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From rock and ice to political convenience: persistent biases in Argentina's protected areas

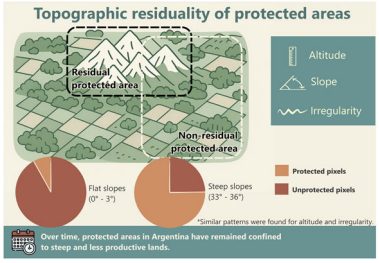
Ana N. Tomba [a,b], Octavio Rojas-Soto [c], Mauricio Díaz-Vallejo [c], Germán Baldi [d], Javier Fajardo [e], Javier Nori [a,b,*]

[a] GeoBio, Instituto de Diversidad y Ecología Animal, Consejo Nacional de Investigaciones Científicas y Técnicas (IDEA-CONICET), Argentina
[b] Fac. de Cs. Exactas Físicas y Naturales, Universidad Nacional de Córdoba (UNC), Argentina
[c] Red Biología Evolutiva, Laboratorio de Bioclimatología, Instituto de Ecología, A. C., Xalapa, Veracruz, México
[d] Grupo de Estudios Ambientales, Instituto de Matemática Aplicada San Luis - Universidad Nacional de San Luis & CONICET, San Luis, D5700HHW, Argentina
[e] Department of Geography, University of Cambridge, Cambridge, CB2 1DB, United Kingdom

HIGHLIGHTS

- Strict PAs (I–IV) are concentrated in higher, steeper, and more irregular terrains.
- Less strict PAs (V–VI) show weaker topographic residuality.
- Protection increases sharply at high elevations and steep slopes.
- Topographic biases persist through time with no signs of correction.

GRAPHICAL ABSTRACT



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ABSTRACT

Protected areas (PAs) are one of the central tools to achieve international conservation targets toward 2030, yet biases in their location often undermine their effectiveness. A recurrent pattern worldwide is the tendency to establish PAs in remote or marginal lands, the so-called "residual conservation" or "rock and ice problem". While elevation has been widely studied as a driver of this bias, other key topographic dimensions have received far less attention. Here we compared altitude, slope, and irregularity within Argentinian PAs against national, local, and ecoregional baselines, and examined their variation with the year of establishment and IUCN category. Our results show that Argentine PAs are disproportionately located in higher, steeper, and more irregular environments, with these biases being most pronounced in strictly protected categories. Protection increases sharply above 2000 m, in slopes steeper than 27 °, and in rugged terrains, while fertile and accessible lowlands remain largely underrepresented. These biases show little evidence of having changed substantially through time, despite Argentina's international commitments on biological representativeness. Overcoming these long-standing topographic biases to truly meet the international agenda will require moving beyond economically convenient expansions and strategically directing protection toward the current deficits of the system, even when this implies political conflict.

* Corresponding author:
E-mail address: javiernori@gmail.com (J. Nori).

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Introduction

Protected areas remain the cornerstone of biodiversity conservation worldwide, covering 17.6% of Earth's terrestrial and inland waters surface (UNEP-WCMC & IUCN, 2024a). Yet their effectiveness in halting biodiversity loss and ensuring Nature's Contributions to People (NCP) has been increasingly questioned, partly because many ecosystems and key species remain poorly represented or inadequately safeguarded within existing protected areas' networks (Watson et al., 2014; Maxwell et al., 2020; Arneth et al., 2023). Despite this global effort, biodiversity continues to decline, with about one million species at risk of extinction (IPBES, 2019). A major factor underlying this limited effectiveness is that protected areas are often biased toward lands of low productive value and difficult access, a phenomenon known as 'residual conservation' or the 'rock and ice problem' (Joppa and Pfaff, 2009; Hoekstra et al., 2005; Baldi et al., 2017; Venter et al., 2018; Tomba et al., 2026; Vieira et al., 2019). In contrast, critical ecosystems that sustain both biodiversity and NCPs remain largely underrepresented (Rodrigues et al., 2004; IPBES, 2019). Consequently, topographic biases may compromise conservation effectiveness by limiting the representativeness of protected-area networks.

Among the critical aspects underlying the patterns of residual conservation, topography stands out as a central factor. Protected areas worldwide tend to be disproportionately located in elevated or mountainous regions (Joppa and Pfaff, 2009), reflecting both lower opportunity costs and reduced accessibility (Baldi et al., 2017; Elsen et al., 2018; Biber et al., 2022). Yet, most analyses of topographic biases in protected areas have focused narrowly on elevation, overlooking that topography is multidimensional. High-elevation areas may include extensive flat and fertile landscapes while steep slopes impose unavoidable physical barriers to agriculture and infrastructure, making them especially eligible to protection (Díaz-Vallejo et al., 2025). Additionally, terrain irregularity captures the fine-scale heterogeneity of relief, influencing habitat diversity (Stein et al., 2014), the more precise measurement of species range sizes (Galindo Cruz and Rojas Soto, 2023), and human accessibility (Weiss et al., 2018). Together, elevation, slope, and terrain irregularity capture complementary dimensions of landscape structure and provide a more comprehensive assessment of protected-area biases than any single metric alone. Although the spatial biases of protected areas have long been recognized, the explicit analysis of their physical representativeness, or how well protected area networks encompass the diversity of topographic settings, has only gained attention over the past decade (see Box 1).

