Revista Iberoamericana de las Ciencias Biológicas y Agropecuarias

Ciba

ISSN: 2007 - 9990

https://doi.org/10.23913/ciba.v12i23.118

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Estudio de los suelos y de la erosión en la vertiente noreste del cerro el cuatro municipio de Tlaquepaque, Jalisco

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Resumen

Antecedentes: La investigación fue realizada debido a que forma parte del estudio del medio físico del Cerro del Cuatro, en el municipio de Tlaquepaque, Jalisco, lugar donde se construirá un Centro Universitario. Objetivos: Describir y analizar la textura, estructura, densidad aparente, profundidad, la infiltración y la materia orgánica del suelo; así como también caracterizar y analizar la erosión por observación en campo. Método: Para la realización de la presente investigación, y debido a la heterogeneidad del área de estudio, fue necesario dividirla en ladera alta, media y baja. Posteriormente, se recolectó una muestra del horizonte "A" de las tres secciones, una de la parte alta, dos de la media y una más de la parte baja. A cada muestra se le determinó: la textura, la densidad aparente, la materia orgánica, el color y el pH; por último, se hizo la descripción de la erosión en toda la vertiente por observación directa en campo. Resultados: Lo más relevante en este aspecto fue la presencia de dos suelos incipientes, uno en la parte con mayor pendiente y otro en la de menor pendiente, ambos con baja cobertura vegetal. Esto ayudó a explicar algunas de las causas de la fuerte erosión. Mientras tanto, en la parte media de la ladera, los suelos son moderadamente más desarrollados y menos erosionados. Conclusión: La degradación de la vertiente es consecuencia de la deforestación intensa, ya que se observa una importante pérdida de la cobertura vegetal. Sin embargo, la mayor afectación está más acentuada en la parte baja, en donde la vegetación se ha perdido por completo.

Palabras clave: erosión, infiltración, pendiente, vegetación,

Abstract

Background: The investigation was carried out because it was part of the study of the physical environment of Cerro del Cuatro in Tlaquepaque, Jal. Place where a University Center will be built. Objectives: Describe and analyze the texture, structure, apparent density, depth, infiltration and organic matter of the soil; as well as characterize and analyze erosion, and estimate soil loss by applying the Universal Equation of soil loss. Method: In order to carry out this investigation and due to the heterogeneity of the study area, it was necessary to divide it into high, medium and low slopes. Subsequently, a sample of the "A" horizon was collected from the three sections, one from the upper part, two from the middle and one more from the lower part. Each sample was determined: texture, apparent density, organic matter, color, pH; Finally, the description of the erosion in the entire slope was made by direct observation in the field. Results: The most relevant thing in this aspect was the presence of two incipient soils, one in the part with the steepest slope and the other in the part with the least slope, both with low vegetation cover, this helped to explain some of the causes of its strong erosion. Meanwhile, in the middle part of the slope, the soils are moderately more developed and less eroded. Conclusion: The degradation of the slope is a consequence of intense deforestation, since a strong loss of vegetation cover is observed, however the greatest affectation is more accentuated in the lower part where the vegetation has been completely lost.

Keywords: erosion, infiltration, slope, vegetation.

Resumo

Antecedentes: A pesquisa foi realizada porque faz parte do estudo do ambiente físico do Cerro del Cuatro, no municipio de Tlaquepaque, Jalisco, donde será construído un Centro Universitário. Objetivos: Descrever e analisar a textura, estrutura, densidade aparente, profundidade, infiltração e matéria orgânica do solo; bem como caracterizar e analisar a erosão por observação de campo. Método: Para a realização desta pesquisa, e devido à heterogeneidade da área de estudo, foi necessário dividi-la em altas, médias e baixas declividades. Posteriormente, foi coletada uma amostra do horizonte "A" das três seções, uma da parte superior, duas do meio e mais uma da parte inferior. Cada amostra foi determinada: textura, densidade aparente, matéria orgânica, cor e pH; Por fim, a descrição da erosão em todo o talude foi feita por observação direta em campo. Resultados: O mais relevante neste aspecto foi a presença de dois solos incipientes, um na parte de maior declividade e outro na de menor declividade, ambos com baixa cobertura vegetal. Isso ajudou a explicar algumas das causas da forte erosão. Enquanto isso, na parte intermediária da encosta, os solos são moderadamente mais desenvolvidos e menos erodidos. Conclusão: A degradação da encosta é consequência do intenso desmatamento, visto que se observa uma importante perda de cobertura vegetal. Porém, a maior afetação é mais acentuada na parte baixa, onde a vegetação foi totalmente perdida.

