THESIS Ref. No.____________

SPATIO TEMPORAL OCCURANCE AND ECONOMIC IMPACT OF RABIES IN HUMANS AND ANIMALS IN SOUTHWEST SHEWA ZONE, ETHIOPIA

BY

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BISHOFTU, ETHIOPIA

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SPATIO TEMPORAL OCCURANCE AND ECONOMIC IMPACT OF RABIES IN HUMANS AND ANIMALS IN SOUTHWEST SHEWA ZONE, WELISO, ETHIOPIA

A thesis submitted to the College of Veterinary Medicine and Agriculture, Addis Ababa University in Partial Fulfillment of the Requirements for the Degre of Master of Science in Veterinary Epidemiology

MSc Thesis

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As member of the examining board of the final MSc. open defense, we certify that we have read and evaluated the thesis prepared by: Tadesse Debele titled: "**Study on Epidemiology and Economic Impact of Rabies in Human and Animals in SouthWest Shewa Zone, Weliso, Ethiopia**" and recommended that it be accepted as fulfilling the thesis requirement for the degree of Master Science in Veterinary Epidemiology.

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LIST OF ABBREVIATIONS

CDC	Centers for Disease Control
CI	Confidence Interval
CNS	Central Nerve System
CSA	Central Statistical Agency
CSF	Cerebro-Spinal Fluid
DALYs	Disability Adjusted Life Years
ELISA	Enzyme-Linked Immuno-Sorbent Assay
FAO	Food and Agriculture Organization
FAT	Fluorescent Antibody Test
GDP	Gross Domestic Product
GPS	Global Positioning System
HDCV	Human Diploid Cell Vaccine
HRIG	Hunan Rabies Immunoglobin
ICU	Intensive Care Units
IMF	International Monetary Fund
KAP	Knowledge ,Attitude and Practice
NBE	National Bank of Ethiopia
OIE	World Organization for Animal Health
OR	Odds Ratio
PCR	Polymerase Chain Reaction
PEP	Post-Exposure Prophylaxis
PrEP	Pre- Exposure Prophylaxis
QGIS	Quantum Geographical Information System
RNA	Ribo Nucleic Acid
RT-PCR	Reverse Transcription Polymerase Chain Reaction
USD	United State Dollar
WB	World Bank
WHO	World Health Organization

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ABSTRACT

Rabies is an important viral zoonotic disease with a high fatality rate and sever economic impact. Epidemiological information can play an important role in the control and prevention of rabies. The current study investigated the spatio-temporal patterns of rabies and associated risk factors in humans and livestock. In addition, estimates the economic burden of rabies and assesses the community's knowledge, attitude, and practice (KAP) and their determinants. A retrospective study was conducted from January 1, 2019, to December 31, 2023, and data was collected from selected health centers, monthly reports of offices, and questionnaire surveys from selected districts of the south-west Shewa zone, namely Kersa Malima and Sodo Dachi. Out of the 506 respondents interviewed, 23.32% of them were females, and about 80.0% of them had their own dogs. Almost 94.07% of the respondents had heard of rabies and identified the mode of transmission of rabies. Moreover, 41.9% had a good level of knowledge, 63.24% had a good level of positive attitude, and 17.78% had a good level of rabies prevention practices. A total of 345 cases of human rabies exposure were reported from 2019 to 2023 in this zone. The incidence of human rabies exposure cases was 6.07, 6.99, 4.36, 3.11, and 4.0 per 100,000 population from 2019 to 2023, respectively. The age group of 5 to 14 years old was highly exposed (31.93%). A larger number of human rabies exposures were reported in males (62.2%). The results of the spatio-temporal analysis identified Kersa Malima, Sodo Dachi, and Weliso districts as hot spots. Strong peaks of human rabies cases occurred in May and August. The estimated total economic impact of canine rabies was over USD 0.41 million. The largest portion of impacts (98.6%) were made up of Post exposure prophylaxis (PEP)-related costs from the total cost of prevention. The findings of this study indicated that preventive measures considering socio-demographic factors can be targeted to high-risk areas for effective control of rabies. Further studies are needed to develop effective strategies for hotspot areas.

Key Words: *Dog, Economic impact, Epidemiology, Human, Livestock, Rabies.*

1. INTRODUCTION

Ethiopia has the second largest human population and the first number of livestock population in Africa. It is particularly vulnerable to the effect of zoonotic diseases because the economy is largely dependent on agriculture and roughly 80% of households have direct contact with domestic animals, which facilitates an opportunity for infection and spread of disease (Pieracci *et al.,* 2016).

This zoonotic disease that huma health problems have been associated with the urban dwelling dog population, especially stray dogs (ownerless dogs) and cats. When dogs are not fully provided with food and shelter by humans, they will roam. Semi-confined and free roaming dog populations can create risks for public health due to zoonotic diseases associated to them. It is known that more than 60 zoonotic diseases transmitted to animals and humans are dog-mediated, including those of significant concern such as rabies and echinococcosis (Kardjadj *et al.,* 2019).

Rabies is a fatal viral disease that affects the central nervous system of all warm-blooded animals, including humans, and it is widespread in many regions of the world (Gebru *et al.,* 2019). This disease is caused by a neurotropic virus that belonging to the class Mononegavirales, the family Rhabdoviridae, and the genus Lyssa virus. The principal manner of transmission to humans is through an animal bite in which the virus in saliva is inoculated. Dogs are identified as the major reservoir and main transmitter of rabies. The virus is a highly neurotropic, pathogen and once it enters the body through a break in the skin or mucous membrane, it migrates along the nerves from the site of infection to the brain where it causes fatal encephalitis. From the brain, the virus travels back to the organs of the body, eventually causing them to shut down (Taylor and Nel, 2015).

The incubation period of the disease varies inversely with the proximity of a bite to the central nervous system, with ranges being from 21-80 days in dogs and up to 209 days in horses and cattle. However, in laboratory infections in cattle, rabies has been shown to occur within 21 days. Furthermore, young animals are more susceptible than adults because young animals are more likely to be curicious and less cautious, increasing their chances of coming into contact with rabid animal with additional of fully undeveloped immune system. The clinical disease first manifests as change in natural behaviors, excessive salivation, excitability, mania and ends in motor paralysis and death. In man and cattle mortality is approximately 100% and susceptibility depends on region and the biotype of the virus (Ibrahim *et al.,* 2017).

In Africa, rabies has also been reported as a potential problem for cattle raised in free-range, mixed crop-livestock and pastoral production systems. In these systems dogs are kept in close contact with cattle, providing an opportunity to transmit the virus to cattle through a bite of an infected dog. Rabies affecting cattle in subsistent systems is said to have extensive economic impacts at the level of the household, the country and human health (Okell *et al.,* 2013). In line with this, several studies showed that the dog population in urban areas including Africa creates favorable conditions for the transmission of dog-borne rabies to humans. It is highly associated with the presence of a large population of uncontrolled and stray dogs. Poor public awareness of rabies is considered one of the bottlenecks to the prevention and control of the disease in Ethiopia (Jibat *et al.,* 2016). In addition, knowledge about dog demography and quantification of rabies-suspected animal bites are relevant for the prevention and control of dog-borne zoonosis (Rinzin *et al.,* 2016).

Rabies has a severe economic impact, causing severe economic losses particular in developing countries (Shwiff *et al.,* 2018). Rabies transmitted by dogs is responsible for the loss of over 1.8 million DALYs (disability adjusted life years) every year, with direct and indirect economic costs (post-exposure prophylaxis (PEP), animal tests, dog vaccination, and livestock losses) estimated at $5.5 billion per year (Gemechu, 2017). Loss of livestock constitutes 8% of estimated total amount of losses. Moreover, rabies outbreaks in livestock species, especially cattle, pose a constant threat to the livelihoods of subsistence farmers in developing countries. Rabies holds great public health significance worldwide. Canine-mediated rabies is responsible for 59,000 human deaths across the globe annually. It is estimated that more than 15 million people receive post-exposure prophylaxis annually (Hampson *et al.,* 2015). This underscores the substantial burden that rabies places on public health systems, particularly in developing regions where access to proper training, treatment and prevention measures may be limited. The knowledge about the spatio-temporal distribution of rabies disease that hinders public and economy is important for the implementation of cost-effective prevention and control measures. Even if accurate information on dog demography and ecology is important for estimating the vaccine coverage needed to control dog-borne rabies This study, therefore, aims to investigate Epidemiology, Economic impact of rabies in humans and animals as well as dog demography and management practices in southwest Shewa zone.

Specific Objectives

- To assess the demography and management practices of homed and stray dogs
- To assess the knowledge, attitude, and practices of dog owners towards rabies
- To investigate the incidence of rabies in livestock and humans
- To estimate economic loss associated with rabies in humans and animals
- To determine the spatial and temporal distribution of rabies in south west Shewa zone

2. LITERATURE REVIEW

2.1. Etiology

Rabies virus is a negative sense single stranded ribo nucleic acid (RNA) virus belonging to the genus Lyssavirus and family, Rhabdoviridae. It is a bullet-shaped enveloped virus measuring 180 nm × 75 nm. The envelope is surrounded by numerous spikes composed of glycoprotein (G), which are important for viral attachment to receptors and is also a major protein for the induction of neutralizing antibodies. The other crucial proteins are the ribonucleoprotein (N), which is intimately closely related with the helical RNA, the phosphoprotein (P) and a matrix protein (M). The rabies genome has approximately 12,000 nucleotides. In different parts of the world, there are seven genotypes of the virus that have been identified (Madhusudana and Sukumaran, 2008).

By using molecular biological analysis and cross-protection tests, it is possible to differentiate seven different genetic lineages within the genus Lyssavirus: the classical rabies virus (RABV, genotype 1, serotype 1), the Lagos bat virus (LBV, genotype 2, serotype 2), the Mokola virus (MOKV, genotype 3, serotype 3), and the Duvenhage virus (DUVV, genotype 4, serotype 4). The European bat lyssaviruses (EBLV), separated into two biotypes (EBLV1, genotype 5 and EBLV2, genotype 6) and Australian bat lyssavirus (ABLV, genotype 7), isolated in Australia, are also members of the Lyssavirus genus, however they have not yet been assigned a serotype. Viruses of Serotypes 2-4, EBLV and ABLV of viruses are rabies-related viruses (OIE, 2008). For RABV, DUVV, EBLV and ABLV, conserved antigenic sites on the surface glycoproteins allow cross neutralization and cross-protective immunity to be elicited by rabies vaccination. Little or no cross-protection against infection with MOKV or LBV is elicited by rabies vaccination and most anti-rabies virus antisera do not neutralize, these lyssaviruses (OIE, 2008; Rinchen, 2018).

2.2. Epidemiology of Rabies

Rabies is a widespread zoonosis causing a significant social and economic burden in many countries in worldwide. In accordance with the provisions of the OIE *Terrestrial Code,* only 32 of the 178 OIE member countries would be eligible to qualify for historical freedom or have successfully eliminated rabies in domestic animals. Rabies is endemic in more than 110 member countries with a global distribution. Of the 178 OIE member countries, rabies is a notifiable disease in dogs in 161 member countries (OIE, 2011).

Certain mammalian reservoir hosts are often responsible for maintaining and transmitting rabies within a particular geographical region. Rabies is endemic in many countries throughout the world and has been documented in all continents except Australia (where only the bat lyssa viruses have been found), New Zealand, UK, Japan, Scandinavian and Caribbean countries, some Islands, and Antarctica, where the major vectors of rabies are absent. Rabies is maintained through two transmission cycles namely, the urban cycle and the sylvatic cycle. Dogs are the primary reservoir in the urban cycle while wildlife species, especially in the order Carnivora (foxes, jackals, wolves, skunks, raccoons, and mongoose) and Chiroptera (bats), are the primary reservoirs in the sylvatic cycle of the disease. Humans and livestock species are considered dead-end hosts for rabies, as these cases do not lead to subsequent transmission of the disease. However, there are reports of atypical human-to-human transmission of rabies through organ transplantation (Rinchen, 2018).

Dog mediated rabies has mostly been eliminated from the western world through the vaccination of free-roaming and pet dogs. However, the disease has persisted in wildlife species often spilling over and causing rabies outbreaks in domestic animals. The primary reservoirs involved are raccoons (*Procyon lotor*), bats, skunks (*Mephitis mephitis*), foxes, and mongooses (*Herpestes sp.*)(Monroe *et al.,* 2016). In Asia and Africa, 99% of rabies cases are due to dog bites. Wildlife reservoirs have been reported maintaining the sylvatic infection cycle with occasional spill over to humans and domestic animals. Mongooses and black-backed jackal (*Canis mesomelas)* are the primary wildlife reservoirs reported from South Africa (Bourhy *et al.,* 2010).

2.2.1. Host range

Rabies occurs in all warm-blooded animals including cattle, sheep, pigs, and horses in most countries. Species susceptibility to rabies virus is important Epidemiologically. Rabies can infect all mammals. Domestic animals and humans are considered to be moderately susceptible, whereas foxes, wolves, coyotes, and jackals are considered to be extremely susceptible to the virus. several animal species can be considered as accidental hosts or 'dead end' hosts and these species have no Epidemiological importance in maintaining rabies epidemics. These include, horses, cattle, sheep and pigs as well as humans and other primates (Meslin *et al.*, 1996).

2.2.2. Transmission rabies

Rabies virus is usually transmitted from animal to animal through bites. A rabies exposure is any bite, scratch, or other situation in which saliva, cerebral spinal fluid, tears, or nervous tissue from a suspect or known rabid animal enters an open wound, is transplanted into, or comes in contact with mucous membranes of another animal or person. The common mode of transmission of rabies in man is by bite of a rabid animal or the contamination of scratch wounds by virus infected saliva of both wild and urban rabies occurs mainly when an animal that is shedding virus in its saliva bites another susceptible animal or humans. The spread of the disease is often seasonal, with high incidence in late summer and autumn because of large scale movement of wild animals at the mating time and in pursuit of food (Radostits *et al.,* 2007; Shite *et al.,* 2015). Respiratory and oral transmission can also occur. The main determinant of transmission is the population density of non-immunized susceptible key host species that are free roaming within an ecosystem (Oyda and Megersa, 2017).

Before signs are evident, the virus may be present in the saliva for periods up to 5 days. Not all bites from rabid animals result in infection because the virus is not always present in the saliva. If saliva is kept clean from the teeth by clothing, the virus may not enter the wound. RABV transmission through aerosol has been reported in a few humans working in bat caves, but alternative natural occurrence of rabies in animals in caves inhabited by infected insectivorous bats, inhalation as a route of infection became suspected. It is now accepted that inter-bat transmission, and transmission from bats to other species is predominantly by bites, but that infection by inhalation also occurs (Constable *et al.,* 2016).

2.3. Rabies Surveillance System

Animal disease surveillance systems comprise passive and active surveillance. In the passive surveillance system, data are collected when the owner reports to the relevant authorities or the animals showing clinical signs of a disease present themselves in some manner, while the animals are sought, caught and tested in active surveillance. Active surveillance systems, although they provide better data, are more expensive The risk-based surveillance concept is gaining importance and can provide a higher benefit-cost ratio with existing or reduced resources (Dorrell, 2007).

Surveillance systems are important to enhance disease prevention, particularly in developing countries, so that the emergence and spread of zoonotic pathogens can potentially be controlled with timely detection and disease reporting (WHO, 2012). Animal rabies surveillance was started as early as the 1970s. The aims of this surveillance are early detection of animal rabies outbreaks in endemic areas, monitoring the spread and progress of outbreaks, determining high-risk areas for intervention, and evaluating the effectiveness of intervention at the level of the animal reservoir. These are necessary to understand how rabies affects public health (Guri *et al.,* 2023).

2.4. Clinical Signs

The initial clinical signs of rabies are often nonspecific and may include fearfulness, restlessness, anorexia or an increased appetite, vomiting, diarrhea, a slight fever, dilation of the pupils, hyperreactivity to stimuli and excessive salivation. After the bite of a rabid animal, such as a bat or dog, the incubation period is usually between 14 and 90 days, but it may be considerably longer. These path may be divided into 3 phases namely prodromal, excitative (excitement) and paralytic or end stage. During the prodromal period which lasts approximately 1-3 days, animals show only vague central nervous system signs, which intensify rapidly. The term “furious rabies” refers to animals in which aggression (excitatory phase) pronounced (Moges, 2015).

Prodromal Stage: After a certain incubation period, the onset of clinical symptoms follows. Behavioral changes might occur, aggressiveness and no fear of humans in wild animals or abnormalities in appetite. The period lasts approximately 1-3 days, animals show only non-specific central nervous system signs, which increased rapidly (Balcha and Abdela, 2017).

Excitement (Furious) stage: Animals experiencing this condition may display restlessness, aimless wandering over extended distances, howling, rapid breathing, excessive drooling, and aggression towards other animals, humans, or objects. Additionally, affected animals may ingest foreign objects like sticks and stones. This refers to "mad-dog syndrome," which may be found in all species. There is rarely evidence of paralysis during this stage (OIE, 2008).

