RiAT Revista Interamericana de Ambiente y Turismo
Interamerican Journal of Environment and Tourism
Print version ISSN - 0717 - 6651, Online version ISSN - 0718 - 235X
http://dx.doi.org/10.4067/S0718-235X20230002000143
http://riat.utalca.cl
www.fen.utalca.cl

Research paper

Regarding hydrographic microbasins' vegetation and hydrological protection. Case: Membrillo, Manabi – Ecuador

Protección hidrológica en relación a la vegetación de microcuencas hidrográficas. Caso: Membrillo, Manabí – Ecuador

Fabricio Enrique Alcívar Intriago[1*], Josselin Dennis Cabezas Cacierra[1], José Manuel Calderon Pincay[1] and Kevin Alexander Patiño Alonzo[1]

[1] Escuela Superior Politécnica Agropecuaria de Manabí Manuel Félix López, Carrera de Ingeniería Ambiental, Calceta, Ecuador
[*] Corresponding author (E-mail corresponding author): falcivar@espam.edu.ec

Received: 2023-11-15 Accepted for publication: 2023-12-05 Published: 2023-12-31

ABSTRACT

This study set out to calculate the Hydrological Protection Index (IPH) based on the vegetation that already existed in the Membrillo micro-basin in Manabi, Ecuador. Two phases were proposed, including the identification of the type of vegetation cover and the determination of the HPI based on seven criteria studied in relation to the local vegetation. The proposed methodology is of a quantitative type, and techniques like observation, bibliographic compilation, and the checklist were applied, allowing the establishment of 28 radiated sampling points to cover the entire extension of the micro-basin. The IPH of each monitoring site was thus determined, allowing the calculation of the Partial Protection Hydrological Index (IHPP), which is in the middle of the classification and favors the preservation of the ecological unit's soil, at 0.68. In conclusion, the Membrillo micro-basin is a region with moderate value and is good for conservation.

Keywords: *micro-watershed, vegetation, hydrological protection index*

RESUMEN

El objetivo de esta investigación fue determinar el Índice de Protección Hidrológico (IPH) en función de la vegetación existente en la microcuenca Membrillo, Manabí (Ecuador). La metodología planteada es de tipo cuantitativa y se aplicaron técnicas como la observación, la recopilación bibliográfica y la lista de chequeo, que permitieron establecer 28 puntos de muestreo radiados para cubrir toda la extensión de la microcuenca; se plantearon dos fases que incluyen la identificación del tipo de cobertura vegetal y la determinación del IPH en función de siete criterios estudiados según la vegetación de la zona. Como resultado, se obtuvo el IPH de cada punto de monitoreo, lo cual permitió obtener un Índice Hidrológico de Protección Parcial (IHPP) de 0,68, que se encuentra de la clasificación media y favorece la protección del suelo de la unidad ecológica. En síntesis, la microcuenca Membrillo es una zona de importancia media y con aptitud de conservación.

Palabras clave: microcuenca, vegetación, índice de protección hidrológica

INTRODUCTION

The very foundation of life on Earth rests on the stability, productivity, and relative health of freshwater ecosystems. Unfortunately, they stand for some of the world's most exploited, undefended, and threatened systems (Krasovskaya, 2022). The water resource is also thought to be crucial for human survival and growth; it is also crucial for the preservation of the environment and the development of the ecological ecosystem, both of which ensure social well-being by ensuring the availability of goods and services. For socioeconomic growth and the sustainability of ecological ecosystems, the conservation of water resources is seen in this light (Makanda et al., 2022; De Vries et al., 2019).

Although freshwater ecosystems have high levels of headwater-to-mouth connectivity and are surrounded by landscape processes, safeguarding such resources is difficult since any damage or deterioration in one location will spread to the remainder of the system (Krasovskaya, 2022). As a result, the need for management strategies that strike a balance between the protection of water resources and their sustainable use is justified (Ibrahim et al., 2017). It has been argued that such strategies should take into account micro-watersheds as logical and natural units for managing water resources. These micro-watersheds are home to a variety of living forms and offer a range of ecological services, such as flood management, habitat for biodiversity, mitigation and adaptation to climate change, as well as social and cultural aspects (Khan et al., 2022).

