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IDENTIFYING PRIORITY AREAS FOR BIODIVERSITY AND SOIL ACCUMULATION ECOSYSTEM SERVICE MANAGEMENT IN TROPICAL FORESTS WITH HIGH GLOBAL CONSERVATION PRIORITY

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ABSTRACT

The Mira River watershed in northern Ecuador is located within the Tropical Andes and Tumbes-Chocó-Magdalena hotspots. This landscape provides many ecosystem services necessary for human well-being. Despite the high worldwide value of biodiversity conservation of this watershed, the degradation of natural forests threatens biodiversity and ecosystem services. In Ecuador, biodiversity is managed separately from ecosystem services. Therefore, an integrated management is necessary, which provides a win-win situation and decreases the cost of management. However, it is unclear how ecosystem services and biodiversity are related and to what extent the management of biodiversity will ensure the supply of services. This study aimed to identify priority areas for biodiversity and soil accumulation ecosystem service simultaneous management in the Rio Mira watershed by 1) assessing the spatial distribution of biodiversity and soil accumulation service, 2) assessing the spatial relationship between both resources, and 3) analyzing the spatial congruence between biodiversity and soil accumulation. This analysis was carried out using spatially explicit models, geographically weighted regression, and overlap analyses. Biodiversity reported a positive spatial relationship with soil accumulation service in 98 % of the subwatersheds studied. Biodiversity can explain up to 92 % of the variance in the supply of soil accumulation. Biodiversity and soil accumulation registered an overlap of 52.5 %. I identified that in 15 % of the subwatersheds studied, the simultaneous management of biodiversity and soil accumulation service can be carried out. Therefore, in these subwatersheds, management strategies and capital investment can be optimized. Also, this study provides key information for land-use planning.

Keyword: conservation planning, habitat diversity, human well-being, tropical forest ecosystems

INTRODUCTION

Biodiversity underpins the ecosystem services supply, which are the benefits that humans obtain from ecosystems. The services include supporting (e.g., soil accumulation and erosion control), provisioning (e.g., food and wood), regulatory (e.g., water and climate regulation), and cultural services (e.g., recreation and cultural identity) (Mori *et al*., 2017; Zhang *et al*., 2019). The loss and unsustainable use of biodiversity and ecosystem services threaten the human well-being of many people worldwide. Therefore, it is necessary to manage both resources (MA 2005; Landscapes for People, Food and Nature Initiative, 2015). Management of biodiversity and ecosystem services may require different strategies. Many cultural and provisioning services are supplied directly by some component of biodiversity. For example, forest ecosystems provide food, medicinal plants, and firewood, among others (IPBES 2016; Zhang *et al*., 2019). However, most support and regulatory services are a function of many ecosystem properties. Therefore, its management cannot be oriented towards any particular components of biodiversity. For example, soil accumulation is provided by the combination of abiotic and biotic factors (Díaz *et al*., 2015; Pascual *et al*., 2017), which requires an approach to land-use management at a landscape level.

One potential strategy for simultaneously managing biodiversity and supporting regulatory ecosystem services is to identify areas where both resources overlap. Thus, management strategies focused on biodiversity will safeguard the supply of ecosystem services and vice versa (Turner *et al*., 2007; Harrison *et al*., 2014; Ricketts *et al*., 2016; Karimi *et al*., 2020). Several conservation scientists have highlighted that it is a priority to have a better understanding of i) how is the spatial relationship between biodiversity and ecosystem services at the landscape level and ii) to what extent the spatial congruence between biodiversity and ecosystem services occurs (MA, 2005; Díaz *et al*., 2006, de Groot *et al*., 2010; Vihervaara *et al*., 2010; Onaindia *et al*., 2013; Harrison *et al*., 2014). The spatial relationships between biodiversity and ecosystem services have not been extensively studied (Bai *et al*., 2011; Onaindia *et al*., 2013). Some studies have reported a high overlap and correlation between biodiversity and ecosystem services (Egoh *et al*., 2009; Chan *et al*., 2011; Harrison *et al*., 2014; Ricketts *et al*., 2016; Rodríguez-Echeverry *et al*., 2017; Lin *et al*., 2018; Karimi *et al*., 2020). Other studies have registered a high overlap and moderate correlation between them (Costanza *et al*., 2007; Turner *et al*., 2007; Bai *et al*., 2011; Manhaes *et al*., 2016; Lin *et al*., 2018; Karimi *et al*., 2020). Other studies have reported low overlap and correlations (Chan *et al*., 2006; Anderson *et al*., 2009; Onaindia *et al*., 2013; Manhaes *et al*., 2016; Morelli *et al.,* 2017). According to the ambiguity of the reported findings, it is necessary to study the spatial relationship between biodiversity and ecosystem services in other regions of the world that have not been widely studied (Manhaes *et al*., 2016; *Ricketts et al*., 2016; Rodríguez-Echeverry *et al*., 2017).