Palavras-chave: erosão, infiltração, talude, vegetação.

Fecha recepción: Julio 2022 **Fecha aceptación:** Enero 2023

Introduction

Soil is one of the essential natural resources of landscapes, but it is often not given the value it really has. Most people are not aware that soil is a living, breathing system that supports most of life on the planet and is vulnerable and difficult to recover (it takes hundreds to thousands of years to form), for what is considered a non-renewable resource. The functions it has in ecosystems vary considerably from one place to another due to climatic differences, the biodiversity that inhabits it, its evolution and its physical-chemical properties.

The physical properties of the soil are those that can be observed and/or measured without chemically altering the composition of the soil. They reflect the way in which the soil stores and provides water to plants and allows root development. Among them are properties such as: structure, bulk density, aggregate stability, infiltration, depth, hydraulic conductivity, and storage capacity. They are related to the movement of air, heat, water, roots and nutrients (López and Estrada, 2015). In this sense, the chemical properties are related to the quality and availability of water and nutrients for plants. Among them, it is worth highlighting: pH and organic matter. These properties are determinant to understand the infiltration capacity of the soil and the processes that cause its erosion.

For this reason, the Food and Agriculture Organization of the United Nations (FAO, 2023) ensures that soil erosion is one of its ten main threats, identified in the 2015 report on the State of soil resources in the world. It defines it as the accelerated removal of the upper layer of soil from the earth's surface through water, wind and tillage.

In a 2021 study, the FAO points out that between 20,000 and 30,000 million tons of soil due to the effect of water are being lost each year due to erosion on arable land, 5,000 million because of tillage and 2,000 million because of the wind action on arable land. According to the latest data for 2017 from the Ministry for the Ecological Transition and the Demographic Challenge, the loss of soil in Spain due to erosion is, on average, 14.2 tons per hectare per year. The erosion process occurs mainly on agricultural land, in which more than 50% of the land is classified as having a medium-high risk of erosion.

Based on the above, the objective of this work was to study and analyze the physical, chemical and biological properties of the soil on the northeast slope of Cerro del Cuatro. However, it is important to point out that a quantitative analysis of soil loss in the study area is still pending by applying the universal equation of soil loss, since this data would significantly contribute to revealing the true magnitude of the problem. in the study area.

Materials and methods

To carry out the present investigation, samples were collected from four specific points. Through a tour of the study area, it was divided into three zones, taking into account the different values of the slope: high, medium and low slope. Once the area was divided, the four representative points of each zone were located and an excavation was made in each one to observe the profile. Next, the general characterization of each well was carried out; Subsequently, a sample of the "A" horizon was taken from the three sections of the slope: one from the upper part, two from the middle and one more from the lower part. They were dried in the laboratory at room temperature. After drying, the following determinations were made: the texture with the Bouyoucos hydrometer method, with this method the percentages of the three particles (sand, silt and clay) that make up the soil were obtained; the structure was determined by observing the aggregates, this characteristic is very useful, together with the texture, to know the hydraulic conductivity; the bulk density was obtained with the cylinder method, which is easy to perform, especially on non-stony surfaces. The value of this property is useful for estimating soil degradation. Regarding the organic matter content, it was determined with the Walkley and Black procedure, the color with the Munsell tables and the pH with the Conductronic PH120 potentiometer. Finally, the description of the erosion in the entire slope was made by direct observation in the field. The estimate of soil loss is pending due to lack of climatological information.

