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Abiotic factors and LULC changes affecting the diversity of wild species of *Solanaceae* in the Ecuadorian Andes

Mario GARCÍA-MORA [1,2*], Mercy ILBAY-YUPA [3]

[1] Facultad de Recursos Naturales, Escuela Superior Politécnica de Chimborazo, Riobamba, Ecuador.
[2] Posgrado, Universidad Politécnica Estatal del Carchi, Carchi, Ecuador.
[3] Grupo de Recursos Hidricos, Universidad Técnica de Cotopaxi, Salache, Latacunga, Ecuador.
* E-mail: victor.garcia@espoch.edu.ec

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ABSTRACT: The diversity of wild species of *Solanaceae* is very important for maintaining ecosystem resilience and food security. This study identified the abiotic conditions that contribute to the presence of wild species of *Solanaceae* and the main changes in Land Use and Land Cover (LULC) that affect their conservation in the Ecuadorian Andes. A Multiple correspondence analysis (MCA), Hierarchical Cluster Analysis and LULC change analysis were performed to elucidate the proposed objectives. The results show the influence that factors such as geographic latitude and precipitation have on wild species of Solanaceae have been observed through the MCA; to a lesser extent, but just as important, so were frosts and droughts. Three groups have also been identified in this study: Group 1 (*S. olmosense*) located in the southwest of the country, higher temperatures (16-22 °C), average rainfall (1207 mm/year), no influence of frost and medium tolerance to droughts; Group 2 (*S. chilliasense* and *S. albornozii*) also to the south, with a high presence of frost and drought, but with lower temperatures (10-14 °C) and precipitation (1115 mm/year) and loam soils; finally, Group 3 (*S. albicans*, *S. andreanum*, *S. chomatophilum*, *S. colombianum* and *S. minutifoliolum*) is the most abundant, with a distribution in the center and north of the country, under a wide range of temperature (2 to 22 °C), precipitation (500-2000 mm/year) and tolerant to frost and drought. The change of LULC evidences a significant decrease ($p<0.001$) of 5.1 km^2/year from Grasslands and Forests and semi-natural to cultivated areas, artificial territory, bare soils and pastures for the three groups. Ecuador's climate variability allows diversity in the distribution of wild species of *Solanaceae*, which are affected by the change of LULC, so it is necessary to take concrete actions to facilitate the conservation of the potato genetic resource.
Keywords: diversity; wild species of Solanacea; land use; land cover.

Fatores abióticos e alterações no LULC afetando a diversidade de espécies silvestres de *Solanaceae* nos Andes equatorianos

RESUMO: A diversidade de espécies silvestres de Solanaceae é muito importante para a manutenção da resiliência dos ecossistemas e da segurança alimentar. Este estudo identificou as condições abióticas que contribuem para a presença de espécies silvestres de Solanaceae e as principais mudanças no Uso e Cobertura da Terra (LULC) que afetam sua conservação nos Andes equatorianos. Uma Análise de Correspondência Múltipla (ACM), Análise de Agrupamento Hierárquico e Análise de Mudanças LULC foram realizadas para elucidar os objetivos propostos. Os resultados mostram a influência que fatores como latitude geográfica e precipitação têm sobre espécies silvestres de Solanaceae têm sido observados através da MCA; em menor grau, mas igualmente importante, assim como geadas e secas. Três grupos também foram identificados neste estudo; Grupo 1 (S. olmosense) localizado no sudoeste do país, temperaturas mais elevadas (16-22 °C), precipitação média (1207 mm/ano), ausência de influência de geadas e média tolerância a secas; Grupo 2 (S. chilliasense e S. albornozii) também ao sul, com alta presença de geadas e secas, mas com temperaturas mais baixas (10-14 °C) e precipitação (1115 mm/ano) e solos francos; finalmente, o Grupo 3 (S. albicans, S. andreanum, S. chomatophilum, S. colombianum e S. minutifoliolum) é o mais abundante, com distribuição no centro e norte do país, sob ampla faixa de temperatura (2 a 22 °C), precipitação (500-2000 mm/ano) e tolerante a geadas e secas. A mudança do LULC evidencia uma diminuição significativa ($p<0{,}001$) de 5,1 km2/ano de Campos e Florestas e áreas seminaturais para cultivadas, território artificial, solos nus e pastagens para os três grupos. A variabilidade climática do Equador permite diversidade na distribuição de espécies silvestres de Solanaceae, que são afetadas pela mudança do LULC, por isso é necessário tomar ações concretas para facilitar a conservação do recurso genético da batata.
Palavras-chave: diversidade; espécies silvestres de Solanaceae; mudanças no uso do solo; mudanças na cobertura do solo.

1. INTRODUCTION

The potato (*Solanum tuberosum L.*) is a highly nutritious and productive crop and, at the same time, economically important, especially for Andean producer families. Potato tubers are rich in starch, carbohydrates, minerals (Fe, Zn, Mg, P and K), vitamins (C, B3, B5, B6), and protein(SINGH et al., 2020). Therefore, improving this crop's productivity is paramount for the food security of a growing population

(FAO et al., 2022). Its production occurs on almost all continents (Asha et al., 2023; Grados et al., 2022) but in cold areas or seasons, under conditions free of frost and excess heat (HAVERKORT et al., 2013). That is to say, many farms depend on potato production. Therefore, continuous improvement processes are important (DEL MAR MARTÍNEZ-PRADA et al., 2021).

