Description of Ecosystem Benefits Indicators in San Martín, Peru

Introduction

The Ecosystem Values and Accounting (EVA) program, funded by the Gordon and Betty Moore Foundation, was developed to pilot ecosystem accounts, with the first case study in the region of San Martín, Peru. This case study was led by Conservation International (CI) in close partnership with the Government of Peru and other partners and has produced quantitative results measuring ecosystem stocks and flows (ecosystem services) in the region over time. Many of the indicators used in the ecosystem accounts are spatially explicit, and therefore they can be usefully applied for landscape planning.

Description of indicators

To develop ecosystem benefits indicators (EBI) we transformed each key indicator from the EVA's ecosystem accounts into a benefit measurement (Table 1). A summary of methods for the generation of each indicator can be found below—for full description consult the EVA Technical Report that was uploaded in *Blackboard*. In all cases, the indicators were rescaled linearly from 0 to 1 using the *Rescale by Function* tool in ArcGIS. The indicators were rescaled this way so that benefits which are measured in different units could be consistently compared. The resulting EBI layers shows the relative ranking of ecosystem benefits from 0 to 1 with low values representing areas with lower relative benefit and higher values representing areas with higher relative benefit for species conservation and/or for humans.

Table 1: Ecosystem Benefits Indicators.

Key indicator	Method	Measured benefit	Account type	Figure
Loss of natural ecosystems	Forest types classification and interpretation of satellite imagery	Places with the highest forest type loss provide most benefits.	Extent	1
Intactness of natural ecosystems	Fragmentation analysis	Least fragmented or least change in configuration of forest cover provides most benefits.	Condition	2
Biodiversity composition	Generalized dissimilarity modelling	Most unique places of biodiversity composition and highest loss in the past provide most benefits.	Condition & Biodiversity	3
Threatened species	Key Biodiversity Areas (KBA)	Globally important sites for threatened species provide most benefits.	Biodiversity	4
Water stress at current rate of water use	Ratio of water balance and water use data	Places of highest water dependence with least	Ecosystem Services supply and use	5

		water yield provide most benefits.		
Maximum water supply	Water balance model	Places of highest water yield/potential provide most benefits.	Ecosystem Services supply and use	6
Prevention of erosion	Sedimentation model	Places where natural ecosystems prevent erosion, compared to a bare earth scenario, have the highest value	Ecosystem Services supply and use	7
Sediment retention	Sedimentation model	Place where natural ecosystems contributes to the retention of sediment, high value indicate greater benefit	Ecosystem Service supply and use	8
Carbon density (climate regulation)	Remotely sensed dataset on above-ground forest Carbon (Asner et al. 2014)	Places with the highest carbon density values provide most benefits.	Ecosystem Services supply and use	9
Location of sites for ecotourism	Government	Presence of sites used for ecotourism provides most benefits.	Ecosystem Services supply and use	10
Firewood provision	Firewood provisioning model	Places where people collect the most firewood from provide the most benefits	Ecosystem Services supply and use	11

Loss of natural ecosystems (Figure 1)

The indicator was derived from the ecosystem extent account and represents the percentage of natural ecosystems that have been lost from their original extent compared to the observed ecosystem extent in 2013. The map of original extents of ecosystem types were modeled using bio-climatic variables (evapotranspiration and precipitation), physiognomy of the vegetation (forest, palm, scrub, and bush), and characteristics of terrain (altitude and slope), and supplemented with information on existing inventory of plants (MINAM 2012). To generate the loss of ecosystems indicator the percentage loss of each ecosystem was calculated, and the value was assigned to all remaining pixel of that ecosystem type. The percentage loss varied from as low as 0.22% in Shrub Thickets to as high as 63.09% in Floodplain Forest. For a complete description of the ecosystem types included in the ecosystem extent account, refer to Table 3 of the EVA Technical Report. The percentage loss was assigned to each ecosystem type and the resulting was rescaled from 0 to 1. In this indicator, high values represent ecosystems that have lost a greater percentage of their original extent, meaning that remaining areas of that ecosystem are providing greater benefits. This is useful for prioritizing management and ensuring that a habitat type is factored into decision making.

Intactness of natural ecosystems (Figure 2)

The intactness indicator refers to the level of fragmentation within the landscape or the lack thereof. Fragmentation is the change in spatial configuration of ecosystems resulting from habitat loss (Esterguil and Mouton, 2009). When habitat is fragmented it can: 1) reduce the amount of remnant habitat; 2) increase the number of habitat patches; 3) decrease the size of habitat patches; 4) increase the isolation of habitat patches; and 5) increase the number of perforations within habitat patches (Esterguil and Mouton, 2009). The fragmentation analysis was constrained only to the remaining natural forest habitats. It is represented by a fragmentation index that was calculated using both information on the level of fragmentation in the landscape and the physical configuration of the forest. In the intactness indicator, higher values represent greater levels of intactness, which has been shown to strongly related to ecosystem function and therefore greater ecosystem benefit.

Biodiversity indicators (Figures 3 and 4)

In San Martín, biodiversity is one of key services that ecosystems provide for the ecotourism and orchid trade sectors. The benefit of biodiversity in the EBI is measured in two ways: using a Generalized Dissimilarity Model (GDM) and the internationally recognized Key Biodiversity Areas (KBAs). Generalized Dissimilarity Modeling (GDM) (Ferrier et al., 2007) is a community-level modeling approach that allows differences in environmental conditions to be represented in terms of their effect on species composition for whole biological groups. It is then possible to compare the expected ecological similarity of any location with all other locations in modeled environmental space. This allows the environmental uniqueness of a location, and its contribution to regional biodiversity, to be assessed. Using this approach, it is then possible to determine the impact of anthropogenic land degradation on the long-term persistence of biodiversity (Allnutt et al., 2008, Ferrier et al., 2004). Three GDM were generated in San Martín, representing vertebrates, invertebrates, and vascular plants. The three GDM were averaged to create a single GDM indicator for biodiversity. The resulting indicator was scaled from 0 to 1 with higher values representing greater levels of local biodiversity and lower value representing lower levels of biodiversity. Key Biodiversity Areas (KBAs) are places of international importance for the conservation of biodiversity. They are identified nationally using simple, standard criteria, based on their importance in maintaining species populations (Langhammer et al., 2007). The KBAs used in this analysis were developed as part of the ecosystem profiling process by the Critical Ecosystem Partnership Fund and a description of the methods used can be found in CEPF (2015). A total of ten KBAs were identified in San Martín. For the purpose of incorporating KBAs into an index, KBAs were reclassified so that areas within the KBAs had values of 1 and areas outside the KBAs had values of 0. Due to the Boolean nature of the KBA indicator, it is recommended, that it be given a lower weight in the weighted summary analysis to avoid over influencing the outcome.