Paralytic (Dumb) stage: The "dumb" form of rabies is characterized by progressive paralysis. It is first manifested by paralysis of the throat and masseters muscle often with profuse salivation and in ability to swallow: Hydrophobia and it can salivate profusely. Laryngeal paralysis can cause a change in vocalization, including an abnormal bellow in cattle or a horse howling in dogs, facial paralysis or the lower jaw may drop. Ruminant animals have been known to exhibit behaviors such as isolating themselves from the herd and displaying signs of drowsiness or despondency. Rumination may stop; ataxia, incoordination, and ascending spinal paresis or paralysis are also seen (OIE, 2008).

Once virus permeated the brain, it spread centrifugally to a different of organs, the spread into the salivary gland, which represents the last phase of infection, is important transmission between animal to animal and animal to human. Destruction of spinal neurons results in paralysis, but when the virus invades the brain, irritation of higher centers leads manias, excitement and convulsions, and death is usually due to respiratory paralysis (drooling of saliva). The clinical manifestation of salivation, indigestion and pica, paralysis of bladder and anus and increased libido all suggest involvement of the autonomic nervous system, including endocrine glands (Moges, 2015).

2.5. Pathogenesis

The neurotropic rabies virus initially replicates in the muscle tissue at the site of the bite (local viral proliferation in non-neural tissue), before entering the peripheral nervous system (viral attachment), where it remains localized for varying durations (days to months). Following infection, degeneration of ganglion cells, infiltration of mononuclear cells around nerves and blood vessels, as well as neuronophagia, are observed in the peripheral nerves, spinal cord, and brain. The dysfunction of neurons due to their degeneration, rather than their death, is the primary cause of disease manifestation (Jackson, 2007). The rabies virus initially targets ganglion cells, triggering an early axotomy response characterized by the presence of multiple autophagic compartments. As the degeneration progresses, ganglion cells exhibit partially membrane-bound empty vacuoles (Rossiter *et al.*, 2009).

2.6. Diagnosis

Laboratory diagnosis of rabies in humans and animals is essential for timely post-exposure prophylaxis. In developing countries, rabies diagnoses are mostly based on clinical signs, history of exposure, and epidemiological information due to a lack of facilities. Brain tissue samples are commonly used in rabies laboratory diagnosis due to the virus's affinity to the nervous system. The brain stem and hippocampus are often preferable as specimens for testing purposes. Also, the cerebellum is recommended to the diagnostic sampling. Rabies virus was frequently detected in brain samples from carnivores (94.5%) than other animal species (Ali, 2022).

Direct Fluorescent Antibody Test: The fluorescent antibody test (FAT) is the most widely used and highly regarded diagnostic method for rabies. It identifies virus antigens in brain samples by using fluorescently label anti-rabies virus antibodies. Current guidelines suggest that sampling from areas such as the hippocampus, medulla oblongata, cerebellum, or gasserian ganglion for testing. The FAT based on antibodies targeting the same protein, but with the addition of fluorescein isothiocyanate, necessitating a fluorescent microscope to observe any specific antibody binding to viral proteins in the test sample (Fooks *et al.*, 2009; Reta *et al.*, 2013).

Direct Rapid Immunohisto chemical Test: The Direct Rapid Immunohistochemical Test utilizes monoclonal antibodies targeting the nucleoprotein of the rabies virus, which is highly expressed during active infection. This test can rapidly detected rabies antigen through direct staining of fresh brain samples within an hour. It involves the use of specific anti-rabies monoclonal antibodies directed against the nucleoprotein, a viral protein that is prominently produces during an active infection (Niezgoda and Rupprecht, 2006; Fooks *et al.,* 2009). For less-developed parts of the world, the CDC has recently developed a RIT It only necessitates an ordinary light microscope for examination and has demonstrated sensitivity and specificity on par with the standard Direct Fluorescent Antibody Test (DFAT) (Ali, 2022).

Molecular techniques and Serological tests: Various molecular diagnostic tests, are detection of viral RNA by RT-PCR, PCR-ELISA, real-time PCR, hemi-nested PCR, and nested PCR are used as rapid and sensitive tests for rabies diagnosis. Serological assays are employed to quantify the presence of virus-neutralizing antibodies in vaccinated individuals and to identify the host's immune reaction to rabies infection by assessing antibodies in cerebrospinal fluid or serum in suspected cases of rabies. Nevertheless, these assays demand specialized laboratory settings and capabilities for managing tissue culture and the virulent rabies virus, making them impractical for widespread screening of field sera (Liu DongYou, 2016).

2.7. Differential Diagnosis

Rabies should be included in the differential diagnosis for potential cases of mammalian meningitis/encephalitis, distemper, infectious canine hepatitis, and cerebral cysticercosis (Taenia solium) in dogs. Additionally, it should be considered for sporadic bovine encephalomyelitis (Chlamydia psittaci), heartwater in cattle and sheep. Other conditions like mineral/ pesticide poisoning and plant poisoning from *Pennisetum clandestinum* (*kikuyu grass*) in cattle, *Cynanchum* spp (monkey rope) in sheep should be considered (Oyda *et al.,* 2017).

2.8. Economic Impact of Rabies

One of the primary obstacles to determining the impact of rabies is the lack of dependable surveillance data in countries where the disease is widespread. Essential data on the human lives lost to rabies and the economic expenses associated with preventing the disease in individuals exposed to it are crucial for promoting sustainable control initiatives. Official reporting of rabies incidence and exposures is severely lacking in many countries where canine rabies is prevalent, leading to a significant underestimation of the actual number of cases (Hampson *et al.*, 2015).

The overall economic impact of canine rabies on a nation encompasses various elements, such as the direct expenses associated with immunizing animals and individuals, as well as the indirect costs (often shoulder by patients and dog owners) related to lost income and travel for seeking vaccination. It also includes losses from livestock deaths due to rabies, surveillance expenditures, expenses for managing the dog population, and productivity declines. Notably, productivity losses constitute the most significant component of the global financial impact of rabies, and recent studies have employed two distinct approaches to calculate these losses. Estimating productivity losses by multiplying the life years lost to rabies by the country-specific gross domestic product per capita produced a figure of $8.6 million lost due to rabies globally per year (Hampson *et al.*, 2015).

However, when the value of lives lost to rabies is assessed using the value of a statistical life, these losses have been estimated at $124 billion globally per year. The value of a statistical life is an economic measure that has only recently been applied in public health. It reflects the economic value placed on a change in mortality risk, derives from an analysis of how wages and spending are affected by mortality risk. (Taylor and Nel, 2015).

Country estimates of unit costs for delivering PEP, dog vaccination and surveillance were largely obtained from surveys. The total economic cost of rabies was obtained by combining data on unit cost per case, livestock losses, and costs of control and prevention. Indirect costs were corrected for differences in income using the ratio of income per capita (expressed in international dollars, I$) calculated using IMF statistics. Livestock losses due to dog rabies were extrapolated from the inferred relationship between coverage and incidence and using livestock population estimates. The cost per head of cattle was multiplied by the incidence of rabies in cattle (Hampson *et al.,* 2015).

The cost-effectiveness studies rabies control has demonstrated that dog rabies elimination is more economical than the intensified use of PEP in humans. The World Animal Health Organization has stated that just 10% of the costs currently used to treat people bitten by potentially rabid dogs would be sufficient to eradicate dog rabies in the world and thereby prevent almost all human rabies cases (OIE, 2011).

2.9. Epidemiological Status of Rabies in Ethiopia

Ethiopia is one of the worst affected by rabies with domestic dogs being the major sources of the infection to humans. Dog management is; however, poor and anti-rabies dog vaccination is generally limited to a small number of dogs found in urban settings (Ali, 2022). The large dog population size in combination with poor dog management contributes to a high endemicity of canine rabies in Ethiopia, which accounting for an estimated death rate of 10,000 people a year (Jemberu *et al.,* 2013) and the mean number human exposure case of 7598 and 59 death per year (Asfaw *et al.,* 2024).

The occurrences of the rabies in varies species of animals in Ethiopia. About 96.2% dogs 5.35% cats and cattle represent the highest rabies case (2.9%) among domestic animals followed by sheep, goat and donkey. Hyaena, Jackal, Mongoose and serval cat were wild animals that rabies source or confirmed in Ethiopia (Yimer *et al.,* 2002).

Rabies suspected human exposure cases and deaths were reported from all parts of the country. The exposure case and mortality incidence rates were 6 and 0.05 per 100,000 populations respectively. Suspected human exposure cases significantly increased at a rate of 2.2. In the same period, animal suspected rabies cases and deaths were reported, predominantly in dogs (71.2%), followed by cattle (27.8%) and other domestic animals (1%). There was variation among regions in terms of rabies burden. Amhara region reported the highest suspected exposure cases and deaths followed by Tigray, Addis Ababa, and Benishangul Gumuz regions while Afar and Somale regions reported very few cases associated with the presence of few dog populations (Asfaw *et al.,* 2024).

2. 10. Demography of Dogs and Ownership Status

The majority (equal to 98%) of dogs in African countries is kept for purposes of socio-economy comprising protecting livestock from predators, homestead from invaders, harvests (crops) from wildlife and hunting. Male dogs take over the female dogs equal to 3.6 times in number within the population (Knobel *et al.,* 2008; Yimer *et al.,* 2012).

Dogs mean age varies between 1.8 and 3.4 years. The percentage of ownerless dog ranges between 0.7% and 20% of a dog population within the 11 represented African countries on Studies regarding ownership of dogs. With the exception of a study in Tanzania. Female dogs were observed to reach sexual maturity at 10 months of age and were capable of reproducing until they were 11 years old. On average, each fertile female dog gave birth to 0.6 litters per year, with an average litter size of 5.5 puppies (Gsell *et al.,* 2012).

2.11. Treatment, Prevention and Control of Rabies

2.11.1. Prevention and control of rabies in dogs

Domestic dogs are the main reservoir of rabies in many developing countries, and account for about 99% of all human rabies cases in Asia and Africa. The principles of canine rabies control program is described elsewhere and should consist of:public awareness education on rabies, one health approach, mass dog vaccination, dog population control and international (global) collaboration (partnership) (WHO, 2018).

Public awareness: One of the most important points in rabies prevention is the level of awareness in both the medical profession and the general public (Lembo *et al.,* 2011). However, because many children are not taught in a formal classroom setting, new approaches that could reach a wider population in endemic areas would save lives (WHO, 2018). Governments should implement public awareness initiatives to promote responsible pet ownership, routine veterinary care, vaccination, and ongoing professional education. Failure to do so may lead to insufficient awareness of the disease burden and the essential methods for preventing and managing rabies (Aga *et al.,* 2016).

Dog vaccination: The fundamental elements of a rabies control strategy for domestic (companion) animals include: vaccination and registration; management of stray animals; reporting, examination, and isolation of animals implicated in bite incidents. Immunizing dogs is the established method for averting human exposure and eradicating the disease at its source. As the majority of human cases result from bites by infected dogs, the most effective approach to lessening the worldwide impact of dog-transmitted human rabies is to eradicate rabies in canines (Hampson *et al.*, 2015).

2.11.2. Prevention and control of rabies in humans

Rabies is an 100% fatal disease and there are no cure once clinical symptoms are present in the patient, but can be prevented by pre-exposure prophylaxis and immediate postexposure prophylaxis following exposure to rabid animals (WHO, 2018).

Pre-exposure prophylaxis (PrEP): This is recommended to individuals who are regularly exposed to the risk of rabies, such as veterinarians, laboratory workers handling the rabies virus, dog catchers, forest rangers, and medical personnel treating rabies patients in intensive care units, are advised to follow a specific vaccination regimen (WHO, 2010). This involves receiving three doses of a modern rabies vaccine on days 0, 7, and 28. Additionally, individuals at continued risk should receive booster doses. Pre-exposure prophylaxis (PrEP) is also recommended for populations in remote and high-risk areas where immediate post-exposure prophylaxis (PEP) may not be readily available. PrEP serves as an important measure for protecting these populations from rabies (Pal *et al.,* 2013).

Post-exposure prophylaxis (PEP): The post-exposure prophylaxis consists of three important ingredients viz. local wound treatment, passive immunization with rabies immunoglobulins and active immunization with rabies vaccines. All these are equally important and treatment failures have occurred due to neglecting any of the procedures, particularly passive immunization. The recommended PEP includes thorough cleaning of the bite wound with soap and water or detergent, administration of rabies vaccine to stimulate an active immune response, and administration of rabies immunoglobulin to provide immediate passive immunity. However, the indication for PEP depends on the type of contact with the suspected rabid animal and should follow the WHO guideline (WHO, 2010).

Wound management: Surgical debridement should be performed without closure to encourage bleeding, followed by thorough cleansing with soap, water, and antiseptic or disinfectant solutions (Tenzin and Ward, 2012).

Passive immunization: The recommended dosage for administering rabies immunoglobulin (RIG) involves infiltration into and around the bite wounds at dose rates: 20 IU/kg body weight for Human Rabies Immunoglobulin (HRIG) and 40 IU/kg body weight for Equine Rabies Immunoglobulin (ERIG). Ideally, the full calculated dose should be injected directly into and around the bite wound, if possible, while being cautious to avoid potential compartment syndrome. Any remaining portion of the dose should be administered intramuscularly at a location separate from the site of vaccine administration (WHO, 2010).

Active immunization: The different types of vaccines used to prevent RABV includes- the Fermi type RABV vaccine (nervous tissue rabies vaccine). The complete course of the vaccine requires 5 doses given 1ml in deltoid area intramuscularly on days 0, 3, 7, 14 and 28. If the person is vaccinated before, no Hunan rabies immunoglobin (HRIG) is used and only two doses of vaccine is given on days 0 and 3. Human Diploid cell vaccine (HDCV) is contains a high titre of RABV, evokes a high immunologic response and causes less severe side effects than Fermi type rabies vaccine which has many side effects such as nervous problems, serous allergic reactions and it is not effective on severe and proximal bites to the central nerve system (CNS) (Yurachai *et al.,* 2020).

3. MATERIALS AND METHODS

3.1. Study Areas

The study was conducted in the South-west Shewa zone, Oromia Regional State of central Ethiopia. The administrative center of Southwest Shewa Zone is Weliso and located 114 Km southwest of Addis Ababa. It has a latitude and longitude of 8°32′N and 37°58′E with an elevation of 2,063 meters above sea level. The mean temperature of the zone is 22.5 and the mean annual rainfall is 1,200mm. Based on the census conducted by the Central Statistics Authority of Ethiopia (CSA, 2022), the total human population of the zone is 1,640,751, of which 823,509 are males and 817,242 are females. From total population of the zone 223,306 people, or 13.61% of the population, are urban residents. There are a total of 233,916 households in this zone, with an average of 4.8 people per household and 341,823 residential units (CSA, 2022). The Zone is known by high population of livestock. There are about 1,094,301 cattle, 263,084 sheep, 260,410 goat, 68,198 horse, 197,111 donkey, 4029 mule,7053 dogs and 694,786 poultry population (CSA, 2020).

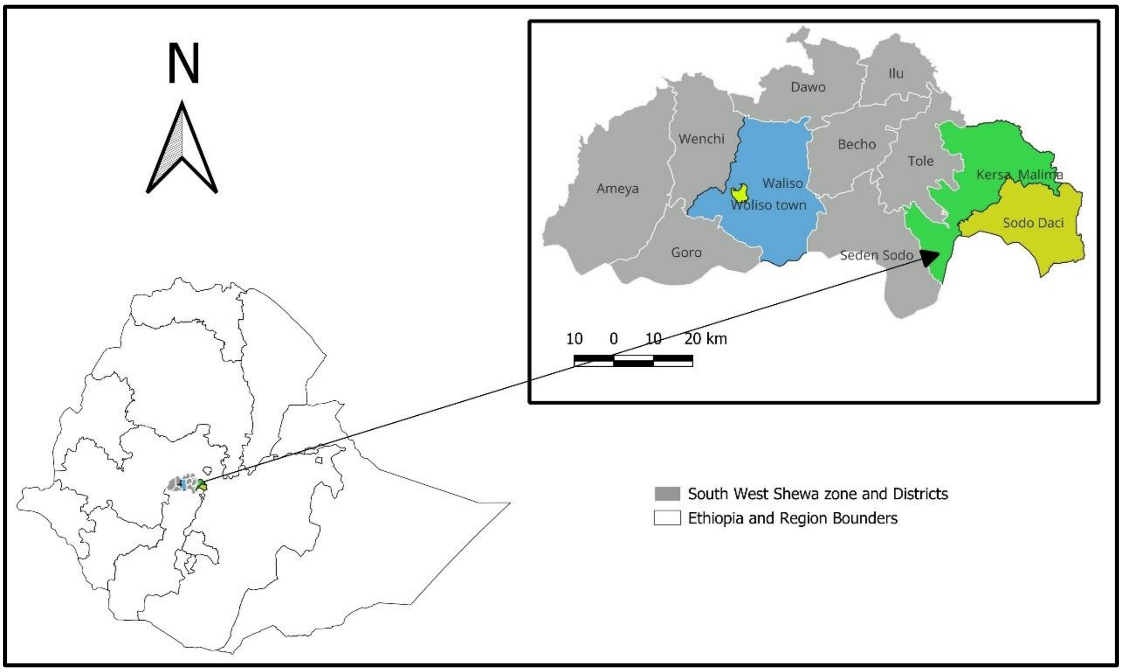

Figure 1: Map of the study areas source: This map was created using QGIS version 3.30 from the Ethiopian admin shapefile of 2021.