Abiotic factors such as light intensity, soil pH and density, slope, temperature and precipitation affect species abundance and distribution (MELIS et al., 2006). However, the rate of species loss is expected to increase due to the increase in global temperature and the deposition of atmospheric nitrogen (SUNDAY, 2020). Climate change affects agriculture and even threatens food security (Qiulan et al., 2023); potato cultivation impacts its productivity, particularly in changes related to rainfall patterns, temperatures, and its indirect effects, such as increased severity and incidence of pest and disease outbreaks (PRADEL et al., 2019; SHIMODA et al., 2018). As well as the shortening of the tubers' latency period and acceleration of shoots' growth rate due to drought (IBAÑEZ et al., 2021). This situation poses a major challenge to ensuring global food demand (DAHAL et al., 2019). It evidences the vulnerability of potato cultivation to biotic (insects and diseases) and abiotic (drought, high salinity, cold and heat) stress (KIPTOO et al., 2018).

Added to this problem are the anthropogenic processes that condition the presence of plant species, such as land use and cover change (LULC); this process is currently the main factor in the transformation and loss of terrestrial biodiversity (Cheruto et al., 2016; López et al., 2020); caused mainly by the expansion of agriculture, livestock, deforestation, afforestation, fires and mining through inappropriate practices (AGIDEW; SINGH, 2017; BRÜCK et al., 2023). LULC studies provide indispensable information for biodiversity conservation, ecological services research, and land management (MELLOR et al., 2015). Thus, the timely availability of historical and future LULC maps is an input for managers and decision-makers in the development of strategies and policies for the conservation of species of extinction (SISAY et al., 2023). In recent years, anthropogenic impacts and climate change have modified their environment on a superlative spatio-temporal scale, causing the decline or extinction of numerous wild populations. Wild species of crops are plants of economic importance for their value in crop improvement (NAEEM et al., 2023). Wild potato species are a great genetic reservoir for breeding, as they provide new genes with abiotic stress-resistant and biotic traits not found in commercial cultivars (BASHIR et al., 2021). Because these plants adapt to their local conditions, their growth and reproduction are temporarily adjusted to environmental conditions (SÄRKINEN et al., 2015). The high genetic diversity of wild species makes it possible to generate new elite potato varieties that are more nutritious, productive, and resistant to environmental stress (MARTÍN et al., 2023).

South America is the center of origin of the potato, and the distribution of wild species is very varied, around 151 species of wild potato are concentrated in the Andes; although they are too bitter to be consumed, their biodiversity includes important characteristics such as natural resistance to pests, diseases, and climatic conditions (CIP, 2016). However, many wild relatives of crops are endangered due to habitat loss due to LULC change and climate change (Von Wettberg et al., 2022), and only 8% to 13% of wild species are conserved by in situ or ex-situ methods (JENDEREK et al., 2023). The climatic influence on biota, in general, is known; however, the specific status of the influence of many abiotic factors (precipitation, temperature, soil type, distribution, among others) and the influence of anthropogenic activities on the conservation of threatened species is not known (MACIEL-MATA et al., 2015). In this context, it is necessary to determine the abiotic conditions and LULC changes that affect the development of wild species of *Solanaceae* in the Ecuadorian Andes.

2. MATERIAL AND METHODS

2.1. Data

In this research, geospatial data, six abiotic factors and forty-four collection points were used:

Geospatial data, ESA's Sentinel-2 imagery with a resolution of 10 m, was used from 2017 (the year of collection) to 2023.

Abiotic factors include climatic (rainfall, temperature and risk of drought and frost), edaphic (texture), geographical (latitude and longitude) and topographic (slope). Because potato production is influenced by the amount and spatiotemporal variation of rainfall (mm/year) (LI et al., 2023). Temperature (°C/year) affects the evaporation process, soil water content, and indirect effects on soil respiration, nitrogen mineralization, host-pathogen interactions, and thus plant productivity (SAVIN et al., 1997; SINGH et al., 2019). They are susceptible to frost as they cause a decrease in yield in *Solanaceae* due to drought stress and are also significantly affected by frost (NASIR; TOTH, 2022). In addition, the surface texture of the soil at 0.20 m depth and the slope (%) were considered. Cartographic information at a scale of 1:25000 was obtained from the regionalization of rainfall (ILBAY-YUPA et al., 2021a) and the SIN (https://sni.gob.ec/).

For the analysis, the geographical location (latitude and longitude) of the collection points of the eight wild species of Solanaceae (GENESYS, 2017) were distributed in eleven provinces along the Ecuadorian Andes (Sierra Region) between 2200 and 3600 meters above sea level. The importance of these species lies in the fact that ≈ 63% are at very high risk of extinction (Endangered), according to the IUCN Red List, as detailed in the following Table 1.

2.2. Methodology

The methodology is developed in two stages, summarized in Fig. 1. The first stage corresponds to determining the abiotic factors that influence the abundance and distribution of wild species of Solanaceae. For this, the superposition of the species' collection points and the abiotic factors was carried out, followed by multiple correspondence analysis (MCA) and hierarchical cluster analysis. The second stage is to evaluate the impact of anthropogenic factors that condition wild species' presence through changes in land use and cover (LULC).