Water stress at current use and maximum water supply indicators (Figures 5 and 6)

In San Martín, fresh water is a critically important benefit that ecosystems provide to people. The supply and use of fresh water are represented by two indicators; 1) maximum water supply, and 2) water stress at current use. The maximum water supply provided by ecosystems in San Martín was derived from an estimate of annual water balance. As such we considered annual water balance, consisting of surface and ground water runoff originating from ecosystems, to be equal to the maximum capacity of ecosystems to supply flows of fresh water to water bodies (such as rivers, streams, lakes, and dams). The estimation of water balance (mm year^{-1}) was realized by running a process-based, spatially distributed, hydrological model within the WaterWorld modeling framework[1]. For this indicator higher values represent areas that generate more fresh water, therefore, greater potential ecosystem benefit; meaning that the provision of fresh water provided by ecosystems continues to produce the service regardless of whether or not those services are being consumed. This distinction is important to consider when thinking about the future provisioning of services and the long-term sustainability of the system. The second freshwater indicator is the water stress at current use. This indicator is calculated by dividing the current water use by downstream users by the maximum water supply (see above). The current water use from water bodies is measured using annual water allocation for different sectors derived from data supplied by the National Water Authority (ANA). The data are organized by the government into two separate tables based on the type of water use: non-agricultural use and agricultural used. However, in many cases the water allocations were not complete for agricultural uses and needed to be supplemented by estimated water allocations to agricultural areas for rice, based on area estimate from satellite imagery and official government allocation estimates. This information was used to spatially map both agricultural and non-agricultural water use in San Martín. After the total water use was estimated, it was divided by the water availability (maximum water supply). The resulting indicator represents areas in which the water resources that ecosystem provide are being consumed. Higher values indicator areas of higher water stress or areas that are being used at their maximum capacity, while low values represent areas that are not currently under stress or are not being used heavily. The water stress at current use indicator is a realized ecosystem benefit, meaning that the value of this indictor is directly related to the consumption of the service that it provides.

Avoided erosion and sediment retention indictors (Figures 7 and 8)

Avoided erosion and sediment retention are two important regulating services that ecosystems can provide. The sediment retention and erosion prevention indicators were calculated using a sediment regulation model and represent the places where natural ecosystems either reduce erosion or trap sediment. To calculate sediment erosion and deposition across the landscape the Unit Stream Power Erosion and Deposition (USPED; Mitasova et al., 1996) model was used. To determine the contribution of natural vegetation to retain sediment and prevent erosion the model was applied twice: 1) for a scenario with the most recent map of vegetation cover, i.e., 2013, and 2) for a hypothetical scenario in which natural vegetation has been removed, referred to here as the 'bare soil scenario'. In the resulting output, positive values represent areas that experience erosion and negative values are the areas that experience retention. The erosion prevention indicator was calculated by taking only the positive values (erosion) from the bare soil scenario and subtracting the positive values from the actual 2013 vegetation scenario. The resulting map shows areas that have lower level of erosion due to the presence of natural vegetation types. The sediment retention indicator on the other hand looks at the changes in sediment retention (negative values) in the USPED model output. Therefore, to obtain sediment retention indicator the absolute values of only the negative values from the bare soil scenario were subtracted from the absolute value of the negative values from the 2013 vegetation scenario. The resulting map

[1] http://WaterWorldModel.org/

shows areas were natural vegetation contributes to the retention of sediment. In both the erosion prevention and sedimentation retention indicators high values represent the sediment regulation benefit provided by natural ecosystem.

Carbon density for climate regulation (Figure 9)

The storage and sequestration of carbon by natural ecosystems is a globally important service for climate regulation. Carbon storage refers to the amount of terrestrial carbon that is stored in natural ecosystems. In the San Martín Ecosystem account carbon storage and change in carbon stock was represented using only the above ground biomass. Carbon sequestration is the accumulation of carbon, through vegetation growth and reforestation, in natural ecosystems, and was not accounted for in the San Martín Ecosystem account due to a lack of data. In the ecosystem account carbon storage was estimated for each natural ecosystem based on the area of that ecosystem and the carbon density (t ha^{-1}). For the purpose of the San Martín Ecosystem Account, the carbon density data was generated by the Ministry of the Environment of Peru with a precision level of tier 2 of IPCC GPC 2006 (MINAM, 2014). However, for the carbon density indicator, a remote sensing derived above ground carbon map was used (Asner et al. 2014) providing continuous above ground carbon density map. This carbon map was masked to natural ecosystems in 2013. High values represent areas with the greatest carbon storage, providing the most benefits for climate regulation.

Location of ecotourism sites (Figure 10)

The department of San Martín is home to several popular tourist sites. A government database with the spatial coordinates of tourism sites was used to identify the key locations of tourism activities. The database included all forms of tourism and needed to be filtered so that it reflected only nature-based tourism, referred to as ecotourism in the Ecosystem Account. The ecotourism site in San Martín were primarily clustered in 3 distinct patches. To represent the natural areas that tourists are likely to visit at each ecotourism site a 5 km buffer was drawn around these three distinct patches. There were few points which fell outside of the three patches, these were also included as individual sites and a similar 5 km buffer was applied. The ecotourism indicator is a Boolean variable, meaning that it only records the presence or absence of ecotourism, similarly to the KBA layer. Therefore, it is recommended that a lower weight is applied to the ecotourism indicator so that it does not overly bias the results.

Firewood provision (Figure 11)

Firewood provisioning was found by the EVA project to be the most economically valuable ecosystem service in San Martín. In Peru, 65.5% of rural households, on average, used firewood as a source of energy between 2003 and 2012 (ENAHO). Given the importance of firewood and the need for natural ecosystems to provide it, it was included in this set of indicators. The extraction of firewood in San Martín was quantified in two ways: 1) by modeling spatial patterns of firewood extraction; and 2) by modeling which ecosystems are the likely sources of extracted firewood. The modeling approach identified the areas that are most likely to be exploited for firewood collection. In this indictor high values represent areas that are more heavily used for firewood provisioning and therefore provided greater benefit.