Soil accumulation ecosystem service is a supporting service directly linked to the accumulation of organic matter in the soil (Egoh *et al*., 2009; Rodríguez-Echeverry *et al*., 2017). Scientists have registered a positive correlation between the organic matter present in the soil with vegetation coverage and soil depth (Egoh *et al*., 2009). The organic matter accumulated in the soil is mainly of plant origin. This consists of senesced or dead shoots and root litter, litter leachates, root exudates, and rhizodeposits, which contain about 50 % of the terrestrial carbon pool (Sokol *et al*., 2018). Soil organic matter is, to a lesser extent, a product of the substrate and soil microorganisms. This supports physical, chemical, and biological processes sustaining vital ecosystem functions (Lal, 2015; Hoffland *et al*., 2020). In addition, it promotes carbon capture and is a source of nutrients and energy for the biota. Consequently, soil organic matter is key to maintaining the ecological integrity of ecosystems, therefore it has been considered as an important indicator of environmental quality (Nciizah & Wakindiki, 2015; Obalum *et al*., 2017).

The Rio Mira watershed in northern Ecuador is part of the Tropical Andes and Tumbes-Chocó-Magdalena hotspots. Despite the high worldwide value of the biodiversity conservation of this watershed, several anthropogenic activities (such as intensive agriculture, cattle raising, overexploitation of native species, and firewood extraction) have generated the loss, fragmentation, and degradation of natural ecosystems (NatureServe & EcoDecision, 2015; Rodríguez-Echeverry & Leiton, 2021). These impacts may alter the soil accumulation ecosystem service supply, consequently affecting human well-being. In the Rio Mira watershed landscape, studies have been conducted on the diversity of flora and fauna, their conservation status, and the landscape transformation (Aguirre *et al*., 2006; Escribano-Ávila, 2016; Cisneros-Heredia *et al*., 2017; Gómez *et al*., 2017; Reyes-Puig *et al*., 2017; Rodríguez-Echeverry & Leiton, 2021; Arevalo-Morocho *et al*., 2023), but no information on the spatial relationship between biodiversity and soil accumulation ecosystem service that allows us to identify priority areas for the management of both resources. Considering the global, regional, and national importance and the intense human pressure on the Rio Mira watershed landscape, it is necessary to carry out this type of study because it can provide key information to management decisions for both resources.

I identified priority areas for biodiversity and soil accumulation ecosystem service simultaneous management in the Rio Mira watershed. The specific objectives were to i) assess the spatial distribution of biodiversity and soil accumulation service, ii) assess the spatial relationship between both resources, and iii) analyze the spatial congruence between biodiversity and soil accumulation service. I hypothesize that there is a spatial relationship between biodiversity and soil accumulation service, and in consequence, there are areas where simultaneous management of both resources can be carried out.

MATERIALS AND METHODS

Study area

The Rio Mira watershed is located in the provinces of Imbabura, Carchi, and, Esmeraldas, in northern Ecuador (1º16' N and 77º 38' O) (Fig. 1). The watershed occupies approximately 5,267 km^2, has a mean temperature of 21.7°C, and is a topographically diverse area where the elevation ranges from 150 to 3,050 m a.s.l. (Instituto Nacional de Meteorología e Hidrología, 2005). Currently, the watershed consists of crops/grassland 47 %, Forest 33 %, Páramo 10 %, shrub vegetation 5 %, and other land-uses types (water bodies, bare land, agricultural infrastructure, and urban areas) 5% (Sistema Nacional de Información, 2023). The watershed has a human population of 493,743 inhabitants, with a population density of nine people km^{-2}. The main economic activity in the watershed is agriculture (Secretaría Nacional de Planificación y Desarrollo, 2013). The study area was divided into 334 subwatersheds, which (ranging 600 - 6000 ha in size), were identified as the spatial units of analysis. The delimitation of the subwatersheds and all spatial analysis was carried out using the ArcGIS 10.5 (ESRI, 2016).

