbors, Liberia and Guinea, as it is the only one to have an autochthonous case of CCHFV reported as of 2021 (Zhang et al., 2019). Crimean Congo Hemorrhagic Fever Virus is a Nairovirus that belongs to the family Bunyaviridae and is transmitted primarily by tick bites. This virus is one of nine pathogens deemed by the World Health Organization to be considered a priority pathogen. This classification is granted to the causative agent of disease due to its potential capability for epidemic spread and for the lack of sufficient countermeasures if a spread should occur (WHO, 2022). The one confirmed case of Crimean Congo Hemorrhagic Fever in the country was verified in a study based out of the capital city, Freetown, where serum samples were analyzed. These serum samples were collected from Sierra Leonean patients who were suffering from febrile jaundice at satellite hospitals across the country. The purpose of the study was to test for a number of potentially endemic diseases. This differed from the country's standard procedure for febrile jaundice, which is to test exclusively for yellow fever. This lack of diversity in surveillance for diseases is a result of scarce resources available and relatively low prioritization to identify cases of diseases such as CCHFV within the country. The sample was collected and confirmed in 2016 and the patient was between the age of 6 to 20 years old (Zhang et al., 2019). Beyond this one confirmed case Sierra Leone has also shown seropositivity for CCHFV within its residents. Also occurring in 2016, the Kenema Hospital Lassa Fever Diagnostic Laboratory analyzed blood samples gathered from patients suspected of having Lassa Fever across the country and tested for a variety of diseases. Of the 641 samples that underwent serological testing, 13 were positive for Crimean Congo Hemorrhagic Fever virus (O'Hearn et al., 2016). The combined factors of having a confirmed case as well as seropositivity within the population put Sierra Leone at a greater classification of risk than its neighbors, Liberia and Guinea. Liberia and Guinea also test for the virus' presence in similar methods across humans, animals, and ticks using qPCR and serological surveys (Mediannikov et al., 2012). Liberia has also demonstrated seropositivity for CCHFV when residents have been tested, but has so far, not reported any active cases. Guinea differs from both of its neighbors in the fact that there is no current confirmation of active cases nor seropositivity in the population. However, studies in Guinea isolated the pathogen within ticks of the genus *Hyalomma* (Temur et al., 2021). Having informed practice is especially important given the evidence of high risk for this priority pathogen in the country and surrounding regions. Specimens of *Hyalomma rufipes, Hyalomma truncatum*, *Rhipicephalus evertsi,* and *Amblyomma variegatum* have been found within Sierra Leone. These are all species that are capable vectors for CCHF, especially those of the genus *Hyalomma* (Table 1). From a public health perspective, knowing of the presence and abundance of competent vectors for the aforementioned diseases within the Districts of Sierra Leone could influence policy and prevention practices (Mackenzie et al., 2019).

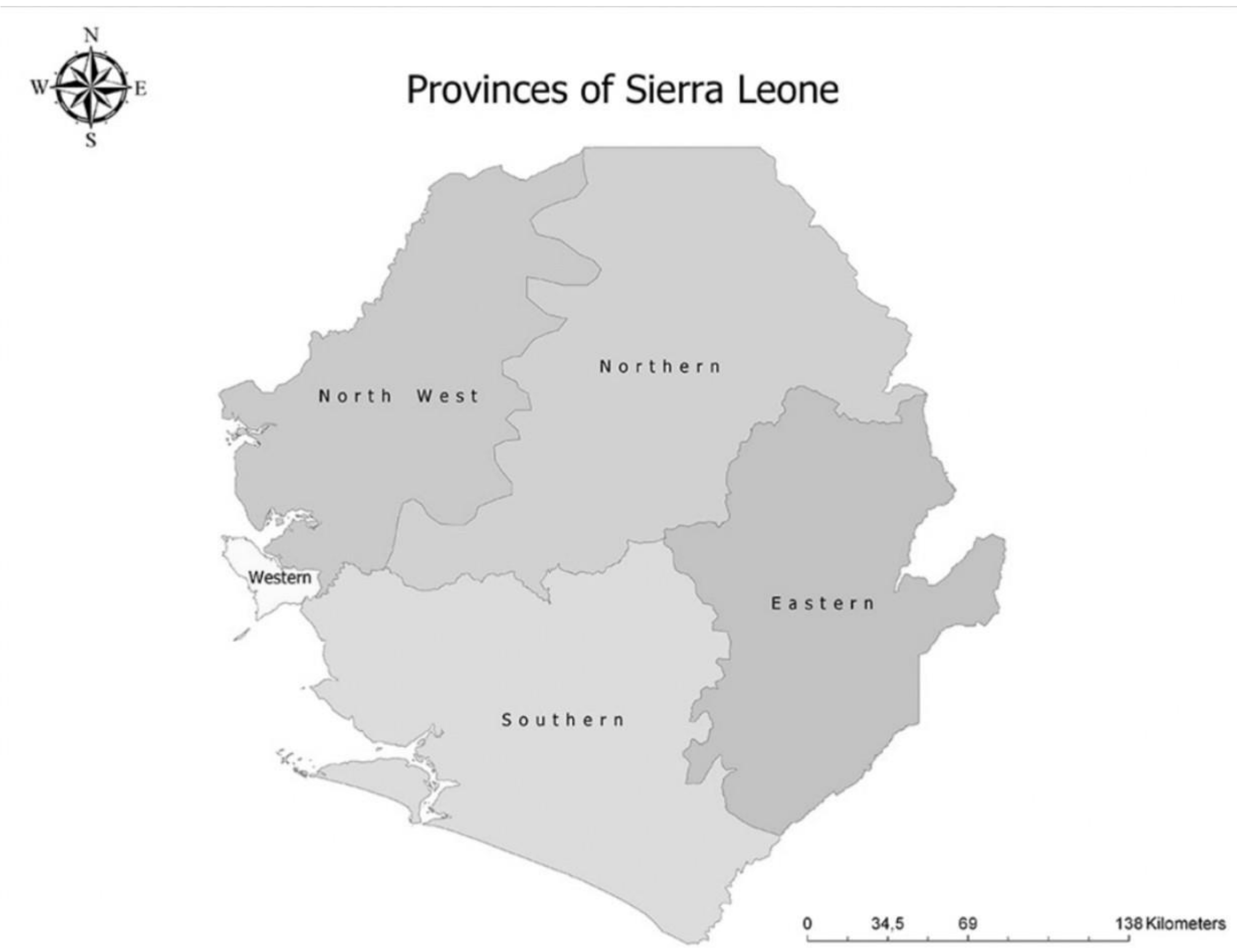
Table 1. Known Tick Species and Associated Pathogens in Sierra Leone and Neighboring Countries				
Genus & Species	Disease Agent Associated	Country Where Identified	Citation	Detection Method
Amblyomma compressum	*Rickettsia africae*	Liberia	(Parola et al., 2013) (Mediannikov et al., 2012)	Ticks collected from domestic and wild animals; disease detected using qPCR.
Rhipicephalus geigyi	*Rickettsia africae*	Liberia	(Parola et al., 2013) (Mediannikov et al., 2012)	Ticks collected from domestic and wild animals; disease detected using qPCR.
Rhipicephalus annulatus	*Rickettsia africae*	Guinea	(Parola et al., 2013) (Mediannikov et al., 2012)	Ticks collected from domestic and wild animals; disease detected using qPCR.
Rhipicephalus senegalensis	*Rickettsia massiliae*	Guinea	(Parola et al., 2013) (Mediannikov et al., 2012)	Ticks collected from domestic and wild animals; disease detected using qPCR.
Haemaphysalis paraleachi	*Rickettsia massiliae*	Guinea	(Parola et al., 2013)	Ticks collected from domestic and wild animals; disease

				detected using qPCR.
Amblyomma variegatum	*Rickettsia africae*	Liberia	(Mediannikov et al., 2012)	Ticks collected from domestic and wild animals; disease detected using qPCR.
Amblyomma variegatum	*None*	Sierra Leone	(Gargili et al., 2017)	Collection of questing specimens
Ixodes muniensis	*Rickettsia Raoultii*	Liberia	(Mediannikov et al., 2012)	Ticks collected from domestic and wild animals; disease detected using qPCR.
Amblyomma variegatum	*Rickettsia africae*	Guinea	(Mediannikov et al., 2012)	Ticks collected from domestic and wild animals; disease detected using qPCR.
Rhipicephalus decoloratus	*Rickettsia africae*	Guinea	(Mediannikov et al., 2012)	Ticks collected from domestic and wild animals; disease detected using qPCR.
Hyalomma marginatum	*Rickettsia africae*	Guinea	(Mediannikov et al., 2012)	Ticks collected from domestic and wild animals; disease detected using qPCR.

Hyalomma rufipes	*None*	Sierra Leone	(Gargili et al., 2017)	Collection of questing specimens
Hyalomma truncatum	*None*	Sierra Leone	(Gargili et al., 2017)	Collection of questing specimens
Rhipicephalus evertsi	*None*	Sierra Leone	(Gargili et al., 2017)	Collection of questing specimens

Environment and Agriculture.

Figure 1: ***Map of Sierra Leone***



Note: (Mappr, 2023)

Sierra Leone is composed of four Provinces and sixteen Districts (Figure 1). The Northern and Eastern provinces are considered the primary producers of agriculture in Sierra Leone, with the Northern province dominating the livestock market (beef, goat, and sheep) as well as having numerous rice paddies. The Eastern Province is the primary part of the country for mixed crop plantation-style agriculture for products such as cocoa and palm oil (Savaria-Matus et al., 2021). The Southern province is known to have high acreage of rice fields, but to a lesser extent than the North. Similarly, the Northwestern Province is known to have plantation style agriculture to a lesser extent than the Eastern Province (Savaria-Matus et al., 2021). The Forest Reserves are important components to the study as they represent a portion of what is left of the natural ecosystems of the Eastern and the northern part of Southern provinces of Sierra Leone (FAO, 2005). It is notable that these have not been converted to agricultural land, and primary forest and savannahs exist within the reserves. These reserves do suffer from human encroachment, as seen in the Kasewe forest; individuals utilize the timber for charcoal production and engage in poaching as explained through personal communications with Emmanuel Kamanda, a collaborator who has conducted research in the area regularly and lives within the District. Meteorological data gathered in the Moyamba District from 1991 to 2020 has shown that there is slight variability of the timing of the rainy and dry seasons' start times, but there is not a significant difference in the rainfall during the rainy season compared to past years (Wadsworth et al., 2019). This information is notable because collection of data for the current study occurred during the rainy season.

The current study was focused on determining the diversity and abundance of ticks based around the dominant agricultural land use types in the Eastern and Southern Provinces of Sierra Leone. Agricultural land usage was chosen as the basis for comparison due to the proximity many fields have to livestock reservoirs, wild animal reservoirs, and natural ecosystems. Within Sierra Leone, agricultural land usage is adjacent to residential areas. Even in District capitals, land dedicated to agriculture will intersect neighborhoods. Time spent engaging physically with plants and livestock increases the risk of exposure to ticks. Individuals working fields or plantations often do so through manual labor due to a lack of utilizing agra-machinery in the country. Many are also small holder subsistence farmers without need of machinery. These farmers are more intimately exposed to the foliage of their crops while utilizing local traditional tools (International Trade Administration U.S., 2023). This intersection of population and land usage could increase the potential for human/vector overlap if the vector is present.

Rationale for Pursuing Tick Surveys.