Figure 1 – Loss of natural ecosystems

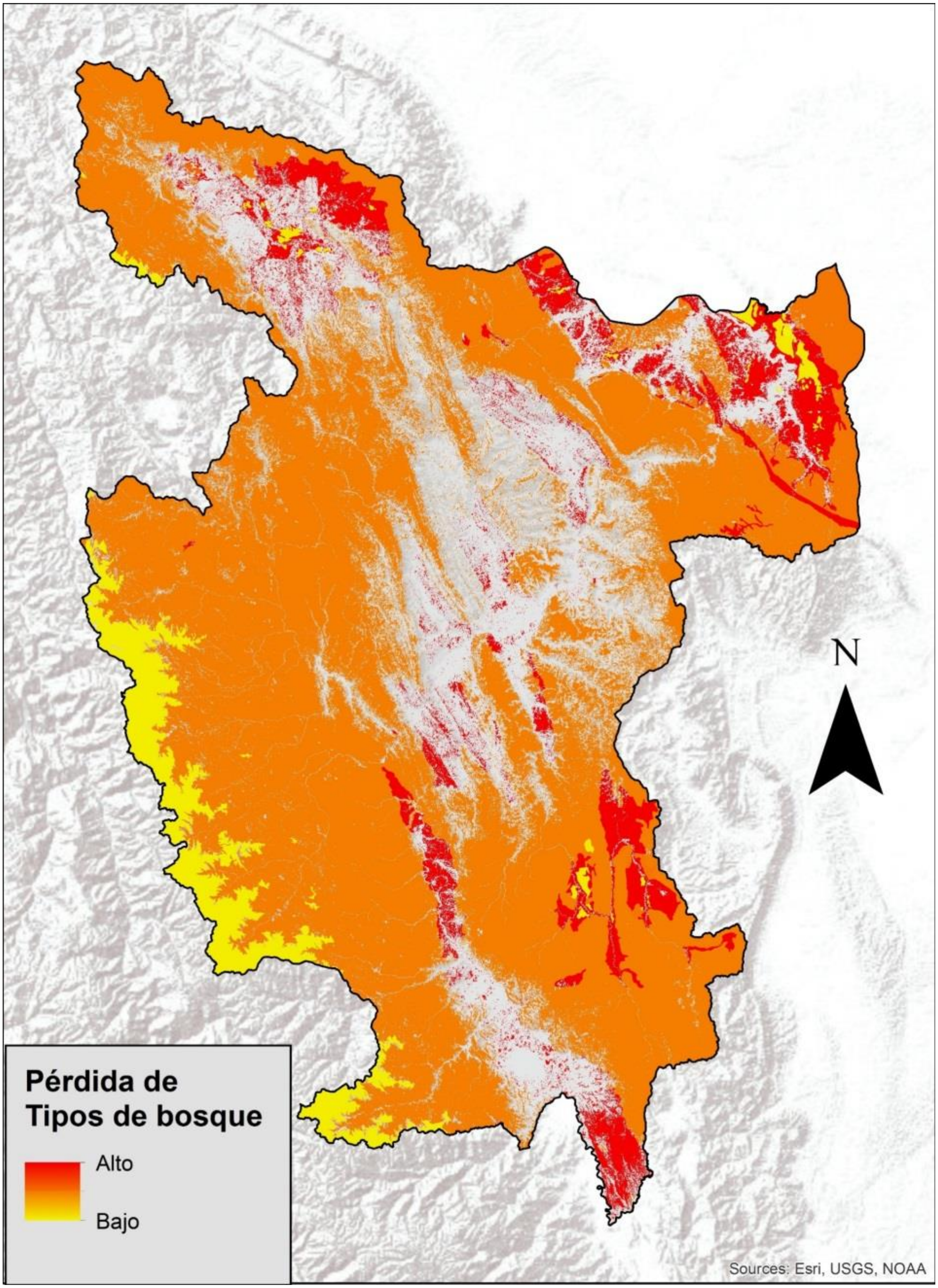

Figure 2 – Intactness of natural ecosystems