2.3. Multivariate Statistics

A sensible way to handle a dataset of categorical origin is correspondence analysis, which generates a contingency table formed from the classification of variables (BEH; LOMBARDO, 2019). This multivariate method was necessary because categorical information was treated to distinguish the pattern related to the variables. However, this study's competence comprises multiple correspondence analysis (MCA) based on simple correspondence analysis (SCA) fundamentals.

Table 1. Collection points for wild species of *Solanaceae*
Tabela 1. Pontos de coleta de espécies silvestres de *Solanaceae*

Species of *Solanaceae*	CP	Political division (province)	State of conservation*
S. albicans Ochoa	3	Chimborazo	Least Concern
S. albornozii Correll	8	Loja	Endangered
S. albornozii Correll	12	Carchi, Imbabura, Bolivar, Napo	Endangered
S. andreanum Baker	2	El Oro	Vulnerable
S. chilliasense Ochoa	6	Pichincha	Endangered
S. chomatophilum Bitter	4	Pichincha and Napo, Morona Santiago	Near Threatened
S. colombianum Dunal	6	Cotopaxi Napo	Endangered
S. minutifoliolum Correll	3	Loja	Endangered
S. olmosense Ochoa	3	Chimborazo	Least Concern

* according to the IUCN; CP = Collection points;

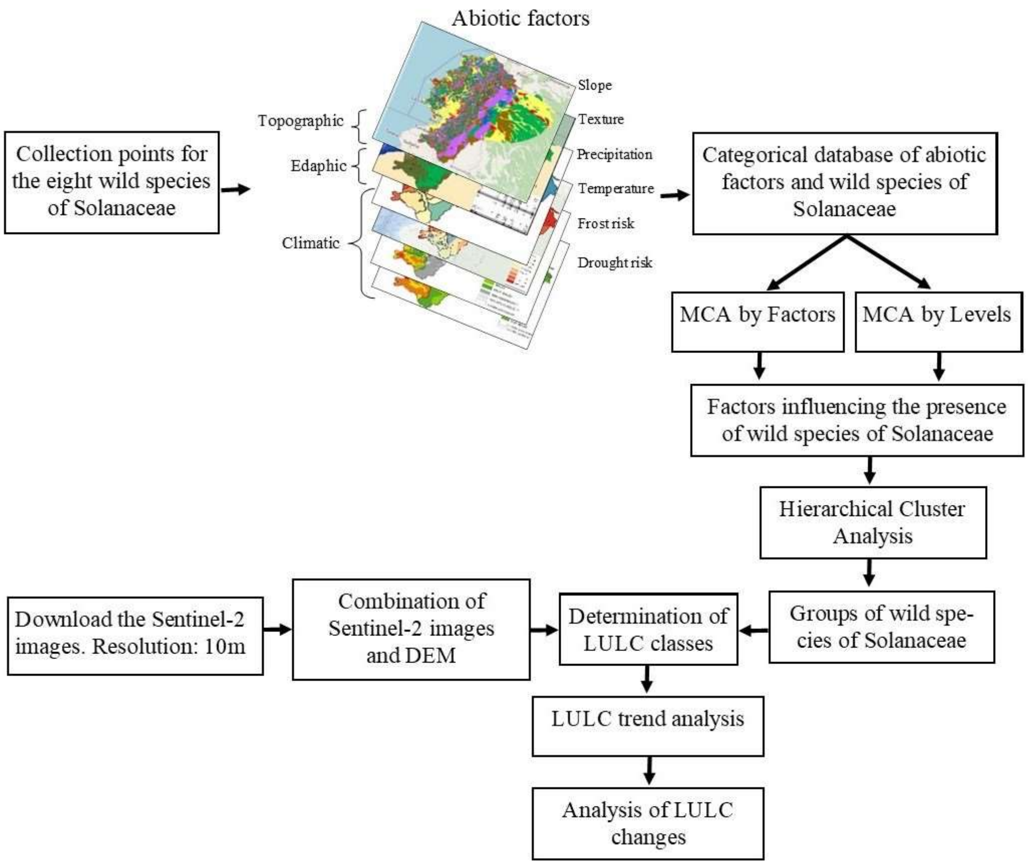

Figure 1. A methodological scheme will be used to evaluate the abiotic factors and LULC changes that affect the development of wild species of *Solanaceae* in the Ecuadorian Andes.
Figura 1. Esquema metodológico para avaliar os fatores abióticos e as alterações no LULC que afetam o desenvolvimento de espécies silvestres de *Solanaceae* nos Andes equatorianos.

The MCA considering the description of Khangar & Kamalja (2017), according to the n observations and the p levels of each categorical variable (VC), where jk represents the number of categories of the k-th levels of VC, from 1, 2, 3, ..., p, which corresponds to our case different levels in each VC. Form an indicator matrix starting from Xk to create $n\,x\,jk$ that has i-th elements of the category, with a value of one if it is present or zero if it is absent. The matrix formed by the combination corresponds to

$$n\,x\,J \quad (01)$$

$$Y = [y_1,\ y_2, \dots, y_p\ ], \quad (02)$$

also called the Superindicator matrix; where,

$$J = \sum_{k=1}^{p} jk \quad (03)$$

Burt's matrix is formed from $J\,x\,J$, whose notation is

$$B = Y^T Y, \quad (04)$$

plays an important role in performing correspondence analysis. From what has been said, Burt's matrix is as follows:

$$\begin{pmatrix} X_1^T X_1 & X_1^T X_2 & \dots & X_1^T X_p \\ X_2^T X_1 & X_2^T X_2 & \dots & X_2^T X_p \\ \vdots & \vdots & \ddots & \vdots \\ X_p^T X_1 & X_p^T X_2 & \dots & X_p^T X_p \end{pmatrix} = \begin{pmatrix} D_1 & X_1^T X_2 & \dots & X_1^T X_p \\ X_2^T X_1 & D_2 & \dots & X_2^T X_p \\ \vdots & \vdots & \ddots & \vdots \\ X_p^T X_1 & X_p^T X_2 & \dots & D_p \end{pmatrix} \quad (05)$$