Argentina provides a critical setting to investigate these questions. The country harbors a wide range of physical environments, including a diverse topography, from the high Andes and Patagonian plateaus to the fertile Pampas and Chaco lowlands, where some of the most intense agricultural expansion and urban sprawl in South America have occurred (Baldi et al., 2014). But, as in many countries, the PA network has historically expanded in mountainous regions of low productive value, while fertile and densely populated lowlands remain underrepresented (Baldi et al., 2019; Tomba et al., 2026), despite the recognized importance of overcoming such biases to meet national and international conservation commitments from the Convention on Biological Diversity (CBD, 2010, 2022). However, no systematic analysis has yet assessed how altitude, slope, and terrain irregularity together shape their patterns, how these variables vary across management categories, and through time.

Here, we provide a systematic assessment of topographic biases in Argentina's PA network. We integrate three complementary approaches to evaluate whether protected areas are disproportionately located in topographically complex environments: (1) absolute topographic mean values (i.e. average altitude, slope, and irregularity of all protected areas groups), (2) local residuality, assessing contrasts with adjacent landscapes, and (3) regional residuality, assessing contrasts within ecoregions, thereby capturing different spatial dimensions of topographic bias (see Methods for details). Our analysis includes all officially designated protected areas in the country, regardless of their governance or management type, to capture general patterns across the national network. We also distinguish between strict and multiple-use protected area categories to examine the persistence of topographic biases through time. By integrating elevation, slope, and terrain irregularity, this study

Box 1
The evolving study of topography in protected area placement

Early national or regional-level assessments (e.g., Rouget et al., 2003; Oldfield et al., 2004; Kamei and Nakagoshi, 2006) highlighted altitudinal and fertility biases within specific territories, but it was not until Joppa and Pfaff (2009) that the topic re-emerged at a global level under the "high and far" paradigm. Despite the broad influence of that study, its conclusions conceal a high degree of geographic heterogeneity, revealing that not all countries follow a consistent mountain bias pattern. Subsequent contributions, such as Baldi et al. (2017, 2019), Elsen et al. (2018, 2020), and Biber et al. (2022), have refined these perspectives by incorporating socio-environmental and other physical gradients, showing that the "high and far" tendency is spatially uneven—strong in some regions like the Andes or southern Africa, but weak or absent in others. However, these studies remain limited by static snapshots that ignore temporal evolution. Overall, these contributions have expanded the discussion on physical representativeness. Yet, no previous work has systematically examined how topographic biases have persisted or changed through time—an aspect essential to evaluate progress toward the commitments of representativeness and equity embedded in the post-2020 Global Biodiversity Framework. A detailed compilation of the studies discussed here is provided in Table S1.

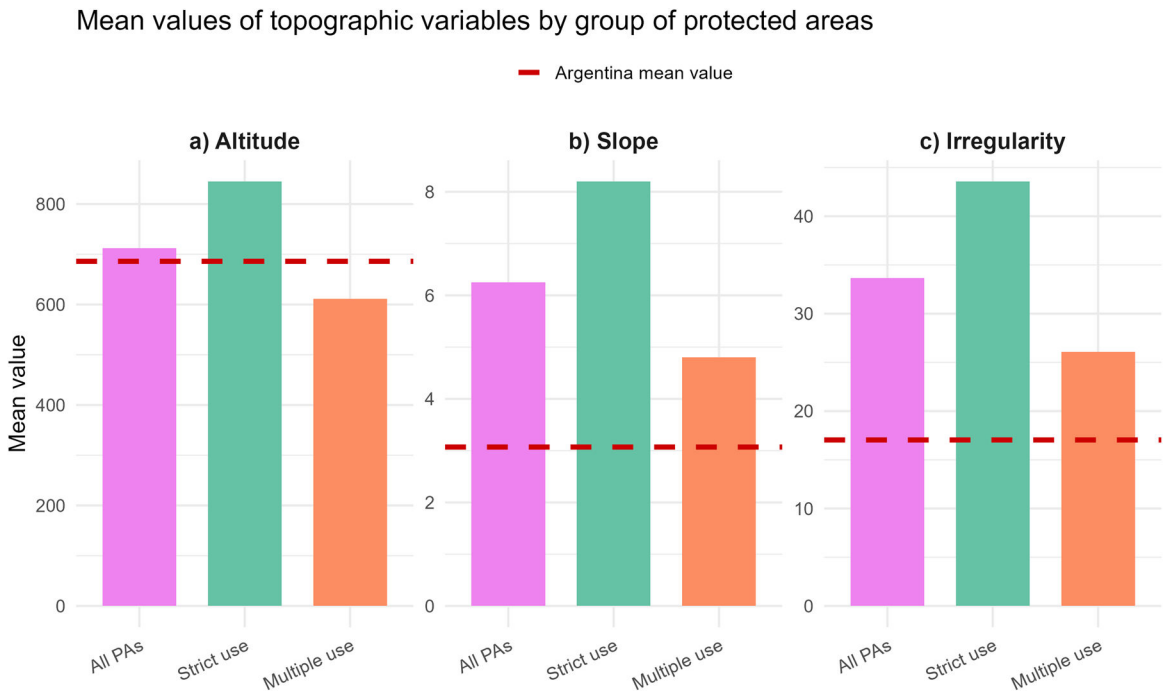

Fig. 1. Mean values of topographical variables for Argentina and its protected areas. Comparisons are shown for (a) altitude (m), (b) slope (°), and (c) terrain irregularity. Groups include the national mean for Argentina in a red dashed horizontal line, and bars with values of: all protected areas, strict protected areas (IUCN categories I-IV), and multiple-use protected areas (IUCN categories V-VI).

provides a comprehensive assessment of the physical representativeness of Argentina's protected area network and its implications for national conservation planning and international biodiversity commitments.