Characterization of the study area

The study area is the northeast slope of Cerro del Cuatro. This relief geoform has a height of 1830 meters above sea level and is part of the volcanic axis to which the Tequila volcano, the volcanoes of the Bosque de la Primavera (Planillas and San Miguel), its neighbor Cerro del Tesoro and, in Tonalá, are added. Queen's Hill. This elevation is the most important of the three that make up the orography of the south of the city. Cerro El Cuatro is famous for being, in practice, the place where the city's telecommunications antennas are located. At the top are those of radio and television, but it is also due to the invasions of the 1970s and 1980s, which practically covered the western slope up to a few meters below the place where these antennas are located (Petersen, 2019).

The geology of the volcano is characterized by being mainly adensitic basaltic rock, with the presence of pumiceous volcanic ash. According to the slope map in the study area, these oscillate in a range of 0 to 35°; in the immediate vicinity of the top or high slope, the value of the slope is from 18 to 35°, while in the middle part it is from 12 to 18°. For its part, the lower slope, where the terrain has been most modified, presents slopes of 0 to 12°.

Regarding the vegetation, Quercus sp or oak predominates on the upper slope, which is a natural or native species of the place, approximately 5 to 10 m high. Under this relict of forest, there is a cover of short vegetation, mainly grassland, and a sparse population of shrubs.

On the other hand, on the middle slope, the dominant vegetation is scrub, which almost completely covers the entire study area, except in some places where, due to deforestation, the surface is completely bare. The anthropization is evident, since there is a paved gap that was built recently to have access to the top of the hill with less difficulty. Added to these alterations is a network of paths traced by the traffic of people on foot.

These drawbacks have made some natural processes more accentuated in places where the vegetation cover has been completely lost and the slope is steeper. For example, on roads, the runoff process is superior to infiltration and, therefore, a high level of degradation is observed. In other words, strong erosion is evident, which has caused the total loss of soil.

For its part, the lower slope presents more drastic changes from the environmental point of view, mainly due to human influence. In this zone, the arboreal vegetation is almost non-existent; The presence of the scrub is sectorized and is located more densely towards the slope of the main channel of the micro-watershed. In the rest of the area, grass 3-5 cm tall is only sparsely observed on the gentle slopes and on a few structural terraces.

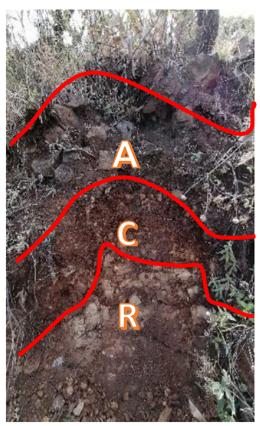
However, the soils that have formed have different nuances: from light and undeveloped on the lower slope, through reddish-brown and more developed on the middle slope, to darker and less developed near the top. where steep slopes dominate with little tree and grassland vegetation.

Soil profile on the high slope

On the high slope, the slopes vary from strong (18°) to very strong (35°). In this area, erosion processes are more evident, especially in those places where vegetation is scarce or has completely disappeared. It is also important to specify that, due to the great inclination of the terrain, the slope is more dynamic and the edaphogenetic processes are conditioned by altitude and slope. A clear domain of erosive processes is observed, which have markedly impeded the evolution of the horizons, giving rise to the formation of an incipient or young soil, that is, with little depth. In such a way, the profile that is observed in this place, and more precisely in the sampling point, is O, A, C, R (Figure 1). The "O" is a layer of litter and humus 2 cm thick, the "A" is the superficial horizon made up of edaphic organic-mineral material, while the "C" are fragments of 0.5 to 1 cm in diameter that come from of the rock that has suffered a strong weathering, from which the formation of the A horizon began. Finally, the "R" is the rock or parent material with moderate alteration.

The environmental conditions that prevail at this point are particularly contrasting with the rest of the slope. The slopes are steep and the fluvial dynamics, conditioned by the geological and geomorphological complexity and the high rainfall, impede the evolution of the soil.

Figure 1. Soil profile on the high slope, at the hill the four sampling point.