Within Sierra Leone, the three most important vectors and reservoir hosts currently known are mosquitoes of the *Anopheles* genus, mosquitoes of the genus *Aedes*, and rodents (Jones et al., 2023). *Anopheles* mosquitoes are known to transmit malaria at significantly high rates within the country, resulting in notably high rates of morbidity and mortality (National Malaria Control Program, 2016). Malaria statistics from 2019 state there were over 6,800 deaths and over 2.5 million cases reported (CDC, 2023c). *Aedes* mosquitoes are known to transmit chikungunya and dengue fever viruses at significant rates. A serosurvey of 1,795 febrile residents in the Bo District reported that 5% were positive for markers of dengue infection and 39% were positive IgM directed against chikungunya (Dariano et al., 2017). Rift Valley fever, yellow fever, and Zika viruses are believed to be transmitted at low rates by *Aedes aegypti* but are only confirmed through serosurvey with no known active cases (Jones et al., 2023). Rodents of the genus *Mastomys* are implicated in the transmission of Lassa fever virus at a moderate to high rate within the country (O'Hearn et al., 2016). All three of these vectors have robust surveillance systems in place for their presence and the diseases they transmit. For the mosquito-borne diseases there is surveillance of both the vectors and disease that is supported through programs such as the U.S. President's Malaria Initiative. Monthly entomological surveillance occurs within 5 representative Districts, and monthly reports of suspected malaria cases are sent for review from chiefdoms across the country (U.S. President's Malaria Initiative, 2022). For Lassa fever there is the Kenema Government Hospital Lassa Fever Diagnostic Lab that acts as a surveillance site, reporting on the disease from the endemic Eastern Province. Ticks are an often overlooked vector in many parts of the world, but should not be in Sierra Leone given the risks they pose.

Little is known about tick diversity and prevalence in Sierra Leone. A majority of domestic and international funding for arthropod diseases is allocated to the treatment and surveillance of mosquito-borne diseases such as malaria and yellow fever. While these diseases are more abundant, the rate at which tick-borne diseases are spreading or at risk of becoming endemic is unknown. There is a lack of resources allocated to surveillance. Species surveys and censuses have occurred in surrounding countries, but there is a severe lack of information on the species present in Sierra Leone regarding tick vectors (Jones et al., 2023).

There are a number of factors that contribute to the lack of surveillance for tick-borne diseases in Sierra Leone. A supplemental conceptual model was developed to visualize probable barriers and their interconnectedness (Appendix A). The major barriers include the number of tick species that can access multiple hosts and carry a wide variety of diseases, the high cost of testing for the wide range of potential diseases, and the lack of availability of storage for reagents for tests at specialized labs. Many cases likely go unrecorded and untreated. It is currently unknown which individuals associated with what land usage or occupations are specifically most at risk or affected. The first step towards addressing this issue is to have a basis of knowledge about the potential tick vector species present in the area. The current study is an early exploratory attempt to identify what tick species are present in the agricultural settings of the Kenema, Bo, and Moyamba Districts.

IV. Aims and Hypotheses

Aim: The aim of this research project is to investigate the diversity and abundance of tick species in relation to different land uses in Sierra Leone.

Objectives: To collect ticks and identify them to species level.

Research Question: Does land use correlate with differences in species diversity and density of ticks within rural Sierra Leone?

Hypotheses:

Hypothesis 1: There will be a greater diversity and abundance of tick species found in land use primarily associated with livestock.

Hypothesis 2: There will be a significant correlation between agricultural land use types and their environmental factors (temperature, humidity, cloud cover, level of land cultivation, prominent plant type, leaf litter, tree cover, sun exposure, animals observed) and tick abundance.

V. Methods & Materials

Study Setting/Site Selection

Site Selection.

Field sites were identified in the Kenema, Bo, and Moyamba Districts of Sierra Leone (Figure 2). These locations were chosen based on their land usage type of major agriculture practice. The land use categories that were the primary targets were livestock grazing land, swamp-agriculture rice paddies, cocoa plantations, oil palm plantations, and tourism-oriented forest reserves. Sites from different areas of the country were compared based on land usage type, environmental factors, and tick abundance. Environmental factors for each site were recorded for comparison and analysis for any correlations where ticks were found. When selecting specific sites within these Districts local collaborators' knowledge was an integral component for determining villages that hosted the land use type that was desired for that District. It was important that they had familiarity with local officials to negotiate the land to be accessible. This study associated each District with a transect directly related to the major agricultural land use type their region of the country is associated. The Kasewe forest reserve was sampled to give insight into the land use of protected forests and savannahs utilized for tourism and human encroachment on the natural ecosystem. Rice paddies and other swamp-fallow agriculture were sampled in Bo at two sites. The first was a recently developed neighborhood that had converted the natural swamps and forest into fallow-agricultural fields that run through the middle. The second was a Chinese owned farm utilizing a more structured terrace approach to rice paddy infrastructure. On the Njala Agricultural Campus livestock ranch sampling occurred to give insight into livestock committed land use as well as in Njala Village. Additionally, a cocoa plantation and oil palm plantation were sampled respectively in Hangha village in the Kenema District. In each of these sites the transects prioritized areas that had an intersection of the crops/livestock or animal reservoirs and daily human interaction. In each of these sites there were at least two 750 meter transects sampled. Three partial transects were also maintained following interruption of collection due to weather. The first of these transects was directly adjacent or through the primary crop/agricultural interest of the region that the site was associated with. The next would conform with the secondary crop of the area, as many of these areas had a primary income crop but also engaged in sustenance farming or mixed-crop farming practices within a village. This secondary crop and land use type was recorded. If there were multiple types of crops grown the following transect was sampled in the same manner. Proximity of residential areas and where semi-domestic animals such as dogs or chickens frequented was taken into consideration. Proximity of animals to areas of human interaction was an important factor that helped influence transect selection on site.

Figure 2: ***Locations of Testing Sites***

Materials & Equipment Construction

Materials & Equipment.

General materials required to complete the study included notebooks, pencils, and safety protocol sheets. For the construction of the flag scissors, 100 cm by 114 cm flannel squares, poles, a stapler, and thread and needle for repairs were utilized. For sampling along the transects measuring tape, nylon cord 10m, wooden stakes for plot marking, a downloaded digital map on ArcGIS app to mark offline, the excel mobile app, a China CDC nationally patented thermo-hygrometer, labels, jars/test tubes, permanent markers, 90% isopropyl alcohol, and tweezers were used. For soil samples a microwave, 1000g Pesola Light-Line Spring Scale, oven mitt, and Ziplock bags were required. For the identification of the collected ticks microscope slides, identification manuals, tweezers, and a Fisherbrand Basic Stereo Zoom Microscope were utilized. For safety all of the field research team wore protective clothing treated with permethrin, carried additional bug spray, and kept duct tape on hand. For statistical analysis and data management excel and the IBM SPSS program were used on a personal laptop.

Tick Flag Construction.

For this study a flag was utilized for collection of questing ticks. To construct the flag a cotton flannel cloth was utilized. The cloth was measured to a rectangle 100 cm in width and 114 cm in length. A top pocket was created by folding the width of the cloth in by 7 cm around the wooden dowel, which must be longer than 1 meter, and utilizing a stapler to fix the cloth to the wood. The wrapping process was repeated once more with another 7 cm of cloth to ensure adherence and stapled once more. The final flag’s dimensions were measured to ensure that it was 100 cm by 100 cm (Espada et al., 2021).

Sampling Protocols/Data Collection

Safety.

Safety protocols used in this study were built on of the CDC's recommendations for researchers engaged in tick surveillance (CDC, 2020). When conducting field work protective clothing was required. Long sleeved shirts and long pants were worn. Light colored knee socks were worn. The light color helps in seeing ticks that try to crawl up legs brushing against foliage. Closed-toe shoes that did not contain space between the flaps and laces were required. These prevented ticks as well as other environmental hazards from entering the shoe. The bottom of pant legs was tucked into the top of socks. This ensured no major gaps and that the socks formed a light 'seal'. Shirts were tucked into pants with attention to no noticeable folds/gaps. Insect repellent containing DEET was applied as instructed by the product label. Clothing and gear were treated with products containing 0.5% permethrin. Application prior to a collection trip was conducted and the clothing was allowed to dry. Upon drying, the clothing was safe to handle and the treatment lasted multiple launderings. This is the method used to treat military uniforms and it has been shown to be effective in reducing tick bites and reducing exposure to pathogens (Vaughn et al. 2014). Permethrin should not be applied to skin. Nitrile gloves were used when handling the flag. While inspecting the flag at each 10 meters, researchers were aware of their proximity to the fabric to prevent accidental exposure. Ticks were collected only by using the provided forceps. If a tick was damaged or fluids from a fed tick came in contact with gloves the contaminated glove was disposed of in a provided waste bag and replaced. It was then ensured by observation that no fluids contacted the researchers' skin. All live ticks were placed directly into the appropriate vial for their life stage and submerged in 95% ethyl alcohol solution to ensure they were euthanized. After every transect researchers were expected to assist one another in a 'tick check'. A clear area was identified, shoes were removed, and areas that smaller ticks of the nymphal and larval stages might be hiding, such as the crease between flaps and laces were inspected. Socks were inspected and once found clear were removed. Areas between the toes were inspected after. Pants and shirts did not need to be removed but needed to be rolled up above the legs and upper arms for visual assessment. Any ticks found on a researcher were removed using duct tape if free roaming or with forceps if attached. This method of checking occurred once again after returning to the vehicle but before driving commenced. Upon completion of the transect all workers closely examined the flag to remove any motile ticks before moving to the next site or placing it in the vehicle. The cloth was laid across a vehicle hood and duct tape was used to remove any ticks from the flag before progressing to other sites.

Tick Surveillance

Transect Establishment & Tick Sampling.

Flagging transects were measured based on the available length of safe land, blockage, and logistical availability. These factors were assessed during site selection and confirmed while obtaining the appropriate local stakeholder permissions. A visual assessment of where animals were commonly present and in near proximity to human activities helped inform sampling paths near the agricultural fields. Transects did not need to be exactly straight, they were allowed to curve slightly to avoid hazards or obstacles. Ideally transects would be 750m, transects shorter than this were included for analysis (CDC, 2020). Along the 750m transect a measured rope of 10 meters was used to designate a plot. At each plot the researcher stopped and checked the flag. Ten meters was chosen due to ticks having been shown to drop off after 15 meters (CDC, 2020). GPS markers were placed in the download off-line map through the ArcGIS Fieldmaps mobile phone app at each of these plots for later mapping and visualization. Flags were slowly skimmed over brush and foliage using a figure-eight pattern going from the top of plants to the bottom.

The pace kept while walking was a wedding march pace. At the marker for each plot detailed notes and photographs of the landscape and plants present on both adjacent sides of the flag were taken. At this time all data was collected for the plot. The thermos-hygrometer was used to measure relative humidity and temperature in degrees Celsius. At the end of every 10 meters the fabric was closely inspected for ticks of all life stages. Both sides were checked. Ticks were removed from the fabric with metal tweezers and placed into a vial filled with 90% ethyl alcohol. There was a vial for each life stage, nymph, larva, and adult, for each transect. The vial was labeled properly with collection date, time, location, transect of the plot from which it was gathered, as well as the researcher's name. Labels were written on duct tape in permanent marker. The number of ticks by life stage, or lack of, and environmental variables were recorded in the mobile Excel document for each plot. Field Team Members were required to report back to the established collection drop off zone after completion of each transect. This was done to ensure vials were properly labeled, stored, and organized.

Sample & Data Analysis.

Collected specimens were brought back to the central location of Njala University where they were identified to genus and species utilizing a dissecting scope. A dichotomous key designed by Harry D. Pratt was utilized to determine specimens to the genus level (Pratt, 1974). A species guide specific to Western Africa was consulted first to confirm the specimen down to the species level based on the pictures and descriptions for identification provided (Madder et al., 2013). A larger guide that includes species from across the continent would also be consulted secondly to ensure that results were consistent for species identification between two separate guides (Walker et al., 2003). Specimens remained in labeled vials of ethyl alcohol and were refrigerated at the Njala University Molecular Diagnostics Lab following their identification to preserve their integrity.

Soil samples were collected at 200 meters, 400 meters, and 600 meters and stored in sealed plastic Ziplock bags to retain moisture. These soil sample bags were weighed, using a 1000g Pesola Light-Line spring scale, shortly after sampling to record wet weight accurately. Soil samples were then brought back to the lab promptly, where they were placed on a microwave safe plate one at a time. Samples were microwaved for 5 minutes, removed and placed back into a bag, where they were reweighed. If there was a change in weight the 5-minute cycle was repeated until there was not an observed change in weight (Schneekloth et al., 2023). Samples were not heated beyond this limit as it could oxidize the organic components.