3.2. Study Design and Methodology

The study was conducted from November 2023 to April 2024 to gather data on dog demography, management practices, and the community's KAP towards rabies using a questionnaire. Two districts were selected purposively for this survey based on the presence of a large number of livestock populations and dogs. Furthermore, five kebele per district were selected purposively based on accessibility and proximity to the towns.

In the current study, a total of 506 households comprising both dog-owning and non-owning households were sampled. These households were drawn from 10 rural kebeles and three town kebeles. Three hundred forty-nine households from the rural kebeles and 157 households from the urban were selected. Retrospective data were collected from supplementary reports of zone and Woreda's Agriculture and Health Offices and case recording books of selected human health centers.

3.2.1. Questionnaire survey

The structured questionnaires were used to collect information on individual's knowledge, attitudes, and practice regarding rabies. Volunteer households were included in the interview. Ownership is verified during the questionnaire survey since there is no dog ownership registration in the country. Questionnaire was administered either in large animals' vaccination sites in rural kebeles and door-to-door survey in the towns.

Each Kebele had three vaccination sites. During vaccination from one site 11-13 household representatives were selected randomly chosen using a lottery system. The selected individuals were informed about the purpose of the study and the collected data were confidential. On the other hand, a door-to-door survey was conducted in the two towns namely Lemen and Tere. The interview was carried out in the local language (Afaan Oromo), but the answers were recorded in English. Based on the number of questions asked of the respondents about their KAP towards rabies disease, number of positive responses was counted and the score was categorized into a binary variable with a score index value (outcome variable) below mean number of questions are zero, and the above are one.

3.2.2. Retrospective data collection

Retrospective data were used to see the spatio-temporal distribution of rabies incidence. The data were obtained from case books of certain human health centers, from reports of the zone, and from woreda's Agriculture and Health Office over past five years (2019-2023). Six health stations in the zone that give rabies PEP vaccines to the local population, provided the registered data on dog bites and suspected cases of rabies, were included in the study. The patient record books provided details on the date of the bite, severity of the bite, status of the dog that bite the victim, the victim's sex, age, and the body area that was bitten. Finally, the spatiotemporal distribution of rabies cases and risk areas were indicated.

3.2.3. Economic estimation

For estimation of the economic impact of diseases, the data was collected from, supplementary reports and primary data. In the case of dogs' data like vaccine cost, vaccinators/animal health worker costs, and livestock cost of animal losses due to rabies were collected from the Agriculture office and Trade and Market office monthly reports. Similarly, the number of dog bites case PEP costs and other costs were collected from monthly reports and patient case cards of human health center and Health office.

3.2.4. Method of economic burden estimation

The economic burden of rabies was calculated based on Jo's cost classification. The PEP costs represented the direct costs, which included both healthcare and non-healthcare expenses (Jo, 2014). The estimation was based on the health workers responses regarding the number of PEP doses administered and the number of visits to the health centers. Costs associated with food and transportation during the medical treatment, obtained from interviewed of previously bitten patients, as well as the productivity lost (time spent) also calculated as GDP per capita daily income. Ethiopia's average per capita income in the last year of the study was 857.32 USD and average daily income of an individual was 2.38 USD (WB, 2022). Using the average annual exchange rate for the study period reported by the National Bank of Ethiopia (1 USD = 56.5472 ETB), all costs were converted from Ethiopian birr (ETB) to US dollars (USD

(NBE, 2023). A complete dose of PEP consists of 17 doses of vaccine administered consecutively for the first 14 days, and the final 3 doses given ten days apart on days 24, 34, and 44.

Livestock species considered in this study were cattle, horses, donkeys and mules. These are among the species that are highly susceptible to the rabies virus. However, there was no reliable data on the prevalence and mortality of canine rabies in livestock in any animals' health clinics of the study areas. Thus, estimates of the impact of canine rabies on livestock were done according to formula of Hampson *et al.* (2015). From primary data gathering for the goal of assessing the global burden of canine rabies, Hampson *et al.*, 2015 noticed the association between rabies in livestock (IL) and dog vaccination coverage (VC), as shown in Eq 1.

$$IL = 0.0017*(1-VC)^9 \quad (1)$$

Livestock losses due to dog rabies were extrapolated from the inferred relationship between coverage and incidence as in Eq 1 and using livestock population estimates from Agriculture office and CSA, 2021/22

3.3. Variable Definition

Rabies case: Rabies is a communicable disease of animals and people caused by rabies virus present in the saliva of rabid animals.

Rabies exposure: any situation where saliva or central nervous system tissue of a suspect rabid animal enters an open, fresh wound or comes in contact with a mucus membrane by entering the eye, nose or mouth.

Dog bite: A dog bite is a bite upon a person or other animal by a dog, including from a rabid dog.

Dog vaccination coverage: Vaccination coverage is the estimated percentage of dogs which have received specific vaccines.

3.4. Data Analysis

The data for KAP and retrospective results were recorded in Microsoft Excel, in 2013 and analyzed using Stata software version 14 (Stata Corp., 2015). Descriptive statistics like percentage and frequency were conducted and presented in tabular form. The Chi-square test was used to determine the statistical association between different risk factors on KAP of rabies disease and dog management practices. In all analyses, the confidence level is held at 95% and the p-value that less than 5%. QGIS and ArcGIS were used for spatial analysis and risk maps. By using global Moran's I and the Getis–Ord statistics to identify clusters of high rabies incidence at the district level and to assess the presence, strength, and direction of rabies disease. The Distance Weighted (IDW) Interpolation technique was employed in this analysis to forecast the value of unknown points based on known points. The Economic burden of rabies was estimated by R software version 4.30 (R Core Team, 2023).

3.5. Ethical Clearance

The study received ethical approval for the research from the College of Veterinary Medicine and Agriculture (CVMA) at Addis Ababa University, as per the minutes of the animal research ethical review committee (reference: (**VM/ERC/01/16/024, 23/01/2024**), and was issued certificate reference number **VM/ERC/01/11/16/2024.**

4. RESULTS

4.1. Incidence Rates of Rabies in Livestock (2023)

The incidence rates of rabies at each species of livestock were calculated from the questionnaire survey collected during 2023 (Table 1). The incidence rate of rabies case was 5.4, 1.7, 1.2, and 1.13, per 1,000 population of dogs, donkeys, mules, and horses, respectively. The incidence rates of cattle and sheep suspected of rabies were 3.6, and 1.9 per 10,000 population, respectively. Among the livestock species, the highest incidence rates were recorded in dogs followed by equine.

Table 1: Incidence of rabies in livestock from data collected by questionnaire survey

Livestock species	Population at risk	Case number	incidence rate (2023)
Cattle	71870	26	0.000362
Horse	3528	4	0.001134
donkey	6383	11	0.001723
Mule	1612	2	0.001241
Sheep	15296	3	0.000196
Goat	13506	0	0
Dog	719	4	0.0056

4.2. Incidence of Rabies and Epidemiological Risk Factors

A total of 119 human rabies cases were recorded from six selected health centers in the southwest Shewa zone such as Lemen, Adadi, Tere, Weliso 02, Obi, and Dilala Health Center. The age group ranging from 5-14 years was the most exposed (31.93%), followed by 15-60 years (27.73%), and more than 60 years (8.4%), and less than 4 years (4.2%). A greater number of human rabies exposures was registered in males (62.2%) than females (37.81%). Out of 119 dog bite cases, 7.56% occurred in the neck region, 29.41% on hands/ arms, and 63.03% on the legs. Across body parts bitten by dogs, the highest proportion of bite sites were on the legs and the lowest proportion were on the neck region. About 40.17% had more than one wound, 50.43% had a single wound or one site bite and only 9.4% had a scratched or simple wound. Similarly, out of all bites made, 72.27% were related to rabies suspected dog and about 27.73 % were unknown status (Table 2).

Table 2: Humans rabies exposure cases and associated risk factors (2019-2023)

Variable		Number case (n=119)	Percentage	Standard error	95% CI
Age	1-4years	5	4.202%	1.85	1.74 - 9.81
	5-14years	38	31.93%	4.29	24.09 - 40.95
	15-29years	33	27.73%	4.12	20.34 - 36.57
	30-64years	33	27.73%	4.12	20.34 - 36.57
	≥65 years	10	8.40%	2.55	4.54 - 15.04
Gender	Female	45	37.81%	4.46	29.46 - 46.97
	Male	74	62.18%	4.46	53.03 - 70.54
Severity of bite	Multi-wound	47	40.17%	4.55	31.57- 49.42
	Single wound	59	50.43%	4.64	41.32- 59.50
	Scratched	11	9.40%	2. 71	5.24 -16.31
Dog status	Suspected	86	72.27%	4.12	63.43 -79.65
	Unknown	33	27.73%	4.12	20.34- 36.57
Site of bite	Neck region	9	7.56%	2.43	3.94- 14.02
	Hand/Arms	35	29.41%	4.19	21.83- 38.33
	Legs	75	63.03%	4.44	53.88- 71.32

During the period from January 2019 to December 2023, a total of 345 bites by rabies-suspected dogs were reported to south west Shewa zone health office which received post-exposure vaccines. The incidence of bite cases as calculated from the mid-year population was 6.07, 6.99, 4.36, 3.11, and 4.00 per 100,000 population for the five respective study years (2019-2023). The mean incidence rate of rabies for five years was 4.7per 1000,000 population. It was observed that the distribution of human rabies exposure cases year to year decreased but, in 2023, it slightly increased (Table 3).

Table 3: Incidence of rabies in humans from annual reports of five years (2019-2023)

Year	Human population	Number of PEPs administered	Incidence of rabies
2019	1169650	71	0.0000607
2020	1301744	91	0.0000699
2021	1491419	65	0.0000436
2022	1640751	51	0.0000311
2023	1701214	68	0.00004

4.3. Spatial and Temporal Distribution of Human Rabies Exposure

The global Moran's index statistic value in each year between 2019 and 2023 was statistically significant and positive; it provides evidence of positive spatial autocorrelation in rabies incidence in the study area (Table 4) These indicated the presence of spatial patterns or Custers of high or low value or the nearby location tend to have similar value. Furthermore, a significant spatial autocorrelation (Z =0.7009, p-value =0.0000) was observed in the average annual rabies incidence, indicating the presence of significantly positive spatial autocorrelation in the rabies incidence rate over the whole study area (Figure 2). These illustrated that the distribution of rabies in the south west Shewa zone was occurred in the cluster pattern.

Table 4: Global spatial autocorrelation rabies incidence in the study area during the five studies year (2019–2023)

Year	Moran's index	Z-score	p- value	pattern
2019	0.786158	4.969857	0.00001	clustered
2020	0.771124	4.947059	0.00001	clustered
2021	0.264781	1.810192	0.07026	clustered
2022	0.208534	1.547269	0.12179	-
2023	0.824964	5.338805	0.00002	clustered
Annual average	0.70093	5.089702	0.00000	clustered

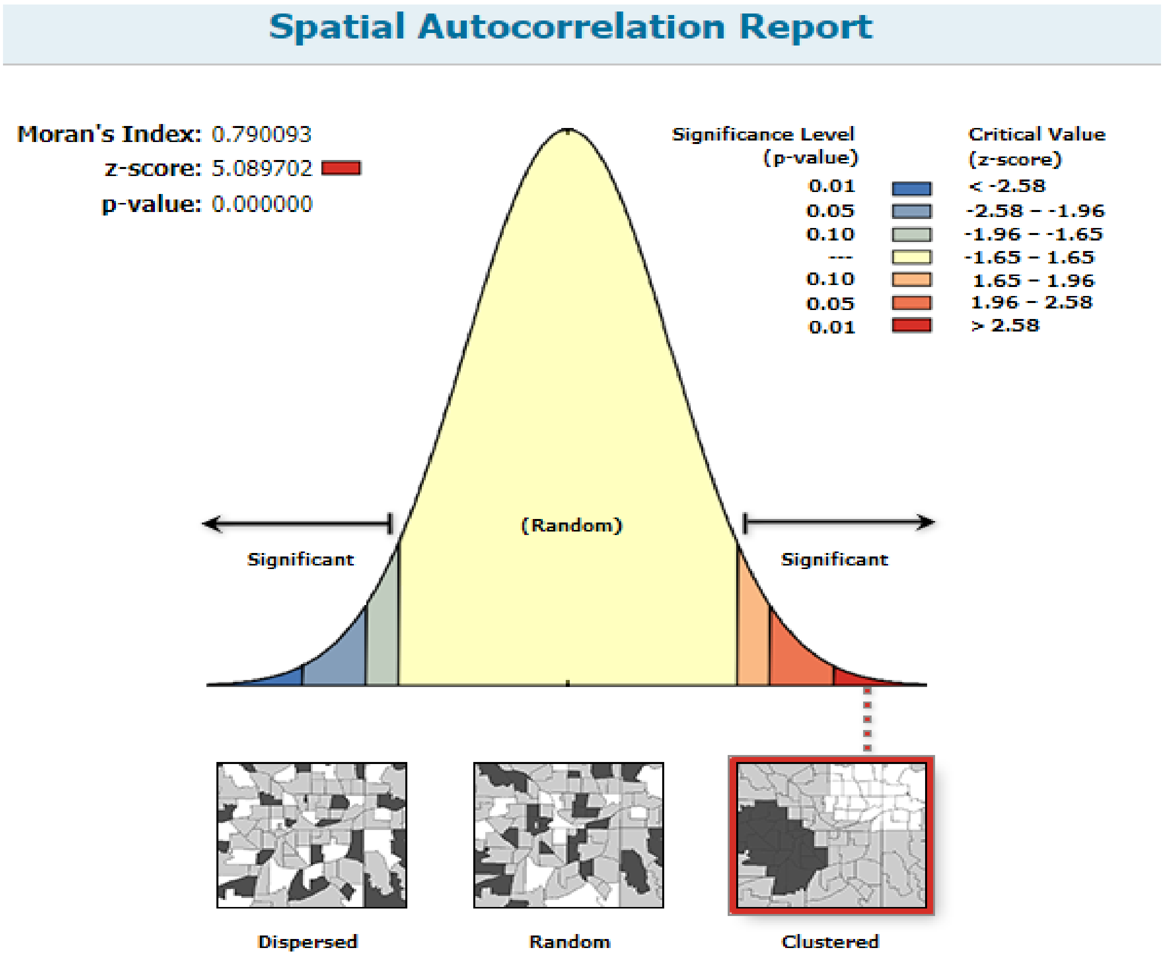

Figure 2: The annual average spatial autocorrelation reports of rabies incidence

Based on our clustering analyses using the Getis–Ord Gi* statistic, some districts were identified as hotspots and cold spots (Figure 6). The hotspot districts indicate a higher-than-expected rabies case and the cold spot districts indicate lower than expected rabies case compared with the zone average. Kersa Malima remained a hot spot for rabies cases for about five years, similarly, Sodo Dachi was a hotspot area from 2020 to 2023 whereas Becho Ilu and Dawo were cold spots for rabies incidence in 2020, 2021 and 2023 with different degree of confidence as shown in figure 3.