Analysis of biodiversity

Cost-effective proxies of biodiversity applicable across a range of spatial scales are needed for setting management priorities and planning action. Habitat is an effective proxy for biodiversity at the landscape level. This is a rapid, efficient, and low-cost measure of spectral signal from digital images. This is a proxy for habitat complexity and correlates with the structure and composition of species in the different ecosystems. Therefore, in spatial terms, it is more precise and effective than using ecosystem types (Mellin *et al.,* 2012; Jongman *et al.,* 2019). I analyzed the diversity of natural forest habitats as a proxy for biodiversity at the landscape level. This was determined by the abundance and variety of the natural forest habitats. I determined the different types of habitats by the presence of natural forests in different climatic zones, soil types, and slopes of the terrain (Table 1).

Fig. 1: Location of the Rio Mira watershed, Ecuador

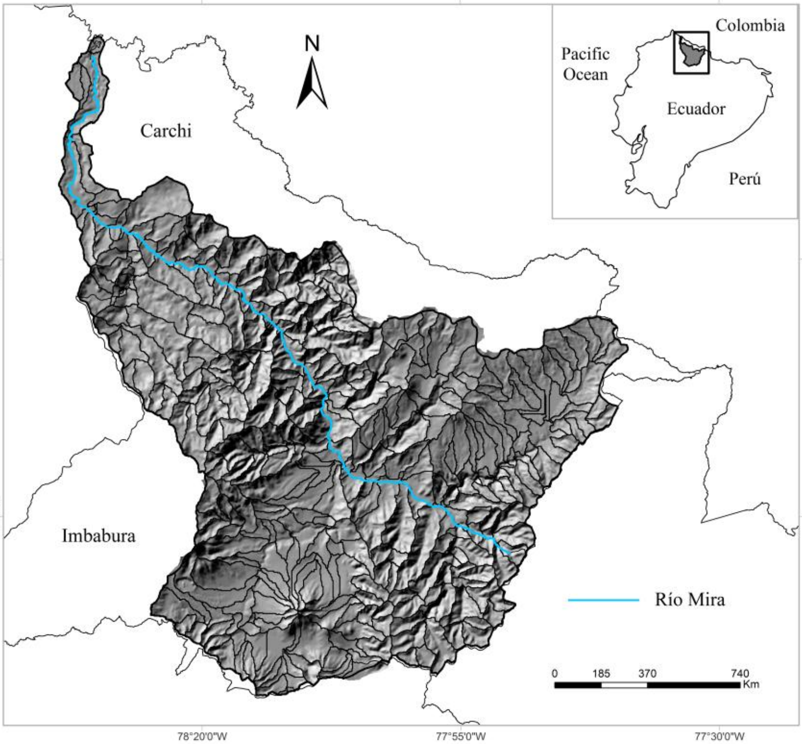


Table 1: Abiotic variables that determined the different types of natural forest habitats

Climatic zone	Soil types	Slope of the terrain (Degrees)
Megathermic or warm	Alfisol	0-15
Mesothermic warm semi	Andisol	15-30
Mesothermic warm temperate	Entisol	30-40
Mesothermic cold temperate	Inceptisol	>40
	Molisol	

Climatic zones determine the type of species (fauna and flora) in the landscape. These zones are defined by the following variables: temperature, moisture, and precipitation (Ministerio del Ambiente del Ecuador, 2013). Soil types determine the establishment of the different types of plant species, due to the morphological characteristics and physical-chemical properties of the soil (FAO-UNESCO, 1971; SIGTIERRAS, 2017). The slope of the terrain allows knowing the location of the different types of vegetation in a landscape (Ma *et al*., 2021). The mapping of natural forest habitats was carried out using the following maps: (1) Map of natural forest, which was extracted from a land-use map for the year 2023 (Leiton *et al*. unpublished results). In this map, the following categories of land-use were identified: Inter-Andean Dry Forest, Thorny Dry Forest, Lower Montane Dry Forest, Montane Rain Forest, Pre-Montane Rain Forest, Lower Montane Moist Forest, Pre-Montane Moist Forest, Lower Montane Very Moist Forest, Very Moist Montane Forest, Very Moist Pre-Montane Forest, Páramo, shrub vegetation, crops/grassland, urban areas, bare land, agricultural infrastructure and water bodies; (2) Map of climatic zones; (3) Map of soil types; and (4) Map of the slope of the terrain. These maps have a spatial resolution of 30 × 30 m pixels and were provided by Sistema Nacional de Información y Gestión de Tierras Rurales e Infraestructura Tecnológica (SIGTIERRAS, 2017). The natural forest habitat map was obtained from the overlap of these maps. The diversity of the natural forest habitats was calculated through the Shannon diversity index using FRAGSTATS software (Mcgarigal *et al*., 2013). This is a landscape index that assesses the abundance and variety of the different habitat types in each spatial unit of analysis. The Shannon diversity index is expressed by the following formula (1) (McGarigal *et al*., 2013):

$$H = -\sum_{i=1}^{s} (pi \text{ x } \ln Pi) \qquad (1)$$

Where P_i is the proportion of the landscape occupied by habitat type “i”.