Twelve categories of variables of land use and their related environmental factors were assessed for each 10-meter plot. The variable "Location" would remain the same along each transect, as it was the identifier of the testing site. Every 10 meters an assessment was made to classify the land based on its primary use to determine the variable "Land Use Type". "Temperature" was measured by the thermos-hygrometer and recorded in degrees Celsius. "Humidity" was also measured by the thermos-hygrometer by percent relative humidity. Visual assessment of the sampled area to determine if it had been directly and purposefully altered by humans for cultivation or construction was the basis for "Cultivated/Uncultivated". Whether the predominant plant type of the area sampled was shrubbery or grass determined the variable "Shrub/Grass". The variable of "Leaf Litter" was identified by the presence or absence of leaf litter along the sampled area. The presence of a tree canopy or cover above the 10 meters sampled was the determinate of the variable "Tree Cover". "Sun Exposure" was assessed by determining if there could be a direct line of sunlight to the soil or lower portions of plant life if unobstructed by clouds. “Cloud Cover” was simply the presence or absence of cloud cover at the time of sampling. “Number of Animals Observed” was measured as the number of animals directly along the 10-meter plot, and their species were noted. No recordings of an animal were duplicated between plots. The variable “Total Ticks” was the total number of ticks of all life stages collected within the 10-meter plot.

For data analysis environmental factors between the sites were assessed in the “Statistical Package for Social Sciences”, or IBM SPSS, and compared through correlation matrices and linear regression tests. Variables that were not numeric originally were normalized and categorized into dummy variables so that tests could be completed. A correlation matrix was chosen as the first statistical test applied, as it showed the interactions between the variables. Linear regression was chosen as the second test to apply because it provides a model to assess the strength of the relationship between the variables. These two tests established the significance of the various land use types and their associated environmental factors on tick presence and abundance. The data was analyzed in two separate data sets. The first data set contained all data gathered across the 7,220 meters of land sampled and will be called the composite data set. It contained 722 entries. All data used in this experiment was collected in the field by the research team. For the correlation matrix and linear regression conducted on the composite data set there were 72 sub-variables (Table 3). To account for the high number of variables that were included in these tests a Bonferroni correction was conducted to obtain an adjusted P-value. The second set of data utilized only plots from the composite set where at least one tick specimen was found. This more focused data set contained the same 12 variable categories as the composite data set, but only 21 sub-variables (Table 4). A correlation matrix and linear regression were carried out on this data set. To account for the multiple testing in the linear regression a Bonferroni correction was completed to obtain an adjusted P-value. The soil samples gathered were representative of the transects and for each location a mean gravimetric water content of the soil was calculated. A linear regression was used to assess the relationship between the mean gravimetric water content of the soil and the abundance of ticks across the tested locations.

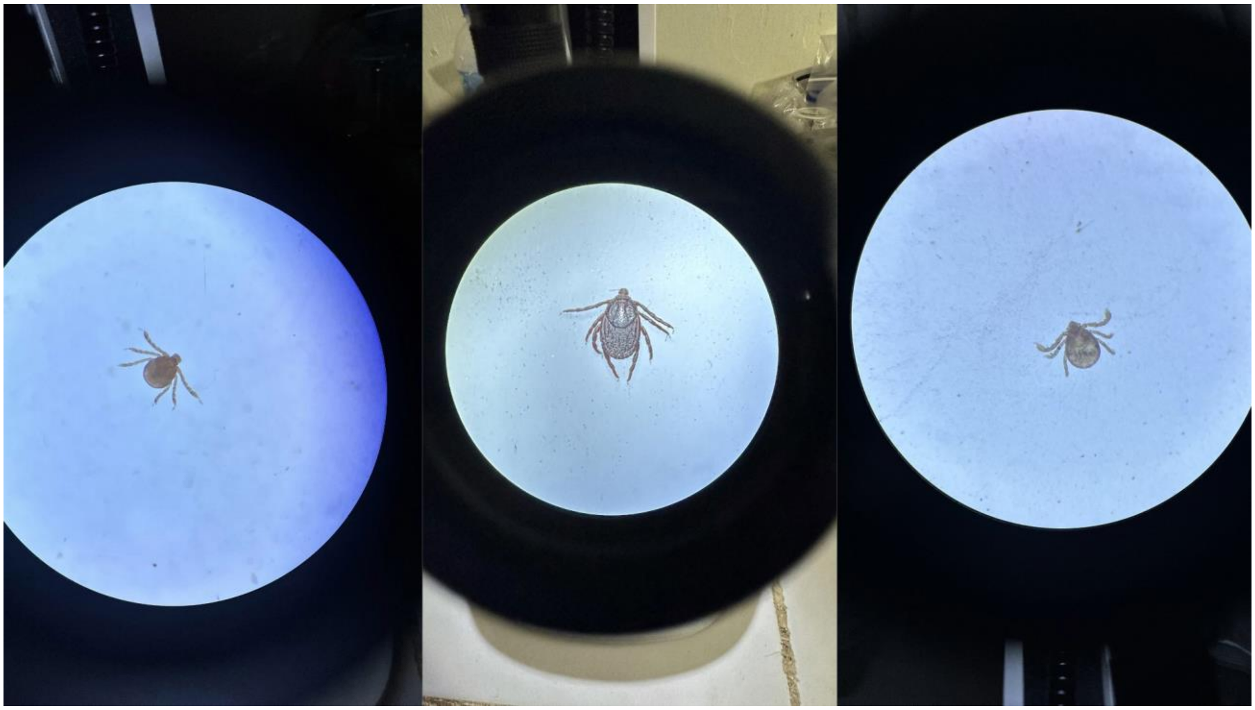
VI. Results

Within this study 7,220 meters of land were sampled, and 18 ticks were found (Table 2). They were found across three locations (Figure 4). The first of which was in Hangha Village's cacao plantation where 7 larval ticks from the genus *Haemaphysalis* were found. The second location was in the recently grazed pasture of the Njala University Mokonde Campus Ranch where 10 larval ticks of the genus *Amblyomma* were found. Lastly, in Njala village an unfed adult female *Hyalomma rufipes* tick was found (Figure 3).

Table 2. Logistics of Tick Collection

Tick Genus (and species if applicable)	Number Collected	Life Stage	Location Found	Land Use Type Found In	Date Collected
Haemaphysalis	7	Larva	Hangha Village Cocoa Plantation	2 Cocoa Plantation 5 Residential Garden (Krain Krain)	7/24/2023
Amblyomma	10	Larva	Njala University Mokonde Campus Ranch	10 Roadside Pasture	7/26/2023
Hyalomma rufipes	1	Adult (Female)	Njala Village	1 Roadside Goat Path	7/31/2023

Figure 3: ***Images of collected tick specimens***



Note: Respectively a larval *amblyomma*, adult *Hyalomma rufipes*, and larval *haemaphysalis* tick.

Figure 4: ***Images of Land Use Types of Tick Collection***

Note: Respectively Cocoa Plantation, Residential Garden (Representative), Roadside Pasture (Recently Grazed), and Roadside Goat Path.

The first test conducted was a bivariate correlation matrix with confidence intervals on the composite data set (Appendix B). Notable results from this analysis included: temperature had a weak negative of -0.059; humidity had a weak positive correlation of 0.056; animalsobserved had a very weak negative correlation of -0.017; leaflitter_1 had a weak negative correlation of -0.076; leaflitter_2 had a weak positive correlation of 0.076; cultured/uncultivated_3 had a weak negative correlation of -0.043; cultured/uncultivated_4 had a weak positive correlation of 0.043; treecover_5 had a weak positive correlation of 0.060; treecover_6 had a weak negative correlation of -0.060; shrubgrass_7 had a weak positive correlation of 0.059; shrubgrass_8 had a weak negative correlation of -0.059; cloudcover_9 had a weak positive correlation of 0.027; cloudcover_10 had a weak negative correlation of -0.027; sunexposure_11 had a weak negative correlation of -0.026; sunexposure_12 had a weak positive correlation of 0.026. Out of all land use type variables only those where ticks were found had a non-negative correlation. These are: landusetype_48 with a correlation of 0.183; landusetype_44 with a correlation of 0.159; landusetype_41 with a correlation of 0.341; landusetype_39 with a correlation of 0.159; landusetype_22 with a correlation of 0.023 (Table 3).

The second test conducted on the compiled data set was a linear regression with an associated ANOVA. The R value of this linear regression was 0.542. The R-squared value of the linear regression was 0.293. The adjusted R square value was 0.225. The standard error of the estimate for this regression was 0.20143. The ANOVA test evidences that the regression of the model was 11.012 and the residual was 26.536, with the total sum of squares as 37.549. The F statistic was 4.308 and P-value was less than 0.01. Of the environmental factors: the B value for temperature was 0.021; the B value for humidity was 0.002; the B value for animalsobserved was -0.005; the B value of leaflitter was 0.049; the B value for cultured/uncultivated was 0.128;

the B value for treecover was -0.137; the B value for cloud cover was 0.039; the B value for sunexposure was -0.128. A Bonferroni correction was made to address the issue of multiple testing. The only variable that demonstrated statistical significance when the adjusted P-value of 0.000794 was considered was landusetype = residential garden (krain krain) (Appendix C).

Table 3: Variable Names & Descriptions for Composite Data Tests		
Variable Name	**Variable Description**	**Correlation Coefficient**
Totalticks	Includes all ticks found both larval and adult	NA
Leaflitter_1	LeafLitterYN=No	-.076
Leaflitter_2	LeafLitterYN=Yes	.076
CulturedUncultivated_3	CulturedUncultivated=Cultured	-.043
CulturedUncultivated_4	CulturedUncultivated=Uncultured	.043
TreeCover_5	TreeCoverYN=No	.060
TreeCover_6	TreeCoverYN=Yes	-.060
ShrubGrass_7	ShrubGrass=Grass	.059
ShrubGrass_8	ShrubGrass=Shrub	-.059
CloudCover_9	CloudCover=High	.027
CloudCover_10	CloudCover=Low	-.027
SunExposure_11	SunExposure=High	-.026
SunExposure_12	SunExposure=Low	.026
LandUseType_13	LandUseType=Agricultural (Corn)	-.011
LandUseType_14	LandUseType=Agricultural (Empty Field Next to Residence)	-.006
LandUseType_15	LandUseType=Agricultural (Okra) Adjacent to Savannah	-.010
LandUseType_16	LandUseType=Agricultural (Peanut)	-.017
LandUseType_17	LandUseType=Agricultural Mixed Crop Plot (Corn, Karin Krain, Beans, "Green")	-.006
LandUseType_18	LandUseType=Agricultural Mixed Crop Plot (Karin Krain, Beans, "Green")	-.007
LandUseType_19	LandUseType=Agricultural Mixed Crop Plot (Potatoe and Cassava)	-.007
LandUseType_20	LandUseType=Agriculture (Banana plantation [bananas cut down due to off season])	-.010
LandUseType_21	LandUseType=Agriculture (Cocoa and Banana Plantation [bananas cut down due to off season])	-.004
LandUseType_22	LandUseType=Cocoa Plantation	.023
LandUseType_23	LandUseType=Cow Pen	-.009
LandUseType_24	LandUseType=Grassland	-.012