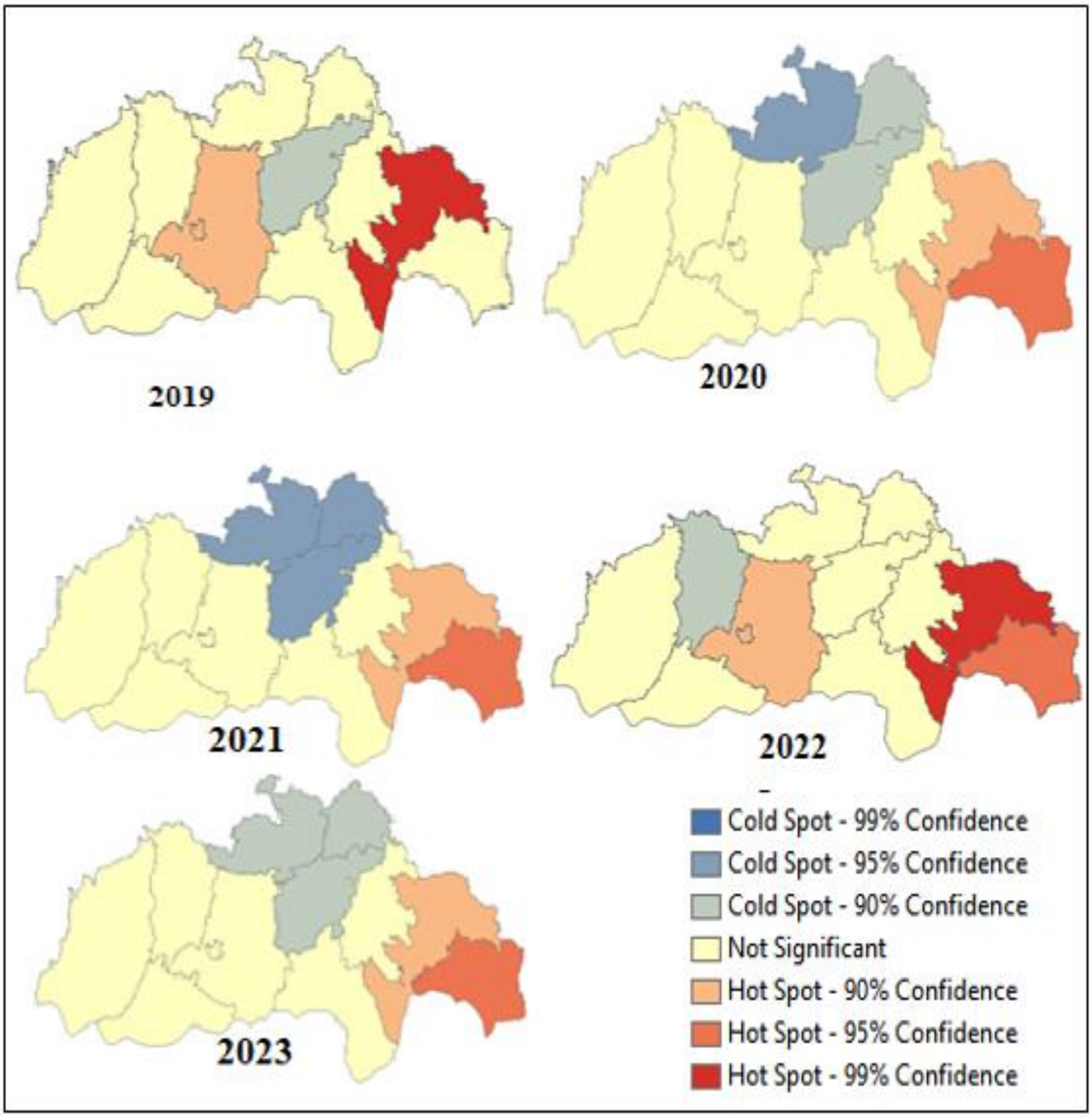

Figure 3: Hotspot and cold spot of rabies exposure incidence in human (2019-2023)

The average number of cases in five years was interpolated to estimate the number or value of unknown points from the known points as shown in Figure 4. The highest cluster of human rabies exposure was indicated in red color which had more than 51 cases recorded or reported annually and the blue color indicated low cluster that less than 12 cases reported in districts.

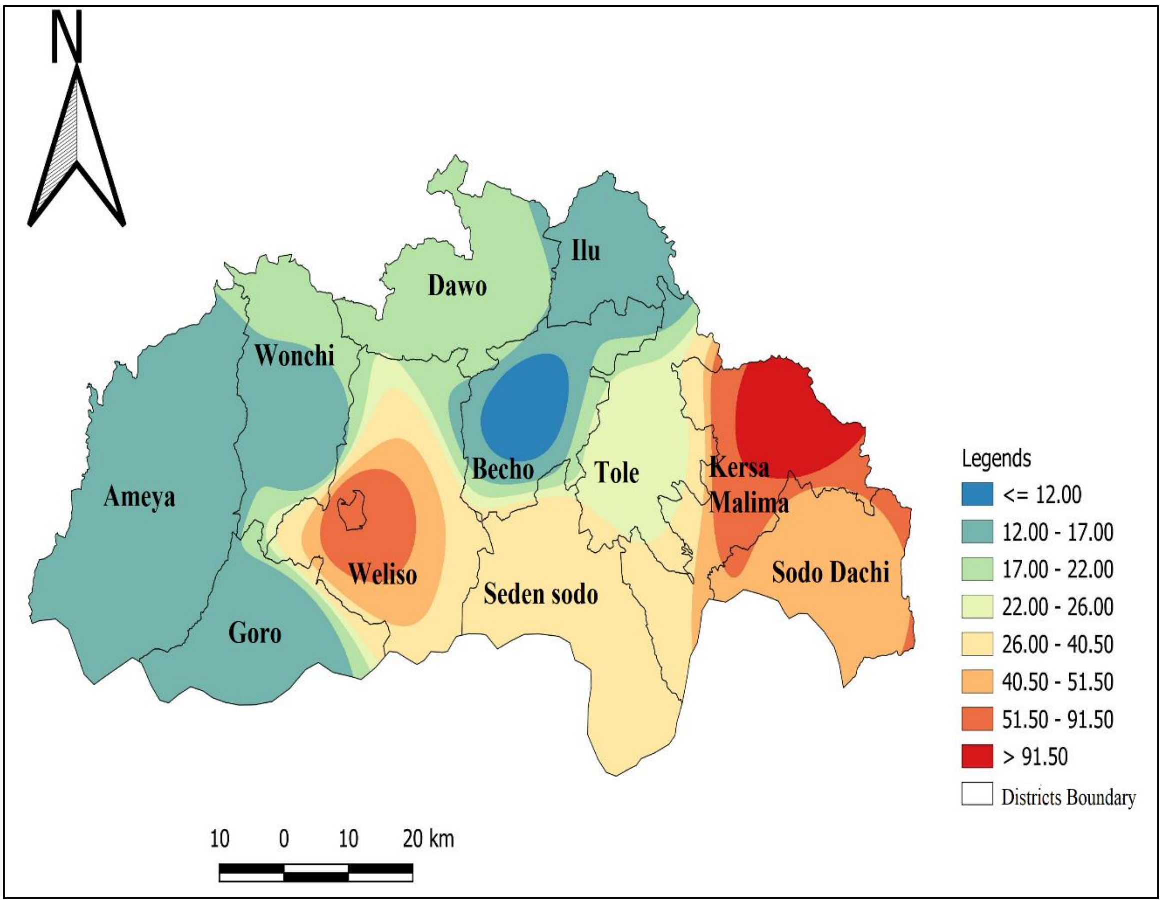

Figure 4: Spatial distribution of human rabies exposure (2019-2023)

Seasonally the highest human rabies exposures were reported in Autumn, in Afaan oromo called *Afrasa* (March to May) followed by Summer in Afaan oromo called *Ganna* (June to August) while the lowest distribution of human rabies exposure was recorded in Spring in Afaan oromo called ***Birraa*** (September to November) (Figur**e** 5).

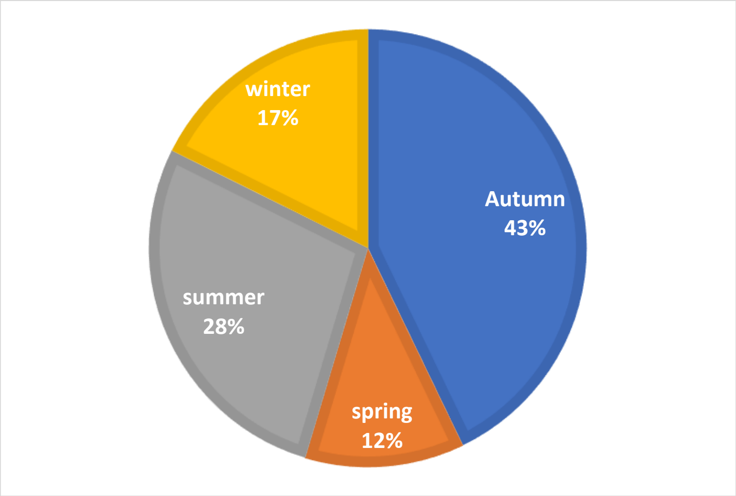

Figure 5: Seasonal occurrence of human rabies case during the studies period (2019-2023)

The line graph indicates the human rabies exposure distribution across months during the study year of selected health centers (Figure 6). The temporal pattern showed that May and August were months with the highest suspected human exposure cases whereas March was the seasons with higher cases reported. However lowest case was reported in October and November months This inconsistency could be associated with the fact that there was feed availability and the breeding season as well as underreporting of cases.

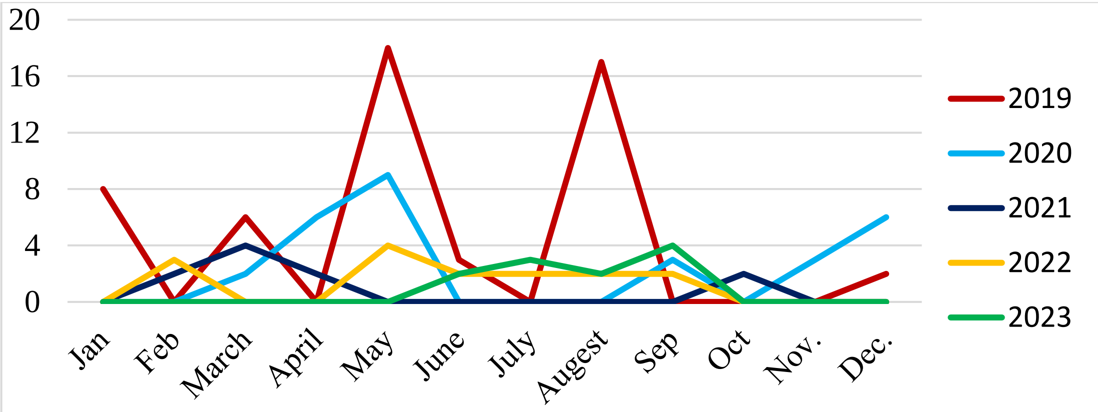

Figure 6: Temporal occurrence of rabies suspected human exposure cases

4.4. Rabies Burden and Economic Estimation

The number of individuals who were administered PEP and associated medical and non-medical costs with regard rabies disease during the study period were provided in table 5. The most of PEP administrations were result from exposure to unknown or suspected rabies positive dogs. A total of 345 people were administered PEP during five years (2019- 2023).

Table 5: The number individual that administered PEP and cost associated for five years (2019-2023)

Data type	Year					Source
	2019	2020	2021	2022	2023	
Number. of PEP case	71	91	65	51	68	Health office
PEP vaccine cost/ case (vaccine cost)	3.5$	3.5$	3.6$	3.6$	3.6$	
Antibiotics/case	1.33$	1.33$	5.3$	5.3$	5.3$	
Wound care/case	3.2$	3.2$	4.1$	4.8$	4.8$	
Total medical cost/case	8.03$	8.03$	13$	13.7$	13.7$	calculated
No. of day visit for PET	17					
GDP per capital of Ethiopia	785.45$	811.25$	834.99$	857.22$	892.04$	WB,2023
Daily per capital income	2. 18$	2.25$	2.32$	2.38$	2.48$	calculated
Income loss/person PET for 10	21.8$	22.5$	23.2$	23.8$	24.8$	
Transportation cost/person/visit	0. 53$	0.53$	0.88$	0.88$	0.88$	patient
Transportation cost/person for 17 times	9$	9$	15$	15$	15$	calculated
Meal cost/person/visit	0.44$	0.62$	0.62$	1.15$	1.15$	patient
Meal cost/person for 17 times	7.5$	10.5$	10.5$	19.55$	19.55$	calculated
Total non-medical cost	38.3$	42$	48.7$	58.35$	59.35$	calculated

Exchange rates USD to Ethiopian Birr on March 2023 1USD= 56.5472EB

Dog population and the number of dogs vaccinated for 2019 through 2023 were taken from south west Shewa zone Agriculture office statistics and reports as provided in table 14. The average of vaccination coverage of the area was 18.9% during five studies years. A cost evaluation for dog vaccinations was carried out using an estimated campaign expenditures, such as vaccine costs, material costs, vaccinator costs and owner income loss cost. The cost of vaccinating dogs was estimated in a campaign context, assuming that one vaccinator would vaccinate about 18-20 dogs per day and owner time loss 2 hour. The overall expenses of mass vaccination of dogs for the period 2019−2023 were then calculated using the unit cost estimated per dog vaccination to understand the economic burden of rabies (Table 6).

Table 6: Dog population, rabies vaccine coverage and associated cost (2019-2023)

Parameters	**Years**					Source
	2019	2020	2021	2022	2023	
Dog population	6245	7053	7240	7620	8045	Agri. office
Number of dogs vaccinated	958	940	1737	1638	1589	Agri. office
Vaccination coverage	15.35 %	13.32%	24%	21.5%	19.75%	Calculated
Cost of vaccine/dogs	0.19$	0.19$	0.27$	0.35$	0.35$	Agri office
Vaccinators cost per dog	0.28$	0.28$	0.28$	0.28$	0.28$	Agri. office
Owner cost (income loss)	0.27$	0.28$	0.29$	0.3$	0.31$	Calculated
Total cost per dog	0.74$	0.75$	0.84$	0.93$	0.94$	Calculated

Exchange rates USD to Ethiopian Birr on March 1USD= 56.5472EB

The incidence of rabies in livestock will increase with a lower level of vaccine coverage. For this analysis, each of the four distinct livestock species is taken into consideration. The same rate of incidence was applied to all species because there is no data recorded that cattle, horses, mules, or donkeys would be exposed to rabid dogs at different frequencies (Table 7).

Table 7: Incidence of rabies disease and corresponding deaths in livestock (2019-2023)

Year	Livestock incidence	Cattle		Horse		Donkey		Mule	
		Total pop.	No. death	Total pop.	No. death	Total pop.	No. death	Total pop.	No. death
2019	0.00038	1010266	384	50941	19	109194	41	3076	1
2020	0.00047	1094301	514	68198	32	197111	93	4029	2
2021	0.00014	1109068	155	74932	10	197123	28	3576	1
2022	0.00019	1243440	236	76202	15	198916	38	4188	1
2023	0.00023	1448320	333	80088	18	201203	46	4521	1

Based on the average cost per head of live animals (cattle, horses, donkeys, and mule), the cost of livestock losses between 2019 and 2023 was calculated. Average cost per head of livestock per year estimates were obtained from woreda trade and market office (as depicted in Table 8).

Table 8: Cost classification for livestock losses due to rabies disease from 2019 to 2023

Parameters	Study years					Source of data
	2019	2020	2021	2022	2023	
Average Cost/ Cattle	60.93$	82.6$	110.2$	148$	170.2$	Trade and ma rket office
Average Cost/ Horse	85.28$	122.73$	127.33$	181.26$	203.72$	,,
Average cost/ Donkey	38.2$	55.9$	62.23$	81.7$	88.84$	,,
Average. cost /Mule	61.9$	74.4$	106.5$	133.2$	162.8$	,,
Total cost/ livestock	306.38 $	418.2$	516.41$	692.2$	795.61$	,,

Exchange rates USD to Ethiopian Birr on March 1USD= 56.5472EB

The average direct medical cost of human PET (including the cost of post exposure vaccine, antibiotic, wound care and material cost) was estimated to be 11.25 USD per patient. The direct patient cost (income loss, transport cost, and meal cost) was estimated to be 46.3USD for one course of PET. Generally, the direct non-medical costs account for the largest part in total PET costs**.** The average cost per dog vaccinated was estimated to be 0.84 USD. These cost include the cost of rabies vaccine, cost of vaccinator and cost dog of owner (income loss during dog vaccination) as shown in table 9.

Table 9: Average (min, max) treatment cost, dogs vaccination costs and livestock value (in USD) per case

	Cost estimate in USD per case		
	Mean cost per case(95%CI)	Minimum	Maximum
Medical cost	11.25(10.82-11.68)	10.39	12.2
Non medical cost	46.30 (44.40-48.20)	42.73	50.11
Total cost per patient	57.56(55.58-59.51)	53.70	61.27
Total vacc. cost perdog	0.84(0.78-0.89)	0.76	0.92
Cattle value perhead	106.6(99.33-113.88)	96.0	117.0
Horse value perhead	127.2 (139.9-136.02)	114.6	139.9
Donkey value perhead	62.22(57.96-66.43)	56.08	68.37
Mule value perhead	106.36 (99.239-113.80)	95.94	117.07

Exchange rates USD to Ethiopian Birr on March 1USD= 56.5472EB

The total of 345 patients were treated with rabies vaccine during the period from 2019 to 2023. The cost expenditure for these treatment (direct medical and non-medical cost was estimated to be USD 0.024 million. During the period, of 5 years 6862 dogs were vaccinated against rabies. The costs associated with the prevention of rabies in dogs, were include vaccinator/animal health worker costs, vaccine cost and dog owner cost that to be estimated USD 0.0058 million. The total cost loss of livestock (cattle, horses, donkeys and mule) due to rabies from 2019 to 2023 was estimated to be USD 0.3786 million (Table 10).

Table 10: Total annual cost lost (in 2023 USD) in south west Shewa zone by rabies case from 2019 to 2023

Year	Total cost of rabies Patients	Total vaccination cost of dogs	Total value of cattle lost	Total value of horse lost	Total value of donkey lost	Total value of mule lost	Total value of livestock lost
2019	4086.76	804.72	46790.4	1620.32	1566.2	61.9	50038.82
2020	5237.96	789.6	84897.38	3927.36	5198.7	148.8	94172.24
2021	2935.56	1459.08	34154.25	1273.3	1742.44	106.5	37276.49
2022	3741.4	1375.92	69865.44	2718.9	3104.6	133.2	75822.14
2023	3914.08	1334.76	113369.85	3666.96	4086.64	162.8	121286.25
Total	23829.84	5764.08	349077.32	13206.84	15698.58	613.2	378595.94

Exchange rates USD to Ethiopian Birr on March 1USD= 56.5472EB

4.5. Sociodemographic Characteristics of Respondents

A total of 506 respondents (one per household) were interviewed in this study. Table 11 shows socio-demographic characteristics of the respondents of Lemen, Tere and ten (10) kebeles in Kersa Malim and Sodo Dachi districts. The median age of the respondents was 39 years (mean 39.9 years, range 18-74 years). In study households, the average number of persons per household was 5.7, ranging from 1-14 persons per household. About 23.32% of the respondents were female. Of the total, 44.7% of the respondents were not educated, 39.7% attended primary and secondary school while 15.6 % of them graduated from college and university. The study revealed that out of 506 households, 17% (86/506) households were non-dog owners and 83% (420/506) households interviewed were found to own one or more dogs.