Source: self made

Physical and chemical properties of horizons

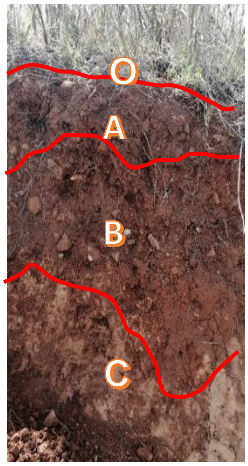
The "O" horizon is a thin layer approximately 10 cm thick, composed mainly of organic residues that come from vegetation, shrubs and grass with different stages of decomposition. The "A" horizon is 55 cm thick and has a loamy texture class. It is characterized by presenting a percentage of 27% sand particles, 38% silt and 45% clay. Also, the organic matter content is 6.5%. The structure is granular, the dry color is 7.5 YR 4/4 (dark brown), and the density of the particles is 1.2 g/cm3. The roots are not abundant. With these physical properties, it would be expected that, together with the vegetal cover that is not very dense, the rate of water infiltration into the soil would be significantly high. However, the slope also plays a very important role in this process, since being too strong, the runoff can be greater than the entry of water into the soil. In this sense, it can be estimated that the infiltration-runoff ratio is 1:3, that is, expressed in percentage units, 25% of the water that precipitates infiltrates and 75% moves superficially. This is due to the fact that runoff, which is greater in the upper parts than in the lower parts of the slopes, occurs when the rainfall intensity exceeds the retention capacity of the surface, depending on the soil conditions: slope and structure (Sampat, 2015).

The "C" horizon is a 40 cm thick layer of regolith, with fragments 0.5 to 1 cm in diameter. The underlying rock is highly weathered at this depth and, as it is a permeable layer, water infiltrating through the "A" horizon will have little or no percolation limitation upon reaching this horizon. However, the precipitation water that reaches the ground is distributed through runoff, which modifies the effective amount that reaches the ground, which also depends on drainage or percolation that feeds the groundwater table.

Soil profile on the middle slope

On the middle slope, the slopes are in the range of 12–18°, but in general terms, the slope is complex, which has contributed to the formation of structural terraces and, with it, less erosion. It is also true that in some places the vegetation is scarce due to deforestation, which directly influences more substantial erosion. However, it should be noted that most of this area maintains a good vegetation cover, sufficient for the edaphogenetic processes to have given rise to a more evolved soil, with an O, A, B, C profile (Figure 2). A cross section through the different levels of the surface until reaching the least weathered material constitutes the profile. (Brady y Weil, 2002).

Figure 2. Profile of the middle slope, hill the four



Source: self made

Physical and chemical properties

The "O" horizon is a very thin organic layer 1.5 cm thick. This is because the organic residues are constantly removed by surface runoff, which is favored by the steep slope, which prevents the residues from entering a state of rest, thus limiting an increase in the thickness of the litter sheet.

The "A" horizon has an average thickness of 30 cm. Its texture is clayey, with 48% clay, 32% silt and 20% sand. "The different types of soil texture are based on the variation in the proportion of sand, silt and clay, expressed as a percentage of each element" (Strahler, 1989). The organic matter content is 2.6%, with an angular block structure. The color is 7.5 YR 2/3 dark brown. The density of the particles is 1.4 gr/cm3, and the roots of 0.2 to 0.5 mm in diameter are scarce.

The "B" horizon has an average thickness of 50 cm, a clayey textural class, with 51% clay, 27% silt and 22% sand. Its structure is made of angular blocks. The organic matter content is 1.9%. Its color is 7.5 YR 4/6 strong brown. The content of roots greater than 0.5 mm in diameter is very scarce, and few are the roots of 0.2 to 0.5 mm in diameter.

