Original Paper

Topographic humidity index and vegetation as management tool for policies decision

Fabricio Enrique Alcívar Intriago, Marcos Javier Vera Vera, Luis Damián Muñoz Anchundia, Diocle Antonio Vera Salavarría

Received: 19 August 2023 | **Accepted:** 30 October 2023 | **Published:** 12 November 2023

Keywords: hydrological protection; microbasin; topographic humidity.

Abstract. *Sustainable management of resources increases the resilience of the systems in which they are implemented. Thus, this study aims to assess the vegetation cover and topographic humidity index of the Trueno microbasin and the Brisas site of the Bolivar canton (Manabi, Ecuador) so it can be used as a tool for policies decision. Starting from a quantitative approach and* *applying the hypothetical-deductive method; the following phases were established: i) determination of the Hydrological Protection Index (HPI), in this case plots made up of "three radiated transects 50 m long, located at 120° from each other; ii) establishment of the topographic humidity index, as a result of the treatment of the information in QGIS 3.30.1 through a Digital Elevation Model (DEM). The primary findings demonstrate that the light forests achieved an HPI per unit of vegetation (HPI-UV) of 0.95, while the dense forests attained a maximum of 1. On the other hand, the whole annual grasslands scored 0.64, while the degraded annual grasslands scored 0.32, the lowest possible score. When paired with other criteria, the ITH's values, which carry out a classification of the soil into five categories, range from 0 to 19, indicating a close association with the microbasin's water network. These assessments serve as a management tool for the creation and implementation of successful policies that ensure the stability of these ecosystems.*

1. Introduction

Water and rich soils are necessary for the development of agriculture and how well they are managed will determine its sustainability. The processes of erosion, floods, and droughts, as well as anthropogenic effects such deforestation and other changes in land use, cause natural deterioration of these resources. Additionally, there are significant and negative effects of population growth and observed climatic changes on water supply (Fries et al., 2020). The quality and quantity of water will change around the world, according to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, especially in semi-arid regions where water supplies are particularly sensitive to precipitation amounts and rates. evaporation, which limit local water availability.

However, in semi-arid areas, the local population's economic growth primarily depends on agriculture and, as a result, on the local availability of water. For this reason, altered climatic conditions, population growth, and unsustainable water management practices are observed, endangering the resource's availability. One of the main implications of land use changes is the recharging of aquifers, which also results in an imbalance in surface runoff and nutrient loss (Valarezo et al., 2021). Despite the abundance of water resources in Ecuador, freshwater ecosystems have reportedly received little research and are under increasing pressure because of rising demand for socioeconomic services (Krasovskaya, 2022).

The increase of economic activity and the development of infrastructure, combined with human interests, have historically been the primary drivers of land use changes in Latin America (Kleemann et al., 2022). The Amazon, coastal, and Andean forests of Ecuador are impacted by changes in land use (Rivas et al., 2021). The conversion of these woods into pasture for animals as well as the expansion and intensification of conventional and/or organic agriculture constitute a threat to them. Additionally, conventional agriculture decreases the ability of soils to store carbon and depletes them of essential nutrients (N, P, and K), which over time results in a decline in floristic diversity (Reyna et al., 2018). Due to the high levels of connectivity that freshwater ecosystems exhibit throughout their extension, that is, from the headwaters to the mouth, as well as the transformation of the landscape that takes place around them, managing water resources is difficult (De Vries et al., 2019).

Given that sustainable management of resources increases the resilience of the systems in which they are implemented (Kucher et al., 2023) and that there are numerous ways to manage hydrographic basins, the Hydrological Protection Index (HPI) stands out because it enables us to understand the influence of vegetation on soil and water resources (Arellano & Ruiz, 2018). The Topographic Humidity Index (THI), on the other hand, is a quantitative tool to consider the spatial variability of soil moisture influenced by topography. It is based on the idea of a steady-state distribution of surface moisture along a variable topography and is more pertinent when infiltration rate conditions exceed storage capacity (Winzeler et al., 2022).