There was an average of 1.4 dogs per household and the mean number of dogs per dog-owning household was 1.7. The estimated dog-to-human ratio for the households was 1:6.5. Most of dogs (95.7%) were kept as guard dogs or for livestock protection purposes and only 18 (4.3%) dog owners were kept as pets in urban households. From the total, 40.7% of the households confined their dogs in day, night, and both while

59.3% of the households allowed freely roam and scavenge in the environment (Table 11).

Table 11: Sociodemographic characteristics of respondents

Variable/category		Location		N = 506
		Rural	Urban	
Ownership	Yes	300(85.9%)	120(76.4%)	420(83%)
	No	49(14.1%)	37(23.6%)	86(17%)
Gender	Female	83 (23.8%)	35(22.3%)	118(23.3%)
	Male	266 (76.2%)	122(77.7%)	388(76.68%)
Educational status	No Education	169 (48.4%)	57(36.3%)	226(44.7%)
	1st and 2nd school	125(35.8%)	76(48.4%)	201 (39.7%)
	Graduated	55(15.6%)	24(15.3%)	79(15.6%)
Marital status	Married	290(83.1%)	132(84.1%)	422(83.4%)
	Single	59 (16.9%)	25(15.9%)	84(16.6%)
Occupation	Farmer	231(66.2%)	108(68.8%)	339(67%)
	Business man/w	53(15.2%)	18(11.5%)	71(14%)
	Student	15(4.3%)	12(7.6%)	27(5.3%)
	Gov. Employer	50(14.3%)	19(10.2%)	69(13.6%)
Mean number dog per dog owning HH		1.9	1.2	1.7
Number of dog per HH		1.6	0.9	1.4

No=Number, HH= Household, 1st= primary, 2nd=secondary

4.6. Dog Demography and Management

The study indicated that a total households included in the study, male dogs make up 69.2% (495) of the total dogs. The female-to-male ratio of dogs was 1:2.25 The study indicated that dog owners in the study area did nothing to control dog breeding. Of the 220 female dogs, none of them had been spayed or sterilized and of 495 male dogs, no one had been castrated. A total of 715 dogs, only 22.7% (95% CI: 24.42 - 33.19) of them vaccinated dogs against rabies.

They were all fed with left-overs from human consumption and left to roam free for food. The majority of the dogs were free roaming (no housing/cages) 61.3% in urban and 64.6% in rural households but during the day 35.91% of urban households and 31.94% of rural households were confined dogs and during night 10.6% of urban and 4.7% in rural households were the confined dogs as well as only 2.52% household confined day and night in both residence. From total dog population, 45.5% were young less than 2 year, 49.7% were adult greater than 2-10 year and 4.6% aged <10 years dogs (Table 12).

Table 12: Dog demography and population management practice

Parameters		Rural	Urban	Total
Total number of dogs		573	142	715
Sex	Female	192(33.5%)	27(19.0%)	220(30.8%)
	Male	381(66.5%)	115(81%)	495(69.2%)
Female: Male ratio		1:1.98	1:4.2	1:2.25
Age	Young(<2yr)	252(43.6%)	75(52.8%)	327(45.5%)
	Adul(2-10yr)	297(51.8%)	58(40.8%)	355(49.7%)
	Aged(>10yr)	24(4.2%)	9(6.4%)	33(4.6%)
Confinement of dogs	Yes	216(37.7%)	75(52.8%)	291(40.7%)
	No	357(62.3%)	67(47.2%)	424(59.3%)
Time of confined	Day	183(31.9%)	51(35.9%)	234(32.7%)
	Night	27(4.7%)	12(10.6%)	39(5.5%)
	Both	6(1.1%)	12(10.6%)	18(2.5%)
Sources of feed of dog	House member	180(31.4%)	63(44.4%)	243(34.0%)
	Find its own	117(20.4%)	4(2.8%)	121(16.9%)
	Combination	276(48.2%)	75(52.8%)	351(49.1%)
Vaccination status	Yes	84(14.7%)	78(54.9%)	162(22.7%)
	No	489(85.3%)	64(45.1%)	553(77.3%)
Housing system	Tied in cage	203(35.4%)	55(38.7%)	258(36.1%)
	Free to roam	370(64.6%)	87(61.3%)	457(63.9%)

4.7. Respondents' Knowledge and Perception of Rabies

The majority of the respondents 94.07% (476) heard about rabies from their family and communities. Of those respondents who had heard of rabies, the majority (74.7%) them believed that rabies is a dangerous and fatal disease. Most of the respondents (88.7%) were aware of zoonotic nature of the disease. About 89.7% of the respondents knew the symptoms and signs of rabid animals or dogs. Only 34.8% of respondents were aware of post-exposure prophylaxis for prevention of rabies in human, while 59.5% of the respondents were aware of dog vaccination as a means of rabies prevention (Figure 7).

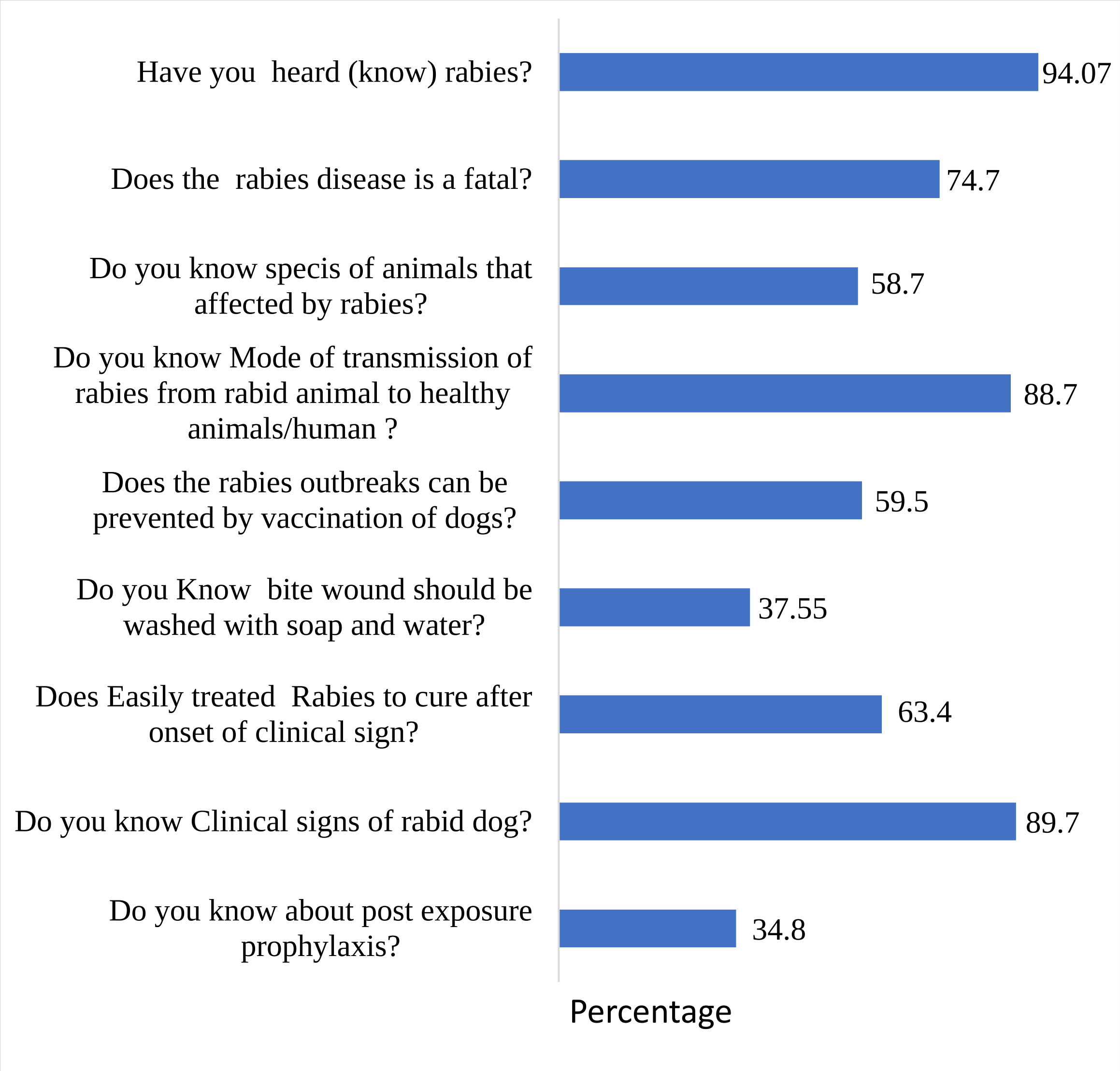

Figure 7: Respondents knowledge and perception of rabies

There were significant differences between dog owners and non-dog owners (P= 0.00), the educational status of the respondents (P = 0.017), and gender of the respondents (P =0.001) with respect to the knowledge of rabies. Similarly, there was a significant difference (P = 0.019) between married and single respondents and the occupations of the respondents(P=0.000) were significant association with knowledge score (Table 13).

Table 13: Association of knowledge scores on rabies and independent variables

variable		Knowledge category			X^2	P-value
		High(7-9)	Moderate(4-6)	Low (<4)		
Education status	No Educ.	99(43.82%)	103(45.58%)	24(10.6%)	12.0	0.017
	1st and 2nd school	82(40.8%)	96(11.4%)	23(47.8%)		
	Graduate	31(39.2%)	48(60.8%)	0		
Residence	Rural	154(44.1%)	165(47.3%)	30(8.6%)	1.6	0.439
	Urban	58(36.9%)	82(52.3%)	17(10.8%)		
Ownership	Yes	202(48.1%)	186(44.3%)	32(7.6%)	40.6	0.00
	No	10(11.6%)	61(70.9%)	15(17.5%)		
Gender	Male	177(45.6%)	187(48.2%)	24(6.2%)	22.9	0.00
	Female	35(29.7%)	60(50.9%)	23(19.5%)		
Marital status	Married	186(44.1%)	193(45.7%)	43(10.2%)	10.1	0.007
	Single	26(30.9%)	54(64.3%)	4(4.8%)		
Occupation	Business man/w	12(17.4%)	45(65.2%)	12(17.4%)	48.7	0.000
	Farmer	170(50.2%)	139(41.0%)	30(8.8%)		
	Gov. Employer	27(38.0%)	42(59.2%)	2(2.8%)		
	student	3(11.1%)	21(77.8%)	3(11.1%)		
Total		212(41.9%)	247(48.8%)	47(9.3%)	N=506	

N=Number household, 1st=primary, 2nd=secondary, No Educ.=no education

4.8. Respondents' Attitudes and Perception of Rabies

About 93.5% of respondents reported the outbreak to the nearby authorities and sought medical treatment if bitten by stray dogs (Figure 8). Almost all (91.7%) respondents believed that stray dogs are a major problem for rabies outbreaks and disease spread in the community. About 90% of respondents kill stray dogs if rabies is suspected and Majority (60.8%) of responds do not feed the stray. Up to 48.7% of the respondents believes that traditional healers did not a solution of rabies cure. Only 34% of respondent seek professional advice during a bite by the dog while the rest believed that traditional medicine like holy water("Tsabel"), plant parts, crossing the river for 40 days and smoking burning rabid dog cadaver healed rabies in human and animals.

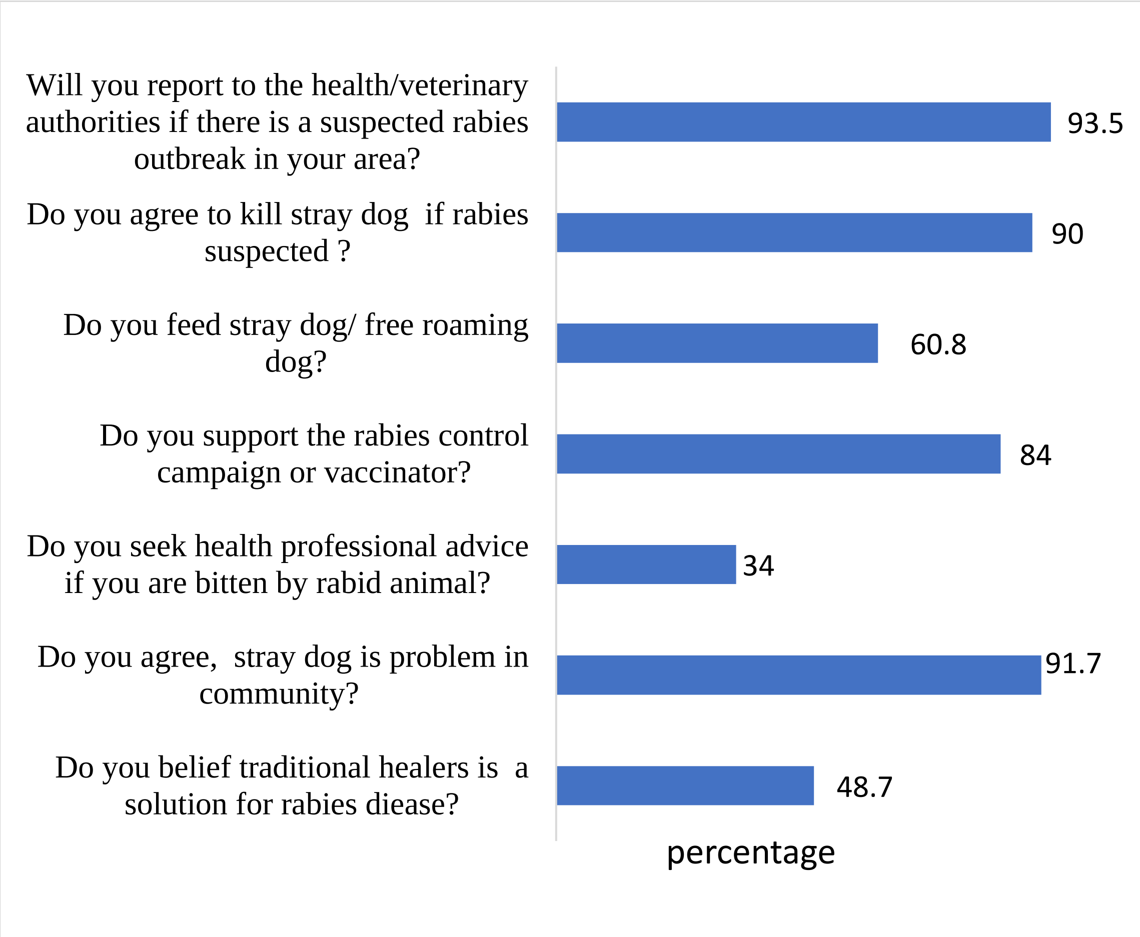

Figure 8: Respondents attitude and perception of rabies

The attitude of the community was shown to be highly associated with a number of demographic and sociodemographic characteristics. Related to attitude towards rabies, there were significant differences between male and female respondents, those owned dogs and those did not, as well as between respondents' different levels of education and different occupation. The marital status and the responses of the respondents from urban and rural areas did not significantly differ from one another (Table 14).

Table 14: Attitude of respondents towards rabies with associated different variable

variable		Attitude category			X^2	P-value
		High(>5)	Moderate(4-5)	Low (<3)		
Education status	No Educ.	122(54.0%)	85(37.6%)	19(8.4%)	51.8	0.00
	1st and 2nd school	158 (78.6%)	42(20.9%)	1(0.5%)		
	Graduate	40(50.6%)	24(30.4%)	15(19%)		
Residence	Rural	229 (65%)	95(27%)	28 (8%)	5.56	0.062
	Urban	91(59.1%)	56(36.4%)	7(4.6%)		
Ownership	Yes	274(65.2%)	135(32.2%)	11(2.6%)	71.93	0.001
	No	46(53.5%)	16(18.6%)	24(27.9%)		
Gender	Male	250(64.5%)	122(31.4%)	16(4.1%)	20.57	0.00
	Female	70(52.3%)	29(24.6%)	19(16.1%)		
Marital status	Married	263 (62.3%)	130(30.8%)	29(6.9%)	1.14	0.566
	Single	57(67.9%)	21(25.0%)	6(7.1%)		
Occupation	Business man/w	57(82.6%)	12(17.4%)	0	44.0	0.00
	Farmer	206(61.1%)	114(33.4%)	19(5.5%)		
	Gov. Employer	36(50.9%)	19(26.6%)	16(22.5%)		
	student	21(77.8%)	6(22.2%)	0		
Total		320(63.24%)	151(29.84%)	35(6.92%)	N=506	

N=Number household, 1st=primary, 2nd=secondary, No Educ.=no education

4.9. Rabies Control Practice of Respondents

Of all the respondents (420), 74.05% had willing to vaccinate their dogs against rabies during vaccination campaign; among them, 27.4% vaccinated their dog and only

34.5% de-wormed their dogs (given any medicine against worms) from total(420) respondents. About 87.62%) of the respondents practiced killing of rabid animals and 55.95% owner had confined their dogs either day or night (Figure 9).