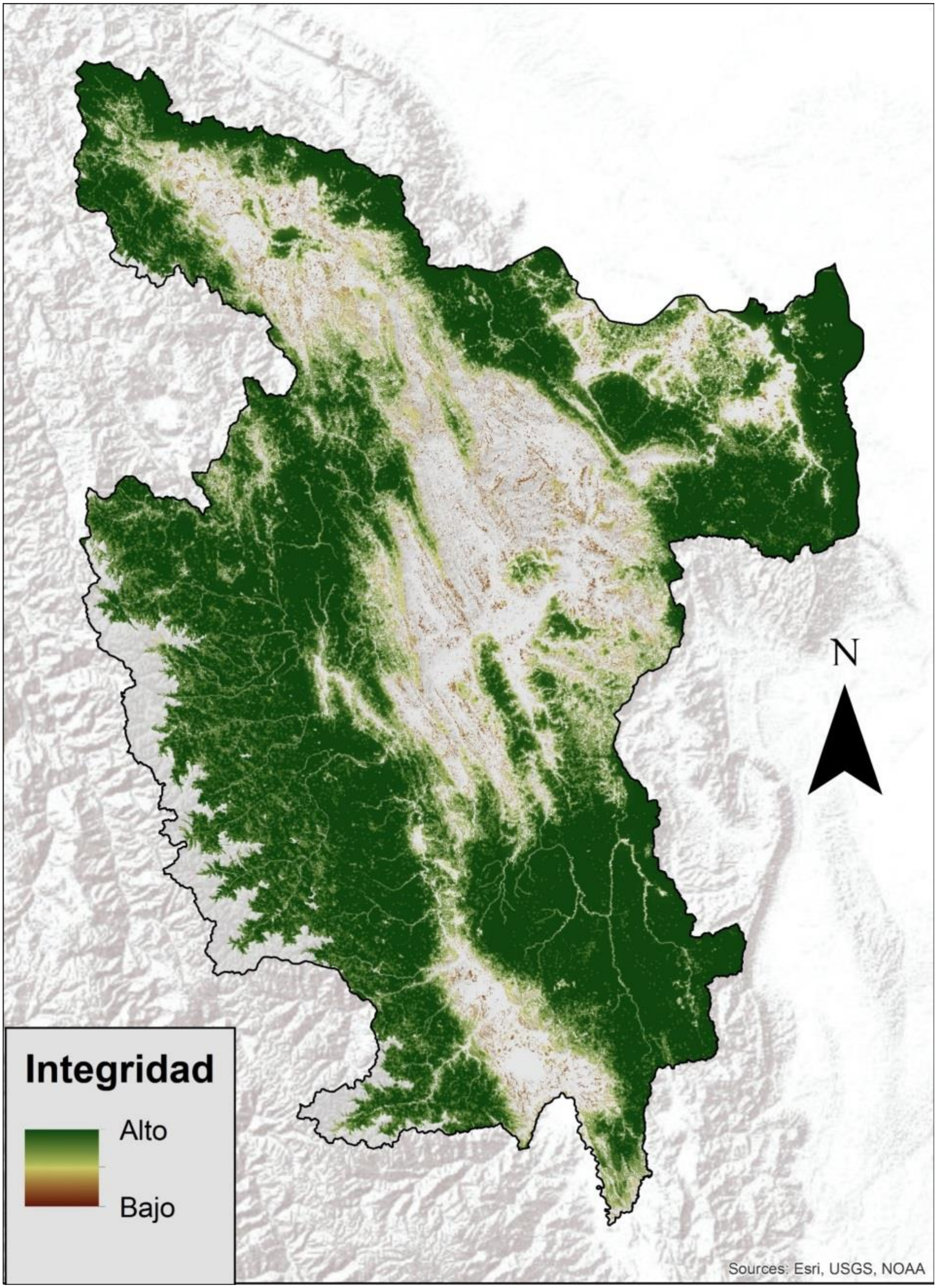

Figure 3 – Composition of biodiversity

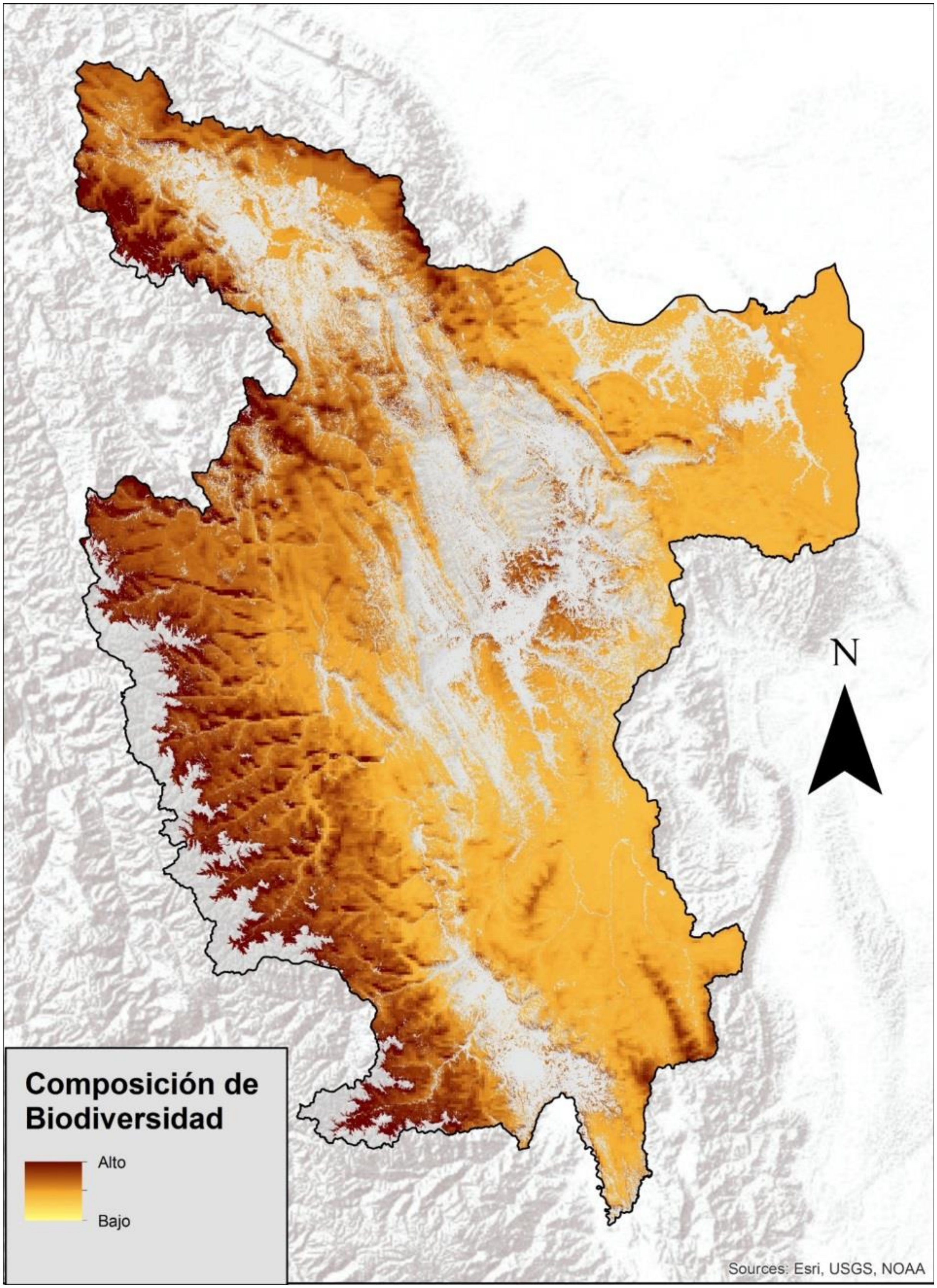

Figure 4 – Threatened species (KBAs)

