Ecología Austral 32:663-669 Aniversario 2022
Asociación Argentina de Ecología
https://doi.org/10.25260/EA.22.32.2.1.1868

Landscape divergence associated with international borders and economic asymmetries

H. Ricardo Grau[1,2,✉]; N. Ignacio Gasparri[1,2]; Ezequiel Aráoz[1,2]; T. Michell Aide[3] & María Piquer-Rodríguez[1,4]

[1] Instituto de Ecología Regional (Universidad Nacional de Tucumán - CONICET). Yerba Buena, Tucumán, Argentina. [2] Facultad de Ciencias Naturales, Universidad Nacional de Tucumán. Tucumán, Argentina. [3] Departamento de Biología, Universidad de Puerto Rico. Río Piedras, San Juan, Puerto Rico. [4] Institute of Geographical Sciences, Freie Universitat. Berlin, Germany.

Abstract. Land cover divergences across international borders reflect how country-level policies influence ecological footprints on the landscape. We identified 30 abrupt transboundary divergences across the globe, with major land cover differences despite similar ecological conditions. Divergences were significantly associated with differences in Gross Domestic Product (GDP) between countries, not with demographic differences. In mountains, unsuitable for mechanized agriculture, wealthier countries have higher forest cover and urbanization, suggesting advanced 'forest transitions'. Lowlands with rainfed agricultural potential showed more agriculture development on the wealthier side of the border, except when the country´s economy was not based on agriculture. In drylands, wealthier countries showed much more irrigation-based agriculture. Despite globalization, transboundary divergences are unlikely to disappear and may even intensify, thus meriting increased research attention as a distinctive feature of Anthropocene ecology.

[Keywords: agriculture expansion, deforestation, forest transition, land cover, land use, transnational comparisons]

Resumen. Diferencias en el paisaje asociadas a límites internacionales y asimetrías económicas. Las divergencias de uso del territorio a través de límites internacionales reflejan en qué medida diferentes políticas nacionales influyen en su impacto sobre el paisaje. Identificamos 30 diferencias abruptas de cobertura del territorio a ambos lados de límites internacionales, bajo condiciones ambientales similares, alrededor del mundo. Las divergencias se asociaron significativamente con diferencias de Producto Bruto Interno (PBI) entre los países, no con diferencias demográficas. En zonas montañosas, no aptas para agricultura mecanizada, los países económicamente más prósperos mostraron mayores coberturas boscosas, sugiriendo etapas avanzadas de 'transición forestal'. Las tierras bajas aptas para agricultura de secano mostraron mayor desarrollo agrícola hacia el lado del límite correspondiente al país con mayor PBI. En zonas áridas, los países más ricos mostraron mayor desarrollo de agricultura bajo riego. A pesar de la globalización, las divergencias entre países en cuanto a cobertura del territorio no son fácilmente reversibles e, inclusive, se pueden intensificar; por lo tanto, requieren mayor atención como una característica distintiva de la ecología del Antropoceno.

[Palabras clave: expansión agrícola, deforestación, transición forestal, uso del territorio, cobertura del territorio, comparaciones transnacionales]

Introduction

Countries are the most important geographic units of decision making. They control the use of natural resources by determining land tenure regimes, taxes, subsidies, market preferences and access, logistics, protected areas, demographic and migratory policy and environmental regulations on climate change, ecosystem services and biodiversity conservation. Each country's combination of norms, rules and economic logic imposes long lasting footprints on the landscape. For example, even though two countries share a similar ecosystem (e.g., tropical lowland forest), the values assigned to this ecosystem can vary greatly depending on a country's development priorities and its capacity to mobilize resources. Neighboring countries may favor different land use decisions, which can result in landscape discontinuities with major ecological consequences (Dallimer and Strange 2015; Piquer Rodríguez et al. 2021). A major feature of the Anthropocene is that humans are a major driver of most ecological processes (e.g., nitrogen and carbon cycles, energy balance). Thus, variation among countries in their environmental decision making, especially related to land use policies, will have important implications at local, regional and global scales. In this context,

Editor asociado: Germán Baldi

✉ chilograu@gmail.com

Recibido: 23 de Septiembre de 2021
Aceptado: 12 de Enero de 2022

borders between countries can function as 'experiments', providing opportunities to test hypotheses about the effects of country-scale land use decisions and their ecological consequences (Diamond and Robinson 2010).

Following the globalization wave of recent decades, the land science and sustainability science communities have emphasized the importance of increased connectivity between countries (e.g., global commodity markets, transnational land acquisition, global environmental agendas, logistic integration and tele-coupled systems) (Verburg et al. 2015; Hull and Liu 2018). However, some socioeconomic trends may run in the opposite direction. Societies and societal identities are primarily anchored in national spaces, and state borders continue to have considerable relevance (Laine 2016). For example, the disruption caused by the Covid-19 pandemic has created a less globalized world with stricter border controls and a surge in nationalist policies (Allen et al. 2020), but this trend is not as new as it may seem.