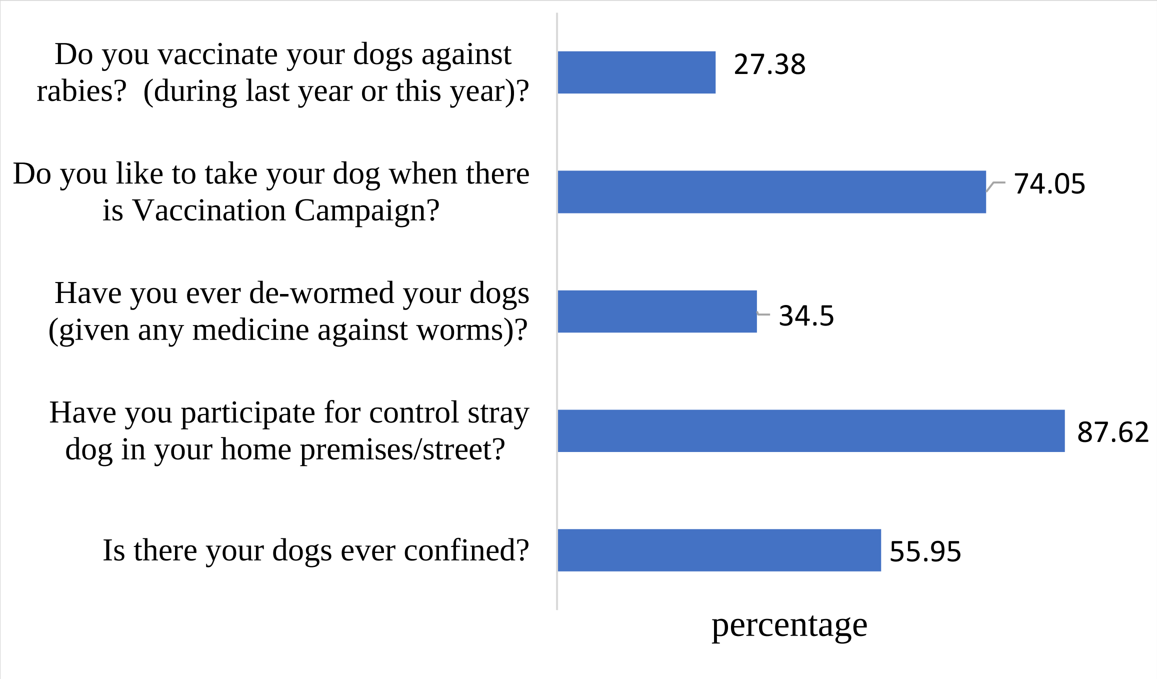

Figure 9: Rabies control activity and dogs management of respondents.

There was significant association between Practice scores and gender of respondent ($p < 0.05$). The good Practice scores were recorded higher in males 25.22% than females 12.66%. Area of respondents were strong significant associated with Practice scores ($p = 0.000$). Respondent from urban residences had good Practice for rabies control as compared to rural settings. As Table 5 indicated, there was no significant association Practice score between educational level, Occupation and marital status of the respondents. Generally, about 67.14% were adequate level rabies control activity and 22.86% were good level rabies control activity (Table 15).

Table 15: Factor associated with rabies Control practice of respondents

Variable		Practice category			X^2	P-value
		Good(>3)	Adequate (2-3)	Inadequate (<2)		
Gender	Female	10 (12.7%)	58(73.4 %)	11(13.9%)	6.5	0.039
	Male	86(25.2%)	224(65.7%)	31(9.1%)		
Education status	No Educ.	41(25.4%)	128(65.1%)	23(9.5%)	4.1	0.397
	$1^{st}$and 2^{nd}	40(22.6%)	124(70.1%)	13(7.3%)		
	Graduated	15(29.4%)	30(58.8%)	6(11.8%)		
Residence	Rural	53(17.5%)	214(70.6%)	36(11.9%)	19.5	0.000
	Urban	43(36.8%)	68(58.1%)	6(5.1%)		
Marital status	Single	16(25.4%)	41(65.1%)	6(9.5%)	0.27	0.872
	Married	80(22.4%)	241(67.5%)	36(10.1%)		
Occupation	Business man/w	8(17.8 %)	33(73.3%)	4(8.9%)	4.0	0.676
	Farmer	69(22.6%)	208(68.2%)	28(9.2%)		
	Gov. employer	14(31.1%)	25(55.6%)	6(13.3%)		
	student	5(20.8%)	16(66.7%)	3(12.5%)		
Total		96(22.9%)	282(67.1%)	42(10.0%)	N=420	

N=Number household, 1^{st}=primary, 2^{nd}=secondary, No Educ.=no education

As showed in table 6 about 41.9%, 63.24 %, and 17.78% of the respondents had a high level of knowledge, attitude scores toward rabies, and good control practices of rabies and stray dogs respectively (Table 16).

Table 16: Number of questions and levels of KAP recorded regarding rabies disease

variable	Number. question	Means score	Range score	High	Medium	Low
Knowledge	9	5.9	0-9	41.9%	48.81%	9.29%
Attitude	7	5.7	3-7	63.24%	29.48%	6.92%
Practice	5	2.8	0-5	17.78%	73.33%	8.89%

The binary logistic models were constructed using the demographic and socio-demographic variables. Respondents who were male 1.88 times (OR= 1.88; 95% CI: 1.19-2.96) better awareness about rabies than female, and respondents who had farmer and government employers were found to be 1.52 (OR= 1.52; 95% CI: 0.86-2.67) and 1.95(OR= 1.95; 95% CI: 0.95-4.0.6) times better knowledge than business men/w, similarly respondents who owned dogs (OR= 2.86; 95% CI: 167-4.86) were 2.86 times a high level of awareness and perception rabies than non-owner.

Respondents who participated from farmer had 0.24 less (OR = 0.24; 95% CI: 0.11-0.53) positive attitude than those from businessmen/women. Attitude was significant association with some education status of respondents. The respondent that had educational level up to high school level were 2.45 more positive attitude (OR= 2.45; 95% CI: 1.56-3.86) than that of no educated respondents. The owner respondents were 1.90 more positive attitude (1.90; 95% CI 1.11 -3.26) than non-owner one. The rest variable not significant difference (Table 8).

The sociodemographic variable was significantly related with the community rabies control practice So, the male respondents 2.06 time better (OR=2.06; 95%CI: 1.22-3.45) than female respondents in control rabies activity, the urban community 2.98 more participated in stray dogs and rabies control awareness' than rural community(OR=2.98; 95%CI: 1.80-4.92). The respondent that had educational level up to high school level were 1.71 better control activity (OR= 1.71; 95% CI: 1.10-2.65) than that of no educated respondents (Table 18).

Table 17: Univariable logistic regression model of factors associated with community KAP towards rabies disease

Variable		Knowledge		Attitude		Practice	
		No.(%)	OR(95%CI)	No. (%)	OR(95%CI)	No.(%)	OR(95%CI)
Gender	Male	273(70.4%)	2.22(1.45-3.38)*	251(64.7%)	1.26(0.82-1.92)	216(63.3%	1.86(1.14-3.05)*
	Female	61(51.7%)	1	70(59.3%)	1.46(1.01- 2.11)	38(48.1%)	1
Educational status	1st and 2nd school	129(64.2%)	0.96(0.64-143)	158(78.6%)	3.08(2.01- 4.72)*	122(69.3%)	1.84(1.20-2.82)*
	Graduated	58(73.4%)	1.48(0.84-1.62)	40(50.6%)	0.86(0.51-1.43)	27(52.9%)	0.93(0.50-1.73)
	No Educated	147(65%)	1	123(54.4%)	1	105(54.7%)	1
Ownership	Yes	297(70.7%)	3.2(1.99-5.15)*	275(65.5%)	1.65(1.03-2.63)*	-	-
	No	37(43%)	1	46(53.5%)	1	-	-
Occupation	Farmar	240(70.8%)	2.22(1.31-3.76)*	206(60.8%)	0.32(0.16-0 .63)*	190(62.3%)	1.0(0.53-1.91)
	Gov. Employer	48(69.6%)	2.1(1.04-4.20)	37(52.2%)	0.23(0.11-0.50)*	24(53.3%)	0.69(0.30-1.60)
	Student	9(33.3%)	0.46(0.18-1.16)	21(77.8%)	0.74(0.24-2.21)	12(50%)	0.61(0.22-1.65)
	Business man/w	36(52.2%)	1	57(82.6%)	1	28(63.6%)	1
Residence	Urban	105(66.9%)	1.06(0.71-1.58)	91(59.1%)	0.77(0.52-1.13)	91(77.8%)	3.0(1.84- 4.91)*
	Rural	231(65.6%)	1	230(65.3%)	1.88(1.51- 2.35)*	163(54%)	1
Marital status	Single	51(60.7%)	0.75(0.46- 1.23)	57(67.9%)	1.26(0. 76-2.08)	221(62.1%)	0.67(0.39-1.16)
	Married	283(67%)	1	264(62.6%)	1	33(52.4%)	1

Note:* indicates statistical significance p-value < 0.05 and 1st= primary, 2nd=secondary, No=number respondents' good score

Table 18: Multivariable logistic regression model of factors associated with community KAP towards rabies disease

Variable		Knowledge		Attitude		Practice	
		OR(95%CI)	p. value	OR(95%CI)	p-value	OR(95%CI)	p- value
Gender	Male	1.88(1.19-2.96)	0.006	-	-	2.06(1.22-3.46)	0.007
Educational status	1st and 2nd school	-	-	2.45(1.56-3.85)	0.000	1.71(1.10-2.65)	0.017
	Graduated	-	-	0.16(0.03-0.74)	0.020	0.94(0.47-1.78)	0.852
Ownership	Yes	2.86(1.67-4.86)	0.00	1.90(1.11-3.26)	0.018	-	-
Occupation	Farmar	1.52(0.86-2.67)	0.144	0.24(0.11-0.53)	0.000	-	-
	G. Employ	1.95(0.95-4.06)	0.075	1.74(0.38-8.06)	0.475	-	-
	Student	0.28(0.11-0.75)	0.011	0.47(0.14-1.65)	0.239	-	-
Residence	Urban	-	-	-	-	2.98(1.80-4.92)	0.000
Constant (b_0)		0.38(0.21-0.72)	0.003	2.64(1,17-5.97)	0.020	0.53(0.31-0.90)	0.018

G. Employ=Government Employes, 1st=primary, 2nd=secondary, No Educ.=no education.

5. DISCUSSION

Rabies remains an important zoonotic disease both in humans and animals in Ethiopia. This implicates an importance of regular epidemiological surveillance programs to know the status of the disease in livestock and humans

In this the incidence rates of rabies were estimated at 0.36 in bovine, 5.4 in dogs, 1.5 in equines, and 0.19 in shoats per 1,000 population annually. The result revealed that dogs were the highest rabies-affected animals followed by Equine. The higher incidence of rabies disease in dog may indicate that the low vaccination coverage, large number of stray dogs, low communities' awareness and poor husbandry practice of dogs. (Wallace *et al.,* 2017).This finding agreement with that reported by Asfaw *et al.,* (2024) and Jemberu *et al.,* (2013).

The analysis of the data from 2019 to 2023 obtained from south west Shewa zone health office revealed a total of 345 human rabies exposure cases and the majority (62.18%) of the rabies cases were among males. This could be due to the socio-cultural difference among societies. Male usually conducted outdoor activity which prone them to more exposed to stray dogs The incidence of human rabies exposure during the study period was 6.07, 6.99, 4.36, 3.11, and 4.00 per 100,000 population for the five respective study years (2019–2013).

This finding is higher than reports from studies in Gondor northern Ethiopia (Yibrah and Damtie, 2015) and significantly lower than previously reported studies undertaken in Northern Tigray, Ethiopia (Teklu *et al.,* 2017). These variation might be due to multiple socio-cultural, level of awareness about disease and difference in rabies control strategies. This result revealed that in age group of 5–14 years were the most commonly exposed to rabies 31.93%. This finding was in harmony with previous study done in Gonder, Ethiopian(Seifu and Girma, 2019), Northwestern Tigray (Teklu *et al.,* 2017), and a Nigerian (Abubakar and Bakari, 2012).

On the contrary, findings by Aklilu *et al.* (2021) in Addis Ababa which age group greater than 14years were more affected. The difference in incidence among age groups may due to variations in socio-cultural differences among various communities. For instance, in some communities, adults may be at high risk of rabies due to the fact that they usually conduct their outdoor activities in distant places away from their home. On the other hand, children might be more commonly exposed to rabies in communities where their kids are not well attended. The overall prevalence of PEP was higher in children, especially for those up to 14 years of age, and then the trend decreased as age increased which is in agreement with (WHO, 2010).This study also demonstrated that higher dog bite injuries (63.3%) were reported on legs and followed by hands. This was consistent with previous findings by Gebru *et al.*, (2019) and it could be due to frequent use of legs and arms to defend during dog's bite.

In the study Hot spot analysis showed that rabies exposure was distributed throughout in all districts of zone. However, the highest number of cases was observed in three districts (Kersa Malima, Weliso, and Sodo Dachi) and the lowest case reported in Becho, Dawo and Iluu districts of the southwest Shewa zone. This variation might be due to the high dog and human population densities in these areas, combined with low levels of awareness about disease among the community and under-reporting issues in some districts. Our study also indicated that rabies case was found to be clustered in the three districts consistently for five years. This geographical clustered trends of distribution was agreement with reports from north Tigray (Gebru *et al.*, 2019) which suggested that spatial and the temporal distributions of the disease was guide to targeted rabies control measures.

Positive spatial autocorrelation indicates that variable values similarity appears in the neighborhood, whereas negative spatial autocorrelation involves considerable inconsistency in values assumed by near areas. This finding can be predicted the positive spatial autocorrelation among disease incidences in neighboring areas throughout the studied period. As Moran's I results showed that global Moran's index was significant and positive in all studies years. This indicated that evidence of positive spatial autocorrelation in rabies incidence in the area. Similar suggestion reported from chin (Guo *et al.,* 2018).

Rabies cases occurrence was not uniformly throughout the year often peak during certain times of the year, it may be due to a combination of human activity, weather condition, and animal behavior. The study revealed significant seasonal variations in the rabies incidence, specifically high in hot and moisture season in the area. A warmer climate means that animals are more active in their surroundings and path over greater distances, which facilitated to the spread of rabies. This is also the farming season when people go out more and are more likely to come into contact with dogs, so the exposure and infection risk is higher (Guo *et al.,* 2018).

In this finding most common months of rabies occurrence were march, May and august. This might be due to the high movement of stray dogs in search of food and breeding season which bring together several dogs intensified and the spread of the infection. this finding agreement study reported in western Amhara region that suggested, temporal pattern of rabies cases was high during May and lower in January (Demil and Shime, 2024) and disagreement with study in Buno-Bedelle zone west Ethiopia that reported the occurrence of rabies is high during the rainy season from June to October and low from December to March (Wakgari *et al.*, 2022). This difference may be due to Seasonal variation and geographical difference between western and central Ethiopia.

The rabies prevention cost categorized into two parts: prevention costs of rabies in dogs through vaccination and prevention costs of rabies in humans through PEP. The majority of rabies expenses are related to livestock losses and PEP and only minimum expenditures are associated with dogs' vaccination. PEP and livestock loss costs are costs that might eventually be eliminated or decreased that by a decreasing the impact of canine rabies. These expenses would be the savings from increased dog vaccination rates and a decline in the rate of PEP in humans and livestock losses. Increasing the levels of dog vaccination coverage may challenges by unwillingness of owners for dogs' vaccination, the lack of dog populations data, the lack of canine rabies surveillance, and lack resources from veterinary services that suggested by Lembo *et al.,* (2011).

The average cost of vaccinating per dog was 0.84 USD and average costs of rabies prevention via PEP per case was 57.56 USD (medical cost 11.25USD and non-medical cost 46.3USD) were estimated in this study. The costs expenditure for prevention of rabies in human much higher than costs of prevention in dogs.

The current study estimation is comparable with the findings of Tenzin and Ward, (2012) which estimated USD 45 direct medical and non-medical expenses per patient and lower than estimation done in Viet Nam that average cost of 163 USD per PEP (Shwiff *et al.,* 2018) as well as little higher than that reported by Beyene, (2017). estimated an average costs of 21 USD per case in Ethiopia. In this finding the average cost of rabies prevention in dog(0.84USD) was slightly lower than that reported from Viet Nam (Shwiff *et al.,* 2018) which was 1.75 USD.

The medical cost losses during bite less than (USD 11.25) that compared to non-medical cost (USD 46.30). Transport, meal and lost income costs of seeking PEP was categorized under non-medical costs to households of exposed individuals. This is especially the problem of the rural communities since PEP is usually restricted to urban areas. This study was in harmony with study done on the global burden of canine rabies (Hampson *et al.*, 2015).