Methods

Study area

Argentina covers 2.78 million km^2 of continental land, and its diversity translates into strong gradients of altitude, slope, and terrain irregularity, coupled with contrasting land-use pressures. The national protected area network (Sistema Nacional de Áreas Protegidas), together with provincial systems, currently covers approximately 8% of the country (UNEP-WCMC & IUCN, 2024b). For analytical purposes, protected areas were grouped into strict (IUCN categories I–IV) and multiple-use categories (V–VI). Further details on the study area, ecoregions, and the distribution of protected areas are provided in Appendix S1.

Topographic variables

We considered three topographic variables: altitude, slope, and terrain irregularity. Altitude (m a.s.l.) was extracted from the Shuttle Radar Topography Mission digital elevation model at 90-m resolution (SRTM; Jarvis et al., 2008). Slope (°) was calculated as the maximum rate of change in elevation between each grid cell and its neighbors. Terrain irregularity was quantified using the Terrain Ruggedness Index (TRI), which measures the mean difference in elevation between a focal cell and its surrounding neighborhood, both calculated in QGIS. All variables were aggregated to a 1-km resolution for computational efficiency and comparability with the extent of protected areas.

Analyses

Protected areas were categorized into strict protection (IUCN categories I-IV) and multiple-use (categories V-VI) to examine differences across management types. First, we characterized the topographic setting of the protected area network by comparing mean altitude, slope, and terrain irregularity within protected areas against national averages. Second, to detect potential representational biases, we compared the distribution of protected and unprotected pixels along these topographic gradients, thus moving beyond average differences to evaluate patterns across the full range of national conditions. Third, we evaluated residuality at two spatial levels. Residuality was calculated as the difference between the mean value of each variable inside and outside protected areas, and subsequently weighted by each protected-area area (km^2). At a local level, the outside reference corresponded to a relative buffer surrounding each protected area (See Supplementary Material for details), whereas at a regional level, it corresponded to the mean value of the ecoregion to which each protected area belongs (sensu Olson et al., 2001). Protected areas spanning multiple ecoregions were assigned to the one covering the largest proportion. This analysis was performed separately for strict protection and multiple-use categories to evaluate topographic residuality within each management type relative to its corresponding reference environment. No direct statistical comparisons were conducted between protection categories. We additionally explored temporal patterns by correlating establishment year with topographic residuality using non-parametric correlations (Spearman's ρ). The main text shows results for the regional analyses, whereas local-level results are provided in Appendix 1. All analyses were conducted in R (version 4.5.1; R Core Team, 2025). We chose this simple approach rather than a more complex alternative (e.g. matching) because our objective was to quantify biases rather than estimate the causal effects of protection.

Results

Across Argentina, protected areas were consistently located in topographically more complex environments than the national average. Mean altitude was 686 m nationally and 712 m within protected areas (3.8% higher); strictly protected categories (I–IV) averaged 845 m (23.2% higher), while multiple-use categories (V–VI) averaged 611 m