Still, forests and moors serve as collectors and regulators of water flow and prevent soil erosion that affects water quality. Deforestation and burning of plant remains to expand agriculture, as well as the use of agrochemicals, interrupt the basin's capacity to provide its services (Kauffman, 2014). The destruction of hydrographic basins is one of the problems, and in Ecuador, it is the expansion of the agricultural frontier.

The Hydrological Protection Index (IPH), one of the tools used to manage hydrographic basins, enables us to comprehend how vegetation affects soil and water resources (Arellano & Ruiz, 2018). Romero & Ferreira (2010) emphasize that this is a factor that determines the degree of the soil's resistance to the effects of rainfall and enables a thorough investigation of the vegetation. With the aforementioned justifications, this study sought to calculate the HPI using the flora already present in the Membrillo micro-basin in Manabi (Ecuador).

METHODOLOGY

Study area

The Membrillo micro-basin, which has a surface size of 116.69 km2, lies in the Bolvar canton of the province of Manab. According to the Holdrigde classification, the bioclimatic map of Ecuador shows that this region has tropical climate characteristics and is a part of an ecological region with tropical dry forests. The movement of the intertropical convergence zone and changes in the Pacific Ocean have an important effect on this region (Aveiga et al., 2023).

In terms of the approaches employed, we began with a quantitative strategy that permitted the numerical processing of the gathered data. In addition, the checklist, bibliographic compiling, and observation are employed approaches. With the aforementioned, the following steps were taken:

Recognition of the vegetation cover type

The sampling stations' physical attributes were specified and they were georeferenced using the GPS. Additionally, official sources such the National Information System and the Military Geographic Institute of Ecuador were consulted for satellite data from the region. With the use of this knowledge, the plant units of the micro-watershed were identified, and the plant cover was defined based on their functions. This allowed the development of 28 sample locations, which essentially cover the whole surface of the micro-watershed.

RESULTS AND DISCUSSION

It was determined from the land coverage and use map created by the Ministries of Agriculture, Livestock, Aquaculture and Fisheries, the Environment, and the National Secretariat for Planning and Development that the Membrillo micro-basin's surface is made up of the following: 37% (5653.91 ha) are of the type 50% fruit - 50% cultivated grass, 36% (5510.38 ha) corresponds to 70% tropical arboriculture - 30% cultivated grass, 20% (3065.44 ha) are tropical arbor (figure 3).

Figure 1 Map of the research area.

