https://doi.org/10.23925/1984-4840.2025v27a1 **Revisão Sistemática** / *Systematic Review*

Land use and land cover factors associated with snakebites: a systematic review

Fatores de uso e cobertura de terra associados a picadas de cobra: uma revisão sistemática

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ABSTRACT

Objective: This study aimed to identify factors related to land use and land cover that affect the incidence and occurrence of snakebite accidents. **Methods**: A systematic review was conducted using published studies from ScienceDirect, Scopus, PubMed, and Web of Science between 2012 and 2022. **Results**: 883 studies were obtained, and five publications were selected after the full-text reading, all conducted in Brazil. Thirteen different variables were found, most of which were related to natural land cover. Vegetation cover was the most studied variable, with its effects depending on the ecological characteristics of the snake involved in the bite. Variables related to urbanization and population density were identified as negatively related to snakebites, while Agriculture and all identified agriculture-related variables showed a positive association. **Conclusion**: Land use and land cover changes impact snakebite accidents, although retrospective studies on the subject are scarce.

Keywords: snake bites; land use; animals; poisonous; environment and public health.

RESUMO

Objetivo: este estudo teve como objetivo identificar fatores de uso e cobertura de terra que afetam a incidência e a ocorrência de acidentes ofídicos. **Métodos**: foi realizada uma revisão sistemática utilizando estudos publicados nas bases ScienceDirect, Scopus, PubMed e Web of Science entre 2012 e 2022. **Resultados**: um total de 883 estudos foi obtido; desses, cinco publicações foram selecionadas após a leitura completa, todas realizadas no Brasil. Foram encontradas 13 variáveis diferentes, e a maioria relacionada à cobertura natural da terra. A cobertura vegetal foi a variável mais estudada, com seus efeitos dependendo das características ecológicas da serpente envolvida na picada. Variáveis relacionadas à urbanização e à densidade populacional foram identificadas como negativamente relacionadas com as picadas de cobra, enquanto a agricultura demonstrou ter uma associação positiva, assim como todas as variáveis relacionadas à atividade agrícola. **Conclusão**: alterações no uso e cobertura da terra têm impactos no ofidismo, no entanto, estudos retrospectivos sobre o assunto são escassos.

Palavras-chave: mordeduras de serpentes; usos do solo; animais peçonhentos; meio ambiente e saúde pública.

INTRODUCTION

A snakebite accident is a negative interspecies interaction and is globally considered a critical public health issue for humans. Studies also show a great impact on livestock.[1,2] Despite the high underreporting rate of snakebite cases, it is known that snakebites cause up to 138,000 deaths worldwide annually.

The number of surviving victims left with temporary or permanent disabilities amounts to over 400,000 every year, with the actual number being much higher.[3]

Snakebite Envenomation has been added back to the World Health Organization's list of Neglected Tropical Diseases (NTD) in 2017.[4] It is the only noninfectious disease in the group, while also being a vastly under-researched subject when compared to other NTDs.[5]

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For being a disease that cannot, logically, be eradicated, snakebite has been overlooked for infectious NTDs. This neglect happens despite snakebite envenoming having a higher mortality rate than some known NTDs like dengue fever.[6] Studies on snakebite envenoming are conducted from a biomedical perspective, focusing on the venom and its biological effects while neglecting the disease's ecological aspects.[7] The effects of environmental changes on snakebite incidence are still unknown, and studies reviewing the association with changes in land use and land cover (LULC) are scarce.[8]

Current knowledge shows that land change is a mid-scale driver of snakebite patterns.[8] Farming and other agricultural activities in tropical regions carry a high incidence of snakebites.[9,10] Specifically, the presence of livestock is positively correlated to snakebite incidence.[11] Anthropic changes in habitat can lead to changes in the snake's assemblages, facilitating the invasion of biting snakes over less aggressive ones.[8]

While there are studies assessing the environmental effects on the incidence of ophidism, they mostly focus on climate variables.[12,13] The same climate variables are used to predict the occurrence of snakebites.[14] In a continuously changing global landscape, this lack of knowledge on the LULC drivers of snakebites is an obstacle to proper health policy planning. It can hinder the development of precise predictive models and impede correct action to mitigate this global health issue.[15]

In this systematic review, we aimed to identify the Land Use and Land Cover factors associated with snakebite accidents and their influence on their incidence and occurrence.

MATERIALS AND METHODS

Search strategy

PubMed, Science Direct, Scopus, and Web of Science were searched for published studies about the relationship between snakebite cases and Land Use and Land Cover. Some changes were necessary due to the difference between the bases' search engines. For PubMed and ScienceDirect, the query was: "snakebite" AND ("land cover" OR "land use"). On Web of Science, the search was: TS = ("snakebite" AND ("land cover" OR "land use")). For Scopus, the query was: ALL ("snakebite" AND ("land cover" OR "land use")).