The marginal frequencies of the matrix of B contain the square blocks on the diagonal of the VC levels, while the two factors associated with VC are outside the diagonal. These two factors form the contingency table, which generates the coordinates of rows and columns to visualize the variables' behavior or associations. The MCA computation uses the same algorithm as simple correspondence analysis but is applied to *B*.

With the information obtained according to the dimensionality and variation of the variables, they were grouped by hierarchical clusters, where each group starts in a small agglomeration, then merges with a similar pair and their group, successively in a hierarchy of groups, according to the degree of similarity (WARREN LIAO, 2005). The hierarchical clustering dendrogram uses the Euclidean distance, where the algorithm iteratively starts from the bottom with the n observations of the same group, with the n-1 groups becoming more and more similar, then n-2 groups, successively until all the groups are similar (JAMES et al., 2021).

2.4. Hierarchical Cluster Analysis

In this analysis, the hierarchical clustering algorithm was applied to analyze clusters of wild Solanaceae species using the Ward method. This method allows for measuring the distance between species groups to generate groupings using a graphical representation such as a tree or dendrogram (ESPINEL, 2015). Within each group, the species should have the least variance (criterion of statistical homogeneity) (CESAR et al., 1999).

2.5. Analysis of temporal change of land use and land cover

The impact of anthropic factors on the presence of wild species of *Solanaceae* was carried out considering the year of collection (2017) and the hierarchical classification, as detailed below:

The first step was determining the species' area of influence within a 10 km radius for the 44 location points corresponding to the eight species.

- Satellite images of the global map with ten classes of LULC derived from ESA Sentinel-2 imagery with a resolution of 10 m were downloaded and prepared over seven years (ESRI; FAO; NOAA, 2023). These satellite images were selected with low cloudiness characteristics, and then digital processing of the images (combination of bands, spectral enhancements, slice, and projection) was performed.
- The first entry (mosaic dataset) was created, and the annual medians of the satellite imagery and the digital elevation model (30 m) of the Shuttle Radar Surveying Mission (SRTM DEM) (Wang et al., 2021) were combined using the Google Earth Engine (GEE) platform.
- Atmospherically corrected Landsat Level 2 imagery was applied to the mosaic dataset. For the orthorectification of the images, ground control points were taken, which are photo-identifiable points in the images and whose absolute position is known, such as roads and rivers. These points serve as guides to evaluate the georeferencing of the image.
- The coverage proposed by the Andean regions (Kosztra et al., 2019) was classified as: artificial territories, cultivated areas, forests and semi-natural areas, moorlands, pastures, water surface, bare soil, artificial territories, and ice and snow (RONDÓN; PEÑA, 2013).
- A trend analysis was performed using the non-parametric Mann-Kendall test (Mann, 1945), widely used in environmental variables (Ilbay-Yupa et al., 2021).
- Finally, the LULC changes for the last seven years (2017-2023) were determined.

3. RESULTS

3.1. Multiple Correspondence Analysis by level

MCA is a multivariate technique widely used to study categorical data information, with the same purpose as principal component analysis, i.e., to reduce large data sets into smaller ones, which summarizes the information contained and can be explained more efficiently. With the formation of 50 dummy or binary dichotomous variables according to the levels of each of the nine variables present in this study, 100% of the contribution up to dimension 34. Dimensions 1 and 2 generated the highest contribution percentage to the variation (31.21%). Although these percentages are low, it is common to observe similar facts in studies involving plant ecology and attributes associated with agricultural practices, for example, when using phenotypic traits of wild populations of plants that adapt to growing conditions for restoration purposes (Leger et al., 2021), in the study of the relationship between soil and plants according to associated symbiotic fungi (PAN et al., 2024). The percentage of dimensionality is affected due to the optimization that the MCA seeks when trying to capture the greatest variation in the first dimensions and the nature of the categorical data (Beh; Lombardo, 2019), which in our case varies in each category and levels; but that, in the graphical visualization, the search for the relationships of the variables is more relevant than explaining the total variability.

The variables were analyzed in the two-dimensional plane and generated with the greatest contribution of the first two dimensions. This has made it possible to appreciate the relationship of the wild species of *Solanaceae* with the other variables. Figure 2 shows that plant species, geographic latitude, and annual rainfall behavior are more related and contribute more to variation. However, although the relationship is lower than the previous ones, the influence of frosts, droughts, and geographical length is appreciable. The smallest contribution corresponds to average temperatures and texture, although their relationship is close. The slope has a minority influence on the variation and is also far from clearly consolidated groups to influence them directly.