Soil accumulation ecosystem service

In this research, the coverage of different natural forest habitats and the soil depth were used as proxies for modeling the soil accumulation service. Values of coverage of different natural forest habitats were obtained from the map of native forest habitats, while values of the depth of the soil types were obtained from Sistema Nacional de Información y Gestión de Tierras Rurales e Infraestructura Tecnológica (SIGTIERRAS, 2017). In the modeling, two thresholds of soil depth were used: ≤ 1 m (slightly depth) and > 1 m (depth); these thresholds were based on the literature. This service was modeled using the index of soil accumulation (Egoh *et al*., 2009; Rodríguez-Echeverry *et al*., 2017). This index was calculated for each spatial unit of analysis by weighting the areas of forest coverage and the areas of the different soil types and then dividing this value by the total area of the corresponding spatial unit of analysis. The index of soil accumulation was spatialized for each spatial unit of analysis through the ArcGIS.

Ecosystem services hotspots

Areas that supply large amounts of an ecosystem service are considered hotspots of that particular service (Bai *et al*., 2011; Onaindia *et al*., 2013). The hotspot mapping for soil accumulation ecosystem service was carried out using the map obtained in the modeling. This map was divided into three classes, with the highest value considered as the hotspot of soil accumulation service. The three classes were determined using the Jenks Natural Breaks classification in ArcGIS. Natural Breaks classes identify similar values, generate groups inherent in the data, and maximize the differences among classes (Onaindia *et al*., 2013).

Evaluating spatial congruence

I used geographically weighted regression and overlap analysis to assess the relationship and spatial congruence between biodiversity and soil accumulation service supply.

Geographically weighted regression model

The geographically weighted regression (GWR) allows spatial heterogeneities in processes and relationships to be investigated through a series of local regression models rather than a single global one (Comber *et al*., 2023). GWR can produce a set of local parameter estimates that show how relationships vary in space and allow examination of the spatial pattern of the local estimates for a better understanding of hidden possible causes of this pattern (Fotheringham *et al*., 2017).

The geographically weighted regression model can be expressed by the following formula (2):

$$yi = \beta_0(uj, vj) + \sum_{i=1}^{p} \beta_i(uj, vj)X_{ij} + \varepsilon_j \qquad (2)$$

Where: u_j and v_j are the coordinates for each location j, β_0 (u_j, v_j) is the intercept for location j, β_i (u_j, v_j) is the local parameter estimate for independent variable x_i at location j.

GWR is calibrated by weighting all biodiversity and soil accumulation ecosystem service values around a sample point using a distance decay function. GWR assumes the values closer to the location of the sample point have a higher impact on the local parameter estimates for the location. The weighting function can be stated using the following formula (3):

$$W_{ij} = exp\left(\frac{-dij^2}{b^2}\right) \qquad (3)$$

Where w_{ij} = weight of observation j for observation i, d_{ij} = distance between observation i and j, b = kernel bandwidth.

I used adaptive kernel bandwidth in this study, as the sample density varies over the study area. The adaptive kernel can adapt bandwidths in size to variations in data density so that bandwidths are larger in the locations where data is sparse and smaller where data is denser. The optimal bandwidth was determined by minimizing the corrected Akaike Information Criterion (Comber *et al*., 2023).

I calculated global Moran's I for the residuals to compare the ability to deal with spatial autocorrelation of the GWR models. Moran's I is an indicator of spatial autocorrelation. The value of Moran's I range from −1 to 1. A value of 1 means perfect positive spatial autocorrelation, a value of −1 suggests perfect negative spatial autocorrelation, and a value of 0 indicates perfect spatial randomness (Fotheringham *et al*., 2017). Spatial relationships varying between biodiversity and soil accumulation supply were analyzed in all spatial units of analysis using GWR. The supply of soil accumulation ecosystem service was used as the dependent variable, while biodiversity was the independent variable. GWR analyses, Moran's I values, and mappings were conducted using ArcGIS 10.5 (ESRI, 2016).