Criteria for inclusion and exclusion

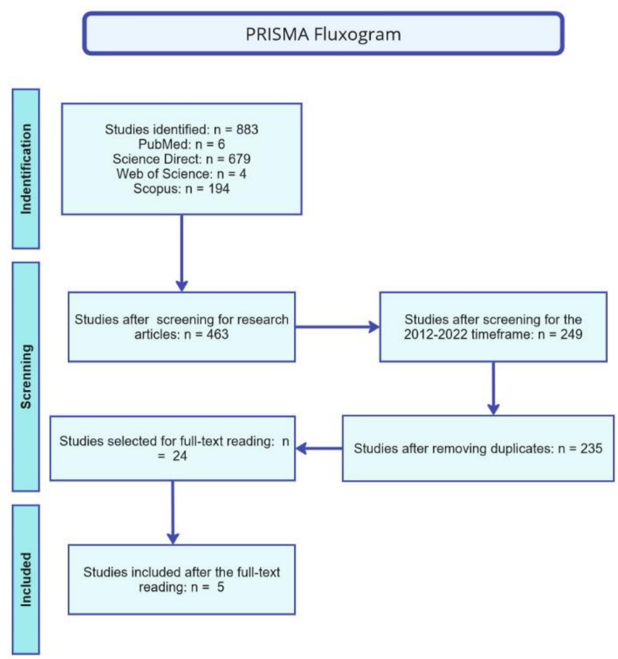
The timeframe chosen was from 2012 to 2022. Only research articles were selected, excluding any bibliographical review. The paper that had the search words related to LULC in its abstract's methods, results, or discussion section was selected for full-text reading. The LULC words included agriculture, biome, geographical descriptions (mountainous, coastal, etc.), human action, urban construction, and population density.

Articles about other human-snake interactions that did not involve a snakebite accident were excluded. Articles with no statistical association between LULC variables and snakebite were excluded during the full-text reading. Purely descriptive, experimental, or predictive studies were not included.

RESULTS

The initial sample consisted of 883 articles. After the filters were applied and duplicate publications were excluded, 24 articles were selected for full reading (Figure1). Out of these, the five that analyzed the association between snakebite and the LULC variables were selected.

Figure 1. PRISMA Fluxogram of the steps of this systematic review.



The LULC variables were extracted from the studies and separated into five categories: Natural Land Cover, Urban infrastructure, Water bodies, Farming, and Natural Landform (Table 1). The variables' correlation with snakebites, the study location, period, snake family, and species involved in the bites were also extracted from the studies assessed. Only a significant association was used when different statistical analyses were performed for the same variable. Snake species not identified were not reported.

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Table 1. Description of the categories used to organize the literature selected.

Land use and Land cover Categories	Description
Anthropic Action	Variables related to anthropic action that do not involve farming (area size, population density, human construction, rural areas when farming activity is not specified, and others).
Farming	Variables related to agriculture, pasture, and livestock.
Natural Land cover	Variables related to natural land cover (biomes, natural vegetation cover, tree canopy).
Natural Landform	Variables related to surface form and location in the landscape (mountains, slopes, hills, altitude, coast, and others).
Water Body	Variables related to lakes, streams, rivers, or seas. Coastal regions were excluded when the water body was not specified.

All the publications are from Brazil, where the primary climate is tropical (Table 2).

Different spatial scales were studied. While Schneider *et al*.[16] assessed the whole country, Alcântara *et al*.,[17] and Santos *et al*.[18] assessed the Brazilian Amazon biome and the states where this biome is located.

Ceron *et al*.[19] and Jucá *et al*.[20] studied a single-state snakebite notification. Species were identified mainly by genus, except for *Lachesis muta* Linnaeus, 1766, and *Crotalus durissus* Linnaeus, 1758, the only species of these genera in Brazil.

Elapidae and *Viperidae* were the only families studied; most species belonged to the *Viperidae* family.

Two studies focused on only one genus or species: Alcântara *et al*.[17] focused on the *Bothrops* genus, and Santos *et al*.[18] on *Crotalus durissus*. Schneider *et al*.[16] studied *Elapidae*, *Bothrops*, *Lachesis*, and *Crotalus* bites.

The other two studies included *Bothrops*, *Crotalus*, *Elapidae*, and *Lachesis*, as well as non-venomous snakes, but their taxonomic information was not specified.

In these three studies, the LULC variables associated with snakebites were not assessed by taxa but by the total number of cases. The most extended study was conducted by Jucá *et al*.,[20] who analyzed 17 years of notifications in Ceará, while Schneider *et al*.[16] investigated five years of ophidism notifications, covering the shortest study period.

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Table 2. Summary of the information extracted from the studies included in this review and the categorization of the identified variables.