LandUseType_25	LandUseType=Mixed Crop Swamp Agriculture (Rice, Krain Krain)	-.006
LandUseType_26	LandUseType=Mixed Crop Swamp Agriculture (Rice, Peanuts)	-.010
LandUseType_27	LandUseType=Mixed Crop Swamp Agriculture (Rice, Sweet Potato)	-.014
LandUseType_28	LandUseType=Mixed Crop Swamp Agriculture (Rice, Sweet Potato, Cassava)	-.026
LandUseType_29	LandUseType=Natural Savannah	-.032
LandUseType_30	LandUseType=Palm Oil Plantation	-.024
LandUseType_31	LandUseType=Pasture	-.012
LandUseType_32	LandUseType=Primary Rain Forest Reserve	-.041
LandUseType_33	LandUseType=Residential	-.031
LandUseType_34	LandUseType=Residential (Seasonal Housing)	-.012
LandUseType_35	LandUseType=Residential Development	-.017
LandUseType_36	LandUseType=Residential Garden (Beans)	-.004
LandUseType_37	LandUseType=Residential Garden (Cassava)	-.008
LandUseType_38	LandUseType=Residential Garden (Corn)	-.006
LandUseType_39	LandUseType=Residential Garden (Corn, Sweet Potato)	.159
LandUseType_40	LandUseType=Residential Garden (Herbs)	-.004
LandUseType_41	LandUseType=Residential Garden (Krain Krain)	.341
LandUseType_42	LandUseType=Residential Garden (Peanut and Okra)	-.007
LandUseType_43	LandUseType=Residential Garden (Sweet Potato)	-.004
LandUseType_44	LandUseType=Residential Garden (Young Palm Potting)	.159
LandUseType_45	LandUseType=Roadside Flood Spill Plain Adjacent to Swamp Agriculture (Rice)	-.011
LandUseType_46	LandUseType=Roadside Goat Path	.000
LandUseType_47	LandUseType=Roadside Goat Path and Small Scale Model of Oil Palm Plantation	-.014
LandUseType_48	LandUseType=Roadside Pasture	.183
LandUseType_49	LandUseType=Roadside of Canal	-.007
LandUseType_50	LandUseType=Secondary Forest (Was Primary, Illegally Farmed for Timber Recently)	-.009
LandUseType_51	LandUseType=Secondary Rain Forest Reserve	-.011
LandUseType_52	LandUseType=Swamp	-.025
LandUseType_53	LandUseType=Swamp Agriculture (Corn)	-.015
LandUseType_54	LandUseType=Swamp Agriculture (Empty Raised Field)	-.010
LandUseType_55	LandUseType=Swamp Agriculture (Rice)	-.037
LandUseType_56	LandUseType=Swamp Agriculture (Rice) and Agricultural Mixed Crop Plot (Corn, Karin Krain, Beans, "Green")	-.007
LandUseType_57	LandUseType=Swamp/Primary Forest Edge	-.008
Location_58	Location=Bo "Reserve Neighborhood" Swamp	-.037
Location_59	Location=Bo Chinese Farm	-.037

Location_60	Location=Hangha Village, Kenema District, Cocoa Plantation Oriented Side of Community	.102
Location_61	Location=Hangha Village, Kenema District, Oil Palm Oriented Side of Community	-.037
Location_62	Location=Kasewe Deep Forest Preserves	-.037
Location_63	Location=Kasewe Savannah Preserve	-.037
Location_64	Location=Kasewe Seasonal Housing and Logging Area	-.027
Location_65	Location=Njala University Mokonde Campus Ranch (Far Rotation Pasture and Seasonal Flood Plain That Separates Them)	-.037
Location_66	Location=Njala University Agricultural Campus	-.026
Location_67	Location=Njala University Mokonde Campus Ranch (Recently Grazed and Middle Rotation Pasture)	.236
Location_68	Location=Njala Village	-.017
Temperature	The temperature in Degrees Celsius	-.059
Humidity	The relative humidity	.056
Animals Observed	The number of animals observed in a plot	-.017

The first test run on the confirmed tick presence data set was a correlation matrix. The correlation between total ticks and temperature is -0.469. There is a positive correlation value for humidity being 0.455. There is a negative correlation for leaflitter_2 with the value of -0.356, with its inverse leaflitter_3 had a positive correlation of 0.356. cultureduncultivated_5 had a correlation value of -0.267, while cultureduncultivated_6 had a correlation value of 0.267. Cloudcover_12 how to value of 0.535, and cloudcover_13 at a value of -0.535. Sunexposure_15 at a value of 0.055, sunexposure_16 had a value of -0.055. The variable categories of animals observed, treecover, and shrub/grass were excluded during this correlation matrix as all values were respectively the same across each plot. The correlation value for landusetype_18 was 0.089, the value for landusetype_19 was -0.117, the value for landusetype_20 was -0.356, the value for landusetype_21 was 0.267 (see the full results of the test can be found in Appendix D).

The second test run on the confirmed tick presence data set was a linear regression with its associated ANOVA. The R value provided is 0.988, the R-squared value was 0.977, the adjusted R-squared value was 0.896, and the estimate of standard error was 0.255. The ANOVA test had a regression value of 5.470 and a residual value of 0.130, making the total sum of squares 5.600. The F-statistic was 12.094, and the P-value was 0.079. After Bonferroni corrections were made no variable had a P-value that represented significance against the adjusted P-value of 0.01 (see the full results of the test in Appendix E).

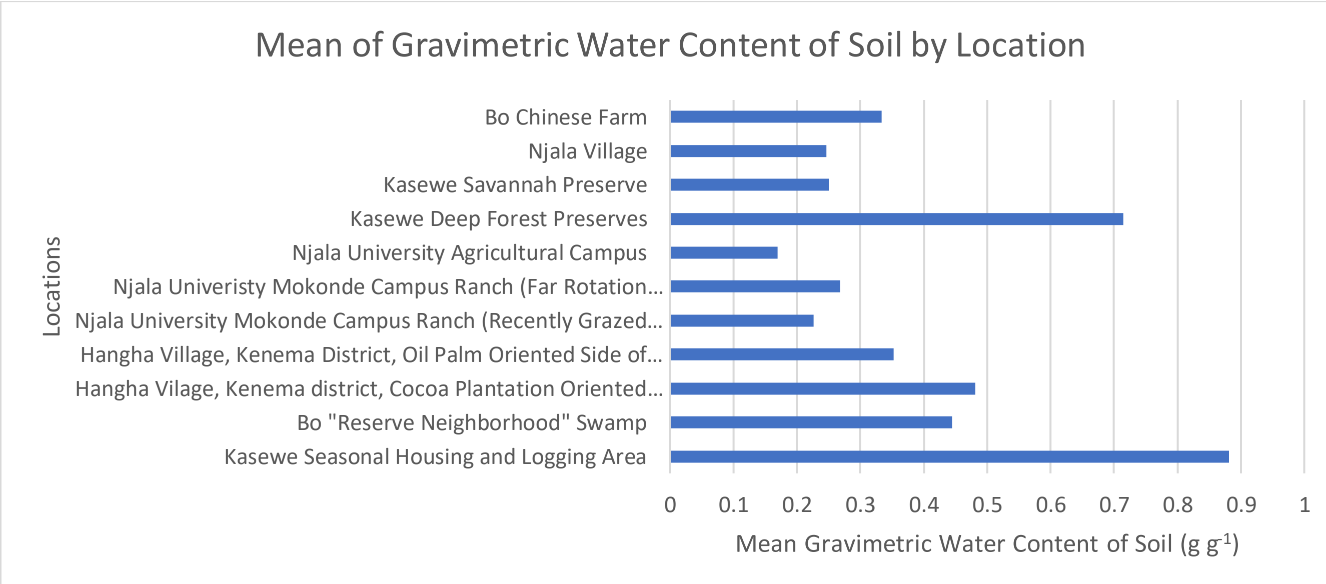
Table 4: Variable Names & Descriptions for Tick Confirmed Plot Data Tests

Variable Name	**Variable Description**	**Correlation Coefficient**
Total Ticks	Includes all ticks found both larval and adult	NA
Temperature	The temperature in Degrees Celsius	-.469
Humidity	The relative humidity	.455
AnimalsObserved	The number of animals observed in a plot	--
Leaflitter_2	LeafLitterYN=No	-.356
Leaflitter_3	LeafLitterYN=Yes	.356
CulturedUncultivated_5	CulturedUncultivated=Cultured	-.267
CulturedUncultivated_6	CulturedUncultivated=Uncultured	.267
TreeCover_8	TreeCoverYN=No	--
ShrubGrass_10	ShrubGrass=Grass	--
CloudCover_12	CloudCover=High	.535
CloudCover_13	CloudCover=Low	-.535
SunExposure_15	SunExposure=High	.055

SunExposure_16	SunExposure=Low	-.055
LandUseType_18	LandUseType=Cocoa plantation	.089
LandUseType_19	LandUseType=Residential Garden	-.117
LandUseType_20	LandUseType=Roadside Goat Path	-.356
LandUseType_21	LandUseType=Roadside pasture	.267
Location_23	Location=Hangha Vilage, Kenema District, Cocoa Plantation Oriented Side of Community)	-.055
Location_24	Location=Njala University Mokonde Campus Ranch (Recently Grazed and Middle Rotation Pasture)	.089
Location_25	Location=Njala Village	-.356
Location_26	Location=Njala, Njala University Mokonde Campus	.218

From the data of the representative soil samples a mean amount of soil water content for each transect was found. Only the Kasewe seasonal housing and logging area possessed a value over 0.8 g g^{-1} indicating that the soil type was oversaturated. The only other site that falls out of the acceptable soil moisture range is the Njala University Agricultural Campus location, with a value just under 0.2 g g^{-1} indicating a slight drought condition of the soil. All other locations had values between 0.2 g g^{-1} and 0.8 g g^{-1} which were within the range of optimal conditions for most plant growth (Figure 5). A linear regression was run with the mean gravimetric water content of soil as the dependent variable and the total number of ticks found amongst the locations as the predictor variable. The ANOVA produced a p-value of 0.629 and an F-statistic of 0.250 (Appendix F).

Figure 5: Mean gravimetric water content of soil by location.



VII. Discussion

The results of the data analyses provided a number of insights into the ways that environmental factors correlated with the abundance of ticks in the different land use types sampled. From the compiled data correlation matrix, it was suggested that on wide scale of the 7,220 total meters sampled across the country there were a number of factors that reflected an influence on the abundance of ticks. From this broader view many of the correlations presented were very weak relationships to the abundance ticks. This was likely due to the small percentage of plots where ticks were found. Temperature with a negative correlation of -0.059 indicated that as the temperature increased, the number of ticks observed tended to decrease slightly. Conversely, humidity with a weak positive correlation of 0.056 indicated that as humidity rose, the number of ticks found would increase slightly. Both of these findings reflect behaviors that were expected of hard ticks. Hard ticks are not often observed in conditions with heat that is too high. Excessive heat poses the risk of dehydration and death. It is also not likely to see them in conditions with very low humidity as they might dry out while questing (Elmieh, 2022). For the variable of animals observed there was a very weak negative correlation of -0.017. It was important to note that ticks were found on animals, both livestock and domestic across multiple sites. This may have influenced the weak negative correlation as the feeding ticks were not collected for inclusion in this data set. The areas where animals were directly observed could have had ticks attached to the animals themselves and not in a questing phase in the underbrush that was being sampled. Animals of note that had ticks attached to them were cows with high densities of ticks around the eyes, ears, and hind quarters; goats with low densities of ticks around their hind quarters and inside of ears; and dogs with ticks across their bodies in low densities. The correlation matrix also showed that leaf litter had a weak positive correlation with a value of 0.076. This aligned with what was expected of ticks as they were likely to be found in areas where they could take refuge in the leaf litter and benefit from the microclimate of such underbrush (Elmieh, 2022). Between cultivated and uncultivated land, there was a weak positive correlation shown for land that is uncultivated. This lack of disturbance may have provided a more suitable set of conditions for the ticks. Areas that were underneath direct tree cover or canopy were shown to have a weak negative correlation with the value of -0.060. This indicated that the ticks were more likely to be found in areas with wider clearings or along the edge of forested patches. There was a higher positive correlation for areas that contained primarily grass vegetation compared to those that were dominated by more woody shrubs. There was a weak positive correlation for the abundance of ticks for the variables of high cloud cover, and low sun exposure. This finding aligned with expectations as low cloud coverage and high sun exposure could respectively lead to dehydration and overheating. This correlation matrix suggested a positive correlation between the land use types that ticks were directly found in and tick abundance. These land use types were primarily associated with livestock in pastures, goat trails, and within residential gardens with variety of crops. The highest correlation of tick abundance and land use type was found in the residential garden solely dedicated to the crop krain krain.