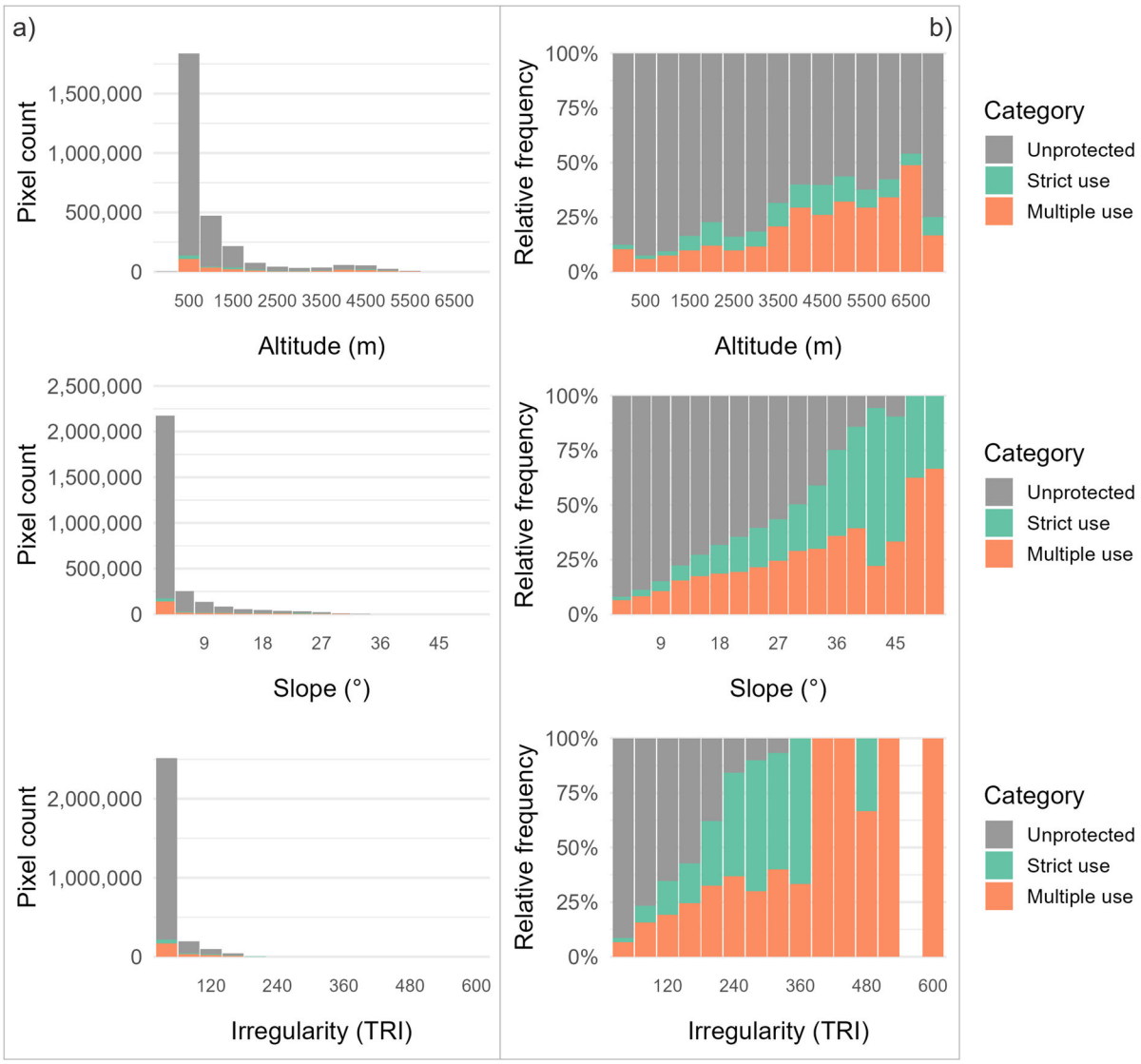

Fig. 2. Absolute frequency (a) and relative proportion (b) of pixels across different variables: altitude, slope, and terrain irregularity. Colors represent one of three land protection categories: unprotected, strict protection (IUCN I-IV), or multiple-use (IUCN V-VI).

(10.9% lower; Fig. 1a). Slope showed a larger contrast (national: 3.07 °, protected areas: 6.25 °, 103% **higher**; I–IV: 8.2 °, 167% **higher**; V–VI: 4.8 °, 56% **higher**; Fig. 1b). Terrain irregularity (TRI) also differed markedly (national: 17.0, protected areas: 33.6, 98% **higher**; I–IV: 43.6, 156% **higher**; V–VI: 26.1, 54% **higher**; Fig. 1c). Together, these comparisons indicate that Argentine protected areas, particularly those designated as strictly protected, are disproportionately located in higher, steeper, and more irregular terrain.

Most of Argentina is low and flat, with over 90% of the territory below 2000 m, nearly 80% on slopes under 3 °, and low terrain irregularity, based on pixel counts (Fig. 2a). In this context, protected areas are concentrated in topographically complex environments. Less than 10% of lowlands and flat areas are protected, whereas coverage increases to 32% at elevations above 2000 m. Similarly, more than half of the areas with slopes above 27 ° or highly irregular terrain are under protection (Fig. 2b).

When we assessed the topographic residuality, strict protected areas (I–IV) consistently exhibited higher residual values than multiple-use protected areas (V–VI) across all three topographic variables. Altitude residuality was higher in strict (I–IV: mean 141 m, SD 498 m) than in multiple-use protected areas (V–VI: mean 49 m, SD 354 m). In the same being, slope was steeper in strict areas (mean 1.56 °, SD 4.26 °) than in multiple-use areas (mean -0.05 °, SD 4.26 °). Irregularity differences were also biased in the same direction, with means of 8.10 (SD 22.8) in strict and −0.08 (SD 16.7) in multiple-use areas, highlighting that strictly protected areas tend to occupy more complex terrain. All results are weighted by area, giving larger protected areas proportionally greater influence. Analyses at the local scale revealed the same overall pattern (Appendix 2), confirming that the tendency of strictly protected areas to occur in steeper, higher, and more irregular terrain is consistent across spatial scales.

Correlations between protected areas establishment year and topographic residuality were weak across all variables ($|\rho| \leq 0.14$), indicating little evidence that residual topographic bias has changed substantially over time. Residual altitude showed a slightly negative association with year of establishment ($\rho = -0.07$ overall; I–IV: −0.13; V–VI: −0.03), whereas slope ($\rho = -0.0005$ overall; I–IV: −0.10; V–VI: 0.13) and terrain irregularity ($\rho = 0.01$ overall; I–IV: −0.09; V–VI: 0.14) showed small differences in the direction of the correlations between protection categories (Fig. 3).