Author	Location	Region	Climate	Study Period	Snake Family	Snake Species	Variables	LULC Categories	Relation
Alcântara *et al.*, 2018	Brazil	Amazon Biome	Tropical	2010-2015	*Viperidae*	*Bothrops* spp.	Altitude	Natural Landform	Negative
							Area Covered by Vegetation	Natural Land Cover	Positive
							Area Covered by Water Bodies	Water Body	Nonsignificant
							Population Density	Anthropic Action	Negative
							Tree Canopy Loss	Natural Land Cover	Negative
Ceron *et al.*, 2021	Brazil	State of Mato Grosso do Sul	Tropical	2007-2017	*Viperidae*	*Bothrops* spp.	Biomes	Natural Land Cover	Nonsignificant
					Viperidae	*Crotalus durissus*	Municipality Area	Anthropic Action	Positive
					Viperidae	*Lachesis muta*	Population Density	Anthropic Action	Nonsignificant
					Elapidae	*Micrurus* spp.			
Jucá *et al.*, 2021	Brazil	State of Ceará	Tropical	2001-2017	*Viperidae*	*Bothrops* spp.	Desertification	Farming	Positive
					Viperidae	*Crotalus durissus*	Pasture Expansion	Farming	Positive
					Viperidae	*Lachesis muta*	Population Density	Anthropic Action	Negative
					Elapidae	*Micrurus* spp.			
Santos *et al.*, 2019	Brazil	Amazon Biome	Tropical	2010-2015	*Viperidae*	*Crotalus* spp.	Altitude	Natural Landform	Positive
							Tree Canopy Loss	Natural Land Cover	Positive
							Area Covered by Vegetation	Natural Land Cover	Negative
							Area Covered by Water Bodies	Water Body	Negative
Schneider *et al.*, 2019	Brazil	Brazil	Tropical	2013-2017	*Viperidae*	*Bothrops* spp.	Altitude	Natural Landform	Positive
					Viperidae	*Crotalus durissus*	Major Habitat Type	Natural Land Cover	Positive
					Viperidae	*Lachesis muta*	Forest Loss	Natural Land Cover	Positive
					Elapidae	*Micrurus* spp.	Forest Cover	Natural Land Cover	Positive
							Urbanization	Anthropic Action	Negative

When extracting the LULC variables, a total of 20 variables were assessed in the five studies; after removing the duplicate variables, 13 different LULC factors were found. Out of these, six were categorized as Natural Land Cover, having the highest number of variables studied, followed by Anthropic Action (Figure 2).

Natural Landforms and Water Bodies only had one variable. Natural Land Cover had the highest frequency, with variables in that category appearing in four of the five studies. Farming-related variables appeared in one research, having the lowest frequency.

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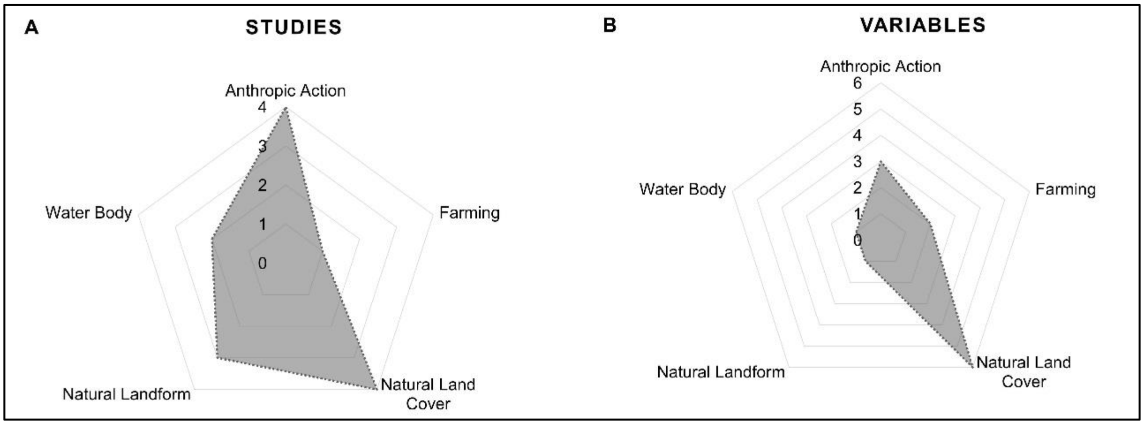
Figures 2. Distribution of results by LULC Category. A) Studies by Category. B) Variables by Category.



Anthropic Action

This category had the second highest number of variables, with Population Density, Municipality Area, and Urbanization included in the group. Population Density showed a negative correlation with snakebites in all the studies. Municipality Area which was only studied by Ceron *et al*.[19] is positively correlated with snakebites, while Urbanization, assessed by Schneider *et al*.[16] was negatively correlated.