From the linear regression of the compiled data set the adjusted R-squared value indicated that there was a moderate positive relationship between the variables assessed and the presence of ticks across the 7,220 meters assessed. The R-squared coefficient of 0.293 indicated that about 29.3% of the variability of tick abundance was accounted for by assessing the independent variables measured. The ANOVA’s F statistic of 4.308 and P value of less than 0.001 indicated that this model was statistically significant. This suggested a correlation between agricultural land use, and its associated environmental factors, and the abundance of ticks. The B values provided from this test gave insight into individual variables if all others were held constant. Temperature's B value suggested that if temperature were to increase there would be a slight increase in the total number of ticks seen. Humidity did not have a significant impact on the number of ticks that would have been seen if it changed. The reason for humidity's low B value may have be due to testing not occurring during periods of active rain, when humidity would have been its highest. Ticks were not collected if questing during these periods of high humidity. The coefficient for the animals observed showed that animals being present led to a slight decrease in questing tick abundance. This may have been related to the ticks not actively questing because they were either on their prey or at a stage where they were not looking for a bloodmeal. The correlation results suggest that if leaf litter was present there would be a higher number of ticks seen. High sun exposure was expected to lower tick abundance. There was a difference to be noted between the results of the correlation matrix and of the correlation results of the linear regression for all other factors involved. Land associated with being cultivated is not as favorable when all other factors were not considered, but when all variables were held constant it was shown to be more favorable for the presence of ticks. Correlation showed that the presence of tree cover or a canopy did lower the likelihood of tick abundance. With all other variables held constant, classification of low cloud cover was expected to increase the total number of ticks found. This finding differed from the finding of the correlation matrix where other variables were considered. The regression conducted separately on the representative soil samples indicated that across all sites there were no significant relationships between the soil moisture of the locations and the abundance of ticks.

The subset of the data containing only plots where ticks were found demonstrated a greater level of correlation between environmental variables, land use type, and tick abundance than the correlation matrix results of the composite data set. Temperature was shown to have a negative correlation, this suggested as temperature increased the number of ticks observed would decrease. Humidity was shown to have a significant positive correlation with tick abundance, which suggested as the humidity increased the number of ticks increased. Both humidity and temperature correlations aligned with those found on the broader scale as shown by the composite data set (Appendix B). Leaf litter was shown to have a positive correlation, which corresponded with earlier results on the broader level. It was suggested that higher tick abundance would be seen in areas with greater leaf litter compared to those that are more barren. A positive correlation was found for cloud cover and tick abundance which also aligned with the broader data set. Sun exposure is an environmental variable that stood out compared to all others noted by having a weak correlation and not aligning with the relationship patterns of the first data set. It had a weak positive correlation. There was no variance within the variables of shrub/grass, tree cover, and animals observed therefore these variables were excluded from this correlation matrix. Within the plots where ticks were found all were primarily grass vegetation, without direct tree cover, and none had animals observed directly. The ANOVA test of the focused data set's linear regression had a P-value of 0.079 which was larger than the expected P value of 0.050, the F-statistic was 12.049. This finding indicated that this linear regression was not statistically significant.

While the level of correlation from the two data sets' correlation matrices differed, in each instance aside from sun exposure both indicated the same trends of negative or positive relationships for each respective variable. The focused data set indicated that 60% of plots that ticks were found in were directly associated with livestock. While direct animal testing was outside the scope of the current study, the relationship between ticks and non-human hosts was evident in follow up conversations with locals. There was also a distinct difference of the genus of each tick collected between the sites. The larval ticks found in Hangha village cacao plantation dedicated area of the community were from the genus *Haemaphysalis*. All of these larval ticks were notably found in areas of human interaction. These areas included trails used through the cacao plantation and residential gardens leading from the cacao plantation to the residence areas, but not areas directly associated with the passing of livestock such as goats. Areas with goat interaction were noted in other areas closer to the residential part of the village, but not within the area ticks were directly found. No ticks were noted by observation on domestic dogs or other animals seen within the Hangha Village community. The larval ticks from the Njala University Mokonde Campus Ranch were of the genus *Amblyomma*. These ticks were all found in the area of pasture which had been recently used for grazing within the past week according to residents and handlers. Ticks were notably not found at the areas of pasture that had been grazed even two weeks beforehand directly next to this freshly grazed plot in the same transect. Ticks were also not found in the areas of pasture noted from the rotation of a month earlier. There were a high number of ticks of multiple life stages observed on cattle that grazed these fields. During negotiations with cattle management staff of Njala University to gain access to the pastures it was reported that cattle from the pens directly adjacent to the pastures sampled were not treated with any kind of acaricides, but livestock from a separate pin area further down the road had received at least one set of tick treatment within their adult lives. Ticks were still noted on the ears and hindquarters of cows, as well as on hind quarters of goats that shared the treated pen. In Njala Village a local who owned a small herd of goats was recruited as a guide to demonstrate the path that goats would walk through the community to get to the market and to pastures regularly. This guide reported that ticks existed and had many questions about them as he had seen them on his herd before. It was along this goat path that the adult female *Hyalomma rufipes* was collected. This was the only adult tick found during flagging. Within Bo's Reserve Neighborhood swamp, a farmer that was contacted for permission to sample reported that the neighborhood had only recently converted what had been a nature reserve into the residential areas and began planting in the swamp fallow style. It was reported that as this transformation occurred there was a high abundance of ticks that affected the workers converting the land. This local farmer was the only individual during the entire research period reporting that they had been bitten by a tick. This individual as well as others in the community still associated ticks with dogs. Within the same neighborhood site after explaining the project to local stakeholders for permission to pass through their land an individual returned several minutes later of their own accord holding three adult ticks that were removed from a neighborhood stray dog. These ticks were not included in the study nor were any samples taken from animals by the research team as one of the limitations of the study was not having Ethics Committee approval for animal experimentation and sampling. However, the unsolicited information shared during the permission gathering process was important to note as it confirmed tick presence in multiple areas.

The limitation of animal experimentation and sampling was self-imposed prior to arriving in the country. It was unclear whether handling animals and specimens would be allowed by local participants, and if doing so would be safe. Permission was not sought beforehand. Another limitation of the study was the lack of accessibility for reagents that would allow for molecular testing at the facilities of Njala University Biological Sciences Department. These reagents needed to be brought from the United States directly as there is not an ability to acquire them in country. Molecular verification was not within the design of the study and was only considered seriously after a majority of ticks being collected were in the larval stage. There was also no established cold chain for commercial delivery. Another limitation of this study was the small sample size of ticks found. The low number of ticks found and the field preservation of specimens in alcohol limited the extent of pathogen screening that could have occurred even if reagents were available. The weather proved to be a barrier as there were three transects that did not get the full 750 meters but were instead cut short due to the rain starting during sampling. The weather at times would prevent sampling for entire days. It was expected that numbers of ticks would be slightly lower than in other seasons in Sierra Leone as this project occurred during the rainy season. While the sample size of ticks found in this study was small, the information gathered is valuable for an exploratory study.

VIII. Conclusions & Recommendations

The results of this study demonstrated that there were correlations between agricultural land use types, their associated environmental factors, and the abundance of ticks found. The hypothesis that there would be a higher number of ticks found within land use areas associated directly with livestock was confirmed. Of plots with ticks 60% were within this category. The other 40% of plots that had confirmed ticks were areas with consistent human interaction. Eighteen ticks from three genera were collected. The environmental factors of temperature, humidity, presence of leaf litter, tree cover, cloud cover, direct exposure to sunlight, prominent vegetation type of grass or shrubbery, and whether the land was cultivated or uncultivated were shown to have very weak effects on the abundance of ticks. Temperature, the number of animals observed, the presence of tree cover, and high sun exposure all had weak negative correlations with tick abundance. Humidity, the presence of leaf litter, the land being uncultivated, the primary vegetation type being grass, and high cloud cover all had weak positive correlations with tick abundance. Land use types that ticks were found in each had a positive correlation with tick abundance as well. The linear regression of the composite data set was statistically significant, and the variable for the land use type of residential garden (krain krain) also held significance after Bonferroni corrections. Within the current study 7,220 meters were sampled across 11 sites with 12 variables being accounted for every ten meters. There were 45 specified land use types inspected within three Districts. Future studies may wish to utilize the current information gathered as a framework and baseline. An additional follow-up study may also include a qualitative methodology to determine local stakeholders' knowledge of ticks. Expanding the scope of future studies to include variance across seasons would add to the current body of knowledge. It is recommended that future studies include animal-collected specimens in their testing. Animal based studies could be very informative and researchers through the Njala Mokonde Campus network have expressed interest in conducting such work in the future, so there is potential for collaboration. Molecular verification to obtain species level classification of larval ticks would be recommended in future studies, as well as a pathogen testing component. Reagents for species identification and disease testing would need to be prearranged prior to departing for future studies. The Njala University Molecular Diagnostics Lab owns most of the machinery necessary to facilitate such tests. This was an exploratory study that helped establish a baseline for the vector ecology of ticks within the project area and provides a framework for future research.

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Appendices

A: Supplementary Conceptual Model of Factors Affecting Tick Surveillance in Sierra Leone

B: Correlation Matrix of Composite Dataset SPSS Output

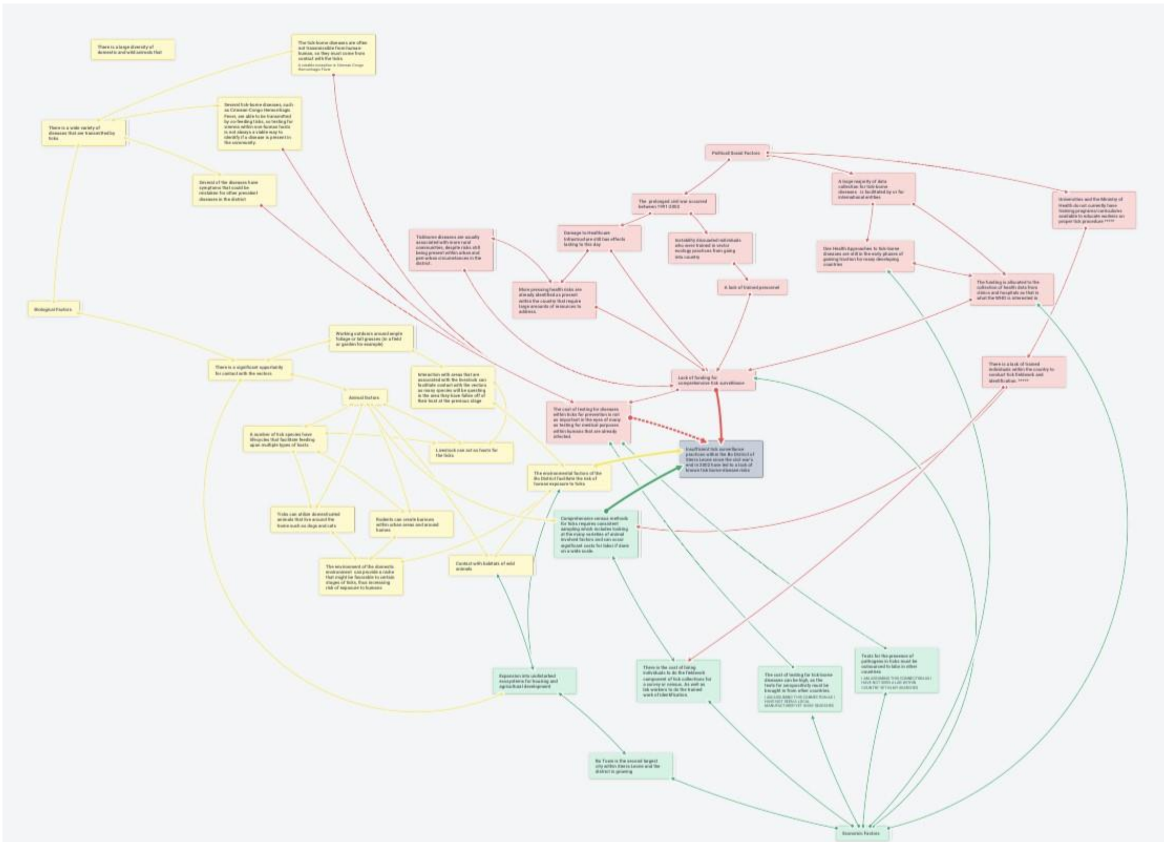
C: Linear Regression of Composite Dataset SPSS Output

D: Correlation Matrix of Tick Confirmed Plots SPSS Output

E: Linear Regression of Plots with Confirmed Tick Presence SPSS Output

F: Linear Regression of Soil Sample Data and Tick Presence SPSS Output

Appendix A: Supplementary Conceptual Model of Factors Affecting Tick Surveillance in Sierra Leone.