Discussion

Although the notion of residual conservation (Tomba et al., 2026;

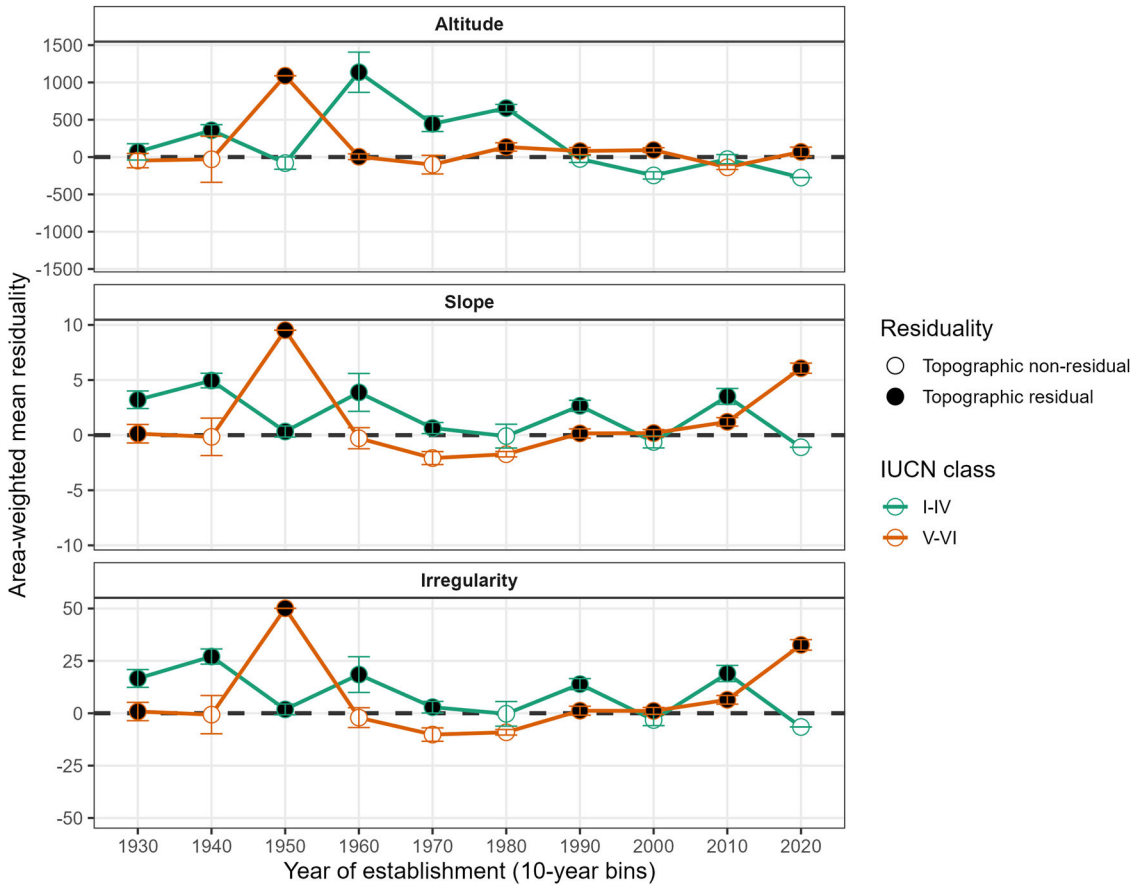

Fig. 3. Decadal changes in area-weighted topographic residuality of protected areas. Residuality for altitude, slope, and terrain irregularity is summarized by decade for IUCN classes I–IV (green) and V–VI (orange), using area-weighted means (km^2). The dashed line marks zero residuality, with black symbols representing above-zero means and white symbols representing below-zero means.

Vieira et al., 2019) as a consequence of the bias toward the "rock and ice" problem is not novel, here we corroborate in a very detailed topographic perspective that this pattern also holds in Argentina. As observed globally before this study (Elsen et al., 2018), protected areas in Argentina are systematically located in areas of rugged terrain. Importantly, our study deepens the current knowledge by showing that this bias is not only a by-product of elevation, but also strongly associated with slope and terrain irregularity, dimensions that have been far less systematically assessed in conservation research (Díaz-Vallejo et al., 2025). A clear message emerging from this is that it has been easier to set aside lands with little productive value than to strategically prioritize ecosystems that are truly representative of Argentina's environmental diversity (Baldi et al., 2019), covering current representative deficits (Nori et al., 2015).

Despite Argentina's international commitments under the Convention on Biological Diversity, including the Strategic Plan for Biodiversity 2011–2020 and the most recent Kunming-Montreal Global Biodiversity Framework (KMGBF) (CBD, 2010, 2022), the correlation analyses revealed no consistent trend toward correcting the topographic bias found. While our correlations between the year of protected area's establishment and residuality regarding topographic variables suggest weak and inconsistent tendencies, they provide little evidence that topographic biases have changed substantially through time (Fig. 3). Protected areas have historically been biased toward higher and steeper environments, and this general pattern remains evident across the current network. This pattern persists despite the qualitative requirements of Aichi Target 11 and Target 3 of the KMGBF, which call for ecologically representative, well-connected, and effectively managed networks of protected and conserved areas. The persistence of this bias in Argentina mirrors findings at a broader spatial level, where progress toward Aichi 11 was largely quantitative (expanding total area under protection) but failed to address representativeness and equity dimensions (Barnes et al., 2018; Maxwell et al., 2020; UNEP-WCMC & IUCN, 2024b). Our results, therefore, confirm that these international frameworks have had limited influence in reshaping conservation planning priorities at the national level. This is true particularly in developing countries, where national economies heavily depend on land use competition (IPBES, 2019).