Since more than 500 years ago, there has been an unsustainable use of natural resources in the province of Manabi, which is in Ecuador's coastal region. This is mostly because to the change in land use brought on by the extension of the agricultural frontier (Quimis et al., 2023). The Trueno river microbasin, which includes the Brisas-Quiroga site (Bolivar canton), has experienced increased forest cover exploitation, putting the area's ability to maintain its water supply in jeopardy. Considering such antecedents, this research aims to ascertain the topographic index of humidity and vegetation cover of this region, which can be used as basis for policies decisions.

2. Methodology

2.1. Study area

The Brisas location and the Trueno river microbasin are both in the Bolivar canton of the Manabi province of Ecuador, where this research was conducted. The Brisas site served as the location for the HPI calculation, whereas the Ro Trueno microbasin's extension served as the location for the IHT calculation. The bioclimatic map of Ecuador indicates that this area has tropical climate characteristics and is a part of an ecological region with tropical dry forests. In addition, the Holdrigde classification states that the movement of the intertropical convergence zone and changes in the Pacific Ocean have a significant impact in this region (Aveiga et al., 2023).

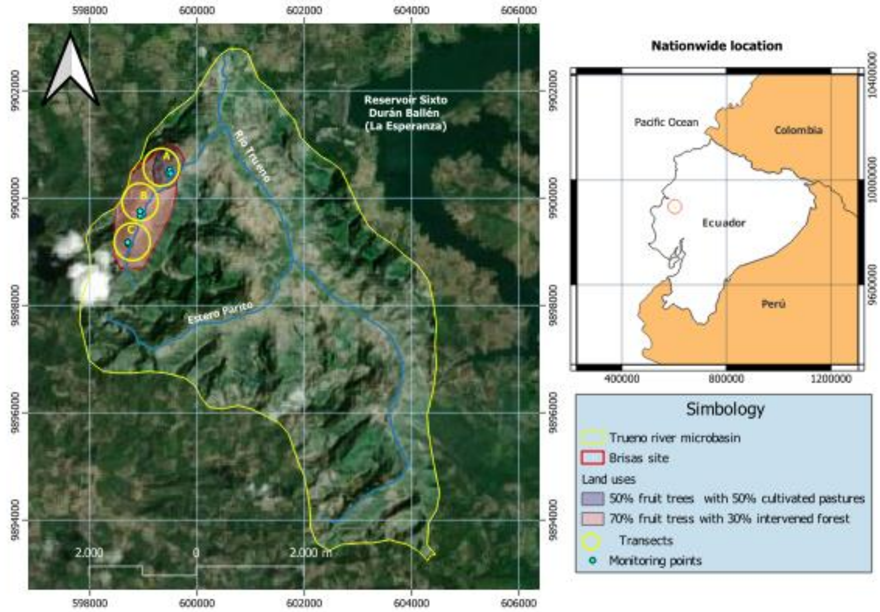

Figure 1. Location of the study area.

2.2. Selection of indexes

The HPI is one of the tools used to manage the basins because it enables us to comprehend how vegetation influences the soil and water resources (Arellano & Ruiz, 2018). It also serves to identify the water potential, which aids in future decisions within the study area where anthropogenic activities have changed and deteriorated the natural areas. Romero & Ferreira (2010) highlight that this is a factor that defines the level of the soil's resilience to the effects of rain and enables an in-depth review of the vegetation. This index will make it feasible to assess the research area's water retention as well as the percentage of runoff and soil erosion. Results from scientific manuscripts have not been included because, at least in Ecuador, publications of this kind are more common in degree works. This illustrates how underdeveloped this area of study is in the nation.

The decision of the IHT is also a result of the compact and understandable way it summarizes the surface water conditions through a sophisticated mathematical process. The IHT's main draws are its elegant simplicity, which captures dynamic and dominant hydrological spatial controls in a semi-distributed form; ease of initial capture application; calculation speed; ease of modification (it is more of a set of concepts than a fixed model structure); and direct relationship to topography as a control of the hydrological response of a catchment, so that predicted storage deficits and saturated conditions can be avoided (Beven et al., 2020).

Additionally, specific index values or thresholds can be linked to management actions by relating them to available surface water levels. To put it another way, this index relates to a theoretical model of semi-distributed rainfall runoff that makes use of topographic data related to runoff generation and aids in predicting the hydrological behavior of basins while considering the topography of the basin and the transmissivity of the soil (Devia et al., 2015).