Overlap analysis

The spatial overlap or shared area between two resources is expressed as a percentage of the area of the resource with the smaller total area (Egoh *et al*., 2009). I used the proportional overlap as a measure of overlap between the biodiversity and soil accumulation hotspots. This overlap was calculated through the maps of biodiversity and soil accumulation hotspots using ArcGIS. The area of soil accumulation hotspot that overlapped with biodiversity was estimated and expressed as a percentage of the total area of the hotspot.

RESULTS

Biodiversity

In the Rio Mira watershed, the ten natural forest ecosystems were spatially distributed across the landscape (Fig. 2). These ecosystems recorded a total of 175 types of natural forest habitats (Table 2). The Inter-Andean Dry Forest (30), Lower Montane Dry Forest (21), Thorny Dry Forest (20), ecosystems registered the highest number of types of habitats, while the Pre-Montane Rain Forest (12) and Montane Rain Forest (6) ecosystems reported the lowest number of habitat types (Table 2). In the 334 subwatersheds the Shannon diversity index ranged from 0.50 to 2.87.

Fig. 2: Spatial distribution of natural forest ecosystems in the Rio Mira watershed, Ecuador

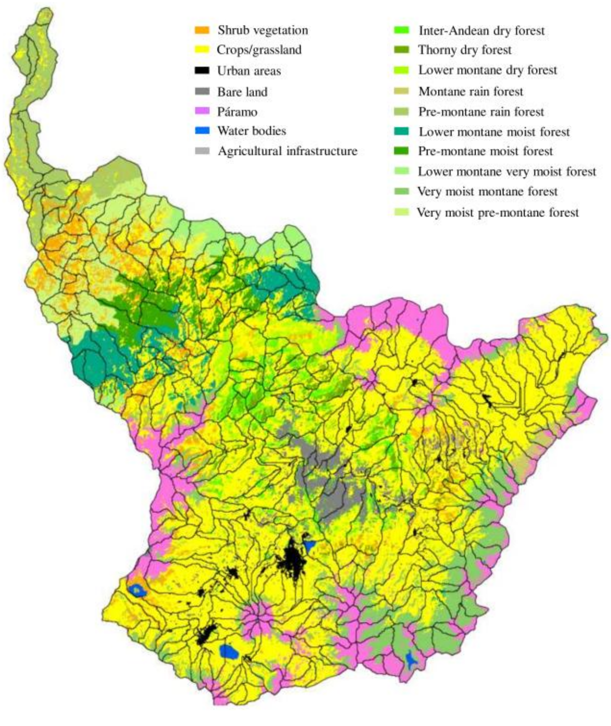


Table 2: Types of natural forest habitat and their area in hectares in the Rio Mira watershed

	Natural forest type									
Habitat type	Inter-Andean Dry Forest	Lower Montane Dry Forest	Thorny Dry Forest	Very Moist Montane Forest	Lower Montane Very Moist Forest	Very Moist Pre-Montane Forest	Pre-Montane Moist Forest	Lower Montane Moist Forest	Pre-Montane Rain Forest	Montane Rain Forest
I	35	73	19	1.3	355	953	48	987	5	660
II	0.5	206	13	2	1,641	1,427	764	298	512	1
III	99	185	156	6	138	422	580	749.6	10	22
IV	24.5	383	32	1	320	91	1,571	27	1,426	2,599
V	272	397	81	0.3	117	31	888	2,504	1,3188	13
VI	91	25	16	1	152	5,543	75	3682	10	25
VII	1.1	127	2	1.2	1,344	9462	5,120	440	2,024	
VIII	285	96	178	1	109	3,061	1,038	21	34	
IX	6.4	116	0.8	1.5	186	2,533	3,212	4,313	2	
X	286	172	116	37	95	67	1046	781	3,766	
XI	9	42	15	13,428	1,673	30	34	540	59	
XII	10	5	151	1,787	316	58	10	186	166	
XIII	143	85	654	1,8867	469	76.5	56	3,942		
XIV	37	17	1226	3,240	34	709	0.3	2,601		
XV	381	1,923	270	17,110	1,920	754	191	396		
XVI	118	308	1,687	1,210	316	1	26	278		
XVII	12	258	315	1,652	359	188	114			
XVIII	1,448	704	1,011	3,010	61					
XIX	229	242	145							
XX	1,036	103	1,366							
XXI	10.3	578								
XXII	578									
XXIII	1,709									
XXIV	339									
XXV	2,694									
XXVI	845									
XXVII	439									
XXVIII	2,005									
XXIX	343									
XXX	3,276									