Strictly protected areas (I–IV) remain the most topographically residual units in the network, occupying higher, steeper, and more irregular terrains (Baldi et al., 2019; Tomba et al., 2026). Over time, these categories exhibit a slight tendency toward lower residuality (Fig. 3), but this suggested trend could be influenced by the comparatively low number of strict PAs designated in recent decades (Tomba et al., 2026) and by the strong initial bias created by the early Andean establishments due to geopolitical reasons (Cansanello and Yujnovsky, 2024). In contrast, multiple-use categories (V–VI) consistently display lower residuality, as expected for areas intended to integrate conservation with human use, and continue to dominate productive lowlands, constrained by the high social and economic costs of strict protection (Huais et al., 2025; Tomba et al., 2026).

Less strict categories represent an important strategy for improving protection in underrepresented lowland ecosystems, where the establishment of strictly protected areas is often socially and economically unfeasible. Interestingly, in other South American countries (Brazil), Indigenous Lands and other less restrictive conservation areas have been shown to contribute substantially to maintaining natural vegetation and reducing deforestation (Nolte et al., 2013). However their effectiveness

depends strongly on governance and management, which remain highly variable across Argentina (Tomba et al., 2026). Under this scenario, and in line with the CBD's international agenda, categories V–VI should play a central role in reconciling conservation and livelihoods, while strictly protected areas remain essential for securing low-impact sites—ideally in ways that help correct, rather than reinforce, existing representational imbalances (CBD, 2022; Pressey et al., 2021).

Nevertheless, questions remain about the capacity of less strict categories to mitigate certain large-scale threats, such as deforestation or extractive activities. Recent global studies found less strict protected areas to be effective (Geldmann et al., 2019; Oldekop et al., 2016), but regional studies, including those from the Brazilian Amazon, indicate that strictly protected areas often perform somewhat better in curbing deforestation than sustainable-use ones (Nolte et al., 2013), although such differences are typically moderate and highly context dependent (Bowker et al., 2017; Butsic et al., 2017). In the Argentine Chaco, for instance, roughly one-third of protected areas effectively reduced woodland loss, with strictly protected areas showing a slightly higher proportion of effectiveness compared to less strict ones (Huais et al., 2025). Beyond effectiveness, the growing prevalence of less strict categories (V–VI) in flatter, more accessible regions has likely contributed more to fulfilling quantitative area targets than to achieving meaningful biodiversity outcomes, since such designations are typically easier for governments to establish given their lower political and economic costs (Barnes et al., 2018; Maxwell et al., 2020). Together, these findings highlight the importance of identifying where stricter protection may be ecologically justified and socially feasible, and ensuring that its implementation helps correct existing representational biases while remaining compatible with local livelihoods.

In summary, our analysis reveals that the Argentine protected area system remains shaped by a persistent topographic bias that privileges low-value lands over equal representativeness of ecosystems (see Pressey et al., 2002; Vieira et al., 2019). By demonstrating that this pattern extends beyond elevation to include slope and terrain irregularity, we provide evidence of how biophysical and socio-economic filters interact to reinforce residual conservation. Correcting this bias does not simply imply increasing protection across all lowland environments. Some low ecosystems, such as the Pampas grasslands, have been extensively transformed, retaining only small remnants. Others, including the Chaco and Espinal, remain poorly represented within the protected-area network despite facing intense land-use pressures (Prieto-Torres et al. 2022). In contrast, some lowland regions, such as the Monte and Patagonian deserts, remain comparatively extensive and less vulnerable. Therefore, future conservation efforts should prioritize underrepresented and highly vulnerable lowland ecosystems, in line with both systematic conservation planning principles (Margules and Pressey, 2000) and international conservation commitments adopted by the country under the Convention on Biological Diversity (CBD).

Declaration of competing interest

The authors declare that they have no conflicts of interest.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.pecon.2026.07.001.

References

Arneth, A., Leadley, P., Claudet, J., Coll, M., Rondinini, C., Rounsevell, M.D.A., Shin, Y. J., Alexander, P., Fuchs, R., 2023. Making protected areas effective for biodiversity, climate and food. In: In Global Change Biology, Vol. 29. John Wiley and Sons Inc, pp. 3883–3894. https://doi.org/10.1111/gcb.16664. Issue 14.

Baldi, G., Houspanossian, J., Murray, F., Rosales, A.A., Rueda, C.V., Jobbágy, E.G., 2014. Cultivating the dry forests of South America: diversity of land users and imprints on ecosystem functioning. J. Arid. Environ. 123, 47–59.

Baldi, G., Texeira, M., Martin, O.A., Grau, H.R., Jobbágy, E.G., 2017. Opportunities drive the global distribution of protected areas. PeerJ (2), e2989. https://doi.org/10.7717/PEERJ.2989/SUPP-1.

Baldi, G., Schauman, S., Texeira, M., Marinaro, S., Martin, O.A., Gandini, P., Jobbágy, E. G., 2019. Nature representation in South American protected areas: Country contrasts and conservation priorities. PeerJ (7), e7155. https://doi.org/10.7717/PEERJ.7155/SUPP-8.

Barnes, M.D., Glew, L., Wyborn, C., Craigie, I.D., 2018. Prevent perverse outcomes from global protected area policy. Nat. Ecol. Evol. 2 (5), 759–762. https://doi.org/10.1038/s41559-018-0501-y.