The average number of dogs vaccinated per year is less than half of the dog population(18.9%), which is insufficient to control and eradicate canine rabies. This finding is similar vaccination coverage with the studies in Addis Ababa which reported rates between 1.8 and 26.9 % (Yoak *et al.,* 2021) as well as it in concur to other canine rabies endemic countries likely that reported from Viet Nam (Shwiff *et al.*, 2018). The study shows more money is spent on PEP prevention than preventing human rabies through dog vaccination. Dog vaccine expenses make up only 1.4% of the costs per case, while PEP costs account for 98.6% of the rabies burden per case. This almost similar finding with the reported in Veit Nam that 92% for PEP costs and 6% for dog vaccination costs expenditure (Shwiff *et al.*, 2018). . In this study, a total of 506 households were interviewed, and 420 (83%) of the households were found to own one or more dogs. From a total of dog owner, about 71.4% in rural household and 28.6% in urban household.

This finding was lower as compared to the previous reports of 33% of urban and 75.5% of the pastoralist households' own dogs from eastern Ethiopia (Tschopp *et al*., 2016). In contrast, a lower proportion of dog ownership was reported from west shew zone of Oromia region (65.1%) (Gebremedhin *et al.*, 2020). This variation could be due to real difference in purpose of kept dogs in the areas of study and living status of the community. This finding was in agreement with reports from other African countries showed lower (82%) than dog ownership in Harare, Zimbabwe (Pfukenyi *et al.,* 2010) and higher (63%) dog ownership in Kenya (Kitala *et al.*, 2001). The variation among the reports could be due to the difference in socio-cultural, economic, and attitude towards pet ownership (Gebremedhin *et al.*, 2020).

The result of this study showed the primary purpose of keeping dogs in the study area was for guard duty accounting 95.5% and only 4.5% of respondents keep dog as a pet in urban community. This result was agreement with study in Ambo town that reports about 83.5% dogs is keeping for security reasons (Alemu *et al.,* 2022). This study also showed all respondents are not aware of spaying (ovarian hysterectomy) of female dogs and castrated male dogs that important to control the population of dogs which in turn has influence on rabies control. This may be due to lack of awareness about spaying and lack of veterinary service. This study also revealed that the majority or about 72.62% of the dog owners interviewed do not vaccinate their dogs while only 27.38% did vaccinated their dogs (22.66% dogs) against rabies. This result is lower than the findings of 71% in Bishoftu town (Worku *et al.,* 2023) this due to lack of awareness of people to vaccinate their dog.

About 45.5% of all dog population were less than two-year-old and 49.9% were between 2-10 years old. This finding similar with the report from Bishoftu about 52% of dogs less than one year (Worku *et al.,* 2023). The population of male dogs(69.23%) in this study higher than that of female, which is supported by study in ambo town indicated the preference of male dogs for the popuse of gaurding (Alemu *et al.,* 2022).

The current study indicated that, almost all respondents (94.07%) had awareness of rabies and dog are the common source of rabies. This was similar with a report in Gondar Zuria District, indicated that 99.3 % of people have heard about rabies (Digafe *et al.,*2015). The results of this study show that most of the participants had a moderate level of knowledge, attitude, and appropriate practices toward rabies disease. About 41.9% respondents had good level of knowledge. Relatively lower than result reported (60.3%) from Debark Woreda, North Gondar (Yalemebrat *et al.,* 2016).

This difference most likely due to variation public education program and source of information. This study revealed that male respondents were 1.88 times more likely to have good knowledge towards rabies as compared to female and dog owner were 2.86 times more likely to have good knowledge towards rabies as compared to non-owner respondents as well as government employers were almost 2 times more knowledge than businessman. This finding was disagreement a study conducted in Mekelle city that female respondents more knowledge towards rabies (Hagos *et al.,* 2020) and agreement with report from Nigeria dog owners are 4.8 time better knowledge than non-owner (Ameh *et al.*, 2014).

About 63.24% of respondents in the current surveyed have high a positive attitude regarding rabies. The current result is lower than that of previous study, which found that 98.6% of respondents had a positive attitude towards of rabies disease by Bahiru *et al.,* (2022) and very close with previous reports from Mekelle town that stated 56.2% of the respondents had a positive attitude towards rabies (Hagos *et al.,* 2020). Respondents of primary and a secondary school educational level were 2.45 mare likely to have positive attitude as compared non-education and farmer 0.24 less likely to have positive attitude towards rabies as compared to businessman. This finding was agreement to the study conducted in Mekelle town (Hagos *et al.,* 2020).

However, in this finding only 17.78% of the respondents had good practices towards rabies control activity. This is much lower than previous reports in Mekelle town (61.3%)(Hagos *et al.,* 2020) and also in other African country, Nigeria (74%) (Edukugho *et al.,* 2018). Male respondents and urban residence were 2.06 and almost 3 times more likely to have good practice toward rabies prevention as compared to those female and rural residence. This study is in line with the study conducted in Tanzania, communities have good practice to vaccination and care of dogs (Sambo *et al.,* 2014).

Limitation: Our study was limited to estimated livestock losses by rabies and DALYs since data on livestock deaths, and human death were not available. Thorough spatial analysis was not undertaken as much as possible since human rabies exposure case data lack geographic coordinates (latitude and longitude). There were also data limitations on dog population and stray dog management**.**

6. CONCLUSION AND RECOMMENDATIONS

The current study revealed a high incidence of rabies in both humans and animals, with a widespread distribution across the study period and locations. Furthermore, cluster analysis identified distinct clusters of human rabies exposure cases in the areas of Kersa Melima, Sodo Dachi, and Weliso throughout the study. Notably, the study also identified significant seasonal variations in rabies incidence, with peaks occurring during the hot and humid seasons, particularly in March, May, and August. This finding underscores the substantial economic burden that rabies imposes on both livestock and human populations in the study areas. Given these concerning findings, the study strongly emphasizes the importance of investing in comprehensive mass dog vaccination programs. The study investigated the basic epidemiological information on the possible risk factors associated with rabies exposure in humans and livestock as well as knowledge gaps in the community. Furthermore, our findings provided the basis for understanding the spatial and seasonal patterns of rabies occurrence within districts of the southwest Shewa zone. This study revealed that rabies is a significant zoonotic disease in the area.

Based on the above conclusion the following recommendations are forwarded:

- Regular vaccination campaigns, dog management, and stray dog population control should be implemented in the study area.
- The preventive measures should consider socio-demographic factors that strategically target high-risk areas
- More research is recommended in hotspot areas to identify detailed risk factors and infection sources,
- A cost-benefit analysis should be done to implement the best feasible rabies control strategies
- All stakeholders work jointly that target the control program, to improve dog vaccination coverage, surveillance, sharing information, public awareness and training veterinary and public health professionals.

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8. ANNEXES

Annex 1: Community KAP questionnaire survey

A. PART I: PROFILE OF RESPONDENTS OR PARTICIPANTS

1. Name of respondents____________________________________
2. Gender of the respondents a) Male b) Female
3. Age of the respondent ________________ years
4. Address or specific name__________________
5. Education level/qualification of the respondent a) No education b) Primary level c) High school level d) college level e) University level
6. Occupation of the respondents a) Farmer b) Student c) Business man d) Gov. employes
7. Religion of the respondents a) Orthodox b) catholic c) Muslim d) wakefata e) Protestant
8. Number of persons in the house (household size)?_____________ Number of children (less than 18 years old) by gender female_________, male___________
9. Do you own the animals? a) Cattle b) Goats/sheep c) Equine d) Poultry

10 Do you keep dogs? if yes how many? female__________ Male________

B. PART II: KNOWLEDGE ABOUT RABIES AND RABIES CONTROL ACTIVITIES

1. Have you heard(know) about rabies? *If the answer is No, do not ask further questions in this section, go to Part III* a) Yes b) No

   if yes, where did you hear it? Professionals/mass media/community/friends/Religious institutions/ others (specify)____________________
2. Do you know that rabies is a dangerous disease (fatal disease)? a) Yes b) No
3. Do you know Mode of transmission of rabies from rabid animal to healthy animals/human ? a) Yes b) No if yes mention ______________________________
4. Do you know that rabies outbreaks can be prevented by regular vaccination of dogs? a) Yes b) No
5. Have you heard about rabies cases or animals' death by rabies? a) Yes b) No

   *if yes Dogs and Other farm animals (cattle/goat/sheep/ equine No*________________
6. Are you aware that dog bite wound should be washed with soap and water? a) Yes b) No

7. Do you know Clinical signs of rabid dog? a) Yesb) No If yes list mention ____________________________

8. Does Easily treated Rabies to cure after onset of clinical sign? a) Yes b) No

9.Is there any traditional method of dog bite wound or rabies treatment? a) yes b) No. If yes Mention______________________________________

C. PART III: ATTITUDE AND PRACTICES ABOUT RABIES AND RABIES CONTROL ACTIVITIES

1. Will you inform/report to the health/veterinary authorities if there is a suspected rabies outbreak in your area/community? a) Yes b) No

2. Do you agree to kill stray dog if rabies suspected ? a)Yes b) No

3. Do you advise children to be careful and not to play with stray dogs? a) Yes b) No

4. Is there any stray dog in your home premises/existed? a) Yes b) No

5. Do you feed stray dogs? a) Yes b) No

6. Is stray dog a problem in your community? a) Yes b) No

7. Do you know where stray dog frequently large number exists? a) yes b) No

If yes, where? a) garbage sites b) Market points c) butcher house d) Slaughterhouse area e) around hotels f) restaurants g) public places

8 Do you support the rabies control campaign or vaccinator? a) yes b) No

D. PART IV: DOG OWNERS AND THEIR PRACTICE

1. Do you keep dogs? a) Yes b) No

2. How many dogs do you own? *male and female in number*______________

3. What is the age of your dog? a) Young (0 – 12 month) b) Adult (12 month-10 Years) c) Aged (more than 10 Years

4 How long do you expect your dog to live? life expectancy Mention in years______

.Has it been neutered or desexed you dog spayed? a) Yes b) No

5. What were the sources of your dogs? a) from Home owned b) Gift c) Adopted from street d) Purchased

6. What are the purposes of keeping dogs? a) To guard house b) Love and affection c) As pet e) Other purposes

6. Is the dog ever confined? a) Yes b) No

If yes, when is it confined? a) Day b) Day and night c) Night

7. How do you keep your dogs? a) Housed in cages/tie outside b) Living inside the house with families c) Free to roam around the house compound during day and night d) Free to roam around the house compound, village/town

8. Have you registered your dog(s) with the Livestock Extension/vaccination in the district/town a) Yes b) No. If yes, who did it? If not registered, are you willing to register?______________________________________

9 Who feeds the dog? a) Household members b) Neighbors c) Finds its own food d) Combination

10. Is your dog(s) vaccinated against rabies (during last year or this year) a) Yes b) No

11. Do you believe it is important to vaccinate dogs against rabies every year? a) Yes b) No

12. Would you like to take your dog to vaccination ? a) Yes b) No

13. Do you vaccinate your dogs against rabies? (during last year or this year)? Yes b) No

14. Do you like to take your dog when there is Vaccination Campaign?

Do you know what age is recommended for a dog's first rabies vaccination? 3month/6-month/1 year/2 year

15. Have you ever de-wormed your dogs (given any medicine against worms)?a) Yes b) No

15. Have you participate for control stray dog in your home premises/street? a)Yes b) No

Annex 2: **R code for economic estimation of human and animals' rabies losses during five years**

```
library(VGAM)
n_rep = 1000000 # number of repetitions
# 1. DIRECT MEDICAL AND NON_MEDICAL COST ESTIMATION FOR PEP IN HUMNAN
# Number of PEP cases: the uncertainty of the parameter values and cost were accounted by
#inputting estimates as triangular distribution with maxima and minima set as +/-10% of
each
#parameter values and then run 100000 repetition.
# theta is the mode or the most likely number of patients that were given PEP from 2019 to
2023
# theta is also the most likely cost for each parameter
# Multiplication by 0.9 or 1.1 is the +/-10%
# PEP means post exposure treatment (vaccine) given
# total number of PEP cases from 2019 to 2023 was 345
################################################################################
```

```
PEP<-rtriangle(n=n_rep, theta=5, lower=5*0.9, upper=5*1.1)
hist(PEP); summary(PEP)
#############################################################################
# annual number of PEP cases =345/5 years=69
PEP_annual<-rtriangle(n=n_rep, theta=69, lower=69*0.9, upper=69*1.1)
hist(PEP_annual); summary(PEP_annual)
#############################################################################
#common costs for PEP:PEP vaccine cost; material cost per vaccine injection; material cost
for wound dressing, overhead/delivery cost for vaccine inj.and wound dressing per patient
per visit
# Number of visit to health center for one course = 17 times and no of inj. per patient = 17
times
# theta is the most likely cost. number day lost work was 10 day. A complete PEP dose
consists of 17 doses of vaccine administered consecutively for
#The first 14 days, with the remaining 3 doses at intervals of 10 days i.e. at day 24, 34 and
44.these 3 day not consider because patient choose non-working day to visit heath center
#############################################################################
number_visits_PEP<-10
vaccine_cost<-rtriangle(n=n_rep, theta=3.6, lower=3.6*0.9, upper=3.6*1.1)
summary(vaccine_cost)
#95 % confidence intervals
q_vaccine_cost<-round(quantile(vaccine_cost, probs = c(0, 0.025, 0.05,
0.25, 0.5, 0.75, 0.95, 0.975, 1), na.rm = T, type=6), 3); q_vaccine_cost
#############################################################################
antibiotic_cost<-rtriangle(n=n_rep, theta=3.65, lower=3.65*0.9,
                          upper=3.65*1.1) # only for different antbiotis)
summary (antibiotic_cost)
#95 % confidence intervals
q_antibiotic_cost<-round(quantile(antibiotic_cost, probs = c(0, 0.025, 0.05,
                                  0.25, 0.5, 0.75, 0.95, 0.975, 1), na.rm = T,type=6),
3);q_antibiotic_cost
q_antibiotic_cost
#############################################################################
```

```
wound_dressing_cost<-rtriangle(n=n_rep, theta=4, lower=4*0.9, upper=4*1.1) #wound
dressing and material cost(material and disinfection (syringe, needles, swabs,antiseptic, etc.)
summary(wound_dressing_cost)
#95 % confidence intervals
q_wound_dressing_cost<-round(quantile(wound_dressing_cost, probs = c(0, 0.025, 0.05,
                                   0.25, 0.5, 0.75, 0.95, 0.975, 1), na.rm = T, type=6),
3); q_wound_dressing_cost
##########################################################################
total_direct_cost_PET <-(vaccine_cost + antibiotic_cost+wound_dressing_cost)
# Total direct costs per patient per course (17 times visits): which is the sum of above costs,
multiplied by the average number of patient five year.
total_direct_cost_PET <-(vaccine_cost + antibiotic_cost+wound_dressing_cost)
total_direct_costs<- total_direct_cost_PET
hist(total_direct_costs); summary(total_direct_costs)
#95 % confidence intervals
q_total_direct_costs<-round(quantile(total_direct_costs, probs = c(0, 0.025, 0.05, 0.25,
0.5,0.75, 0.95, 0.975, 1), na.rm = T, type=6), 3); q_total_direct_costs
##########################################################################
total_direct_cost_annual <-(vaccine_cost +
antibiotic_cost+wound_dressing_cost)*PEP_annual
total_annaul<-total_direct_cost_annual
summary(total_direct_cost_annual)
#95 % confidence intervals
q_total_direct_cost_annual<-round(quantile(total_direct_cost_annual, probs = c(0, 0.025,
0.05, 0.25, 0.5,0.75, 0.95, 0.975, 1), na.rm = T, type=6), 3); q_total_direct_cost_annual
##########################################################################
#INDIRECT PATIENT COSTS ESTIMATION (income loss, meal cost and transport cost)
transport_cost<-rtriangle(n=n_rep, theta=12.6, lower=12.6*0.9, upper=12.6*1.1)
summary(transport_cost)
#95 % confidence intervals
q_transport_cost<-round(quantile(transport_cost, probs = c(0, 0.025, 0.05,
               0.25, 0.5, 0.75, 0.95, 0.975, 1), na.rm = T, type=6), 3); q_transport_cost
##########################################################################
income_loss_cost<-rtriangle(n=n_rep, theta=23.2, lower=23.2*0.9,
```