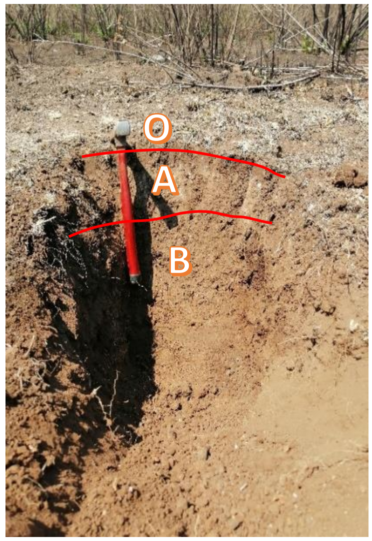
Since the clay content is high and the organic matter content is low in the "A" horizon, the infiltration rate is very slow. This is mainly because the spaces between the particles are microscopic, which together form a semi-permeable layer that prevents the rapid movement of water. When all the pores are saturated, the air stops circulating. If you add to this the low amount of organic matter, the situation becomes even more chaotic, since it does not significantly contribute to an increase in the volume of interparticle spaces, which further retards the movement of water at greater depths.

Soil profile on the lower slope

For its part, the lower slope is the most anthropized area of the entire slope and the slope is not homogeneous, ranging between 2 and 12°. The impact of human activity is evident, to such an extent that there is an important loss of natural vegetation and, with it, the appearance of scarce secondary vegetation. With the disappearance of the vegetation cover and the alteration of the original soil material, infiltration is affected, since it is directly subject to the type of texture of the upper soil horizon, to an extensive superficial vegetation cover, to the type of rock and to the relief shape.

Likewise, what is most notable in this part of the slope is the lack of adequate management of both the vegetation and the soil, since both present strong anthropization in 90% of the surface, presumably caused by the conditioning work for the formation of terraces on which sports fields have been built. This is how the soil has been completely removed in three quarters of the lower slope. While in the ecologically best preserved part, and despite the fact that the slopes are between 2 and 12° and that the dynamics of the edaphic materials is quite significant, physical, chemical and biological processes have given rise to the formation of a soil thicker at the sampling point. This soil presents a profile O, A, B (Figures 3), it is a more developed soil, with characteristics that are described below. Soil mineral horizons are designated by a group of capital letters, beginning with the letter A at the top, followed by the letter B. These are the most characteristic and dynamic layers. Finally, the letter C, which by contrast represents the mother material or substrate, occupies a place below the level of activity of the roots. (Strahler, 1989).

Figure 3. Soil profile in the northeast part on the lower slope



Source: self made

Physical and chemical properties

In this profile, the "O" horizon is 0.5 mm thick and barely visible, incipient. Apparently, due to the intense human activity and the low contribution of organic residues to the soil surface, there is the possibility that the slope has a decisive influence on the dynamics of the site and prevents the accumulation of edaphic materials in significant quantities that increase the thickness of this horizon. The only source of contribution of organic material in minimal quantities is the grass, which serves as a protective cover against erosion, since there is no evidence in this part of an important loss of soil due to runoff.

However, what is certain is that the grass develops a very dense root system, holding the soil with great force, thus preventing its movement down the slope. In addition, it acts as a buffer against raindrops, slows runoff and considerably increases infiltration, at least up to 20 cm deep, due to the abundant quantity of small roots.

The “A” horizon has a thickness of 0.5 to 30 cm. Its texture is clay loam, with 38% clay, 32% silt and 30% sand. "Soil texture is a fact inherent to the soil itself and depends largely on the composition of its substrate" (Strahler, 1989). The organic matter content is 2.6%, the structure is granular and the density is 1.1 gr/cm3. Up to 20 cm deep there are abundant roots with diameters ranging from 0.2 to 0.3 mm.

For the "B" horizon, the characterization in the field and the laboratory analyzes yielded the following results: it is observed from 30 to 90 cm deep, it has a clayey texture with 46% clay, 35% silt and 19 % of sand. The structure is made of subangular blocks, the organic matter content is 1.7%, and the apparent density is 1.4 gr/cm3. In this horizon, the roots are very scarce and, due to this simple fact, what is most remarkable is the increase in bulk density as organic matter decreases with depth. Inside the soil, the texture-organic matter-apparent density relationship has a direct influence on the speed of water infiltration. In soils with a clayey texture and low organic matter content, the pore space is significantly reduced and, consequently, the bulk density rises, as occurs in this analyzed soil.