It should be understood that the lower contributions are because the species are distributed in similar categories for the variables analyzed; thus, it is evidenced in the case of elevations greater than 40% observed in this study, although this fact is not convenient, since the adverse activity generated in the soil by factors such as the loss of vegetation or human activities can favor erosion (Osman et al., 2021), this assertion also allows us to consider that the diversity of conditions to which the studied wild species of *Solanaceae* species are exposed has allowed their presence under different conditions; Moreover, ecological activities suggest the use of native plants due to their ability to adapt (Leger et al., 2021), which allows a parameter to be considered for their conservation.

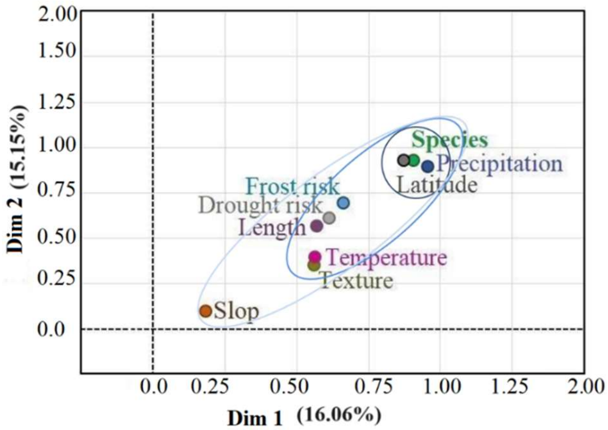

Figure 2. Multiple correspondence analysis and classification of groups according to the proximity of the variables.
Figura 2. Análise de correspondência múltipla e classificação dos grupos de acordo com a proximidade das variáveis.

3.2. Analysis of multiple correspondences by factors

Notably, the contribution percentage to the total variation of dimension one is located horizontally, and dimension two is located vertically. However, it is appreciable in Figure 3; this fact is emphasized to attend to the most important or perhaps least relevant axis of contribution, according to the location plan. The closer they are to the center of gravity, the lower the degree of contribution to the variation, and the greater the degree of grouping, the greater the relationship between them. Under the premise above, we value the greatest contribution to variation to the wild species *S. olmosense* (11.95%) because it does not share the two-dimensional space with any other *Solanaceae* in this study; however, if it does so with the latitude of 5° to 6° S, which allows rainfall of 1207 mm/year, although it is also related to the longitude of 80° W and temperatures of 20 °C to 22 °C, which allows it to explain 50.2% of the total variation in dimension 1. The grouping of medium droughts and clay soils, without risk of frost, stands out because they are more related to the group containing the variables described above, although more dispersed. The same variables described cover 8.36% of the contribution to the variation in dimension 2, which is interesting because the most representative variables in this dimension are closely related to *S. albornozii* and *S. chilliasense* and correspond to the latitude of 1° to 2° S, annual precipitation of 1115 mm, frosts and high and very high droughts which represent 39.40% of contribution to the variation.

On the other hand, the location in the negative plane of the temperature variables from 10 °C to 14 °C, loam texture and sandy loam represent 6.44% and suggest that the presence of the related species would be different if the conditions of the variables were also different. In dimension 1, these same variables represent 3.33%. In another location plane, the variability in the distribution of the most significant categorical information in dimension 1 corresponds to the species *S. minutifoliolum*, *S. colombianum* and *S. chomatofilum*, located on the negative axis, affected by the location from 77 °W to 78 °W and 1 °S to 2 °S, rainfall from 1064 to 1338 mm/year, With the presence of frosts, variable slopes and little drought, which corresponds to fine-textured soils such as silty loam and clay loam, it also explains that the presence of these plant species is sensitive to changes that may occur in the described variables, more than in dimension 2, because the contribution to variation, in this case, is lower. In the species *S. albicans* and *S. andreanum*, there is the lowest contribution among the wild species of Solanaceae; however, the related variables present a certain degree of variation, which could affect their presence under changes due to climatic or anthropogenic factors.

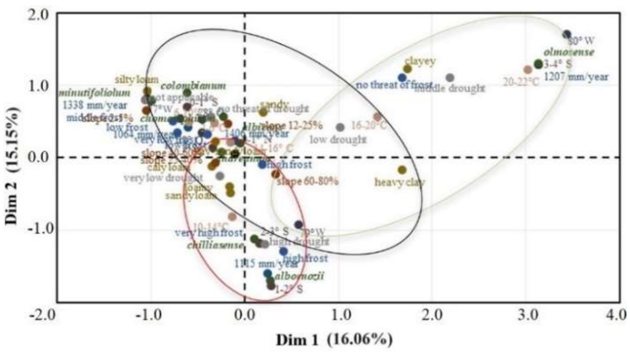

Figure 3. Multiple correspondence analysis and classification of groups according to the proximity and influence of each level of the variables.
Figura 3. Análise de correspondência múltipla e classificação dos grupos de acordo com a proximidade e influência de cada nível das variáveis.

3.3. Grouping of wild species of *Solanaceae*

The selection of the three groups in the hierarchical clusters, presented in Figure 4, was defined based on the association that the variables showed in the MCA, where the first group (G1) corresponds to *S. olmosense* located towards the south of the country, on the other hand, in the second group (G2) we find *S. albornozii* and *S. chilliasense* also located to the south and in the third group (G3) *S. albicans*, *S. andreanum*, *S. chomatophilum*, *S. colombianum* and *S. minutifoliolum*, with the greatest variability and location from the north to the center of the country.