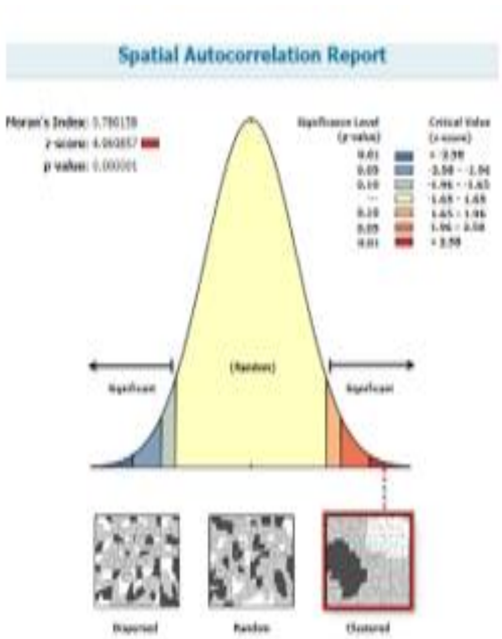
```
                    upper=23.2*1.1) # the income lost during seeking of PET of working 10
day(10-time visits)
summary (income_loss_cost)
#95 % confidence intervals
q_income_loss_cost<-round(quantile(income_loss_cost, probs = c(0, 0.025, 0.05,
                      0.25, 0.5, 0.75, 0.95, 0.975, 1), na.rm = T,type=6), 3);q_income_loss_cost
##########################################################################
meal_cost<-rtriangle(n=n_rep, theta=10.5, lower=10.5*0.9, upper=10.5*1.1) #average cost
of meal for 17 day of complete course treament.
summary(meal_cost)
#95 % confidence intervals
q_meal_cost<-round(quantile(meal_cost, probs = c(0, 0.025, 0.05,
                                          0.25, 0.5, 0.75, 0.95, 0.975, 1), na.rm = T, type=6), 3);
q_meal_cost
##########################################################################
# Total direct costs per patient per course (17 times visits): which is the sum of above cost,
multiplied by theaverage number of patientof five year.
total_non_direct_cost_PET <-(transport_cost + income_loss_cost+meal_cost)
total_non_direct_costs<- total_non_direct_cost_PET
hist(total_direct_costs); summary(total_non_direct_costs)
plot(total_direct_costs)
#95 % confidence intervals
q_total_non_direct_costs<-round(quantile(total_non_direct_costs, probs = c(0, 0.025, 0.05,
0.25, 0.5,0.75, 0.95, 0.975, 1), na.rm = T, type=6), 3); q_total_non_direct_costs
##########################################################################
total_non_direct_cost_annual <-(transport_cost +
income_loss_cost+meal_cost)*PET_annual
total_annaul<-total_non_direct_cost_annual
summary(total_non_direct_cost_annual)
#95 % confidence intervals
q_total_non_direct_cost_annual<-round(quantile(total_non_direct_cost_annual, probs =
c(0, 0.025, 0.05, 0.25, 0.5,0.75, 0.95, 0.975, 1), na.rm = T, type=6), 3);
q_total_non_direct_cost_annual
##########################################################################
```

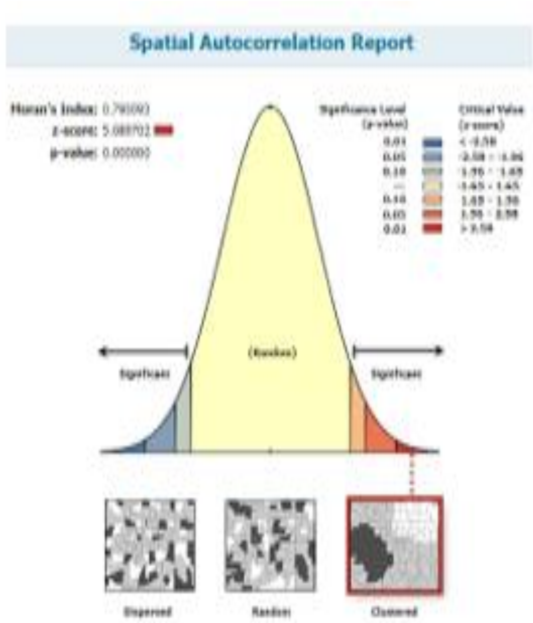
```
# 2. DOG VACCINATION
# Have to consider income loss for the owners to bring dogs to the center
# assumed about 2 hours would be lost for the dog owners to bring dog for vaccination
# vaccinator cost would be 5.4 since the vaccinator give to 18-20 dogs per day. 5.4 USD divide by number dog vaccinated perday
# The following formula is to calculate total dog vaccination cost without including income loss between 2019 and 2023, 1372 dogs were vaccinated USD 0.84 per dog (this is theta)
num_dogs_vacc <- rtriangle(n=n_rep, theta=1372, lower=1372*0.9,
                   upper=1372*1.1)
summary (num_dogs_vacc)
cost_per_dog_vacc <- rtriangle(n=n_rep, theta=0.84, lower=0.84*0.9, upper=0.84*1.1)
summary (cost_per_dog_vacc)
total_dog_vacc_cost <- num_dogs_vacc * cost_per_dog_vacc;
summary(total_dog_vacc_cost)
#95 % confidence intervals
q_total_dog_vacc_cost<-round(quantile(total_dog_vacc_cost, probs = c(0, 0.025, 0.05,
                                   0.25, 0.5, 0.75, 0.95, 0.975, 1), na.rm = T, type=6), 3);
q_total_dog_vacc_cost
cost_per_dog_vacc <- rtriangle(n=n_rep, theta=0.84, lower=0.84*0.9, upper=0.84*1.1)
summary (cost_per_dog_vacc)
q_total_dog_vacc_cost<-round(quantile(cost_per_dog_vacc, probs = c(0, 0.025, 0.05,
                                   0.25, 0.5, 0.75, 0.95, 0.975, 1), na.rm = T, type=6), 3);
q_total_dog_vacc_cost

##############################################################################
#3. LIVESTOCK LOSSES COST
#The average direct economic losses resulting from rabies mortality in livestock during the period 2019 to  2023 were approximately 110.2 USD per cattle, 127.3 USD per horse,62.2 USD per donkey and 106.5 per mule.
#110.2 salvage value of cattle loss cost at rate of 0.5 ( The cattle infect by rabies are sluaghter by estimation of half cost of normal one)
cattle_loss <-rtriangle(n=n_rep, theta=324, lower=324*0.9, upper=324*1.1)
cost_loss <-rtriangle(n=n_rep, theta=110.5, lower=110.5*0.9,
                     upper=110.5*1.1)
```

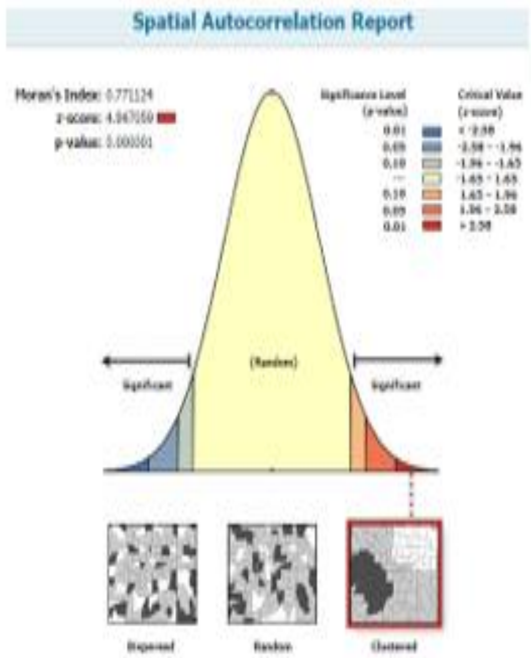
```
summary(cost_loss)
#95 % confidence intervals
q_cost_loss<-round(quantile(cost_loss, probs = c(0, 0.025, 0.05, 0.25, 0.5,
                                        0.75, 0.95, 0.975, 1), na.rm = T, type=6), 3); q_cost_loss
cattle <-cattle_loss * cost_loss;
summary(cattle)
#95 % confidence intervals
q_cattle<-round(quantile(cattle, probs = c(0, 0.025, 0.05, 0.25, 0.5,
                                                   0.75, 0.95, 0.975, 1), na.rm = T, type=6), 3); q_cattle
# cost of horse was estimated number of death horse multiplied by average cost perhorse
horse_loss <-rtriangle(n=n_rep, theta=19, lower=19*0.9, upper=19*1.1)
cost_loss <-rtriangle(n=n_rep, theta=127.3, lower=127.3*0.9,
                    upper=127.3*1.1)
horse <-horse_loss * cost_loss; summary(horse)
#95 % confidence intervals
q_horse<-round(quantile(horse, probs = c(0, 0.025, 0.05, 0.25, 0.5,
                                                  0.75, 0.95, 0.975, 1), na.rm = T, type=6), 3); q_horse
summary(cost_loss)
#95 % confidence intervals
q_cost_loss<-round(quantile(cost_loss, probs = c(0, 0.025, 0.05, 0.25, 0.5,
                                           0.75, 0.95, 0.975, 1), na.rm = T, type=6), 3); q_cost_loss
#Donkey death cost # there were 49 deaths and the average cost per donkey62.2
donkey_loss <- rtriangle(n=n_rep, theta=49, lower=49*0.9, upper=49*1.1)
cost_loss <- rtriangle(n=n_rep, theta=62.2, lower=62.2*0.9,
                    upper=62.2*1.1)
summary(cost_loss)
#95 % confidence intervals
q_cost_loss<-round(quantile(cost_loss, probs = c(0, 0.025, 0.05, 0.25, 0.5,
                                           0.75, 0.95, 0.975, 1), na.rm = T, type=6), 3); q_cost_loss
donkey <- donkey_loss * cost_loss; summary(donkey)
#95 % confidence intervals
q_donkey<-round(quantile(donkey, probs = c(0, 0.025, 0.05, 0.25, 0.5, 0.75,
                                              0.95, 0.975, 1), na.rm = T, type=6), 3); q_donkey
# mule death cost # there were 5 deaths of goat and the average cost was 106.5
```

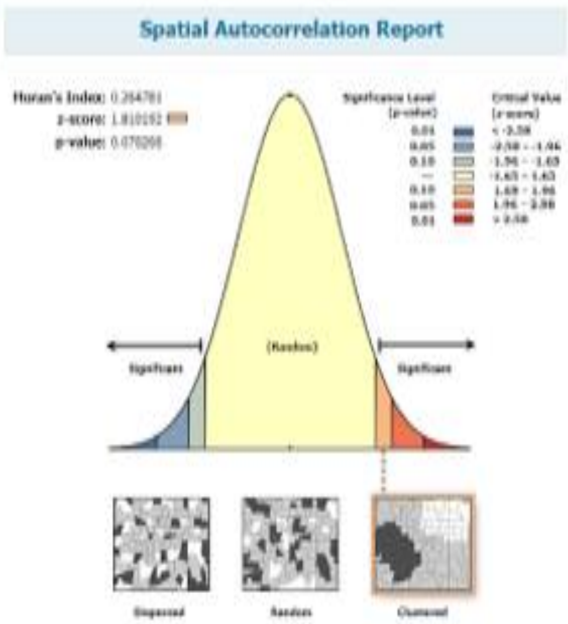
```
mule_loss <- rtriangle(n=n_rep, theta=2, lower=2*0.9, upper=2*1.1)
cost_loss <-rtriangle(n=n_rep, theta=106.5, lower=106.5*0.9, upper=106.50*1.1)
summary(cost_loss)
#95 % confidence intervals
q_cost_loss<-round(quantile(cost_loss, probs = c(0, 0.025, 0.05, 0.25, 0.5,
                                  0.75, 0.95, 0.975, 1), na.rm = T, type=6), 3); q_cost_loss
mule <-mule_loss * cost_loss; summary(mule)
#95 % confidence intervals
q_mule<-round(quantile(mule, probs = c(0, 0.025, 0.05, 0.25, 0.5, 0.75,
                                         0.95, 0.975, 1), na.rm = T, type=6), 3); q_mule
# Total livestock losses cost
livestock_losses<-(cattle+ horse +donkey+
                   mule); summary(livestock_losses)
#95 % confidence intervals
q_livestock_losses<-round(quantile(livestock_losses, probs = c(0, 0.025, 0.05,
                                                  0.25, 0.5, 0.75, 0.95, 0.975, 1), na.rm = T, type=6),
3); q_livestock_losses
Total_medical_cost<-(total_non_direct_costs+total_direct_costs)
total<- Total_medical_cost
summary(total)
hist(total); summary(total)
#95 % confidence intervals
q_total<-round(quantile(total, probs = c(0, 0.025, 0.05, 0.25, 0.5,0.75, 0.95, 0.975, 1), na.rm
= T, type=6), 3); q_total
```

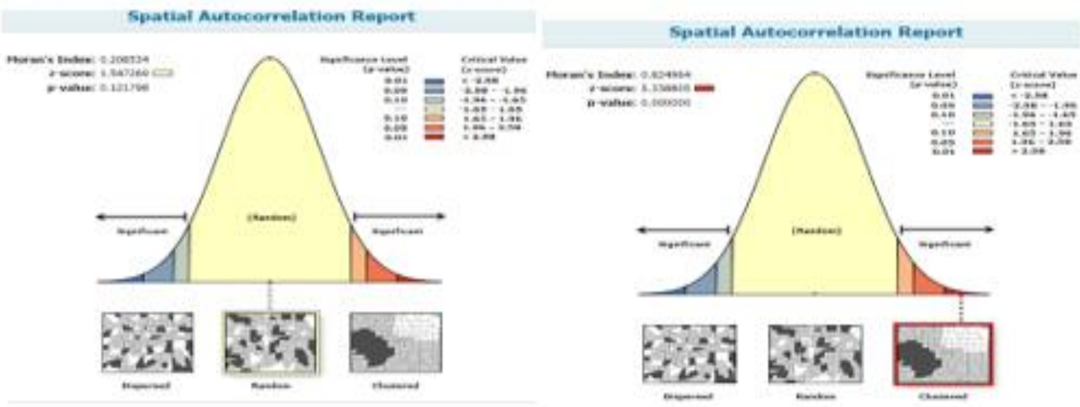
Appendix 3: **The Moran’s I report and some picture during spatial analysis**





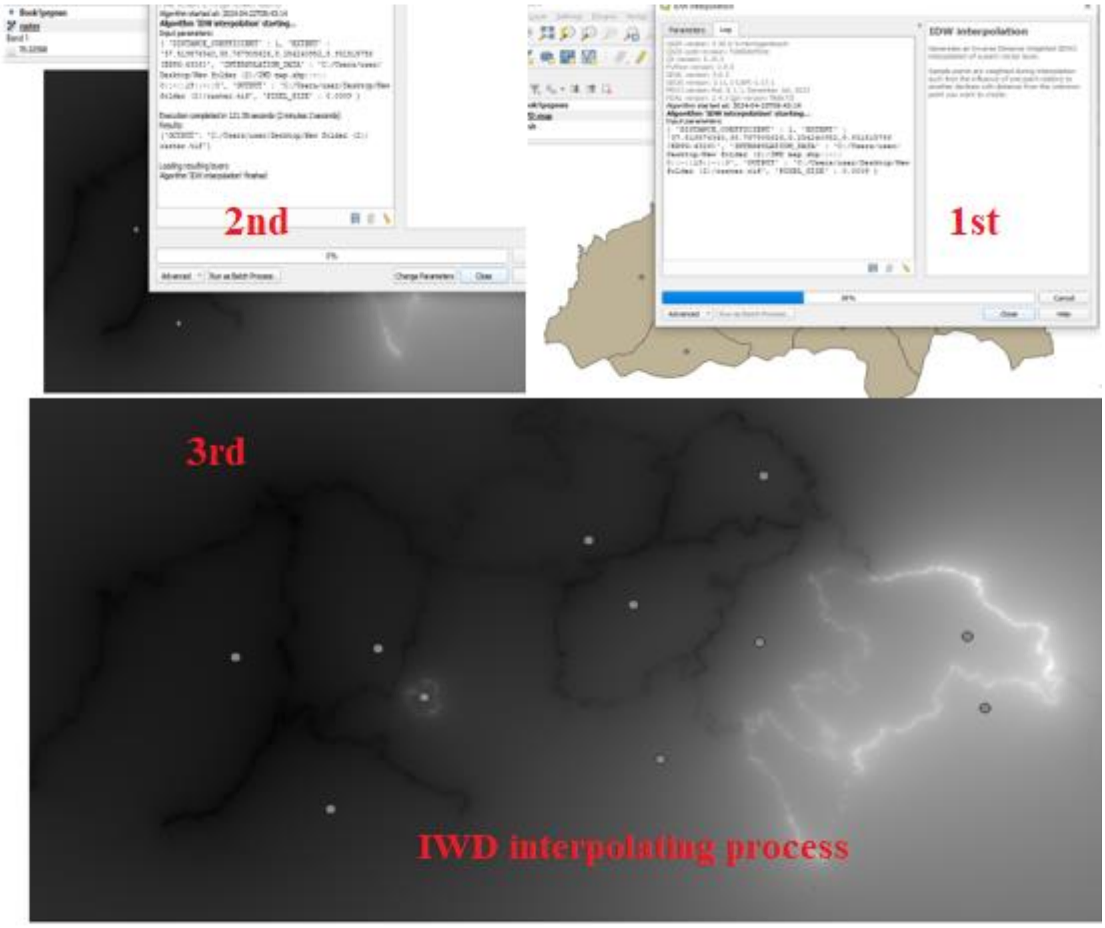






Given the z-score of 5.08970245629, there is a less than 1% likelihood that this clustered pattern could be the result of random chance.

Global Moran's I Summary	
Moran's Index:	0.790093
Expected Index:	-0.038462
Variance:	0.026501
z-score:	5.089702
p-value:	0.000000



Annex 4**:The collected data during observation**