Farming

Variables related to Farming were found only in Jucá *et al*.;[20] both Pasture Expansion and Desertification were positively associated with snakebites. Desertification, as defined by the authors, was the proportion of native vegetation that was turned into pasture.

Natural Land Cover

The six variables in this category were Area Covered by Vegetation, Biomes, Forest Cover, Forest Loss, Major Habitat Type, and Tree Canopy Loss. Only major habitat types and biomes did not assess vegetation cover somehow.

The Major Habitat Type analyzed Brazilian municipalities as tropical and non-tropical (yes or no), having a significantly positive association with snakebite cases. Biomes showed no statistical significance. The vegetation cover variables had different correlations; according to Schneider *et al*.,[16] Forest Loss and Forest Cover positively correlated to snakebites. In the study of Alcântara *et al*.,[17] *Bothrops* spp. bites had a negative correlation with Tree Canopy Loss and a positive correlation with Area Covered by Vegetation. Santos *et al*.[18] found the opposite: *C. durissus* bites had a negative correlation with Area Covered by Vegetation and a positive correlation with Tree Canopy loss.

Natural Landform

The only variable in this category was Altitude, which had a positive correlation in all studies where it was investigated, except for the study of Alcântara *et al*.,[17] who found altitude to have a negative relation with *Bothrops* spp. bites.

Water Body

As studied by Alcântara *et al*.[17] and Santos *et al*.[18], areas covered by water bodies were the only variable in this category. It showed a negative correlation with *C. durissus* bites and a nonsignificant association with *Bothrops* spp.

DISCUSSION

The Land Use and Land Cover associated with snakebite accidents found in this review show evidence of the effect of land change on the occurrence and incidence of ophidism. The variables identified in the results showed a great focus on change in vegetation cover, which is mainly connected with forest vegetation. Two of the five studies investigated the Amazon biome.[17,18]

The Amazon region is a focus for snakebite research; it is the home of the four genera of medically important snakes in Brazil and has a high diversity of snakes.[21-23] It also has one of the country's highest snake bite incidences.[16,24] The biome has been and continues to be affected by large anthropic landscape disturbances, with a growing deforestation rate.[25]

The variables Forest Loss and Tree Canopy Loss are variables used to measure these types of landscape changes, followed by the Area Covered by Vegetation and Forest Cover.

In the Amazon biome, the results showed that the ecological traits of the snakes assessed dictate the association between snakebite and land change. Even though only two genera were assessed, these snakes responded differently to the same LULC variables. *Bothrops* spp. bites had a negative correlation with Tree Canopy Loss and a positive correlation with the Area Covered by Vegetation. This is consistent with what is known about *Bothrops* spp. behavior, as these snakes are more common in vegetated areas and shady environments.[26] Thus, reducing forest cover would restrict the encounter between this snake and its victims. The opposite is true for *C. durissus*. This venomous species thrives in open, savannah-like areas, where most crotalid bites occur areas.[13,24,27]

It is expected that its bite occurrence will have a negative correlation with the Area Covered by Vegetation and a positive

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correlation with Tree Canopy Loss. As for differences in the response to the altitude variables between the snakes, in the Brazilian Amazon region, crotalid bites occurred in high-altitude areas. *Bothrops* spp., on the other hand, tends to be more commonly found in the lowlands in the Amazon region.[18,26]

The Pasture Expansion and Desertification variables, while only showing up in one study, are also an example of this loss of natural vegetation cover, albeit in the Caatinga biome. Both variables positively relate to snakebite incidence and corroborate what is already known about farming activities as a focus of ophidism.[11]

The negative correlation between urbanization and population density is possibly due to the scarcity of habitats for snakes in highly populated regions.

Urbanization has been shown to reduce wildlife presence and cause habitat fragmentation, while snakebite incidence is higher in rural and isolated communities.[28-30] Snakebite was shown to be influenced by land use and change factors. Changes in the natural land cover can increase snakebite in areas without the health infrastructure to deal with it. The scarcity of studies and the fact that they are all from the same country were limitations for this review.

CONCLUSION

In this review, Land use and Land Cover factors associated with snakebites have been identified. A total of 13 different variables and their correlation with snakebites were described. Vegetation Cover was the most assessed Land Cover factor, with six different variables connected to this aspect. Snakebite incidence can respond differently to the same variables depending on the ecological traits of the snake involved in the accident.

The low sample of publications reviewed shows the scarcity of research about the effects of land factors on snakebite accidents. The narrow global distribution of publications also shows the worldwide neglect of this issue. This indicates a focus for present and future researchers on the need for more retrospective studies and an expansion of knowledge on the environmental determinants of this health issue.

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Conflict of Interest

The authors have no conflicts of interest to declare in the realization of this study.

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