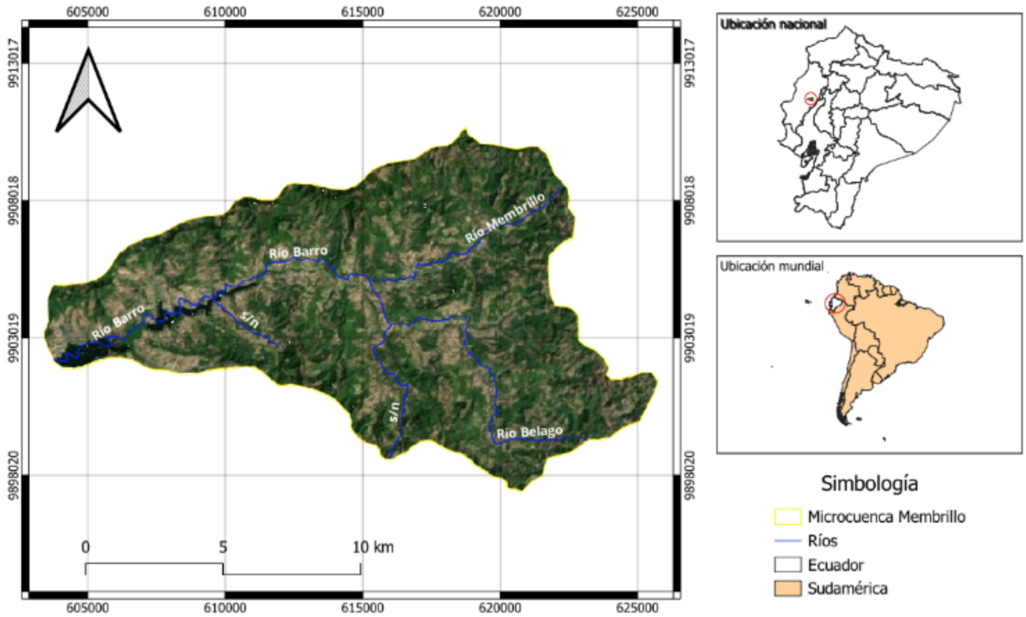


Figure 2. Criteria for determining the HPI.

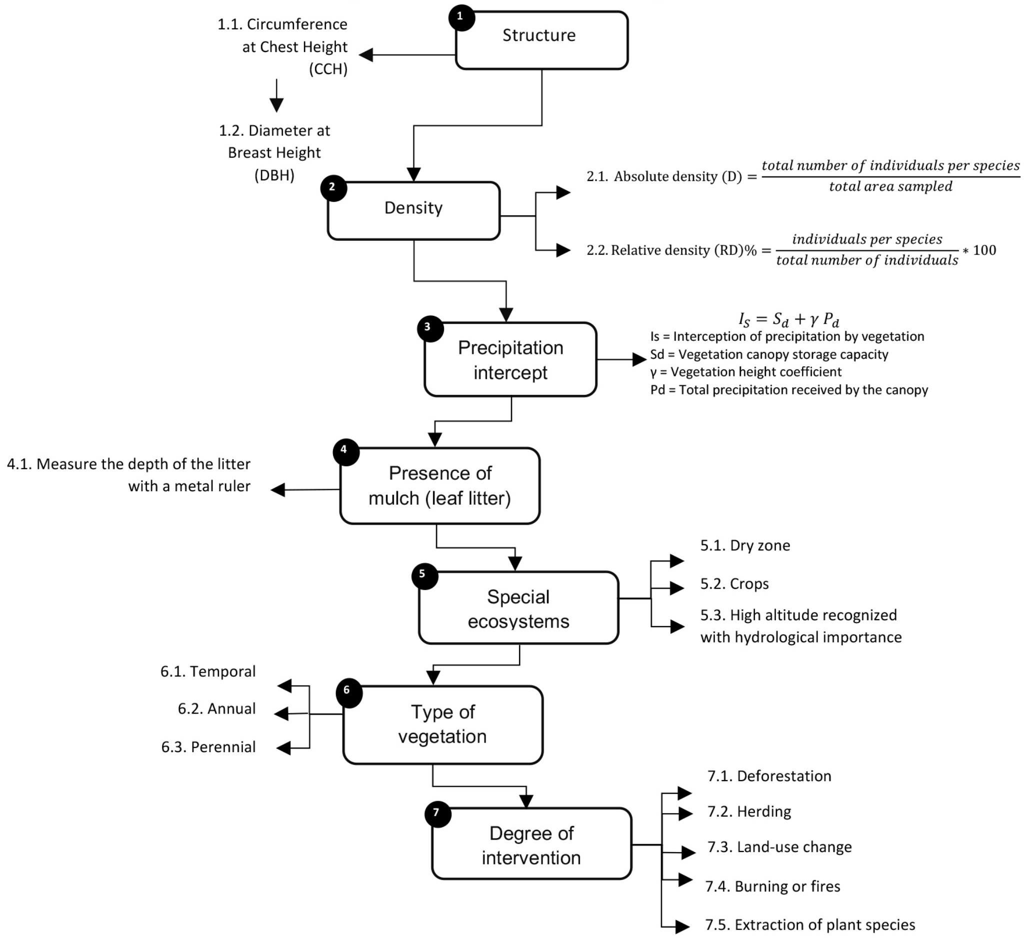
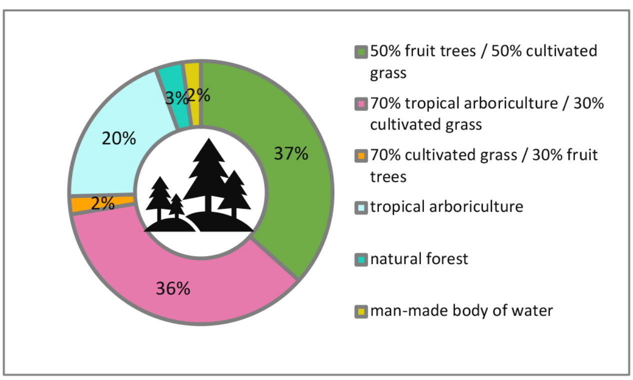