(Plectica Account Necessary to Access)

Appendix B: Correlation Matrix of Composite Dataset.

Correlations

Variable	Variable2	Statistic Correlation	Count	Lower C.I.	Upper C.I.	Notes
Totalticks	Temperature	-.059	722	-.132	.014	
	Humidity	.056	722	-.017	.129	
	AnimalsObserved	-.017	718	-.090	.057	
	Leaflitter_1	-.076	722	-.149	-.003	
	Leaflitter_2	.076	722	.003	.149	
	CulturedUncultivated_3	-.043	722	-.115	.030	
	CulturedUncultivated_4	.043	722	-.030	.115	
	TreeCover_5	.060	722	-.013	.133	
	TreeCover_6	-.060	722	-.133	.013	
	ShrubGrass_7	.059	722	-.014	.131	
	ShrubGrass_8	-.059	722	-.131	.014	
	CloudCover_9	.027	722	-.046	.100	
	CloudCover_10	-.027	722	-.100	.046	
	SunExposure_11	-.026	722	-.099	.047	
	SunExposure_12	.026	722	-.047	.099	
	LandUseType_13	-.011	722	-.084	.062	
	LandUseType_14	-.006	722	-.079	.067	
	LandUseType_15	-.010	722	-.083	.063	
	LandUseType_16	-.017	722	-.090	.056	
	LandUseType_17	-.006	722	-.079	.067	
	LandUseType_18	-.007	722	-.080	.066	
	LandUseType_19	-.007	722	-.080	.066	
	LandUseType_20	-.010	722	-.083	.063	
	LandUseType_21	-.004	722	-.077	.069	
	LandUseType_22	.023	722	-.050	.096	
	LandUseType_23	-.009	722	-.082	.064	
	LandUseType_24	-.012	722	-.085	.061	
	LandUseType_25	-.006	722	-.079	.067	
	LandUseType_26	-.010	722	-.083	.063	
	LandUseType_27	-.014	722	-.087	.059	

	LandUseType_28	-.026	722	-.099	.047	
	LandUseType_29	-.032	722	-.105	.041	
	LandUseType_30	-.024	722	-.097	.049	
	LandUseType_31	-.012	722	-.084	.061	
	LandUseType_32	-.041	722	-.114	.032	
	LandUseType_33	-.031	722	-.104	.042	
	LandUseType_34	-.012	722	-.084	.061	
	LandUseType_35	-.017	722	-.090	.056	
	LandUseType_36	-.004	722	-.077	.069	
	LandUseType_37	-.008	722	-.081	.065	
	LandUseType_38	-.006	722	-.079	.067	
	LandUseType_39	.159	722	.087	.230	
	LandUseType_40	-.004	722	-.077	.069	
	LandUseType_41	.341	722	.275	.404	
	LandUseType_42	-.007	722	-.080	.066	
	LandUseType_43	-.004	722	-.077	.069	
	LandUseType_44	.159	722	.087	.230	
	LandUseType_45	-.011	722	-.084	.062	
	LandUseType_46	.000	722	-.073	.073	
	LandUseType_47	-.014	722	-.086	.059	
	LandUseType_48	.183	722	.112	.253	
	LandUseType_49	-.007	722	-.080	.066	
	LandUseType_50	-.009	722	-.082	.064	
	LandUseType_51	-.011	722	-.084	.062	
	LandUseType_52	-.025	722	-.098	.048	
	LandUseType_53	-.015	722	-.088	.058	
	LandUseType_54	-.010	722	-.083	.063	
	LandUseType_55	-.037	722	-.110	.036	
	LandUseType_56	-.007	722	-.080	.066	
	LandUseType_57	-.008	722	-.081	.065	
	Location_58	-.037	722	-.110	.036	
	Location_59	-.037	722	-.110	.036	
	Location_60	.102	722	.029	.174	
	Location_61	-.037	722	-.110	.036	
	Location_62	-.037	722	-.110	.036	
	Location_63	-.037	722	-.110	.036	
	Location_64	-.027	722	-.100	.046	
	Location_65	-.037	722	-.110	.036	

	Location_66	-.026	722	-.099	.047	
	Location_67	.236	722	.165	.303	
	Location_68	-.017	722	-.090	.056	

Missing value handling: PAIRWISE, EXCLUDE. C.I. Level: 95.0

Appendix C: Linear Regression of Composite Dataset

Regression

Notes

Comments		
Input		Data
Input Missing Value Handling	Active Dataset	C:\Users\bryce\OneDrive \Documents\Masters Thesis\Sierra Leone Compiled Data SPSS.sav
	Filter	DataSet3
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	<none>
	Definition of Missing	722
Missing Value Handling Syntax	Cases Used	User-defined missing values are treated as missing.

	REGRESSION /MISSING LISTWISE /STATISTICS COEFF OUTS R ANOVA /CRITERIA=PIN(.05) POUT(.10) /NOORIGIN /DEPENDENT Totalticks /METHOD=ENTER Temperature Humidity Leaflitter_1 Leaflitter_2 CulturedUncultivated_3 CulturedUncultivated_4 TreeCover_5 TreeCover_6 ShrubGrass_7 ShrubGrass_8 CloudCover_9 CloudCover_10 SunExposure_11 SunExposure_12 LandUseType_13 LandUseType_14 LandUseType_15 LandUseType_16 LandUseType_17 LandUseType_18 LandUseType_19 LandUseType_20 LandUseType_21 LandUseType_22 LandUseType_23 LandUseType_24 LandUseType_25 LandUseType_26 LandUseType_27 LandUseType_28	Statistics are based on cases with no missing values for any variable used.

	LandUseType_29 LandUseType_30 LandUseType_31 LandUseType_32 LandUseType_33 LandUseType_34 LandUseType_35 LandUseType_36 LandUseType_37 LandUseType_38 LandUseType_39 LandUseType_40 LandUseType_41 LandUseType_42 LandUseType_43 LandUseType_44 LandUseType_45 LandUseType_46 LandUseType_47 LandUseType_48 LandUseType_49 LandUseType_50 LandUseType_51 LandUseType_52 LandUseType_53 LandUseType_54 LandUseType_55 LandUseType_56 LandUseType_57 Location_58 Location_59 Location_60 Location_61 Location_62 Location_63 Location_64 Location_65 Location_66 Location_67 Location_68 AnimalsObserved.	

Resources		Processor Time
Resources	Elapsed Time	00:00:00.00
	Memory Required	00:00:00.03

	Additional Memory Required for Residual Plots	193328 bytes

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method

1	Animals Observed, LandUseType =Residential Garden (Young Palm Potting), LandUseType =Residential Garden (Sweet Potato), LandUseType =Residential Garden (Herbs), LandUseType =Residential Garden (Corn, Sweet Potato), LandUseType =Residential Garden (Beans), LandUseType =Cow Pen, LandUseType =Agriculture (Cocoa and Banana Plantation [bananas cut down due to off season]), LandUseType =Residential Garden (Krain Krain), LandUseType	.	Enter

	=Mixed Crop Swamp Agriculture (Rice, Krain Krain), LandUseType =Agricultural Mixed Crop Plot (Corn, Karin Krain, Beans, "Green"), LandUseType =Swamp Agriculture (Rice) and Agricultural Mixed Crop Plot (Corn, Karin Krain, Beans, "Green"), LandUseType =Roadside of Canal, LandUseType =Residential Garden (Peanut and Okra), LandUseType =Agricultural Mixed Crop Plot (Potatoe and Cassava), LandUseType =Agricultural Mixed Crop Plot (Karin Krain, Beans,		

	"Green"), LandUseType =Swamp/Primary Forest Edge, LandUseType =Residential Garden (Cassava), LandUseType =Secondary Forest (Was Primary, Illegally Farmed for Timber Recently), LandUseType =Swamp Agriculture (Empty Raised Field), LandUseType =Mixed Crop Swamp Agriculture (Rice, Peanuts), LandUseType =Agriculture (Banana plantation [bananas cut down due to off season]), LandUseType =Agricultural (Okra) Adjacent to Savannah,		

	LandUseType =Secondary Rain Forest Reserve, LandUseType =Roadside Flood Spill Plain Adjacent to Swamp Agriculture (Rice), LandUseType =Agricultural (Corn), LandUseType =Pasture, LandUseType =Residential (Seasonal Housing), LandUseType =Grassland, LandUseType =Roadside Goat Path and Small Scale Model of Oil Palm Plantation, LandUseType =Swamp Agriculture (Corn), LandUseType =Mixed Crop Swamp Agriculture (Rice, Sweet Potato), LandUseType		

	=Residential Development, LandUseType =Agricultural (Peanut), LandUseType =Palm Oil Plantation, LandUseType =Agricultural (Empty Field Next to Residence), LandUseType =Mixed Crop Swamp Agriculture (Rice, Sweet Potato, Cassava), LandUseType =Swamp, LandUseType =Roadside Goat Path, LandUseType =Cocoa Plantation, LandUseType =Natural Savannah, LandUseType =Residential Garden (Corn), LandUseType =Roadside Pasture, LandUseType =Residential,		

	Temperature, Location=Kasewe Deep Forest Preserves, CloudCover=Low, Location=Kasewe Seasonal Housing and Logging Area, TreeCoverYN=Yes, Location=Njala University Mokonde Campus Ranch (Recently Grazed and Middle Rotation Pasture), Location=Njala Village, ShrubGrass=Shrub, Location=Njala Univeristy Mokonde Campus Ranch (Far Rotation Pasture and Seasonal Flood Plain That Separates Them), Location=Bo		

	"Reserve Neighborhood" Swamp, LandUseType=Swamp Agriculture (Rice), Location=Bo Chinese Farm, Location=Njala University Agricultural Campus, Location=Hangha Village, Kenema District, Oil Palm Oriented Side of Community, Humidity, SunExposure=Low, LeafLitterYN=No, CulturedUncultivated=Uncultured, Location=Kasewe Savannah Preserve[b]		

a. Dependent Variable: Totalticks

b. Tolerance = .000 limit reached.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.542[a]	.293	.225	.20143

a. Predictors: (Constant), Animals Observed, LandUseType=Residential Garden (Young Palm Potting), LandUseType=Residential Garden (Sweet Potato), LandUseType=Residential Garden (Herbs), LandUseType=Residential Garden (Corn, Sweet Potato), LandUseType=Residential Garden (Beans), LandUseType=Cow Pen, LandUseType=Agriculture (Cocoa and Banana Plantation [bananas cut down due to off season]), LandUseType=Residential Garden (Krain Krain), LandUseType=Mixed Crop Swamp Agriculture (Rice, Krain Krain), LandUseType=Agricultural Mixed Crop Plot (Corn, Karin Krain, Beans, "Green"), LandUseType=Swamp Agriculture (Rice) and Agricultural Mixed Crop Plot (Corn, Karin Krain, Beans, "Green"), LandUseType=Roadside of Canal, LandUseType=Residential Garden (Peanut and Okra), LandUseType=Agricultural Mixed Crop Plot (Potatoe and Cassava), LandUseType=Agricultural Mixed Crop Plot (Karin Krain, Beans, "Green"), LandUseType=Swamp/Primary Forest Edge, LandUseType=Residential Garden (Cassava), LandUseType=Secondary Forest (Was Primary, Illegally Farmed for Timber Recently), LandUseType=Swamp Agriculture (Empty Raised Field), LandUseType=Mixed Crop Swamp Agriculture (Rice, Peanuts), LandUseType=Agriculture (Banana plantation [bananas cut down due to off season]), LandUseType=Agricultural (Okra) Adjacent to Savannah, LandUseType=Secondary Rain Forest Reserve, LandUseType=Roadside Flood Spill Plain Adjacent to Swamp Agriculture (Rice), LandUseType=Agricultural (Corn), LandUseType=Pasture, LandUseType=Residential (Seasonal Housing), LandUseType=Grassland, LandUseType=Roadside Goat Path and Small Scale Model of Oil Palm Plantation, LandUseType=Swamp Agriculture (Corn), LandUseType=Mixed Crop Swamp Agriculture (Rice, Sweet Potato), LandUseType=Residential Development, LandUseType=Agricultural (Peanut), LandUseType=Palm Oil Plantation, LandUseType=Agricultural (Empty Field Next to Residence), LandUseType=Mixed Crop Swamp Agriculture (Rice, Sweet Potato, Cassava), LandUseType=Swamp, LandUseType=Roadside Goat Path, LandUseType=Cocoa Plantation, LandUseType=Natural Savannah, LandUseType=Residential Garden (Corn), LandUseType=Roadside Pasture, LandUseType=Residential, Temperature, Location=Kasewe Deep Forest Preserves, CloudCover=Low, Location=Kasewe Seasonal Housing and Logging Area, TreeCoverYN=Yes, Location=Njala University Mokonde Campus Ranch (Recently Grazed and Middle Rotation Pasture), Location=Njala Village, ShrubGrass=Shrub, Location=Njala Univeristy Mokonde Campus Ranch (Far Rotation Pasture and Seasonal Flood Plain That Separates Them), Location=Bo "Reserve Neighborhood" Swamp, LandUseType=Swamp Agriculture (Rice), Location=Bo Chinese Farm, Location=Njala University Agricultural Campus, Location=Hangha Village, Kenema District, Oil Palm Oriented Side of Community, Humidity, SunExposure=Low, LeafLitterYN=No, CulturedUncultivated=Uncultured, Location=Kasewe Savannah Preserve