The IHT was developed within the TOP MODEL runoff model (Beven & Kirkby, 1979), which has produced 565 publications, 31,999 citations, and an h-index of 89, making it one of the most cited articles in hydrology. It has also found widespread application in engineering and ecological studies with the development of digital elevation models. The contribution of this work, under this broad range of applicability, is the application of this index to a particular research area where no studies of this sort have been conducted, and it is anticipated that it would be used as a management tool for policy decisions.

The conclusions are based on the quantification of the results as well as their processing, using the hypothetical-deductive method to respond to the specified purpose. This research is quantitative in nature (Sánchez, 2019). Additionally, the following phases were established:

2.3. Calculation of the Hydrological Protection Index

The information in figure 1 was utilized as a starting point to determine the locations with the most vegetation cover and their land uses. To do this, satellite pictures from ESRI Stellite were used and processed in QGIS 3.30.1. floor. Plots consisting of "three radiated transects of 50 m long, located at 120° from each other" were developed for the sample sites (Romero & Ferreira, 2010). The Food and Agriculture Organization of the United Nations' observation sheet was used to record the data that had been gathered (FAO, 2009).

1. Structure: A pattern of vegetation distribution was used to determine the chest height circumference (CAP) of the adult individuals in the tree layer at a height of 1.30 meters away from them. Using this information as input, the diameter at breast height (DBH) of each individual was calculated using:

$$DBH = \frac{\mathrm{CCH}}{\pi}$$

Where:

DBH: Diameter at Breast Height

CCH: Circumference at Chest Height

In the case of shrubs, herbaceous species and other strata, a visual inspection was carried out considering the following criteria:

a. Shrub stratum: height less than 2 meters, without main trunk.

b. Herbaceous stratum: plants less than 10 cm tall (herbs for grazing).

c. Muscinal layer: formations that lie on the limestone rock (lichen appearance).

d. Scandent stratum: guiding or climbing plants, unable to support themselves (lianas).

e. EpHPIytic stratum: lichens, promoss and ferns.

2. Density: It was obtained considering the type of stratum, for the tree stratum the absolute and relative density was calculated:

$$\text{Absolute density (D)} = \frac{total\ number\ of\ individuals\ per\ species}{total\ area\ sampled}$$

$$\text{Relative density (RD)\%} = \frac{individuals\ per\ species}{total\ number\ of\ individuals} * 100$$

For the other strata (x) intercept points (touches) were applied, above a line (drawn with a tape) a series of points was created with a rod that has been previously divided into 5 cm portions and is calculated by source of:

$$Cob(x) = \frac{\text{Touches in x}}{Total\ touches} * 100$$

3. Interception of precipitation by vegetation (Is): it was calculated applying the Horton method (1919):$I_S = S_d + \gamma\, P_d$

Where:

Is = Interception of precipitation by vegetation

Sd = Vegetation canopy storage capacity

γ = Vegetation height coefficient

Pd = Total precipitation received by the canopy

4. Mulch presence: It was determined by using a metallic ruler to measure the height of the litter, considering that an average of 10 cm shows high content, 5 cm to 3 cm is a medium indicator, and less than 3 cm indicates it is interpreted. as low.
5. Unique ecosystems: These factors were taken into account for this parameter:
   a. Dry zone: including four sub-classifications (dry, semi-arid, arid and hyper-arid sub-humid zones).
   b. Planted ecosystems: or cultivated species.
   c. Ecosystems of recognized height with hydrological importance: All kinds of forests with a height greater than 15 meters.

6. Type of vegetation: Differentiated into three categories:
    a. Seasonal: short cycle crops.
    b. Annual: Its vegetal cycle is less than 12 months (cassava crops and pastures).
    c. Perennial: vegetal cycle greater than 10 years (timber trees, shrubs and certain fruit crops).
7. Degree of intervention: Its value was obtained with a scale of 1 to 3 based on:
    a. Land-use change
    b. Herding
    c. Burning or fires
    d. Wood sale
    e. Species extraction

Criterion	Indicator	Score
Structure	1 - 2 Strata	1.0
	1 - 3 Strata	2.0
	3 or more strata: arboreal, shrubby, herbaceous and epiphytic	3.0
Density	Low	1.0
	Medium	2.0
	High	3.0
Precipitation intercept	Low	1.0
	Medium	2.0
	High	3.0
Presence of mulch (leaf litter)	Low	1.0
	Medium	2.0
	High	3.0
Special ecosystems	Dry zone	1.0
	Crops	2.0
	High altitude recognized with hydrological importance	3.0
Type of vegetation	Temporal	1.0
	Annual	2.0
	Perennial	3.0
Degree of intervention	High	1.0
	Medium	2.0
	Low	3.0

Table 1. Assessment of HPI indicators.