Table 1. Assessment of HPI indicators.

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	Low	1.0
	Medium	2.0
	High	3.0

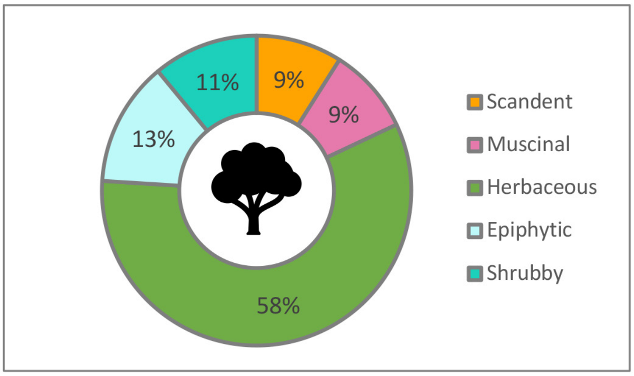
Figure 3. Distribution of vegetation cover in the Membrillo micro-basin.



According to the facts previously mentioned, the Membrillo micro-basin has a noteworthy commitment of land to productive uses, particularly cattle and agriculture. According to Guarderas et al. (2022), deforestation and agricultural intensification are the two main transitions in the Ecuadorian territory, and as predicted, the stability of native forests is deteriorating over time. Heredia et al. (2021) discovered that there have been changes in the dynamics of land use and cover in the Yasun Reserve between 2009 and 2018, with an increase in deforestation and an expansion of various traditional systems of production.

Based on the physical characteristics of the different plant species, there was a predominance of the herbáceo (58%), followed by the epiftico (13%), and arbustivo (11%), while the escandente and muscinal estratos both reached 9% (figure 4). According to Suárez et al. (2013)'s criteria, during dry seasons, water infiltration rates differ significantly depending on the type of vegetation or soil cover. The bosque, which has a mean infiltration rate of 56 cm/min, experiences the highest rates, while the matorral, pastizal, and pinar categories experience higher rates (between 3 and 8 times), respectively.

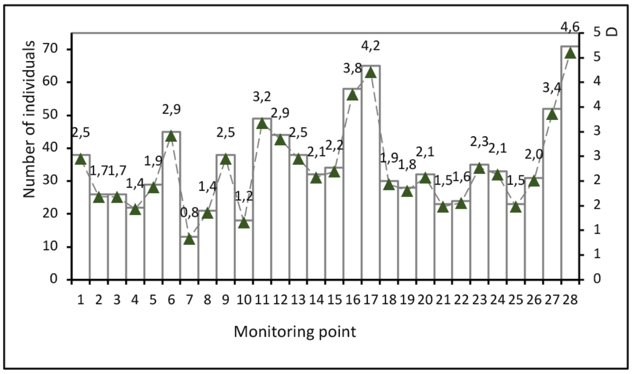
Figure 4. Land cover according to the identified strata.



From an alternate perspective, 978 tree individuals were found in the study area with a heterogeneous distribution, where point 28 (natural forest) stands out with 71 individuals and points 17 and 16 with 65 and 58, respectively; the others maintain a number of less than 50 individuals, as shown in figure 4. It should be emphasized that the number of trees per monitoring point shows an incidence that is inversely related to the growth of productive activities. The annual rate of deforestation in Ecuador between 1990 and 2018 was 1.12%; in addition, the reticular fragmentation index increased by 11.61% as a result of the tendency for small forest fragments to disappear while large fragments to split into smaller ones (Rivas et al. 2021).