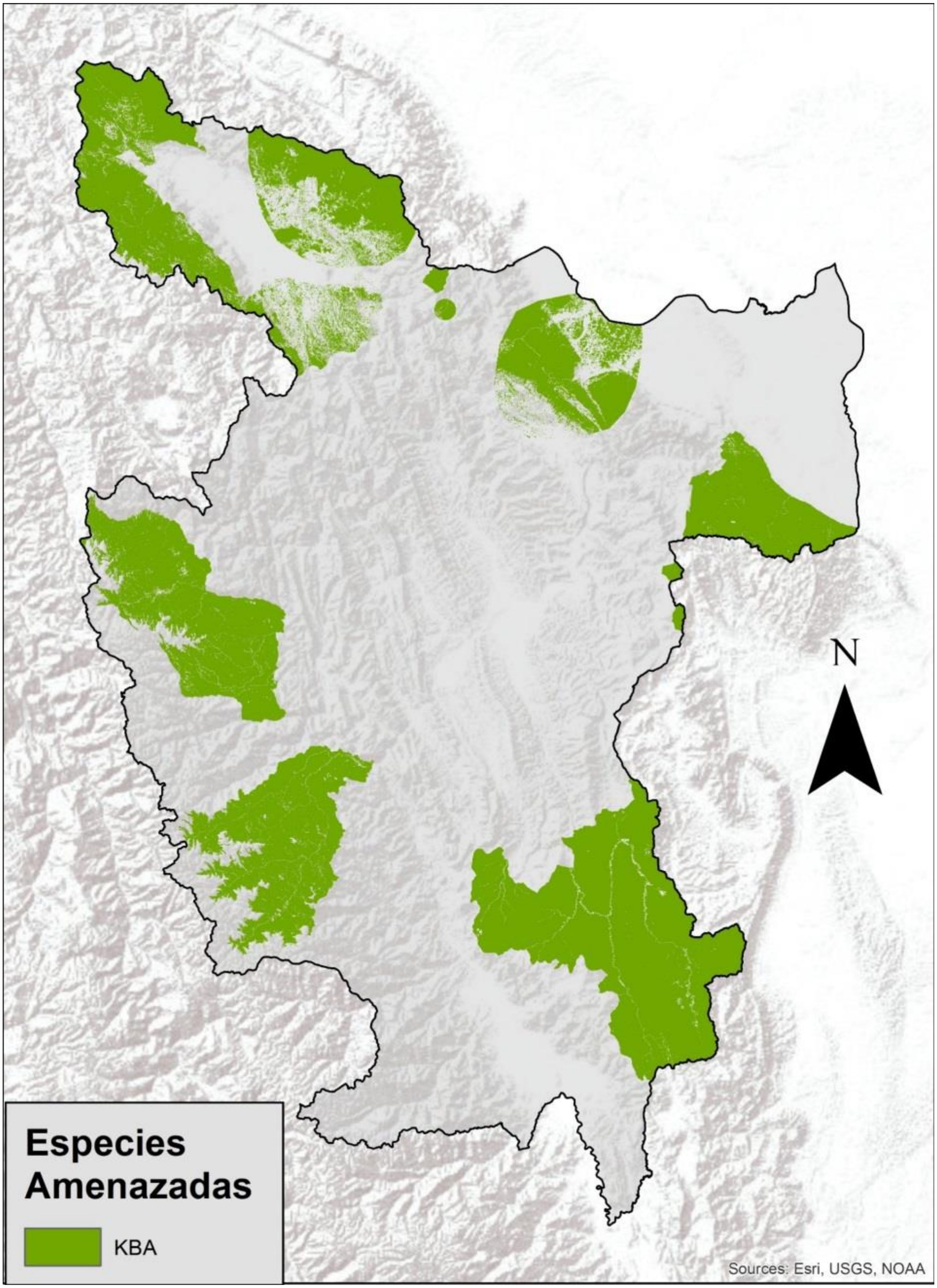

Figure 5 – Water stress

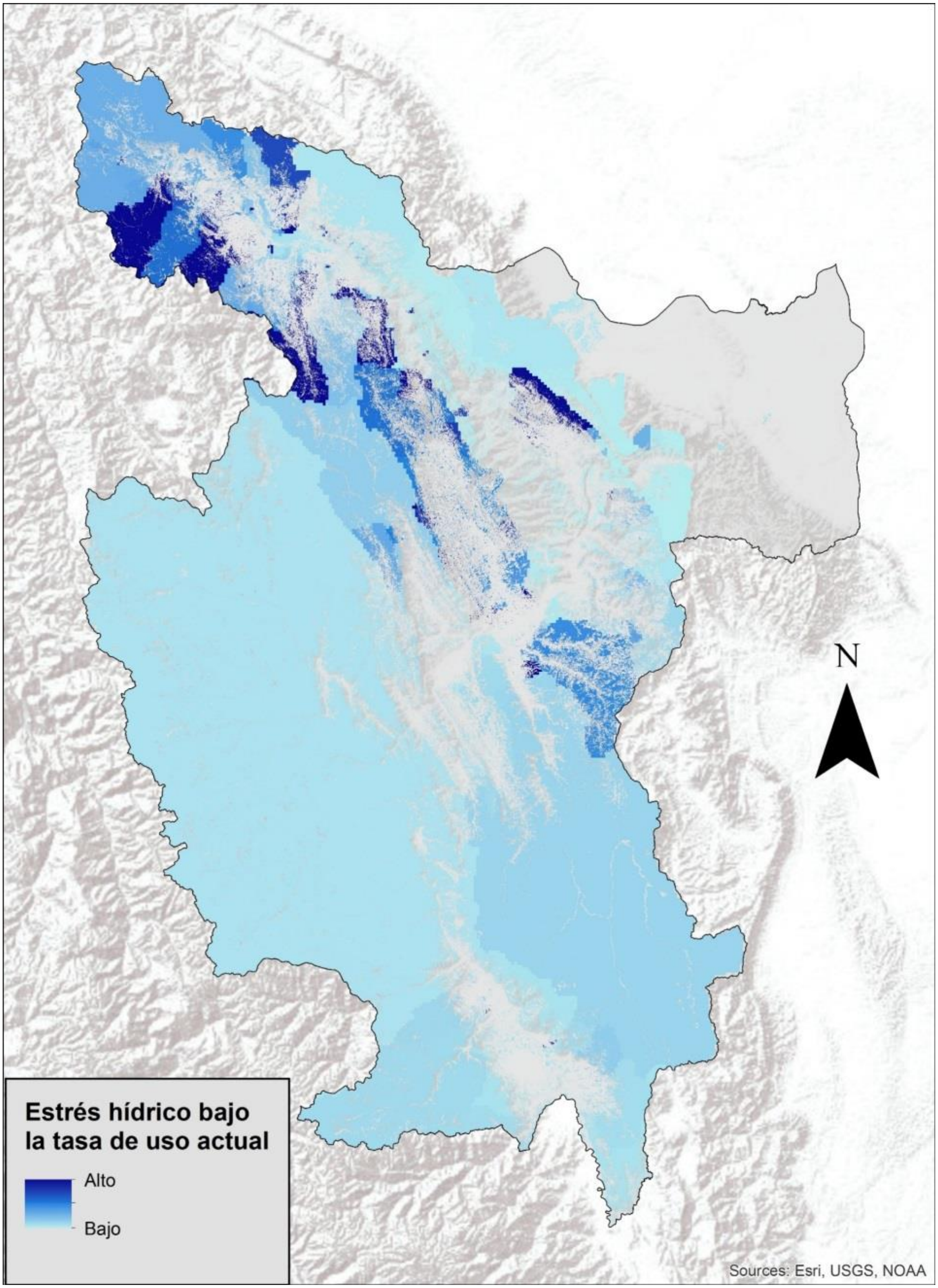

Figure 6 – Maximum water supply