2.4. Establishment of the Topographic humidity index

Finally, the THI is the end result of processing the data in QGIS 3.30.1 using a Digital Elevation Model (DEM), where the propensity of a cell to store water is reflected, which reflects the soil humidity. Thus, the model's applied formula is in accordance with Beven & Kirkby's (1979) proposal, while the process's specifics were based on Arteaga et al.'s (2020) proposal. The model's applied formula is expressed as follows:

$$THI = Ln\left(\frac{a}{Tan\beta}\right)$$

Where:

a: drained area

Tanβ: Angle of slope

3. Results and discussion

In the study area, there is a clear expansion of the agricultural frontier, which is consistent with findings made by Zamora et al. (2017), who claim that the Quiroga parish's mountainous soils have been cleared of trees to create environments that will increase the production of crops and grazing. According to the results shown in Table 2, only the first point (forests) had the highest values, totaling 18 to 20 points for the criteria examined. In contrast, the HPI criteria for points two (pastures) and three (crops/orchards) were lower, ranging from 12 to 14 points and 10 to 15, respectively.

According to the results shown in Table 3, light forests achieved an HPI-UV of 0.95, while dense forests reached a maximum of 1. This type of vegetation aids in the filtering of rainfall and the gradual storing of water in aquifers, as well as providing resistance to extreme weather events like droughts and floods (Oscanoa & Flores, 2019). In the work of Aguirre et al. (2018), plant cover and water quality are closely related. At point 2, the full annual grasslands attained a score of 0.64, the degraded perennial plant grasslands had a score of 0.43, and the degraded annual grasslands had a score of 0.32. Furthermore, annual crops without terraces have the lowest HPI-UV of all the covers investigated (0.22), whereas terraced orchards have the highest HPI-UV (0.88), followed by annual crops on terraces (0.74). It should be emphasized that plant cover and water quality are closely related, which affects the HPI's value (Aguirre et al., 2018).

Point	Transect	Vegetal cover	Criterion							
			Structure	Density	Interception of precipitation	Mulch presence	Unique ecosystems	Type of vegetation	Degree of intervention	∑
1	A	Light forests (with dense herbaceous substrate)	3	3	1	2	3	3	3	18
	B	Dense forests (without any soil erosion)	3	3	2	3	3	3	3	20
	C	Light forests (with dense herbaceous substrate)	3	3	1	2	3	3	3	18
2	A	Entire annual grasslands with apparent evidence of erosion	2	2	3	1	2	2	1	13
	B	Degraded perennial grassland with apparent erosion	2	1	3	1	2	2	1	12
	C	Degraded annual grasslands with apparent erosion	2	1	3	2	2	2	1	14
3	A	Annual crops on terraces	3	3	1	3	1	2	2	15
	B	Orchards on terraces	1	2	1	3	1	1	1	10
	C	Annual crops without terraces	1	1	1	2	2	2	1	10

Table 2. HPI criteria.

Point	Transect	Vegetal cover	HPI-UV
1	A	Light forests (with dense herbaceous substrate)	0,95
	B	Dense forests (without any soil erosion)	1,00
	C	Light forests (with dense herbaceous substrate)	0,95
2	A	Entire annual grasslands with apparent evidence of erosion	0,64
	B	Degraded perennial grassland with apparent erosion	0,43
	C	Degraded annual grasslands with apparent erosion	0,32
3	A	Annual crops on terraces	0,74
	B	Orchards on terraces	0,88
	C	Annual crops without terraces	0,22

Table 3. HPI -UV

The Hydrological Index of Partial Protection (HIPP) for the Brisas site was calculated by linking the HPI-UV with the share of each vegetation cover on the site's surface, and it is 0.66 (table 4). As a result, it may be concluded that the study area is suitable for conservation, in a relatively excellent state, and of medium importance. Lucas (2019) calculated the PPI sub-basin of the Carrizal river, which includes the research area, to be 0.59, which is regarded as regular, from a broader extension.