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	11.012	63	.175	4.308	<.001[b]
	Residual	26.536	654	.041		
	Total	37.549	717			

a. Dependent Variable: Totalticks

b. Predictors: (Constant), Animals Observed, LandUseType=Residential Garden (Young Palm Potting), LandUseType=Residential Garden (Sweet Potato), LandUseType=Residential Garden (Herbs), LandUseType=Residential Garden (Corn, Sweet Potato), LandUseType=Residential Garden (Beans), LandUseType=Cow Pen, LandUseType=Agriculture (Cocoa and Banana Plantation [bananas cut down due to off season]), LandUseType=Residential Garden (Krain Krain), LandUseType=Mixed Crop Swamp Agriculture (Rice, Krain Krain), LandUseType=Agricultural Mixed Crop Plot (Corn, Karin Krain, Beans, "Green"), LandUseType=Swamp Agriculture (Rice) and Agricultural Mixed Crop Plot (Corn, Karin Krain, Beans, "Green"), LandUseType=Roadside of Canal, LandUseType=Residential Garden (Peanut and Okra), LandUseType=Agricultural Mixed Crop Plot (Potatoe and Cassava), LandUseType=Agricultural Mixed Crop Plot (Karin Krain, Beans, "Green"), LandUseType=Swamp/Primary Forest Edge, LandUseType=Residential Garden (Cassava), LandUseType=Secondary Forest (Was Primary, Illegally Farmed for Timber Recently), LandUseType=Swamp Agriculture (Empty Raised Field), LandUseType=Mixed Crop Swamp Agriculture (Rice, Peanuts), LandUseType=Agriculture (Banana plantation [bananas cut down due to off season]), LandUseType=Agricultural (Okra) Adjacent to Savannah, LandUseType=Secondary Rain Forest Reserve, LandUseType=Roadside Flood Spill Plain Adjacent to Swamp Agriculture (Rice), LandUseType=Agricultural (Corn), LandUseType=Pasture, LandUseType=Residential (Seasonal Housing), LandUseType=Grassland, LandUseType=Roadside Goat Path and Small Scale Model of Oil Palm Plantation, LandUseType=Swamp Agriculture (Corn), LandUseType=Mixed Crop Swamp Agriculture (Rice, Sweet Potato), LandUseType=Residential Development, LandUseType=Agricultural (Peanut), LandUseType=Palm Oil Plantation, LandUseType=Agricultural (Empty Field Next to Residence), LandUseType=Mixed Crop Swamp Agriculture (Rice, Sweet Potato, Cassava), LandUseType=Swamp, LandUseType=Roadside Goat Path, LandUseType=Cocoa Plantation, LandUseType=Natural Savannah, LandUseType=Residential Garden (Corn), LandUseType=Roadside Pasture, LandUseType=Residential, Temperature, Location=Kasewe Deep Forest Preserves, CloudCover=Low, Location=Kasewe Seasonal Housing and Logging Area, TreeCoverYN=Yes, Location=Njala University Mokonde Campus Ranch (Recently Grazed and Middle Rotation Pasture), Location=Njala Village, ShrubGrass=Shrub, Location=Njala Univeristy Mokonde Campus Ranch (Far Rotation Pasture and Seasonal Flood Plain That Separates Them), Location=Bo "Reserve Neighborhood" Swamp, LandUseType=Swamp Agriculture (Rice), Location=Bo Chinese Farm, Location=Njala University Agricultural Campus, Location=Hangha Village, Kenema District, Oil Palm Oriented Side of Community, Humidity, SunExposure=Low, LeafLitterYN=No, CulturedUncultivated=Uncultured, Location=Kasewe Savannah Preserve

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	-.741	.545		-1.360	.174
	Temperature	.021	.011	.233	2.001	.046
	Humidity	.002	.003	.106	.818	.413
	LeafLitterYN=No	-.049	.071	-.106	-.692	.489
	CulturedUncultivated=Uncultured	-.128	.083	-.270	-1.549	.122
	TreeCoverYN=Yes	-.137	.058	-.254	-2.369	.018
	ShrubGrass=Shrub	-.021	.040	-.038	-.518	.605
	CloudCover=Low	.039	.035	.070	1.127	.260
	SunExposure=Low	.128	.068	.251	1.871	.062
	LandUseType=Agricultural (Corn)	-.200	.110	-.086	-1.828	.068
	LandUseType=Agricultural (Empty Field Next to Residence)	-.137	.198	-.032	-.692	.489
	LandUseType=Agricultural (Okra) Adjacent to Savannah	-.040	.128	-.016	-.312	.755
	LandUseType=Agricultural (Peanut)	-.102	.146	-.068	-.699	.485
	LandUseType=Agricultural Mixed Crop Plot (Corn, Karin Krain, Beans, "Green")	-.101	.213	-.023	-.474	.635
	LandUseType=Agricultural Mixed Crop Plot (Karin Krain, Beans, "Green")	-.088	.196	-.025	-.450	.653
	LandUseType=Agricultural Mixed Crop Plot (Potatoe and Cassava)	-.033	.179	-.009	-.184	.854

	LandUseType=Agriculture (Banana plantation [bananas cut down due to off season])	-.103	.165	-.041	-.621	.535
	LandUseType=Agriculture (Cocoa and Banana Plantation [bananas cut down due to off season])	-.106	.246	-.017	-.432	.666
	LandUseType=Cocoa Plantation	-.024	.150	-.025	-.160	.873
	LandUseType=Cow Pen	-.338	.222	-.055	-1.525	.128
	LandUseType=Grassland	.050	.113	.024	.440	.660
	LandUseType=Mixed Crop Swamp Agriculture (Rice, Krain Krain)	-.073	.195	-.017	-.376	.707
	LandUseType=Mixed Crop Swamp Agriculture (Rice, Peanuts)	-.109	.154	-.043	-.704	.482
	LandUseType=Mixed Crop Swamp Agriculture (Rice, Sweet Potato)	-.101	.141	-.056	-.713	.476
	LandUseType=Mixed Crop Swamp Agriculture (Rice, Sweet Potato, Cassava)	-.093	.135	-.091	-.689	.491
	LandUseType=Natural Savannah	-.042	.100	-.051	-.425	.671
	LandUseType=Palm Oil Plantation	-.049	.166	-.045	-.294	.769
	LandUseType=Pasture	-.297	.122	-.137	-2.446	.015
	LandUseType=Residential	-.141	.135	-.163	-1.049	.295
	LandUseType=Residential (Seasonal Housing)	-.133	.139	-.061	-.954	.340
	LandUseType=Residential Development	-.115	.145	-.076	-.789	.430
	LandUseType=Residential Garden (Beans)	-.245	.249	-.040	-.985	.325

	LandUseType=Residential Garden (Cassava)	-.110	.171	-.036	-.647	.518
	LandUseType=Residential Garden (Corn)	-.140	.204	-.032	-.688	.492
	LandUseType=Residential Garden (Corn, Sweet Potato)	.755	.249	.123	3.029	.003
	LandUseType=Residential Garden (Herbs)	-.109	.245	-.018	-.444	.657
	LandUseType=Residential Garden (Krain Krain)	1.286	.207	.296	6.217	<.001
	LandUseType=Residential Garden (Peanut and Okra)	-.129	.180	-.036	-.715	.475
	LandUseType=Residential Garden (Sweet Potato)	-.054	.256	-.009	-.211	.833
	LandUseType=Residential Garden (Young Palm Potting)	.766	.250	.125	3.066	.002
	LandUseType=Roadside Flood Spill Plain Adjacent to Swamp Agriculture (Rice)	-.070	.154	-.030	-.451	.652
	LandUseType=Roadside Goat Path	-.052	.149	-.052	-.348	.728
	LandUseType=Roadside Goat Path and Small Scale Model of Oil Palm Plantation	.009	.172	.005	.052	.959
	LandUseType=Roadside Pasture	.108	.089	.133	1.216	.224
	LandUseType=Roadside of Canal	-.097	.175	-.027	-.556	.578
	LandUseType=Secondary Forest (Was Primary, Illegally Farmed for Timber Recently)	-.029	.124	-.011	-.237	.813
	LandUseType=Secondary Rain Forest Reserve	.026	.084	.011	.311	.756

	LandUseType=Swamp	-.155	.124	-.150	-1.243	.214
	LandUseType=Swamp Agriculture (Corn)	-.152	.146	-.092	-1.041	.298
	LandUseType=Swamp Agriculture (Empty Raised Field)	-.138	.174	-.055	-.795	.427
	LandUseType=Swamp Agriculture (Rice)	-.073	.124	-.098	-.589	.556
	LandUseType=Swamp Agriculture (Rice) and Agricultural Mixed Crop Plot (Corn, Karin Krain, Beans, "Green")	-.082	.198	-.023	-.412	.681
	LandUseType=Swamp/Primary Forest Edge	.151	.122	.049	1.242	.215
	Location=Bo "Reserve Neighborhood" Swamp	.081	.108	.109	.754	.451
	Location=Bo Chinese Farm	.035	.134	.047	.264	.792
	Location=Hangha Village, Kenema District, Oil Palm Oriented Side of Community	-.016	.130	-.022	-.127	.899
	Location=Kasewe Deep Forest Preserves	.055	.134	.074	.414	.679
	Location=Kasewe Savannah Preserve	.047	.152	.063	.310	.756
	Location=Kasewe Seasonal Housing and Logging Area	-.062	.125	-.063	-.495	.621
	Location=Njala Univeristy Mokonde Campus Ranch (Far Rotation Pasture and Seasonal Flood Plain That Separates Them)	-.114	.116	-.152	-.982	.327
	Location=Njala University Agricultural Campus	.035	.130	.036	.272	.785