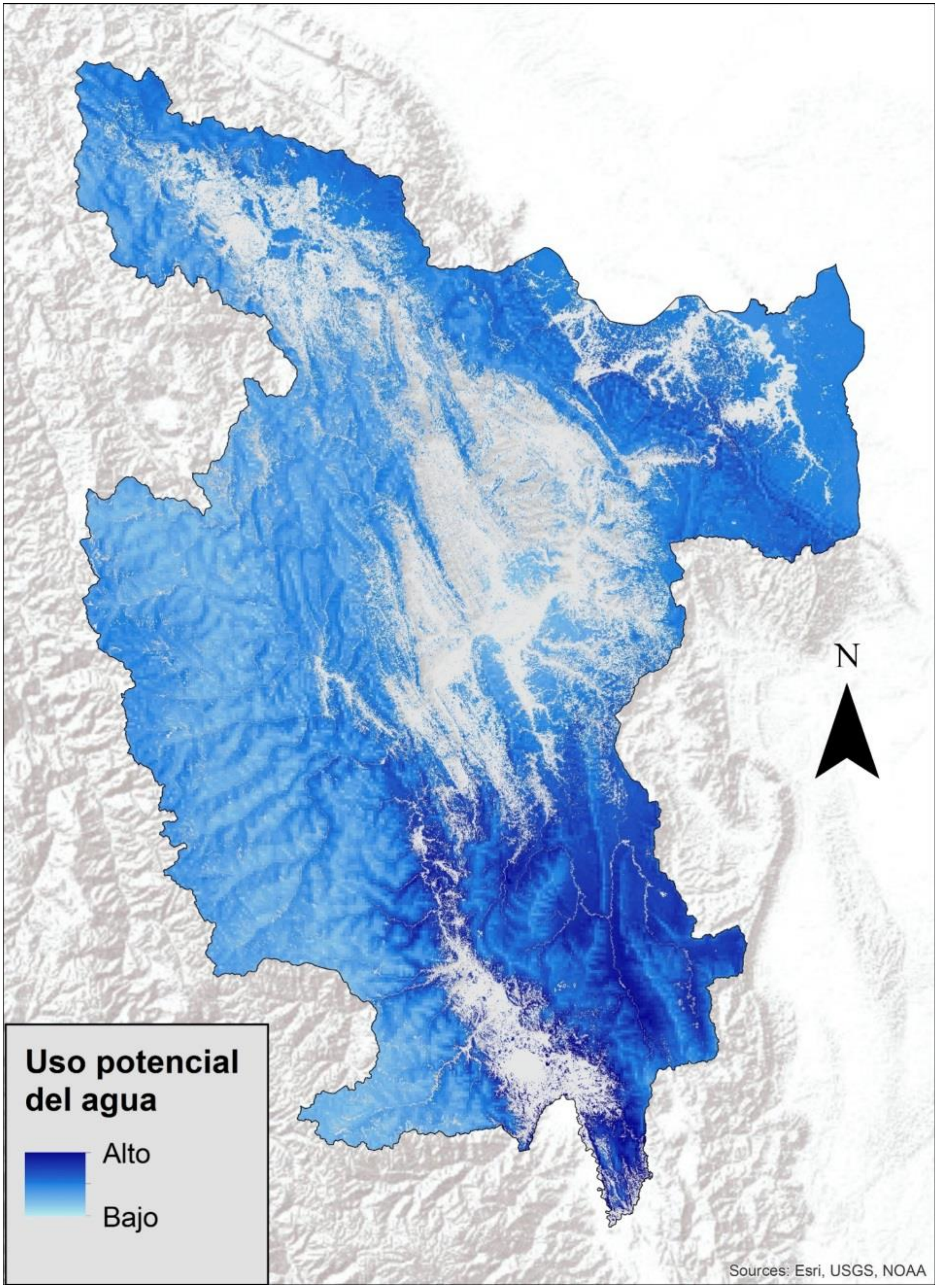

Figure 7 – Prevention of erosion

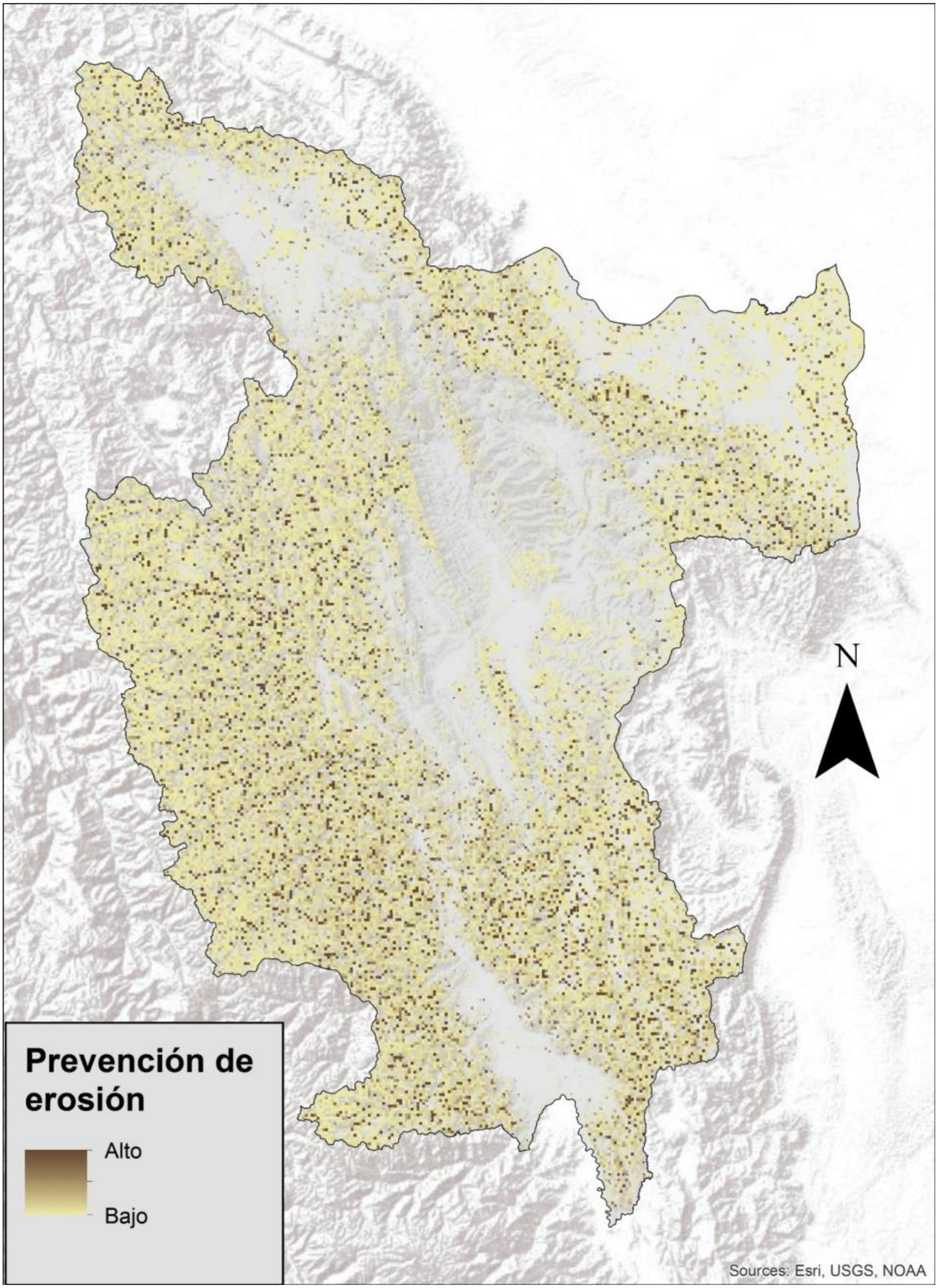