Vegetal cover	Area (ha)	%	PPI
Forest area	35,00	22,30%	0,22
Herbaceous vegetation	36,60	23,31%	0,11
Cultivated land	85,40	54,39%	0,33
Total	157,00	100%	**0,66**

Table 4. HIPP

Regarding the ITH, a classification of five categories yielded a range of 0 to 19. The microbasin's water network is clearly related to this index, as shown in figure 2, but it also allows for estimates of properties like soil pH, groundwater level, and soil wetness (Arteaga et al., 2020). Comparatively, it has been demonstrated that soil moisture regulates environmental processes and the distribution of species, with the ITH obtained from the digital elevation model being employed as an indication of soil moisture (Kopeck et al., 2021).

Since the significant pressure on the water resource does not consider the principles of intergenerational responsibility that, today, must be guaranteed to future generations, the results of this research provide a baseline that points to better management of the significant amount of forest resources in the study area. They also lead to the formulation of conservation strategies.

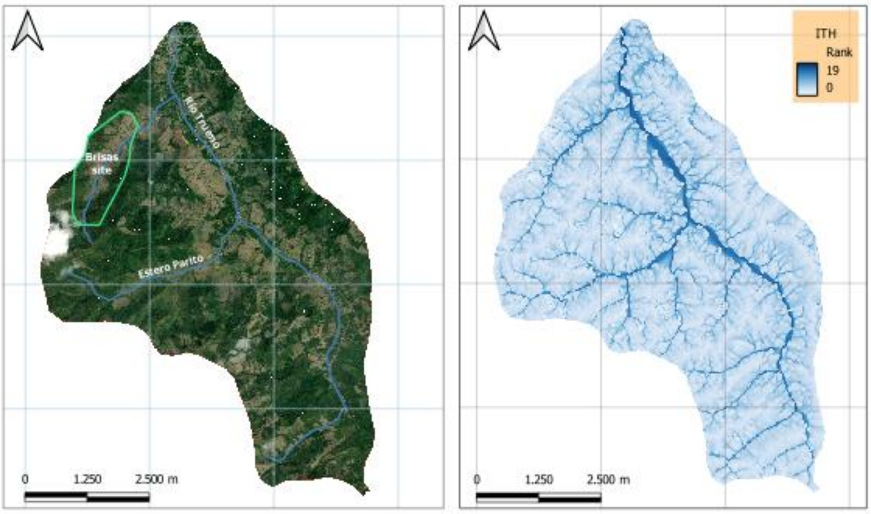

Figure 2. ITH of the Trueno microbasin.

Water availability, water quality, flood protection, agriculture, ecology, and other factors should all be considered simultaneously as part of the decision support system for planning and managing water resources (Haberlandt, 2010). The outcomes of this work must: i) consider the HPI of the entire micro-basin; ii) create a baseline of the meteorological parameters in the study region; and iii) apply a metamodel that incorporates the outcomes of field data, HPI, and ITH. This work must support decision making with an integrative approach. For the time being, the results show a clear projection of the water resource availability and the precision exerted on the surface flows of the Trueno micro-basin. In the light of this, policymaking could concentrate on the protection of the water resource through the implementation of a program that promotes sustainable production practices and environmental care.

4. Conclusions

In summary, the vegetation at the Brisas site has an HPI (Mean Basin of the Carrizal River) of 0.66, which places it in a moderately excellent condition with a high conservation importance. Likewise, it was discovered that the vegetation cover with the highest score (0.97), perceiving a recovery aptitude, is the woodland area; in contrast, herbaceous vegetation received the lowest rank (0.46). Regarding the IHT, the Trueno microbasin exhibits a humidity level that varies between 0 and 19. Even though it can aid in classifying the soil when used in conjunction with other factors, this index by itself is a useful variable to characterize the quality of the soil. as a gauge for the soil's quality and surface. In turn, these assessments serve as a management tool for the creation and implementation of successful policies that ensure the stability of these ecosystems. This research's contributions to policy formulation center on demonstrating the accessibility of water resources and the control over surface flows in the study area, which will make it easier to protect water resources through the implementation of a program that encourages environmentally friendly production methods.