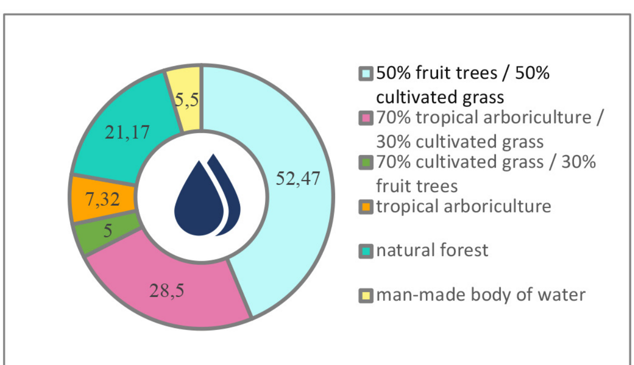
The quantity of individuals has a direct impact on the absolute density. In the points with greater populations, as seen in figure 5, the absolute density is higher. The maximum values of this parameter are shown by points 28, 17, and 16, in this sense. It should be highlighted that since point 28 relates to a natural forest, this type of ecosystem regulates atmospheric moisture flows through evapotranspiration, which is also a crucial component of the water cycle (Blanco, 2017).

Figure 5. Number of individuals and absolute density per monitoring point.



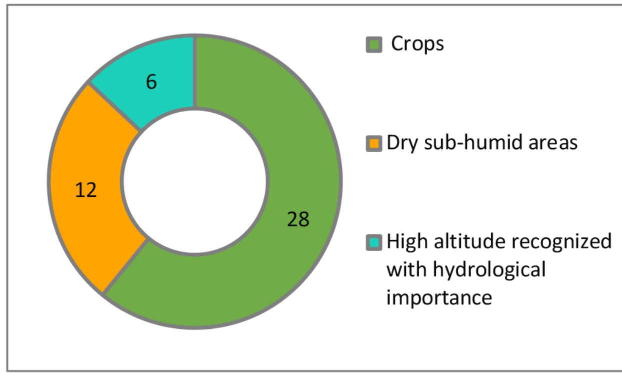
Based on records from the closest weather station (M1230 ESPAM "MFL," Calceta), the results of the interception of precipitation, given in mm, were calculated on the Horton approach and the data used correspond to 8.8 mm (July 2020). Figure 6 shows that tropical arboriculture intercepts the greatest amount of rainfall (52.47 mm), followed by strata. 70% tropical arboriculture - 30% cultivated grass (33.50 mm) yielded 21, 17 mm for tropical arboriculture, 7.32 mm for 70% cultivated grass - 30% fruit trees, and 5.50 mm for the natural forest. Rainfall in vegetated areas is initially absorbed and briefly stored in organic materials such leaves, branches, stems, lichens, or the forest floor. A large portion of this material is then recycled back into the atmosphere, reducing the intensity of the rainfall. Rainfall distributes the surface water that is currently available and gives the atmospheric water cycle quick moisture feedbacks (Lian et al., 2022).

Figure 6. Interception of precipitation by stratum.



Only 2 of the 28 monitoring points relate to high-altitude ecosystems regarded as having hydrological importance, and the sum of the ecosystem qualification reflects the prevalence of planted ecosystems, which make up 14 of the 28 monitoring points (figure 7). According to data at the national level, the agricultural sector, particularly when using basic technologies, fully utilizes production factors including labor, land, and capital.

Figure 7. Ecosystems found in the study area.



In 13 transects, the vegetation is perennial, 13 have yearly plantations, and 2 maintain temporary vegetation. This is because the kind of vegetation was decided based on the time of life (figure 8). From a national perspective, the literature suggests that Ecuador has 24 bioclimatic formations or vegetation systems and high biodiversity, which are suitable for developing different agricultural activities that allow obtaining products in accordance with market demands. As a result, if its territory, perennial crops are located in 11.83% of Ecuadorian soils, 29.8% have mountains and forests, 29% are cultivated pastures, while natural pastures represent 12.84%, moors the 4.59%, and the remaining 1% is covered by wetlands.