Biber, M.F., Voskamp, A., Hof, C., 2022. Representation of the world's biophysical conditions by the global protected area network. Conserv. Biol. 36 (2). https://doi.org/10.1111/COBI.13822.

Bowker, J.N., De Vos, A., Ament, J.M., Cumming, G.S., 2017. Effectiveness of Africa's tropical protected areas for maintaining forest cover. Conserv. Biol. 31 (3), 559–569.

Butsic, V., Munteanu, C., Griffiths, P., Knorn, J., Radeloff, V.C., Lieskovský, J., Kuemmerle, T., 2017. The effect of protected areas on forest disturbance in the Carpathian Mountains 1985–2010. Conserv. Biol. 31 (3), 570–580.

Cansanello, P., Yujnovsky, I., 2024. Paradigmas de conservación ambiental en Argentina: Parques Nacionales (1903-2001). Administración de Parques Nacionales.

CBD, 2010. "X/2. The Strategic Plan for Biodiversity 2011-2020 and the Aichi Biodiversity Targets.". Paper presented at COP10, Nagoya, Japan. https://www.cbd.int/doc/decisions/cop-10/cop-10-dec-02-en.pdf.

CBD, 2022. Decision Adopted by the Conference of the Parties to the Convention on Biological Diversity 15/4. Kunming-Montreal Global Biodiversity Framework, Montreal, Canada.

Díaz-Vallejo, M., Toro-Cardona, F.A., Bonilla-Moheno, M., Parra, J.L., Rojas-Soto, O., 2025. The relationship between the terrain slope and biodiversity conservation: a perspective from the specialist avifauna of Mexico. Biol. Conserv. 308, 111219. https://doi.org/10.1016/J.BIOCON.2025.111219.

Elsen, P.R., Monahan, W.B., Merenlender, A.M., 2018. Global patterns of protection of elevational gradients in mountain ranges. Proc. Natl. Acad. Sci. USA 115 (23), 6004–6009. https://doi.org/10.1073/PNAS.1720141115.

Elsen, P., Monahan, W., Merenlender, A., 2020. Topography and human pressure in mountain ranges alter expected species responses to climate change. Nat. Commun. 11. https://doi.org/10.1038/s41467-020-15881-x.

Galindo Cruz, A., Rojas Soto, O., 2023. The effect of topographic complexity on species range size estimation and its conservation implications: a subtle oversight. Biodivers. Conserv. 32 (6), 1839–1856. https://doi.org/10.1007/s10531-023-02580-4.

Geldmann, J., Manica, A., Burgess, N.D., Coad, L., Balmford, A., 2019. A global-level assessment of the effectiveness of protected areas at resisting anthropogenic pressures. Proc. Natl. Acad. Sci. USA 116 (46), 23209–23215. https://doi.org/10.1073/pnas.1908221116.

Hoekstra, J.M., Boucher, T.M., Ricketts, T.H., Roberts, C., 2005. Confronting a biome crisis: global disparities of habitat loss and protection. Ecol. Lett. 8 (1), 23–29. https://doi.org/10.1111/J.1461-0248.2004.00686.X.

Huais, P.Y., Osorio-Olvera, L., Cordier, J.M., Tomba, A.N., Soberón, J., Loyola, R., Nori, J., 2025. Rethinking Global Hotspots for Threatened Terrestrial Vertebrates. Global Ecol. Biogeogr. 34 (1), e13942. https://doi.org/10.1111/GEB.13942.

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), 2019. Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on biodiversity and ecosystem services. Zenodo. https://doi.org/10.5281/zenodo.6417333.

Jarvis, A., Reuter, H.I., Nelson, A., Guevara, E., 2008. Hole-filled SRTM for the globe: Version 4. CGIAR Consortium for Spatial Information. Recuperado de. https://srtm.csi.cgiar.org.

Joppa, L.N., Pfaff, A., 2009. High and far: biases in the location of protected areas. PLoS One 4 (12), e8273. https://doi.org/10.1371/JOURNAL.PONE.0008273.

Kamei, M., Nakagoshi, N., 2006. Geographic assessment of present protected areas in Japan for representativeness of forest communities. Biodivers. Conserv. 15, 4583–4600. https://doi.org/10.1007/s10531-005-5822-x.

Margules, C.R., Pressey, R.L., 2000. Systematic conservation planning. Nature 405 (6783), 243–253. https://doi.org/10.1038/35012251.

Nolte, C., Agrawal, A., Silvius, K.M., Soares-Filho, B.S., 2013. Governance regime and location influence avoided deforestation success of protected areas in the Brazilian Amazon. Proc. Natl. Acad. Sci. 110 (13), 4956–4961.

Nori, J., Lemes, P., Urbina-Cardona, N., Baldo, D., Lescano, J., Loyola, R., 2015. Amphibian conservation, land-use changes and protected areas: a global overview. Biol. Conserv. 191, 367–374. https://doi.org/10.1016/j.biocon.2015.07.028.

Oldekop, J.A., Sims, K.R.E., Holmes, G., Harris, W.E., Evans, K.L., 2016. A global assessment of the social and conservation outcomes of protected areas. Conserv. Biol. 30 (1), 133–141. https://doi.org/10.1111/cobi.12568.