References

Aguirre, N., Alvarado, J., & Granda, J. (2018). Bienes y servicios ecosistémicos de los bosques secos de la provincia de Loja. *Bosques Latitud Cero, 8*(2). https://revistas.unl.edu.ec/index.php/bosques/article/view/499

Arellano, J., & Ruiz, L. (2018). Evaluación y tendencias de los servicios ecosistémicos hidrológicos de la cuenca del río Zanatenco, Chiapas. *Investigaciones geográficas*, (95). https://doi.org/10.14350/rig.59467

Arteaga, E., Veliz, L., Giler, A., & Alarcón, J. (2020). Determinación del Índice de Humedad Topográfica para la microcuenca "La Mina" de la costa ecuatoriana. *Revista Dilemas Contemporáneos: Educación, Política y Valores,* (1). https://dilemascontemporaneoseducacionpoliticayvalores.com/index.php/dilemas/article/view/2473/2518

Aveiga, A. M., Banchón, C., Sabando, R., & Delgado, M. (2023). Exploring the Phytoremediation Capability of Athyrium filix-femina, Ludwigia peruviana and Sphagneticola trilobata for Heavy Metal Contamination. *Journal of Ecological Engineering, 24*(7), 165–174. https://doi.org/10.12911/22998993/164758

Beven, K. J., Lamb, R., Kirkby, M. J., & Freer, J. E. (2020). *A history of TOPMODEL*. https://doi.org/10.5194/hess-2020-409

Beven, K. J., & Kirkby, M. J. (1979). A physically based, variable contributing area model of basin hydrology / Un modèle à base physique de zone d'appel variable de l'hydrologie du bassin versant. *Hydrological Sciences Bulletin, 24*(1), 43–69. https://doi.org/10.1080/02626667909491834

Bravo, E., Castillo, T., Sellers, C., & Delgado, J. (2023). Analysis of conditioning factors in Cuenca, Ecuador, for landslide susceptibility maps generation employing Machine Learning methods. *Land, 12*(6), 1135. https://doi.org/10.3390/land12061135

Devia, G., Ganasri, B.., & Dwarakish, G. (2015). A review on hydrological models. *Aquatic Procedia*, *4*, 1001–1007. https://doi.org/10.1016/j.aqpro.2015.02.126

De Vries, A., Van Ham, I., & Bastmeijer, K. (2019). Protection through property: from private to river-held rights. *Water International, 44*(6–7), 736–751. https://doi.org/10.1080/02508060.2019.1641882

Dueñas, D., Guevara, O., & Santacruz, S. (2022). Valoración económica de los bienes y servicios ecosistémicos del bosque protector Jatumpamba-Jorupe. *Revista GEOESPACIAL, 19*(1). 12-32. https://journal.espe.edu.ec/ojs/index.php/revista-geoespacial/article/view/2816/2216

FAO. (2009). *Monitoreo y Evaluación de los Recursos Forestales Nacionales – Manual para la recolección integrada de datos de campo*. Roma: NFMA 37/S.

Fries, A., Silva, K., Pucha, F., Oñate, F., & Ochoa, P. (2020). Water balance and soil moisture deficit of different vegetation units under semiarid conditions in the Andes of southern Ecuador. *Climate, 8*(2). https://doi.org/10.3390/cli8020030

Haberlandt, U. (2010). From hydrological modelling to decision support. *Adv. Geosci, 27*, 11-19. https://doi.org/10.5194/adgeo-27-11-2010

Kleemann, J., Zamora, C., Villacis, A., Cuenca, P., Koo, H., Noh, J., Fürst, C., & Thiel, M. (2022). Deforestation in continental Ecuador with a focus on protected areas. *Land, 11*(2), 268. https://doi.org/10.3390/land11020268

Kopecký, M., Macek, M., & Wild, J. (2021). Topographic Wetness Index calculation guidelines based on measured soil moisture and plant species composition. *The Science of the Total Environment, 75*. https://doi.org/10.1016/j.scitotenv.2020.143785