Figure 8 – Sediment retention

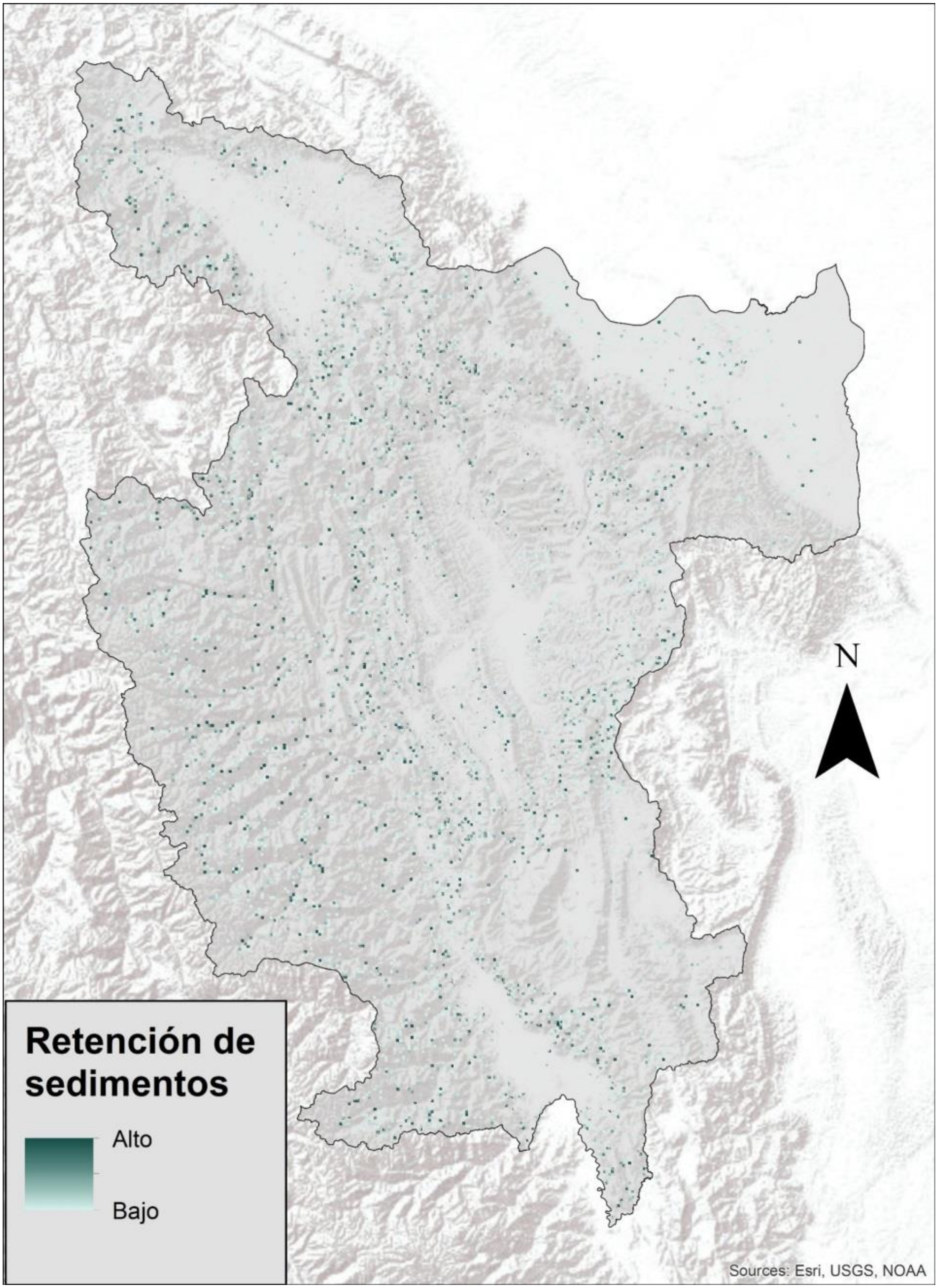

Figure 9 – Carbon density