	Location=Njala University Mokonde Campus Ranch (Recently Grazed and Middle Rotation Pasture)	.391	.118	.378	3.326	<.001
	Location=Njala Village	.061	.121	.081	.502	.616
	Animals Observed	-.005	.026	-.006	-.175	.861

a. Dependent Variable: Totalticks

Excluded Variables[a]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics Tolerance
1	LeafLitterYN=Yes	.[b]	.	.	.	.000
	CulturedUncultivated=Cultured	.[b]	.	.	.	.000
	TreeCoverYN=No	.[b]	.	.	.	.000
	ShrubGrass=Grass	.[b]	.	.	.	.000
	CloudCover=High	.[b]	.	.	.	.000
	SunExposure=High	.[b]	.	.	.	.000
	LandUseType=Primary Rain Forest Reserve	.[b]	.	.	.	.000
	Location=Hangha Vilage, Kenema District, Cocoa Plantation Oriented Side of Community	.[b]	.	.	.	.000

a. Dependent Variable: Totalticks

b. Predictors in the Model: (Constant), Animals Observed, LandUseType=Residential Garden (Young Palm Potting), LandUseType=Residential Garden (Sweet Potato), LandUseType=Residential Garden (Herbs), LandUseType=Residential Garden (Corn, Sweet Potato), LandUseType=Residential Garden (Beans), LandUseType=Cow Pen, LandUseType=Agriculture (Cocoa and Banana Plantation [bananas cut down due to off season]), LandUseType=Residential Garden (Krain Krain), LandUseType=Mixed Crop Swamp Agriculture (Rice, Krain Krain), LandUseType=Agricultural Mixed Crop Plot (Corn, Karin Krain, Beans, "Green"), LandUseType=Swamp Agriculture (Rice) and Agricultural Mixed Crop Plot (Corn, Karin Krain, Beans, "Green"), LandUseType=Roadside of Canal, LandUseType=Residential Garden (Peanut and Okra), LandUseType=Agricultural Mixed Crop Plot (Potatoe and Cassava), LandUseType=Agricultural Mixed Crop Plot (Karin Krain, Beans, "Green"), LandUseType=Swamp/Primary Forest Edge, LandUseType=Residential Garden (Cassava), LandUseType=Secondary Forest (Was Primary, Illegally Farmed for Timber Recently), LandUseType=Swamp Agriculture (Empty Raised Field), LandUseType=Mixed Crop Swamp Agriculture (Rice, Peanuts), LandUseType=Agriculture (Banana plantation [bananas cut down due to off season]), LandUseType=Agricultural (Okra) Adjacent to Savannah, LandUseType=Secondary Rain Forest Reserve, LandUseType=Roadside Flood Spill Plain Adjacent to Swamp Agriculture (Rice), LandUseType=Agricultural (Corn), LandUseType=Pasture, LandUseType=Residential (Seasonal Housing), LandUseType=Grassland, LandUseType=Roadside Goat Path and Small Scale Model of Oil Palm Plantation, LandUseType=Swamp Agriculture (Corn), LandUseType=Mixed Crop Swamp Agriculture (Rice, Sweet Potato), LandUseType=Residential Development, LandUseType=Agricultural (Peanut), LandUseType=Palm Oil Plantation, LandUseType=Agricultural (Empty Field Next to Residence), LandUseType=Mixed Crop Swamp Agriculture (Rice, Sweet Potato, Cassava), LandUseType=Swamp, LandUseType=Roadside Goat Path, LandUseType=Cocoa Plantation, LandUseType=Natural Savannah, LandUseType=Residential Garden (Corn), LandUseType=Roadside Pasture, LandUseType=Residential, Temperature, Location=Kasewe Deep Forest Preserves, CloudCover=Low, Location=Kasewe Seasonal Housing and Logging Area, TreeCoverYN=Yes, Location=Njala University Mokonde Campus Ranch (Recently Grazed and Middle Rotation Pasture), Location=Njala Village, ShrubGrass=Shrub, Location=Njala Univeristy Mokonde Campus Ranch (Far Rotation Pasture and Seasonal Flood Plain That Separates Them), Location=Bo "Reserve Neighborhood" Swamp, LandUseType=Swamp Agriculture (Rice), Location=Bo Chinese Farm, Location=Njala University Agricultural Campus, Location=Hangha Village, Kenema District, Oil Palm Oriented Side of Community, Humidity, SunExposure=Low, LeafLitterYN=No, CulturedUncultivated=Uncultured, Location=Kasewe Savannah Preserve

Appendix D: Correlation Matrix of Tick Confirmed Plots

Correlations

Variable	Variable2	Statistic: Correlation	Statistic: Count	Statistic: Lower C.I.	Statistic: Upper C.I.	Notes
TotalTicks	Temperature	-.469	10	-.848	.228	Normality assumption is not accurate
	Humidity	.455	10	-.244	.843	Normality assumption is not accurate
	AnimalsObserved	--	10	--	--	Normality assumption is not accurate
	Leaflitter_2	-.356	10	-.805	.352	Normality assumption is not accurate
	Leaflitter_3	.356	10	-.352	.805	Normality assumption is not accurate
	CulturedUncultivated_5	-.267	10	-.768	.436	Normality assumption is not accurate
	CulturedUncultivated_6	.267	10	-.436	.768	Normality assumption is not accurate
	TreeCover_8	--	10	--	--	Normality assumption is not accurate

	ShrubGrass_10	--	10	--	--	Normality assumption is not accurate
	CloudCover_12	.535	10	-.143	.871	Normality assumption is not accurate
	CloudCover_13	-.535	10	-.871	.143	Normality assumption is not accurate
	SunExposure_15	.055	10	-.596	.661	Normality assumption is not accurate
	SunExposure_16	-.055	10	-.661	.596	Normality assumption is not accurate
	LandUseType_18	.089	10	-.573	.681	Normality assumption is not accurate
	LandUseType_19	-.117	10	-.695	.554	Normality assumption is not accurate
	LandUseType_20	-.356	10	-.805	.352	Normality assumption is not accurate
	LandUseType_21	.267	10	-.436	.768	Normality assumption is not accurate

	Location_23	-.055	10	-.661	.596	Normality assumption is not accurate
	Location_24	.089	10	-.573	.681	Normality assumption is not accurate
	Location_25	-.356	10	-.805	.352	Normality assumption is not accurate
	Location_26	.218	10	-.477	.745	Normality assumption is not accurate

Missing value handling: PAIRWISE, EXCLUDE. C.I. Level: 95.0

Appendix E: Linear Regression of Plots with Confirmed Tick Presence

Regression

Notes

Comments		
Input		Data
Input Missing Value Handling	Active Dataset	C:\Users\bryce\OneDrive \Documents\Masters Thesis\Sierra Leone Confirmed Tick Location Data Analysis SPSS.sav
	Filter	DataSet1
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	<none>
	Definition of Missing	23
Missing Value Handling Syntax	Cases Used	User-defined missing values are treated as missing.

	REGRESSION /MISSING LISTWISE /STATISTICS COEFF OUTS R ANOVA /CRITERIA=PIN(.05) POUT(.10) /NOORIGIN /DEPENDENT TotalTicks /METHOD=ENTER Temperature Humidity Leaflitter_2 Leaflitter_3 CulturedUncultivated_5 CulturedUncultivated_6 TreeCover_8 ShrubGrass_10 CloudCover_12 CloudCover_13 SunExposure_15 SunExposure_16 LandUseType_18 LandUseType_19 LandUseType_20 LandUseType_21 Location_23 Location_24 Location_25 Location_26.	Statistics are based on cases with no missing values for any variable used.
Resources		Processor Time
Resources	Elapsed Time	00:00:00.00
	Memory Required	00:00:00.01
	Additional Memory Required for Residual Plots	24448 bytes

Warnings

For models with dependent variable Total Number of Ticks Found, the following variables are constants or have missing correlations: TreeCoverYN=No, ShrubGrass=Grass. They will be deleted from the analysis.

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	Location=Njala, Njala University Mokonde Campus, Location=Njala Village, Location=Njala University Mokonde Campus Ranch (Recently Grazed and Middle Rotation Pasture), LandUseType=Cocoa plantation, CloudCover=Low, Temperature, Humidity[b]	.	Enter

a. Dependent Variable: Total Number of Ticks Found

b. Tolerance = .000 limit reached.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.988[a]	.977	.896	.255

a. Predictors: (Constant), Location=Njala, Njala University Mokonde Campus, Location=Njala Village, Location=Njala University Mokonde Campus Ranch (Recently Grazed and Middle Rotation Pasture), LandUseType=Cocoa plantation, CloudCover=Low, Temperature, Humidity

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	5.470	7	.781	12.049	.079[b]
	Residual	.130	2	.065		
	Total	5.600	9			

a. Dependent Variable: Total Number of Ticks Found

b. Predictors: (Constant), Location=Njala, Njala University Mokonde Campus, Location=Njala Village, Location=Njala University Mokonde Campus Ranch (Recently Grazed and Middle Rotation Pasture), LandUseType=Cocoa plantation, CloudCover=Low, Temperature, Humidity

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	42.747	8.032		5.322	.034
	Temperature	-.935	.174	-1.532	-5.370	.033
	Humidity	-.154	.050	-1.303	-3.080	.091
	CloudCover=Low	-2.929	.377	-1.566	-7.765	.016
	LandUseType=Cocoa plantation	-1.627	.387	-.652	-4.201	.052
	Location=Njala University Mokonde Campus Ranch (Recently Grazed and Middle Rotation Pasture)	-.231	.438	-.093	-.527	.651

	Location=Njala Village	-1.964	.820	-.787	-2.396	.139
	Location=Njala, Njala University Mokonde Campus	-1.392	.298	-.911	-4.666	.043

a. Dependent Variable: Total Number of Ticks Found

Excluded Variables[a]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics Tolerance
1	LeafLitterYN=No	.[b]	.	.	.	.000
	LeafLitterYN=Yes	.[b]	.	.	.	.000
	CulturedUncultivated=Cultured	.[b]	.	.	.	.000
	CulturedUncultivated=Uncultured	.[b]	.	.	.	.000
	CloudCover=High	.[b]	.	.	.	.000
	SunExposure=High	.[b]	.	.	.	.000
	SunExposure=Low	.[b]	.	.	.	.000
	LandUseType=Residential Garden	.[b]	.	.	.	.000
	LandUseType=Roadside Goat Path	.[b]	.	.	.	.000
	LandUseType=Roadside pasture	.[b]	.	.	.	.000
	Location=Hangha Vilage, Kenema District, Cocoa Plantation Oriented Side of Community)	.[b]	.	.	.	.000

a. Dependent Variable: Total Number of Ticks Found
b. Predictors in the Model: (Constant), Location=Njala, Njala University Mokonde Campus, Location=Njala Village, Location=Njala University Mokonde Campus Ranch (Recently Grazed and Middle Rotation Pasture), LandUseType=Cocoa plantation, CloudCover=Low, Temperature, Humidity

Appendix F: Linear Regression of Soil Sample Data and Tick Presence

Regression

Notes

Output Created		04-DEC-2023 11:18:31
Comments		
Input	Active Dataset	DataSet5
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	11
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on cases with no missing values for any variable used.
Syntax		REGRESSION /DESCRIPTIVES MEAN STDDEV CORR SIG N /MISSING LISTWISE /STATISTICS COEFF OUTS R ANOVA /CRITERIA=PIN(.05) POUT(.10) /NOORIGIN /DEPENDENT totalticksbylocation /METHOD=ENTER Meangravimetricsoilwatercontentbylocation.
Resources	Processor Time	00:00:00.00
	Elapsed Time	00:00:00.00
	Memory Required	2880 bytes

	Additional Memory Required for Residual Plots	0 bytes

Descriptive Statistics

	Mean	Std. Deviation	N
totalticksbylocation	1.6364	3.47197	11
Meangravimetricsoilwatercontentbylocation	.3972	.22179	11

Correlations

		totalticksbylocation	Meangravimetricsoilwatercontentbylocation
Pearson Correlation	totalticksbylocation	1.000	-.164
	Meangravimetricsoilwatercontentbylocation	-.164	1.000
Sig. (1-tailed)	totalticksbylocation	.	.315
	Meangravimetricsoilwatercontentbylocation	.315	.
N	totalticksbylocation	11	11
	Meangravimetricsoilwatercontentbylocation	11	11

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	Meangravimetricsoilwatercontentbylocation[b]	.	Enter

a. Dependent Variable: totalticksbylocation

b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.164[a]	.027	-.081	3.60996

a. Predictors: (Constant), Meangravimetricsoilwatercontentbylocation

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3.259	1	3.259	.250	.629[b]
	Residual	117.287	9	13.032		
	Total	120.545	10			

a. Dependent Variable: totalticksbylocation

b. Predictors: (Constant), Meangravimetricsoilwatercontentbylocation

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.659	2.316		1.148	.281
	Meangravimetricsoilwater contentbylocation	-2.574	5.147	-.164	-.500	.629

a. Dependent Variable: totalticksbylocation