Spatial distribution and spatial relationship

Biodiversity and soil accumulation hotspots registered differences in spatial distribution across the landscape. Biodiversity registered their distribution in the high, middle, and low parts of the watershed, while soil accumulation hotspots reported more than 70 % of their distribution in the lower part of the watershed (Fig. 3). The local parameter estimate was positive for the supply of soil accumulation service. The positive relationship between biodiversity and soil accumulation supply were registered in 98 % of the subwatersheds studied (Fig. 3). Regarding local R^2 value, biodiversity can explain up to 92 % of the variance in the supply of soil accumulation ecosystem service (Fig. 4). Standardized residuals for the model ranged from -1.52 to 1.67 (Fig. 3). The result of Moran´s I statistics was -0.02 ($P < 0.05$), which shows there are no significant spatial autocorrelations in the residuals. Consequently, the geographically weighted regression model is efficient. The soil accumulation hotspot reported the largest area in the landscape (43.4 %), while the biodiversity hotspot area was 26.4 %. Biodiversity and soil accumulation hotspots registered an overlap of 52.5 % (Fig. 4). The study landscape registered 10 % of subwatersheds (33) with spatial overlaps between the biodiversity and soil accumulation hotspots (Fig. 5).

Fig. 3: Spatial distribution of biodiversity and soil accumulation ecosystem service hotspots in the Rio Mira watershed, Ecuador. The "high class" correspond to the hotspots

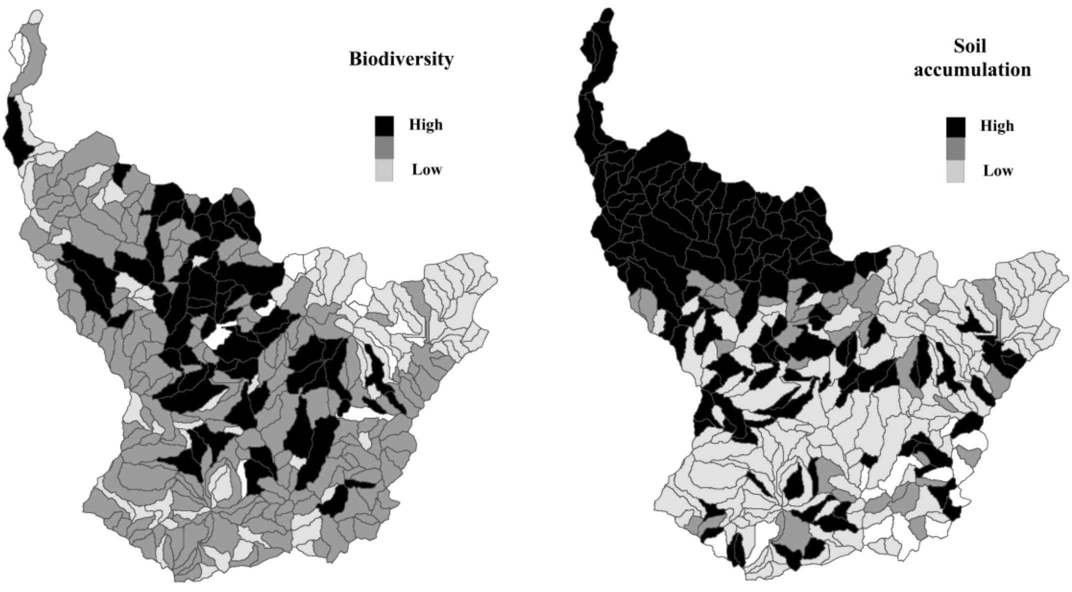


Fig. 4: Spatial patterns of local R2, standardized residuals (StdResid), and local parameter estimation obtained from geographically weighted regression model between biodiversity and soil accumulation service