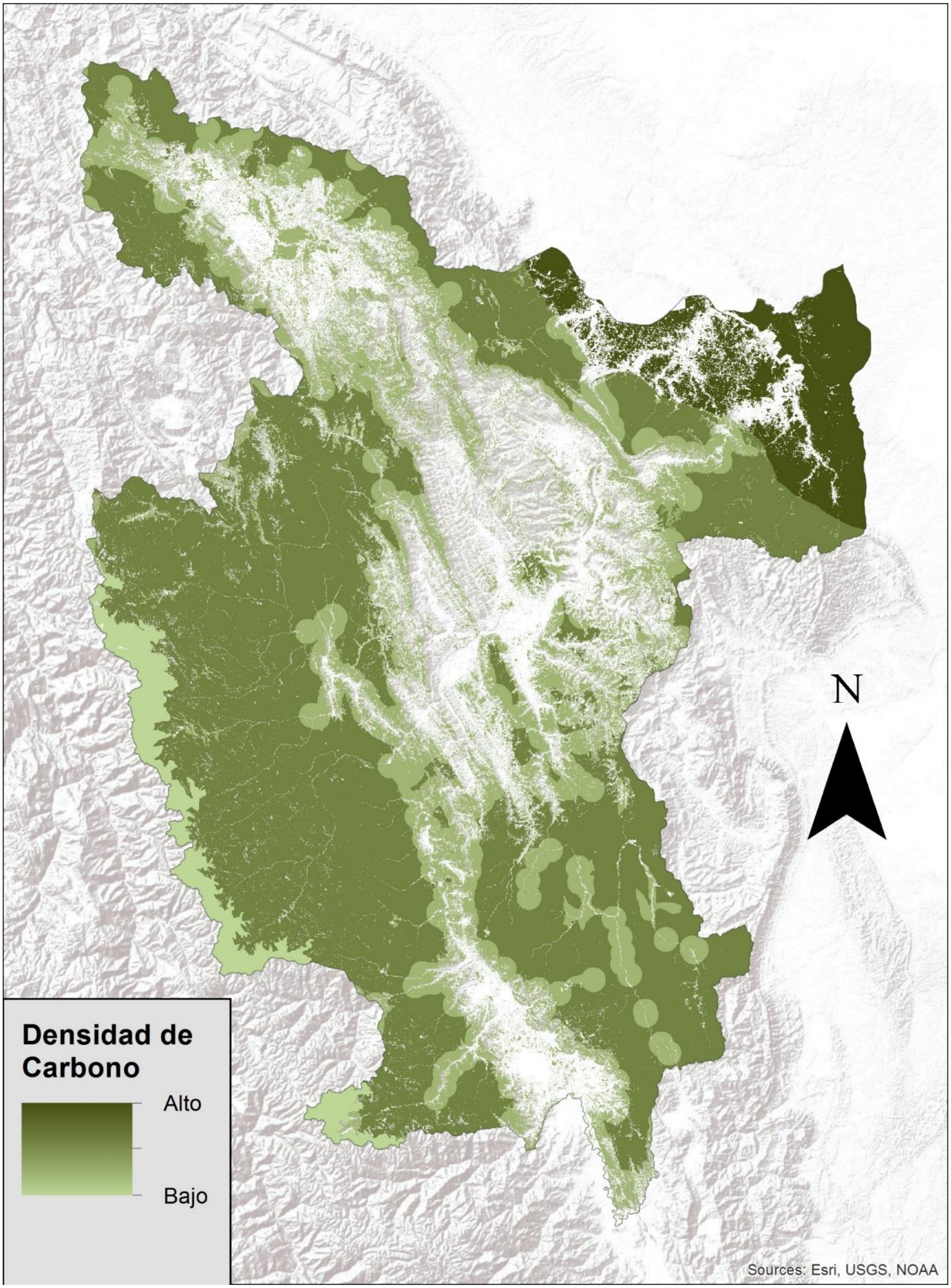

Figure 10 – Ecotourism sites

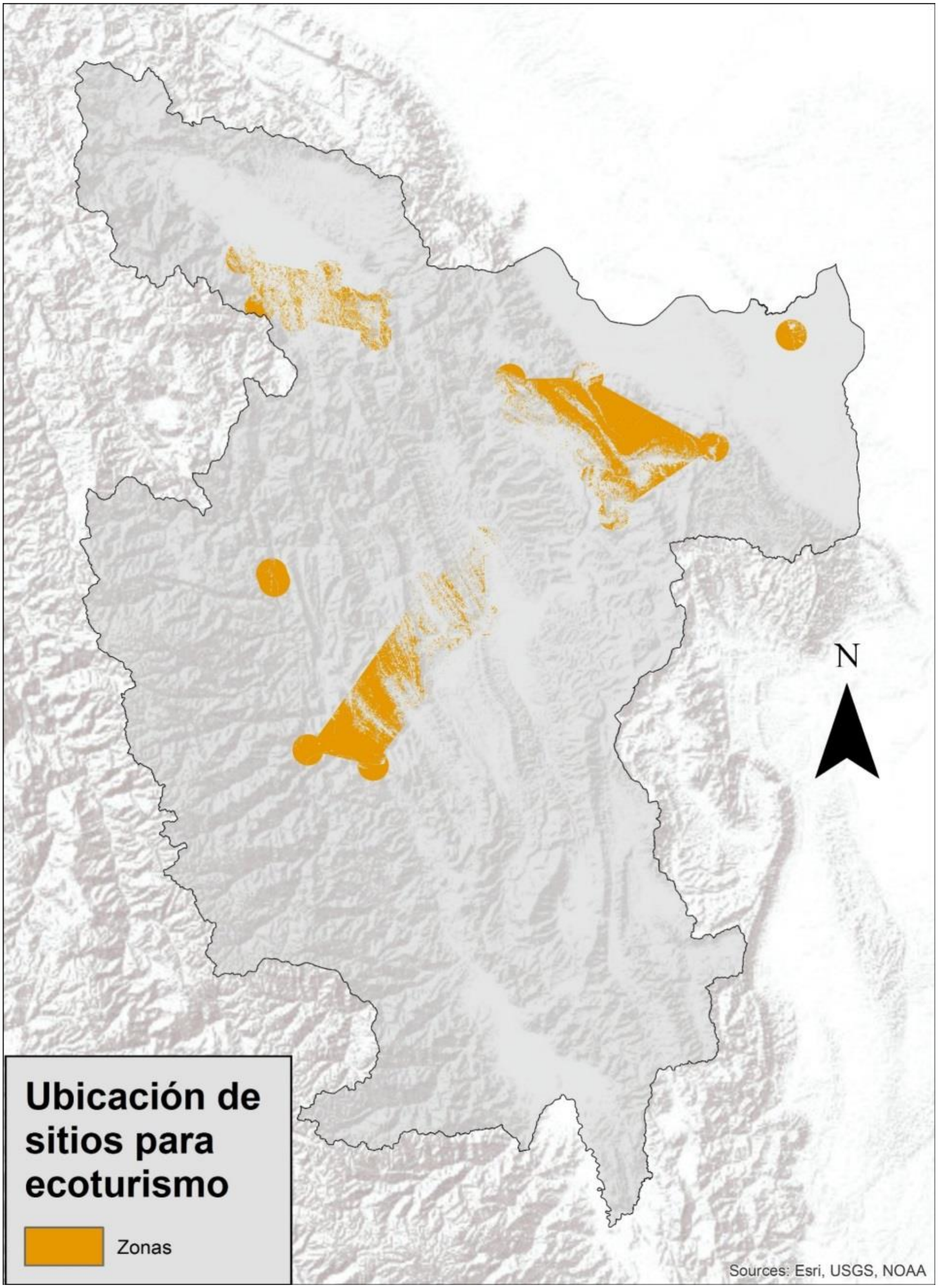

Figure 11 – Provision of firewood