Figure 8. Type of vegetation in the study area.

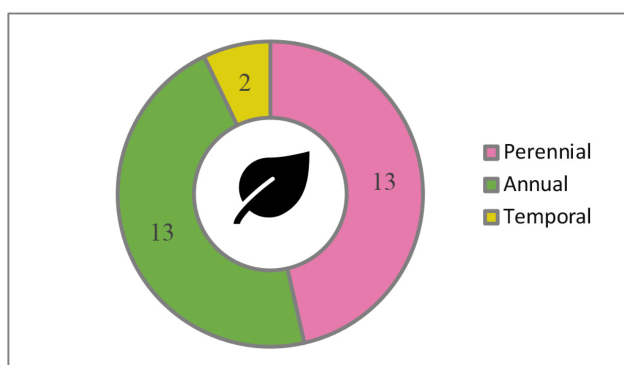


Table 2 provides quantitative information for each of the criteria, with 14 of the 28 transects showing a medium degree of intervention (2), 12 transects showing high levels of intervention (1), and only 2 transects (points 27 and 28) showing low levels of intervention (3). All of this is a part of the national reality; up until 2014, continuous fragmentation predominated as a result of a decline in the density of rare forest species on the Coast and the Andes (Noh et al., 2022).

Table 2. Quantification of the HPI indicators.

N°	Vegetation cover	Criterion						
		Structure	Density	Precipitation intercept	Presence of mulch (leaf litter)	Special ecosystems	Type of vegetation	Degree of intervention
1	50% fruit trees / 50% cultivated grass	3	1	3	2	2	3	1
2	50% fruit trees / 50% cultivated grass	3	2	3	2	2	3	2
3	50% fruit trees / 50% cultivated grass	2	2	3	3	2	2	2
4	50% fruit trees / 50% cultivated grass	1	2	3	3	1	2	1
5	50% fruit trees / 50% cultivated grass	2	2	3	3	1	2	1
6	50% fruit trees / 50% cultivated grass	3	2	3	2	2	2	2
7	50% fruit trees / 50% cultivated grass	3	1	3	2	2	2	1
8	50% fruit trees / 50% cultivated grass	3	1	3	3	2	2	2
9	50% fruit trees / 50% cultivated grass	3	1	3	1	1	3	1
10	50% fruit trees / 50% cultivated grass	2	2	3	1	2	3	1
11	70% tropical arboriculture / 30% cultivated grass	3	1	2	2	1	2	2
12	70% tropical arboriculture / 30% cultivated grass	3	1	3	3	1	3	1
13	70% tropical arboriculture / 30% cultivated grass	2	2	3	2	2	3	1
14	70% tropical arboriculture / 30% cultivated grass	3	1	2	3	2	3	2
15	70% tropical arboriculture / 30% cultivated grass	2	2	1	2	1	1	2
16	70% tropical arboriculture / 30% cultivated grass	3	2	3	3	1	3	2
17	70% tropical arboriculture / 30% cultivated grass	3	2	3	2	2	2	2
18	70% tropical arboriculture / 30% cultivated grass	3	2	3	2	1	2	2
19	70% tropical arboriculture / 30% cultivated grass	3	2	2	1	1	3	2
20	70% cultivated grass / 30% fruit trees	3	3	3	3	2	2	1
21	70% cultivated grass / 30% fruit trees	3	2	2	2	2	2	1

22	Tropical arboriculture	3	2	1	2	2	1	2
23	Tropical arboriculture	3	2	3	2	1	2	2
24	Tropical arboriculture	3	2	3	2	1	2	2
25	Tropical arboriculture	3	2	3	2	1	3	1
26	Tropical arboriculture	3	2	2	2	2	3	1
27	Natural forest	3	3	2	2	3	3	3
28	Natural forest	3	3	2	2	3	3	3