Table 2 shows the abiotic factors that influence the abundance and distribution of wild species of *Solanaceae*. In G1, the only species present is found in areas without the presence of frost, but in areas of low to medium risk of frost, with a medium range of precipitation (850 to 1500 mm/year) and adapted only to clay soils and with higher temperatures, when compared to the other groups. In G2, the species develop in areas at high risk of frost, may or may not be influenced by droughts, and develop under average temperatures and loam soils. Finally, G3 presents greater variability because the range of precipitation (550 to 2200 mm/year), temperature (2 to 20°3C), and risk of frost and drought are wide, with greater spatial dispersion in the Ecuadorian Andes. In other words, group three has broad characteristics, which would allow a greater degree of adaptation.

3.4. Temporary change in land use and land cover

The classification of the proposed covers for the Andean regions determined only two classes of LULC, in which the eight wild species of *Solanaceae* of Ecuador in 2017 were distributed. Table 3 shows that Group 1 is found in semi-natural areas and forests, as well as Group 2 and Group 3. Although the latter two are also distributed in the grasslands class. The seven-year Mann-Kendall temporal trend analysis showed that from 2017 to 2023, there were significant negative trends ($p<0.001$) for Group 1, with a decrease of 4.2 km2/year of Forest and semi-natural areas. Likewise, a significant decrease ($p<0.001$) of 7.2 km2 (Group 1) and 4.1 km2 (Group 3) of two LULC classes (grasslands, forests and semi-natural) per year was determined, as seen in Figure 5.

The analyses of the changes in LULC between 2017 and 2023 in the three groups of wild species of Solanaceae are presented in Table 3, where it is evident that 78.1% of Group 1 showed no change in coverage for the seven years of study. Still, the rest became bare ground (12.3%), crop area (6%) and artificial territories (3.6%). Group 2 reached 66.1% with no change in LULC; transitions from forest and grassland to crop area, artificial territories and bare ground account for 18.4% and 15.5%, respectively. For Group 3, the area with no change in coverage was 78.6%; however, 13.2% of grasslands were converted to crops and artificial territories, and 8.2% of forests and semi-natural were converted to artificial pastures and artificial territories.

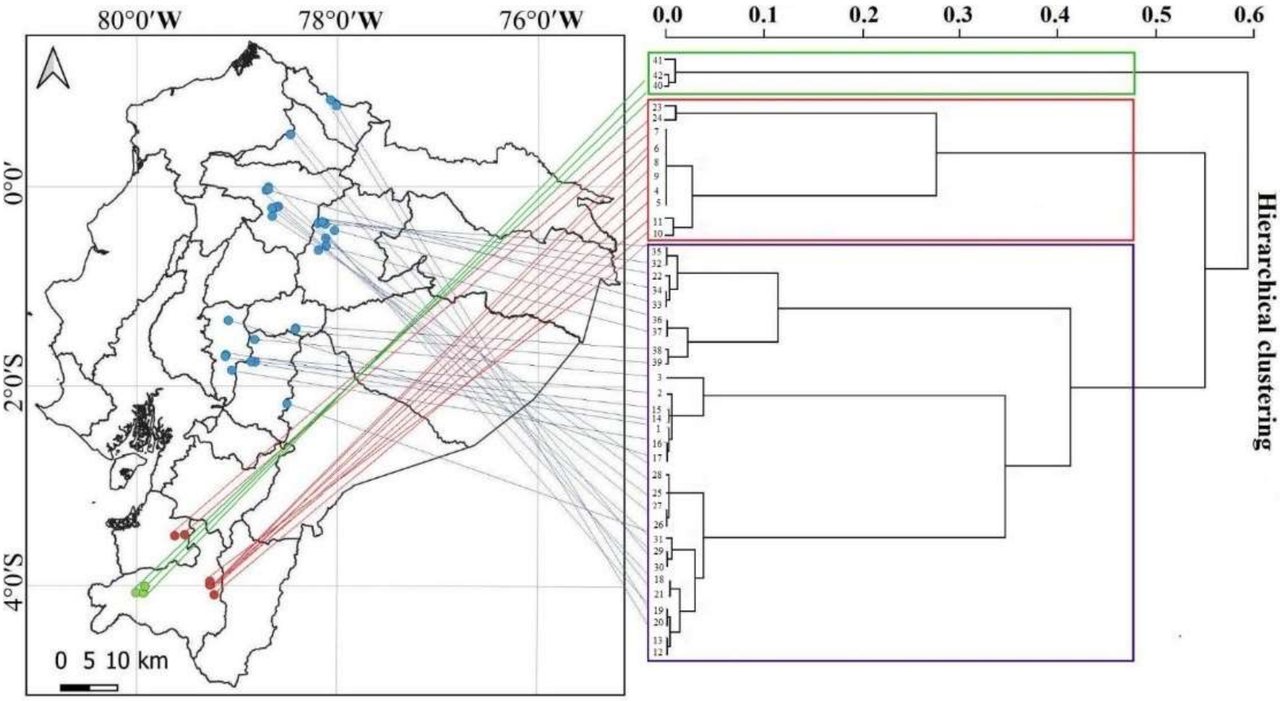

Figure 4. Distribution and classification of groups of wild species of *Solanaceae*.
Figura 4. Distribuição e classificação de grupos de espécies silvestres de *Solanaceae*.