Oldfield, T.E.E., Smith, R.J., Harrop, S.R., Leader-Williams, N., 2004. A gap analysis of terrestrial protected areas in England and its implications for conservation policy. Biol. Conserv. 120, 303–309. https://doi.org/10.1016/j.biocon.2004.03.003.

Olson, D.M., Dinerstein, E., Wikramanayake, E.D., Burgess, N.D., Powell, G.V.N., Underwood, E.C., D'Amico, J.A., Itoua, I., Strand, H.E., Morrison, J.C., Loucks, C.J.,

Allnutt, T.F., Ricketts, T.H., Kura, Y., Lamoreux, J.F., Wettengel, W.W., Hedao, P., Kassem, K.R., 2001. Terrestrial ecoregions of the world: a new map of life on Earth. BioScience 51 (11), 933–938. https://doi.org/10.1641/0006-3568(2001)051[0933:TEOTWA]2.0.CO;2.

Pressey, R.L., Whish, G.L., Barrett, T.W., Watts, M.E., 2002. Effectiveness of protected areas in north-eastern New South Wales: recent trends in six measures. Biol. Conserv. 106 (1), 57–69. https://doi.org/10.1016/S0006-3207(01)00229-4.

Pressey, R.L., Visconti, P., McKinnon, M.C., Gurney, G.G., Barnes, M.D., Glew, L., Maron, M., 2021. The mismeasure of conservation. Trends Ecol. Evol. 36 (9), 808–821. https://doi.org/10.1016/j.tree.2021.06.008.

Prieto-Torres, D.A., Díaz, S., Cordier, J.M., Torres, R., Caron, M., Nori, J., 2022. Analyzing individual drivers of global changes promotes inaccurate long-term policies in deforestation hotspots: the case of Gran Chaco. Biol. Conserv. 269, 109536.

R Core Team, 2025. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Version 4.5.1. https://www.R-project.org/.

Rodrigues, A.S.L., Andelman, S.J., Bakan, M.I., Boitani, L., Brooks, T.M., Cowling, R.M., Fishpool, L.D.C., Da Fonseca, G.A.B., Gaston, K.J., Hoffmann, M., Long, J.S., Marquet, P.A., Pilgrim, J.D., Pressey, R.L., Schipper, J., Sechrest, W., Stuart, S.H., Underhill, L.G., Waller, R.W., Yan, X., 2004. Effectiveness of the global protected area network in representing species diversity. Nature 428 (6983), 640–643. https://doi.org/10.1038/nature02422.

Rouget, M., Richardson, D.M., Cowling, R.M., 2003. The current configuration of protected areas in the Cape Floristic Region, South Africa—reservation bias and representation of biodiversity patterns and processes. Biol. Conserv. 112, 129–145. https://doi.org/10.1016/S0006-3207(02)00396-8.

Maxwell, S.L., Cazalis, V., Dudley, N., Hoffmann, M., Rodrigues, A.S.L., Stolton, S., Visconti, P., Woodley, S., Kingston, N., Lewis, E., Maron, M., Strassburg, B.B.N., Wenger, A., Jonas, H.D., Venter, O., Watson, J.E.M., 2020. Area-based conservation in the twenty-first century. Nature 586, 217–227.

Stein, A., Gerstner, K., Kreft, H., 2014. Environmental heterogeneity as a universal driver of species richness across taxa, biomes and spatial scales. Ecol. Lett. 17, 866–880. https://doi.org/10.1111/ele.12277.

Tomba, A.N., Kuemmerle, T., Sangermano, F., Huais, P.Y., Landi, M., Cordier, M., Nori, J., 2026. Economic priorities shape protected area placement: the role of land competition in Argentina. Biol. Conserv. 313, 111594.

UNEP-WCMC & IUCN, 2024a. Protected Planet Report 2024: The first global assessment of progress towards Target 3 of the Kunming-Montreal global Biodiversity Framework. UNEP-WCMC and IUCN.

UNEP-WCMC & IUCN, 2024b. Protected Area Profile for Argentina from the World Database on Protected Areas, October 2025. Recovered from https://www.protectedplanet.net/country/ARG.

Venter, O., Magrach, A., Outram, N., Klein, C.J., Possingham, H.P., Di Marco, M., Watson, J.E.M., 2018. Bias in protected-area location and its effects on long-term aspirations of biodiversity conventions. Conserv. Biol. 32 (1), 127–134. https://doi.org/10.1111/COBI.12970.

Vieira, R.R.S., Pressey, R.L., Loyola, R., 2019. The residual nature of protected areas in Brazil. Biol. Conserv. 233, 152–161. https://doi.org/10.1016/j.biocon.2019.02.010.

Watson, J.E.M., Dudley, N., Segan, D.B., Hockings, M., 2014. The performance and potential of protected areas. Nature 515 (7525), 67–73. https://doi.org/10.1038/nature13947.

Weiss, D.J., Nelson, A., Gibson, H.S., Temperley, W., Peedell, S., Lieber, A., Hancher, M., Poyart, E., Belchior, S., Fullman, N., Mappin, B., Dalrymple, U., Rozier, J., Lucas, T.C.D., Howes, R.E., Tusting, L.S., Kang, S.Y., Cameron, E., Bisanzio, D., Battle, K.E., Bhatt, S., Gething, P.W., 2018. A global map of travel time to cities to assess inequalities in accessibility in 2015. Nature 553 (7688), 333–336. https://doi.org/10.1038/nature25181.