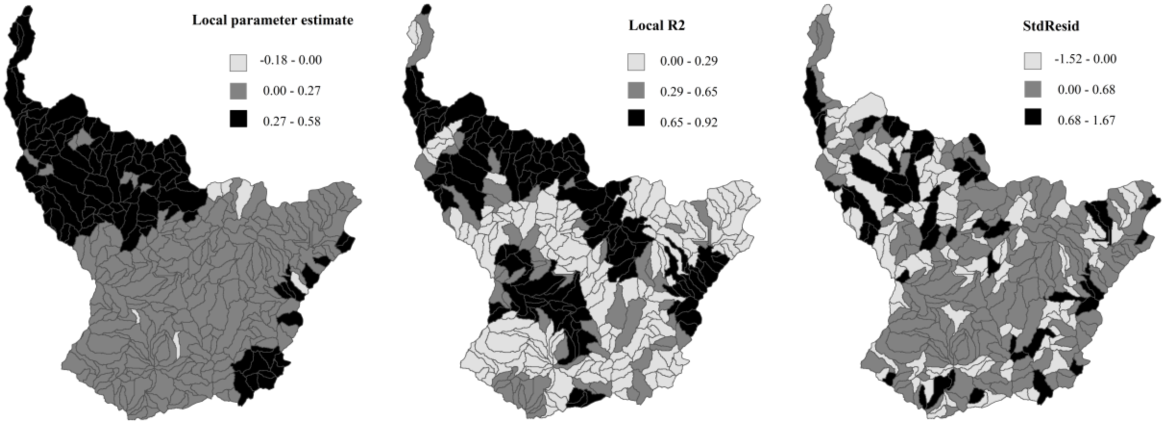
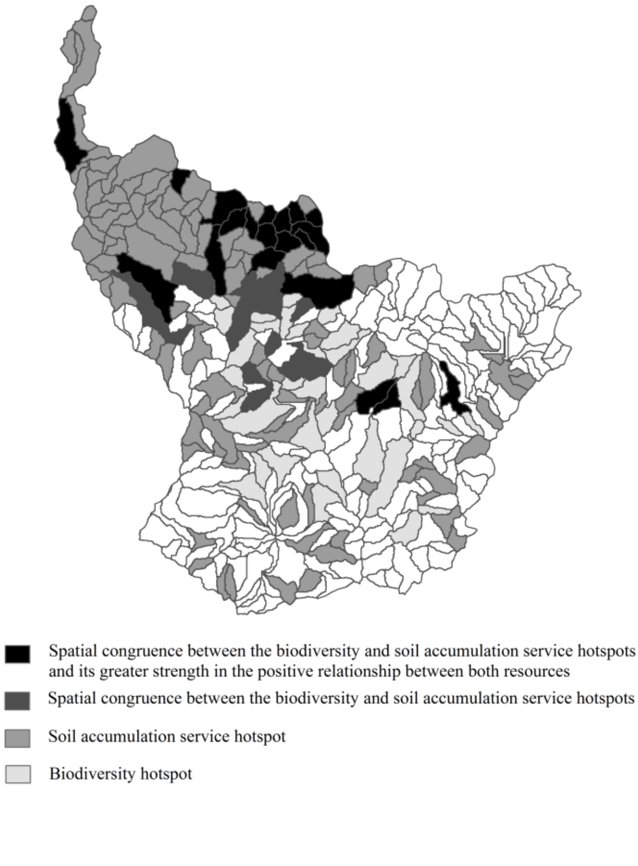


Fig. 5: Spatial congruence between biodiversity and soil accumulation ecosystem service hotspots in the Rio Mira watershed, Ecuador



DISCUSSION

The diversity of natural forest habitats was used as a proxy for biodiversity. This is a suitable proxy across a broad spatial scale because it provides effective information for setting management priorities and planning action. Studying habitat diversity as a proxy for biodiversity provides more detailed spatial information at the landscape level than studying ecosystem diversity (Jongman *et al.,* 2019). A single ecosystem type can record the presence of several habitat types because it can occupy different climatic zones, soil types, and terrain slopes. Therefore, different habitat types are nested within a single ecosystem type (Mellin *et al.,* 2012). Consequently, habitat type is the smallest spatial unit considered a proxy for biodiversity at the landscape level. On the other hand, both researchers and decision-makers confront difficulties when addressing issues that underlie efforts to manage biodiversity and ecosystem services for the forests. These difficulties mainly lie in the spatial scale. Studying a process at a fine scale does not necessarily explain what happens over larger areas (Bunnell & Huggard, 1999; Romport *et al.,* 2008). So that research at the fine spatial scale does not contribute to maintaining the complexity and diversity in the ecosystems, because it creates management problems when they are transferred to broad-scale management (Jongman *et al.,* 2019). The present study was conducted at a broad spatial scale. This spatial scale allowed the study of the relationship between the diversity of natural forest habitats and the provision of the soil accumulation service without simplifying the complexity of this relationship. Consequently, this spatial scale contributed to the identification of priority areas for the management of both resources, which provides effective information for decision-making.