Table 2. Abiotic factors for wild species of *Solanaceae* groups in the Ecuadorian Andes.
Tabela 2. Fatores abióticos para grupos de espécies silvestres de *Solanaceae* nos Andes equatorianos.

Grupo	Sp	Precipitation range (mm/ year)	Risk of frost	Drought risk	Temperature (°C)	Soil texture
G1	S. olmosense	850–1500	No Threat	Low–medium	16 –22	Clayey
G2	*S. chilliasense* *S. albornozii*	900–1300	High–very high	Very low-high	10 –16	Loam (sandy clay)
G3	*S. albicans,* *S. andreanum,* *S. chomatophilum,* *S. colombianum y* *S. minutifoliolum*	550-2000	Low-High	Very low-high	2–20	From sandy to loamy (sandy, clayey and silty)

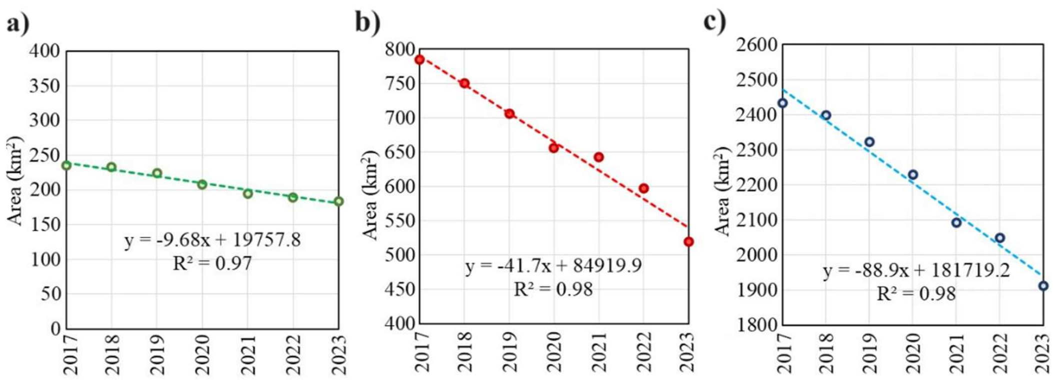

Figure 5. Trend analysis at a significance level of 99% for Group 1(a), Group 2(b) and Group 3(c) of wild species of *Solanaceae* species in the period 2017-2023.
Figura 5. Análise de tendência a um nível de significância de 99% para o Grupo 1(a), Grupo 2(b) e Grupo 3(c) de espécies silvestres de *Solanaceae* no período 2017-2023.

Table 3. LULC classes and transitions for wild species of Solanaceae between the period 2017 to 2023
Tabela 3. Classes de LULC e transições para espécies silvestres de Solanaceae entre o período de 2017 a 2023.

Group	LULC Class of 2017	Area (km²)	Conversion to:			
			Crop (%)	Pasture (%)	Artificial territories (%)	Bare ground (%)
G1	Forests and semi-natural	235.6	6.0		3.6	12.3
	Total change period	235.6	6.0		4.0	12.0
G2	Forests and semi-natural	314.2	10.4		3,0	5.0
	Grasslands	471.2	3.7		1.1	10.7
	Total change period	785.4	14.1		4.1	15.7
G3	Forests and semi-natural	1335.2		5.4	2.8	
	Grasslands	1099.6	5.0		8.2	
	Total change period	2434.7	5.0	5.4	11.0	

4. DISCUSSION

Conventional potato crops have less genetic variation than their wild relatives (Duan et al., 2019; Hardigan et al., 2015; Kolech et al., 2016); therefore, it is clarified that the wild species of *Solanaceae* analyzed constitute an important source of genes for genetic improvement (gonzález-orozco et al., 2024; Nagel et al., 2022); however, most species are at risk of extinction (Table 1). Ecuador is part of the center of origin of the potato (De Haan; Rodriguez, 2016), characterized by a complex climate system influenced by topography and air movement (Hastenrath; Lamb, 2004), as well as latitude, which favors the greater reception of solar radiation and anomalous temperatures under certain conditions of marine warming (El Niño phenomenon) (MORÁN-TEJEDA et al., 2016; VICENTE-SERRANO et al., 2017). These assertions confirm the intricate abiotic conditions that wild species of *Solanaceae* species circumvent; however, they are present in Ecuadorian territory.

The distribution of abiotic conditions in Ecuador is very variable. Its influence on wild species of *Solanaceae* is notorious, which was evidenced by distinguishing temperatures ranging from 2°C to 22°C and that, according to the climate change scenario projected for the end of the century, will rise by 1.2°C (Fernandez-Palomino et al., 2024), which could transgress the permanence of wild species of *Solanaceae*. They were also found in areas with slopes of more than 60%, where soil deterioration due to erosion is evident, as studies reveal that the decrease in soil quality due to inadequate agricultural practices in the high Andean region of Ecuador (Escudero et al., 2014; Monar et al., 2013; Mosquera et al., 2019), is a constant in production systems.