Qualitative characterization of erosion

Water erosion is a natural or induced phenomenon, and is the main cause of soil loss worldwide, a resource on which vegetation is sustained and, at the same time, serves as protection. Consequently, different forms (classes) of erosion can occur: laminar, rills, gullies, furrows and pinnacles. In this sense, soil erosion consists of the removal, uprooting and transport of the materials that constitute the most superficial layer of the soil, whatever the responsible agent: water, wind, ice, human actions (De Alba, et al. , 2011).

In the Cerro del Cuatro three forms of erosion can be seen: laminar, rills and gullies, with surface runoff being the main agent of erosion. Each one of them is observed in the whole slope, but its magnitude and dominance varies according to the zone and the environmental conditions. In accordance with the above, Ramos et al. (2020) express that there are several works that try to determine those factors that influence soil erosion. From these, a wide list of important variables is derived, among which stand out: the intensity, duration and frequency of rain, the types of rocks, the relief, the vegetation cover and some physical properties of the soil (texture, structure and organic matter content). For their part, Gaitán et al. (2017) affirm that soils with intermediate textures are more erodible than soils with coarse textures and those with fine textures, given the role of the clay fraction as a stabilizer of the soil structure. In addition, the organic matter content also contributes to providing greater stability to the soil structure, and therefore, with a higher organic matter content, the soil is more resistant to the impact of raindrops.

On the high slope, the vegetation cover is low density; the dominant tree species is Querqus. These trees are separated with wide spaces covered sparsely by shrubs and grass (Figure 4). The slopes are from 18 to 35%; the soil texture is loam and the structure granular. However, although the physical properties of the soil are optimal to cushion raindrops and allow greater infiltration, these are overcome by runoff, which overcomes the cohesion of the particles of the soil mass and causes their transport. This is mainly due to the fact that the slopes are greater than 20%, but also to the scarce vegetation due to natural loss and deforestation, which has left open spaces where erosion is severe. The dominant form of erosion is gullies, which can be seen with the naked eye (Figure 5). Camargo et al. (2017) point out that: In accordance with the above, Ramos et al. (2020) express that there are several works that try to determine those factors that influence soil erosion. From these, a wide list of important variables is derived, among which stand out: the intensity, duration and frequency of rain, the types of rocks, the relief, the vegetation cover and some physical properties of the soil (texture, structure and organic matter content). For their part, Gaitán et al. (2017) affirm that soils with intermediate textures are more erodible than soils with coarse textures and those with fine textures, given the role of the clay fraction as a stabilizer of the soil structure. In addition, the organic matter content also contributes to providing greater stability to the soil structure, and therefore, with a higher organic matter content, the soil is more resistant to the impact of raindrops.

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> The main factors that control water erosion are precipitation, vegetation cover, length and inclination of the slope, and soil properties. The interactive effects of these factors determine the magnitude and rate of soil erosion. Thus, the longer and steeper the slope, the more soil will be affected by erosion and, on the other hand, the greater the runoff transport capacity under intense rain, the higher the rate of soil loss due to soil loss. erosion. The role of vegetation in preventing soil erosion is widely recognized: vegetation cover improves its resistance by increasing its organic matter content, stabilizing its structure, and promoting the activity of macro and microorganisms.

Figure 4. Dominant vegetation on the top

Source: self made

Figure 5. Gully erosion

Source: self made

On the intermediate slope, the slopes are less than 20% and the vegetation cover is predominantly scrub, covering 90% of the ground. Two soil profiles that present contrasting properties were analyzed. In the first profile, the texture is clayey, the organic matter is 2.8% and the structure in the A horizon is subangular blocks. In the second profile, the texture is clay-sandy loam, organic matter is 3.6% and the structure is angular blocks. These environmental characteristics favor infiltration, while runoff increases in places where vegetation has disappeared due to anthropization, contributing decisively to the removal of soil particles and generating sheet-type erosion (Figure 6). However, the most evident erosion is rill erosion, which affects 5% of the surface (Figure 7).