Identifying the spatial distribution of biodiversity and ecosystem services on the landscape is critical for their management (Turner *et al.,* 2014; Lin *et al.,* 2018). I identified areas where biodiversity co-occurs with soil accumulation service supply. These areas provide opportunities for the simultaneous management of both resources. These opportunities exist mainly in the lower parts of the watershed, where a large distribution of soil accumulation hotspots overlaps with biodiversity hotspots. Besides, the findings indicate that the relationship between biodiversity and soil accumulation service varies spatially, which can depend on the extent of anthropogenic land use (Arévalo-Morocho *et al*., 2023). These results imply an intensive task for its management, which should focus efforts on areas where biodiversity and soil accumulation overlap.

I observed a positive spatial relationship between biodiversity and soil accumulation ecosystem service in 98 % of the subwatersheds studied. On the contrary, the subwatersheds that report a negative spatial relationship are conflict areas that do not supply soil accumulation as a rationale for biodiversity management. This positive spatial relationship is similar to that reported by Egoh *et al.* (2009), Rodríguez-Echeverry *et al.* (2017) and Lin *et al.* (2018), who also found a strong evidence base supporting a positive relationship between different components of biodiversity and soil accumulation supply. Managing based on spatially explicit relationships between biodiversity and ecosystem services can strengthen landscape resilience, enhance the supply of multiple services, and help avoid their losses (Turner *et al.,* 2014; Karimi *et al.,* 2020). The findings of this study can contribute to management planning to maintain and increase biodiversity and the supply of soil accumulation services.

The spatial congruence between biodiversity and ecosystem services varies among landscapes depending on the presence of vegetation, the climate, the soil types, and the slopes of the terrain (Turner *et al*., 2007; Fastré *et al.,* 2020). The studied landscape reported a high diversity of natural forest habitats distributed heterogeneously across the landscape. The findings indicate a moderate spatial congruence (52.5 %) between biodiversity and soil accumulation service hotspots, which is similar to those registered in other biodiversity hotspots (Chan *et al*., 2006; Egoh *et al*., 2009; Morelli, *et al*. 2017; Rodríguez-Echeverry *et al.,* 2017). These results indicate that management efforts for both resources should be focused on areas of spatial congruence. It is important to highlight that there may be conflicts between biodiversity management actions and the management actions that would promote the supply of soil accumulation service in the areas that reported spatial congruence. Consequently, it is necessary to carry out research that allows an understanding of the compatibility between management efforts for biodiversity and soil accumulation services in the studied landscape.

The results indicate that 33 subwatersheds (10 % of the subwatersheds studied) registered a greater strength in the positive relationship between biodiversity and soil accumulation service and spatial congruence between their hotspots (Fig. 5). I suggest that simultaneous management efforts for both resources in these 33 subwatersheds should focus on conservation. This type of management must be carried out in the absence of human activity to protect natural forest habitats, their natural processes, biological diversity, ecosystem services, and human well-being. Moreover, these 33 subwatersheds would be key areas for performing scientific studies, education, and environmental monitoring. In addition, I suggest that the management efforts should also focus on ecological monitoring and protection because these areas are of special importance to prevent the decrease of both resources. This type of effort can generate opportunities to align biodiversity management with the sustainable supply of soil accumulation service.

CONCLUSIONS

My study addressed the challenge of identifying priority areas for biodiversity and soil accumulation ecosystem service simultaneous management in the Rio Mira watershed, located within Tropical Andes and Tumbes-Chocó-Magdalena hotspots. I identified that spatial congruence between biodiversity and soil accumulation hotspots was mainly recorded in the low-lying areas of the watershed. I found that 10 % of subwatersheds have a high priority for the simultaneous conservation of biodiversity and soil accumulation supply. Therefore, the management efforts for biodiversity and soil accumulation service should be focused on these areas. These simultaneous management efforts will allow the optimization of monitoring, conservation, and protection strategies and capital investment. These findings can contribute to land use planning, in which the spatial relationship between biodiversity and the soil accumulation service should be considered the central axis.

The findings of this study provide an integrated approach to management, which provides a win-win situation and decreases the cost. Consequently, it can contribute to the simultaneous management of biodiversity and soil accumulation service in this globally important biodiverse region. Also, it provides key knowledge that can contribute to the development of environmental policies. Finally, this study provides a broader understanding of the complex spatial relationship between biodiversity and the soil accumulation ecosystem service at the landscape level.

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CONFLICT OF INTEREST

The authors declare that they have no competing interests.

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