Table 3 displays the calculation of this index per unit of vegetation (IPH UV), as well as the IPH calculation for each transect. The maximum IPH and IPH UV were, as anticipated, attained in the two transects that are natural forests (1). The coverage of 70% cultivated grass / 30% fruit trees ranks second with 0.74 70%, while the lowest value was for tropical arboriculture / 30% cultivated grass with 0.59. Lucas (2019) discovered that the HPI of the Carrizal river sub-basin is regular (0.59) in a larger context, but within the same region, underlining the necessity to implement medical mitigating measures. In addition to providing resistance to unfavorable weather events like droughts and floods, tropical arboriculture with grown grass helps filter water from rainfall and gradually stores it in aquifers, according to Oscanoa & Flores (2019). According to Aguirre et al. (2018), plant cover and water quality are closely related.

Table 3. HPI and HPI VU.

Point	Tpe of vegetation cover	Total	HPI	HPI UV
1	50% fruit trees / 50% cultivated grass	15	0,75	0,69
2	50% fruit trees / 50% cultivated grass	17	0,74	
3	50% fruit trees / 50% cultivated grass	16	0,74	
4	50% fruit trees / 50% cultivated grass	13	0,65	
5	50% fruit trees / 50% cultivated grass	14	0,64	
6	50% fruit trees / 50% cultivated grass	16	0,74	
7	50% fruit trees / 50% cultivated grass	14	0,64	
8	50% fruit trees / 50% cultivated grass	16	0,74	
9	50% fruit trees / 50% cultivated grass	13	0,65	
10	50% fruit trees / 50% cultivated grass	14	0,64	
11	70% tropical arboriculture / 30% cultivated grass	13	0,54	0,59
12	70% tropical arboriculture / 30% cultivated grass	15	0,53	
13	70% tropical arboriculture / 30% cultivated grass	15	0,53	
14	70% tropical arboriculture / 30% cultivated grass	16	0,74	
15	70% tropical arboriculture / 30% cultivated grass	11	0,44	
16	70% tropical arboriculture / 30% cultivated grass	17	0,74	
17	70% tropical arboriculture / 30% cultivated grass	16	0,74	
18	70% tropical arboriculture / 30% cultivated grass	15	0,53	
19	70% tropical arboriculture / 30% cultivated grass	14	0,54	
20	70% cultivated grass / 30% fruit trees	17	0,85	0,74
21	70% cultivated grass / 30% fruit trees	14	0,64	
22	Tropical arboriculture	13	0,65	0,73
23	Tropical arboriculture	15	0,75	
24	Tropical arboriculture	15	0,75	
25	Tropical arboriculture	15	0,75	
26	Tropical arboriculture	15	0,75	
27	Natural forest	19	1	1
28	Natural forest	19	1	

The Hydrological Index of Partial Protection (HIPP) of the Membrillo micro-watershed was calculated using these findings, yielding a total of 0.68 (table 4), which is in the medium classification and favors the protection of the ecological unit's soil. As a result, it may be concluded that the study area is suitable for conservation, in a relatively excellent state, and of medium importance. According to Lucas (2019), the sub-basin of the Carrizal River measures 0.59, which means it belongs to the normal group.

Table 4. HIPP of the Membrillo microbasin.

Vegetation cover	Area (ha)	HPI UV	%	HIP P
50% fruit trees / 50% cultivated grass	5653,91	0,69	36,64	0,22
70% tropical arboriculture / 30% cultivated grass	5510,38	0,59	35,71	0,25
70% cultivated grass / 30% fruit trees	340,62	0,74	2,21	0,02
Tropical arboriculture	3065,44	0,73	19,86	0,14
Natural forest	513,69	1	3,33	0,03
Man-made body of water	347,46	-	2,25	0,02
Total	15431,5	3,75	100%	0,68

CONCLUSIONS

There are five different plant cover types in the Membrillo micro-basin, with cultivated grass and fruit trees making up the majority of the plant cover. Its HPI therefore comes out to be 0.68, defining it as a reasonably good condition, medium importance, and conservation-friendly place. One notable feature is the presence of a small patch of natural forest, which has the highest HPI (1) and whose preservation is essential to the preservation of the micro-watershed's overall HPI. In this way, it is made clear how important it is to implement environmental management programs in this microbasin that involve ecosystem conservation and protection.