Figure 6. Sheet erosion

Source: self made

Figure 7. Erosion in furrows

Source: self made

Finally, the lower part of the slope, although it presents slopes with less angle (12%), is the one that shows the greatest degradation in this entire area, caused mainly by anthropization. The soil has a clay loam texture, an organic matter content of 2.6% and a granular structure in the superficial horizon. Even with these properties that would allow greater infiltration, a clear trace of anthropic activity is observed, revealing opposite effects: greater runoff, but without generating significant removal, only causing laminar-type erosion (Figures 8) or in a trickle (Figure 9). Erosion causes soils to compact, lose organic matter, nutrients and the ability to retain water. In summary, eroded soils have lower quality and do not have the capacity to maintain all their functions, such as moisture and nutrient retention, as well as an acceptable rooting depth. (Cottler, 2020).

Figure 8. Sheet erosion.

Source: self made

Figure 9. Stream erosion

Source: self made

Results

The characterization of the soil profiles was essential to determine the degree of development of each one of them. In this way, it was observed that on the upper slope the soil is incipient, with a thin A horizon, loamy texture and a moderately high percentage of organic matter. In the middle part, the soil presents greater development, with an incipient O horizon, an A with a moderately deep thickness and a clayey texture. Meanwhile, the B horizon presents a thickness of 50 cm and a clayey texture. In the lower part, the soil profile is, like the profile of the middle slope, moderately developed, with an approximate depth of 90 cm. This is the result of the strong erosion to which it has been subjected for a long time, especially by human activity.

Regarding the permeability in the three areas of the slope, it is considered slow to moderately fast, taking the textures in each of the profiles as a reference point. This indicates that the estimated infiltration rate is also considered to be in the slow to moderately fast range. However, for this parameter, it is important to note that it was not only the texture that was taken into consideration; The value of the slope, the vegetation cover and the organic matter content also play an important role.

Likewise, the determination of the physical-chemical and biological properties, such as organic matter, texture and apparent density, revealed the level of degradation that the slope has experienced for a long time due to intense human deforestation.

On the other hand, erosion, the result of the gradual loss of vegetation, is caused by water runoff that occurs on the earth's surface throughout the slope. This manifests itself as laminar and gully water erosion. These types of erosion are produced by the impact of water droplets on the ground and by the consequent dragging of the same in concentrated runoff, with the inclination of the terrain and the vegetation playing a very important role. These factors can in turn slow down or increase the process. Water is the causal agent of this type of erosion, through the breaking and dragging of the aggregates and particles that make up the soil or larger fragments, such as rocks or large masses of soil, either by the direct hitting of raindrops rain or surface runoff.

The degradation of the slope is a consequence of human activity that has intensely modified the soil. A strong loss of vegetation cover is observed; however, the greatest affectation is more accentuated in the lower part, where the vegetation has been completely and definitively lost due to the construction of infrastructure works in that area.

Discussion

In the results of the work it can be seen that the soils present a strong contrast in the degree of development, mainly due to their position (they are located at different heights) in the relief. For this reason, their morphological properties differ in each of them. This difference contributes to their being more exposed to erosion, which is the cause of the loss of fertility and their low capacity to capture water. On the other hand, the soils have lost a large part of the "A" horizon in the areas with the steepest slope and substantial loss of vegetation. In an extremely high area, Pimentel et al. (Science magazine, 1995) stated that the total costs of in-situ and ex-situ effects caused by wind and water erosion damage, along with prevention costs, each year amount to US$44,399,000,000 in the US alone. At the other extreme, Crosson (Journal of Environmental Economics, 2007) estimates that the loss of farm income is only $100 million per year in the US (FAO, 2023). However, although the loss of soil is not recoverable, it is possible to minimize it by implementing a reforestation program in the areas with the greatest environmental damage. Previously, an evaluation, both qualitative and quantitative, of the physical conditions of the soil must be made to help establish indicators with a more rigorous and rapid low-cost approach for the evaluation and qualification of soil characteristics with an established scoring system. for general assessment of soil erosion. For their part, Hudson, N. and Bedford, A. (1997), point out that few attempts have been made to systematically observe and measure soil erosion as part of the evaluation and integrated management (soil, vegetation , water and ecosystems), except for the LADA manual at the local level. Unfortunately, the FAO (2023) points out that soil erosion in arable, forest and pastoral lands is a main indicator of soil water or wind degradation, and is often caused by the decrease in vegetation cover. Finally, soil erosion through loss of topsoil indicates a reduction in the fertility of the land and its productivity potential.