Krasovskaya, O. (2022). Public danger of water pollution and the mechanism of protection of the surrounding water environment. *IOP Conf. Series: Earth and Environmental Science 979*. https://doi:10.1088/1755-1315/979/1/012170

Kucher, A., Krupin, V., Rudenko, D., Kucher, L., Serbov, M., & Gradziuk, P. (2023). Sustainable and efficient water management for resilient regional development: The case of Ukraine. *Agriculture*, *13*(7), 1367. https://doi.org/10.3390/agriculture13071367

Lucas, K. (2019). Relación entre la protección hidrológica y la cobertura vegetal de la subcuenca hidrográfica del Carrizal. *Revista de Ciencias Agropecuarias "ALLPA", 2*(3). https://publicacionescd.uleam.edu.ec/index.php/allpa/article/view/59

Oscanoa, L. & Flores, E. (2019). Efecto de las técnicas de mejora ecohidrológica del pastizal sobre el rendimiento hídrico de la microcuenca alto andina Urpay. *Ecología Aplicada, 18*(1), 1-9. https://dx.doi.org/10.21704/rea.v18i1.1303

Quimis, A., Rivas, C., González, P., & Navarro-Cerrillo, R. (2023). Forest plantations in Manabí (Ecuador): Assessment of fragmentation and connectivity to support dry tropical forests conservation. *Applied Sciences (Basel, Switzerland), 13*(11). https://doi.org/10.3390/app13116418

Reyna, L., Vera, L., & Reyna, L. (2018). Soil-organic-carbon concentration and storage under different land uses in the Carrizal-Chone valley in Ecuador. *Applied Sciences (Basel, Switzerland), 9*(1), 45. https://doi.org/10.3390/app9010045

Rivas, C., Guerrero, J., & Navarro, R. (2021). Deforestation and fragmentation trends of seasonal dry tropical forest in Ecuador: impact on conservation. *Forest Ecosystems, 8*(1). https://doi.org/10.1186/s40663-021-00329-5

Romero, E., & Ferreira, S. (2010). Índices de Protección Hidrológica de la Vegetación en la Cuenca del Río Potrero (Provincia de Salta). *Revista Ciencia, 5*(16).

Sánchez, F. (2019). Fundamentos epistémicos de la investigación cualitativa y cuantitativa: consensos y disensos. *Revista Digital de Investigación en Docencia Universitaria, 13*(1), 102-122. https://dx.doi.org/10.19083/ridu.2019.644

Valarezo, G., Carrión, H., Capa, E., & Jiménez, L. (2021). Soil quality/health indicators in a disturbed ecosystem in southern Ecuador. *Soil Science Annual, 72*(2), 1–12. https://doi.org/10.37501/soilsa/135991

Winzeler, H., Owens, P., Read, Q., Libohova, Z., Ashworth, A., & Sauer, T. (2022). Topographic wetness index as a proxy for soil moisture in a hillslope Catena: Flow algorithms and map generalization. *Land, 11*(11), 2018. https://doi.org/10.3390/land11112018

Zamora, Y., Montesdeoca, M., Alcívar, K., & Hidalgo, M. (2017). La gestión productiva agrícola en el sector minorista del cantón Bolívar de la provincia Manabí, Ecuador. *Mikarimin. Revista Científica Multidisciplinaria, 3*(3), 43–58. https://revista.uniandes.edu.ec/ojs/index.php/mikarimin/article/view/797/306

Authors

Fabricio Enrique Alcívar Intriago *(corresponding author)*, falcivar@espam.edu.ec
Marcos Javier Vera Vera,
Luis Damián Muñoz Anchundia,
Diocle Antonio Vera Salavarría

Escuela Superior Politécnica Agropecuaria de Manabí Manuel Félix Lopez, Calceta, Ecuador.

Funds

This research received no specific grant from any funding agency in the public, commercial, or no-profit sectors.

Competing Interests

The authors hereby state that there are no financial or non-financial competing interests.

Citation

Alcívar Intriago, F.E., Vera Vera, M.J., Muñoz Anchundia, L.D., & Vera Salavarría, D.A. (2023). Topographic humidity index and vegetation as management tool for policies decision. *Visions for Sustainability*, 20, 8110, 47-62.
http://dx.doi.org/10.13135/2384-8677/8110