The exploratory study of the eight wild species of *Solanaceae* showed a distribution throughout the geographical area of the Ecuadorian Andes, framed only by certain abiotic factors, revealing the largest grouping with precipitation and its latitudinal location, which is explained by the climatic variation in the small territorial space that constitutes the country (MORA; WILLEMS, 2012; TOBAR; WYSEURE, 2018). *S. olmosense* showed a particular variation related to the rest of the species, forming a single group (G1), limited in the southern part of the country, with average rainfall but high temperatures, according to the information indicated by the catalog of wild species of Ecuador (LIMA et al., 2018). Therefore, its usefulness to adaptation to climate change is beneficial for genetic improvement (Fumia et al., 2022) and of high priority, as it is not found in international germplasm reserves (CASTAÑEDA-ÁLVAREZ et al., 2015; SOTOMAYOR et al., 2023). The species *S. albornozii and S. chilliasense* share similar latitudinal space, forming the same group (G2) towards the south of the country and with precipitation and average temperature, corroborating what has been described in previous studies (FUMIA et al., 2022; LIMA et al., 2018). The species *S. albornozi*i is resistant to late blight (Karki et al., 2021), to Bactericera cockerelli (Castillo C. et al., 2021) and with the capacity for use in genetic improvement, as well as *S. chilliasense*, as promising for the future scenario of climate change (Fumia et al., 2022) and resistance to pests and diseases (AMES; SPOONER, 2010). *S. albicans, S. andreanum, S. chomatophilum, S. Colombianum* and *S. minutifoliolum* formed a cluster (G3), with greater variability, located from the north to the center of the country, with higher rainfall and variable temperatures (2-20°C). *S. andreanum* is particularly commonly found in northern Ecuador, as far as Colombia (Ames; Spooner, 2010), documented as resistant to *Phytophthora infestans*, as well as *S. albicans* (Khiutti et al., 2015), on the other hand, *S. Colombianu*m scores well for climate change resistance (Fumia et al., 2022), while *S. chomatophilum* is resistant to aphids (POMPON et al., 2011).

The LULC analysis for all three groups shows that wild species of *Solanaceae* in 2017 are distributed in semi-natural areas: forests and grasslands; this distribution in only two classes of LULC is because wild species of *Solanaceae* have developed as weeds associated with grassland systems and semi-natural areas (DE HAAN; RODRIGUEZ, 2016). Over seven years, significant changes occurred in the LULC, in Group 1 and Group 2; the main change in LULC is the conversion of semi-natural forests and grasslands to bare soil; this may be due to mining developments in the tropical Andes of southern Ecuador, which has led to the development of bare soils at the expense of forest reduction, as has been observed in the Corazón de Oro Protective Forest (LÓPEZ et al., 2020). Mining activities have become a serious environmental problem, including removing vegetation cover and topsoil, permanent topographic changes, and dramatic changes in soil and structures (JING et al., 2018). For Group 3, the main transition is with the increase in artificialized territories caused by urbanization, which is developing rapidly in intensity and scope in developing countries (HARDIGAN et al., 2015). Also, in this group, there is a decrease in forests and semi-natural forests, especially in the Amazon, to make way for pastures for cattle ranching, concomitantly with the expansion of livestock production at the expense of the Amazon forests (FRANÇA et al., 2021). LULC changes contribute to the ecosystem's fragmentation, hosting native solanaceous species by reducing biological diversity, increasing soil erosion and altering other important ecosystem services (KINDU et al., 2013).

5. CONCLUSIONS

The abiotic variables were contrasting, which allowed us to define that the wild species of *Solanaceae* in this study have adapted to the divergent conditions of Ecuador. This fact recognizes the country as an important center of potato diversification. Analyses have shown the relevance of geographic latitude and rainfall on the abiotic variables, which were contrasting, which allowed us to define that the wild *solanaceous* species in this study have adapted to the divergent conditions of Ecuador. This fact recognizes the country as an important center of potato diversification. Analyses have shown that the relevance of geographic latitude and rainfall on wild species of *Solanaceae* has been observed through the MCA has been observed through the MCA; to a lesser extent, but just as important, so were frosts and droughts. In particular, *S. olmosense* showed a greater effect on variation, defining a specific group towards the southwest of the country, higher temperatures (16-22 °C), average rainfall of 1207 mm/year, without the influence of frost and average tolerance to droughts; a second group formed by *S. chilliasense and S. albornozii* also located to the south, but with lower temperatures (10 -14 °C) and precipitation (1115 mm/year), located in areas with high presence of frost and drought and loam soils; finally, the most abundant group (*S. albicans, S. andreanum, S. chomatophilum, S. colombianum and S. minutifoliolum*), whose distribution is more frequent in the center and north of the country, under a wide range of temperature (2-22 °C), precipitation (500-2000 mm/year) and tolerant to frost and drought.

In the wild species of *Solanaceae* analyzed in this study, the abiotic conditions that favor their presence in the Ecuadorian territory were relevant; however, its conservation requires consideration of anthropogenic impacts, such as the change in LULC that occurred between 2017 and 2023. In these seven years, a significant trend ($p<0.001$) of decrease of two classes of LULC (Grasslands and Forests and semi-natural) was observed for the three groups of species. This decrease of 5.1 km^2/year on average is reflected in the change of LULC; for Group 1 and Group 2, the main conversions are to cultivated areas, artificial territory and bare soils. For Group 3, the conversion is to artificial territory, pasture area and crops.

The genetic resource is essential to overcome the challenges inherent to the adaptation necessary to incorporate into the potato to favor its improvement. Although the outlook is not very encouraging about land change and use, measures are suggested to generate germplasm conservation programs and produce potatoes with characteristics of resistance to different abiotic conditions in the face of climate change worldwide.

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