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

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

Blanco, J. (2017). Bosques, suelo y agua: explorando sus interacciones. Ecosistemas, 26(2), 1-9. https://doi.org/10.7818/ECOS.2017.26-2.01

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

Guarderas, P., Smith, F., & Dufrene, M. (2022). Land use and land cover change in a tropical mountain landscape of northern Ecuador: Altitudinal patterns and driving forces. PloS One, 17(7). https://doi.org/10.1371/journal.pone.0260191

Heredia, M., Torres, B., Cabrera, F., Torres, E., Díaz, C., & Pappalardo, S. (2021). Land use and land cover changes in the Diversity and Life Zone for uncontacted indigenous people: Deforestation hotspots in the Yasuní Biosphere Reserve, Ecuadorian Amazon. Forests, 12(11), 1539. https://doi.org/10.3390/f12111539

Ibrahim, A., & Patrick, R. (2017). Source Water Protection planning and management in metropolitan Canada: A preliminary assessment. Water, 9(7), 497. https://doi.org/10.3390/w9070497

Kauffman, C. (2014). Financing watershed conservation: Lessons from Ecuador's evolving water trust funds. Agricultural Water Management, 145, 39–49. https://doi.org/10.1016/j.agwat.2013.09.013

Khan, N., Jhariya, M., Banerjee, A., Meena, R., Raj, A., & Yadav, S. (2022). Riparian conservation and restoration for ecological sustainability. En M. K. Jhariya, R. S. Meena, A. Banerjee, & S. N. Meena (Eds.), Natural Resources Conservation and Advances for Sustainability (pp. 195–216). Elsevier.

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

Ley Orgánica de Recursos Hídricos Usos y Aprovechamiento del Agua (06 de agosto de 2014). http://www.regulacionagua.gob.ec/wp-content/uploads/2019/06/Ley-Org%C3%A1nica-de-Recursos-H%C3%ADdricos-Usos-y-Aprovechamiento-del-Agua.pdf

Lian, X., Zhao, W., & Gentine, P. (2022). Recent global decline in rainfall interception loss due to altered rainfall regimes. Nature Communications, 13(1), 7642. https://doi.org/10.1038/s41467-022-35414-y

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

Makanda, K., Nzama, S., & Kanyerere, T. (2022). Assessing the role of water resources protection practice for sustainable water resources management: A review. Water, 14(19), 3153. https://doi.org/10.3390/w14193153

Mihai, R., Melo, E., Terán, V., Espinoza, I., Pinto, E., & Catana, R. (2023). The panoramic view of Ecuadorian soil nutrients (deficit/toxicity) from different climatic regions and their possible influence on the metabolism of important crops. Toxics, 11(2). https://doi.org/10.3390/toxics11020123

Noh, J., Echeverria, C., Gaona, G., Kleemann, J., Koo, H., Fürst, C., & Cuenca, P. (2022). Forest ecosystem fragmentation in Ecuador: Challenges for sustainable land use in the tropical Andean. Land, 11(2), https://doi.org/10.3390/land11020287

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

Pacheco, J., Ochoa, W., Ordoñez, J., & Izquierdo, L. (2018). Agricultural diversification and economic growth in Ecuador. Sustainability, 10(7). https://doi.org/10.3390/su10072257

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

Rojas, J. (2003). Valoración económica de agua de uso doméstico en Quilangua Loja. Ibarra - Ecuador: PUCE.

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).

Suárez, E., Arcos, E., Moreno, C., Encalada, A., & Álvarez, M. (2013). Influence of vegetation types and ground cover on soil water infiltration capacity in a high-altitude páramo ecosystem. ACI Avances en Ciencias e Ingenierías, 5(1), B14-B21. https://revistas.usfq.edu.ec/index.php/avances/article/download/117/119/