Conclusion

On the high slope, the vegetation is sparse. Because the slope is very steep, the soil is incipient and its texture is loamy. Likewise, although it is estimated that infiltration is moderately fast, it is exceeded by runoff. For its part, the middle slope has a dense vegetation cover, the slope is moderate, the soil has a clayey texture and its thickness is greater than one meter (it is a developed soil); however, the infiltration is slow to moderately fast and the erosion process is not intense. On the other hand, in almost three quarters of the lower slope, the vegetation is sparse and the natural soil has been almost completely removed by human activity, while at the sampling point it is more than one meter deep and has a texture clay loam. The slopes are flat to gentle and the infiltration is slow to moderately fast. With respect to erosion, it is moderate to very strong, and the loss of soil is conditioned by the slope and the vegetation cover.

Regarding surface runoff, the result of the steep slopes in most of the slope and the low infiltration through the superficial layer, the water moves vertiginously giving rise to the erosive processes that are observed throughout the study area. from the top to the bottom. Likewise, the rainwater that manages to enter the subsoil does so at a low speed in sites with a clayey texture and quickly in those with a clay-sandy loam texture. However, there are other factors that also influence infiltration, one of them is the vegetation cover of the soil, as well as the shape of the relief and the geology, which, unfortunately, do not significantly favor the flow towards deeper layers, but they have caused significant soil removal.

It is estimated that 35% of the surface under study presents a risk of erosion above 20 t/ha/year (potential erosion considered high and very high). The geomorphological zones that present this condition are the high slope and the low slope. 65% of the remaining area presents soil loss above 5 t/ha/year, with levels ranging from very high to moderate. The middle slope is in this situation, which presents a better state of conservation, in terms of plant cover and, consequently, of the soil. The role of the natural cover (forest and grasslands) of the land and that induced by man (crops) in this case, is decisive for the control of water erosion. This makes it necessary, on the one hand, to reduce deforestation and forest degradation (change of land use) and promote the conservation and increase of forest reserves, by maintaining the entire slope as a protected natural area and reforestation programs. On the other hand, it is important to promote, maintain and improve good agricultural practices and avoid those that favor soil degradation, especially urbanization on all high slopes due to steep slopes.

Finally, due to the lack of meteorological stations in the vicinity of the study area, it was not possible to obtain the necessary information required for the method that had been proposed in this investigation to estimate soil loss. The method referred to is the Universal Soil Loss Equation (USLE). For this reason, this task is still pending and could be considered as a new and first line of research in future work. The loss of soil due to water erosion continues to be one of the problems that decrease soil fertility and is one of the great challenges that soil science has on its agenda, and one that continues to be one of the most difficult to eradicate.

A second line of research that is intended to be addressed in the future is the loss of organic matter. Because it is one of the most dynamic properties of soils, it is necessary to always be aware of it. Organic matter is one of the reserves and main sources of nutrients for plants, and although its decrease does not always have an impact on plant nutrition, it does have an impact on the development of a good structure that improves the infiltration capacity of water in soils and considerably reduces its loss (erosion).

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Conceptualización	Martín Vargas Inclán 75% Guadalupe Quezada Chico 25%
Metodología	Martín Vargas Inclán 100%
Investigación	Martín Vargas Inclán 50% Guadalupe Quezada Chico 30% Antonio González Salazar 20%
Escritura - Preparación del borrador original	Martín Vargas Inclán 100%
Escritura - Revisión y edición	Martín Vargas Inclán 50% Antonio González Salazar 50%
Visualización	Antonio González Salazar 100%
Administración de Proyectos	Martín Vargas Inclán 60% Guadalupe Quezada chico 40%