In 1945 there were approximately 50 countries in the world; currently, there are almost 200. 'Devolution' (Rodríguez Pose and Gill 2004; Khana 2016) has been described as a tendency towards down-scaling the territory into smaller authorities. Current geopolitical trends suggest a more multipolar world (O´Sullivan 2018), in which some borders may be reinforced. Large political units have or are in the process of fragmenting into smaller units (e.g., Soviet Union, Sudan), the number of international borders may increase further as nationalist movements promote the secession of sub-national political units (e.g., Catalonia, Scotland, Tibet, Quebec, Palestine, Assam, Kashmir, Donbas) and existing borders are hardening (e.g., USA-México, Ireland-Britain). Even transnational agreements and regional infrastructure integration (typically perceived as components of 'globalization') may sometimes be limited by discrepancies between countries. For example, NAFTA has been used as a bargaining tool to limit migration across the USA-México and México-Guatemala borders. Hard-to-solve cultural and political identities have even resulted in the construction of physical barriers (e.g., Israel/Gaza/Egypt; North-South Korea; USA-México), similar to barriers of the past (e.g., Germany east-west division, China Great Wall, Hadrian's Wall). Armed conflicts (e.g., Israel-Lebanon, Russia-Ukraine) and international migration, often due to failed national-level policies (e.g., Syria, Haiti, Venezuela), are leading to changing policy and border reinforcement (e.g., USA, Western Europe). The strengthening of borders is likely to persist as countries continue to take independent national-scale decisions in response to global processes (e.g., Covid-19, climate change). Among the diverse effects will be distinctive landscape patterns, which will have implications for planetary ecology and sustainable development.

Given these assumptions, important questions appear: to what extent do international borders generate ecological divergences between countries? what are the conditions promoting these divergences? With political fragmentation, multipolarity and 'devolution', will transnational landscape divergences become a major feature of the Anthropocene? In this article, we explore these questions by comparing variables associated with 30 transboundary divergences and argue that this general approach should be incorporated into land use and sustainability science agendas.

EXAMPLES OF LANDSCAPE DIVERGENCE ASSOCIATED WITH INTERNATIONAL BORDERS

To explore these questions, we visually searched Google Earth® to identify 30 clear international borders where divergent land cover could not be explained by biophysical background (e.g., changes in topography, WWF ecoregions [worldwildlife.org/biome-categories/terrestrial-ecoregions]) (Supplementary Material 1, Table S1, Supplementary Material 2 - Google Earth® 'project'). 'Divergences' were defined as strong differences in the degree of agriculture development on both sides of an international border; in comparison to the amount of forest or other natural cover types (e.g., desert, bare soil, grasslands). Given the exploratory character of this research, we did not follow a systematic quantitative procedure to find the borders. The criteria were: 1) the divergence was visually obvious, 2) the region in consideration occurred within the same ecoregion on both sides of the border, and 3) all authors agreed on the classification. We then compared a limited set of national-scale variables as potential explanations of the cross-border differences:

total population, population density, Human Development Index (HDI), median Gross Domestic Product (GDP), per capita GDP and agriculture GDP. These variables were used because they reflect the overall socio-economic condition of each country and the data collection of these variables is easy and based on a standardized method (e.g., World Bank, CIA Factbook).

Except for polar and very high elevation ecosystems, the main limitation for any type of agriculture is water availability, and the main limitation for modern mechanized agriculture is slope (Zabel et al. 2014). Arid lands, rough terrain, and mesic or humid lowlands are, as a result, useful categories to assess agriculture potential and its relationship with investments needs. Based on this, using the qualitative criteria mentioned above, we categorized the divergent borders into three main groups related to their potential for agriculture production (Figure 1): a) mountains (rough terrain with at least part of the landscape above 1000 m a. s. l.) (11 borders), b) lowlands with rainfed agriculture potential (11 borders), and c) irrigated drylands where agriculture appears to be possible only with substantial water subside (8 borders).

Our sample of countries with strong transboundary divergence in a section of their shared border did not vary significantly in terms of total population (P=0.52), population density (P=0.72), Human Development Index (P=0.13), or agriculture GDP (P=0.12). In contrast, the median GDP ratio (wealthier/poorer) of countries with divergent borders was significantly higher than expected by chance (P=0.019). The distribution of differences in per-capita GDP also varied among the three categories (Figure 2).

In mountain areas, countries with higher GDP showed more forest cover than its comparatively poorer neighbor in nine of the 11 cases (Figure 2). Higher forest cover was often spatially associated with higher urbanization development in valleys, suggesting patterns of 'forest transition' related with land abandonment in marginal agricultural areas (Rudet et al. 2005) and rural-urban migration (Aide and Grau 2004). Economic wealth appears to favor land use patterns with better preserved mountains, resulting in overall benefits for biodiversity and watershed conservation. However, ecosystems highly transformed by intensive agriculture and urbanization are expected to threaten the biodiversity of valley bottoms, while agrodiversity and ethnobiological values may be lost as small-scale agriculture in the mountains is outcompeted by industrial agriculture in lowlands (Redo et al. 2012; Nanni and Grau 2017).

Lowlands with potential for rainfed agriculture tended to show the opposite pattern: in seven of 11 pairs, the wealthier countries were the ones where agriculture has expanded more, often at the expense of tropical and subtropical forests. This pattern supports the notion that available capital and infrastructure are major drivers of tropical deforestation (Geist and Lambin 2002; Crespo Cuaresma and Heger 2019). Without specific

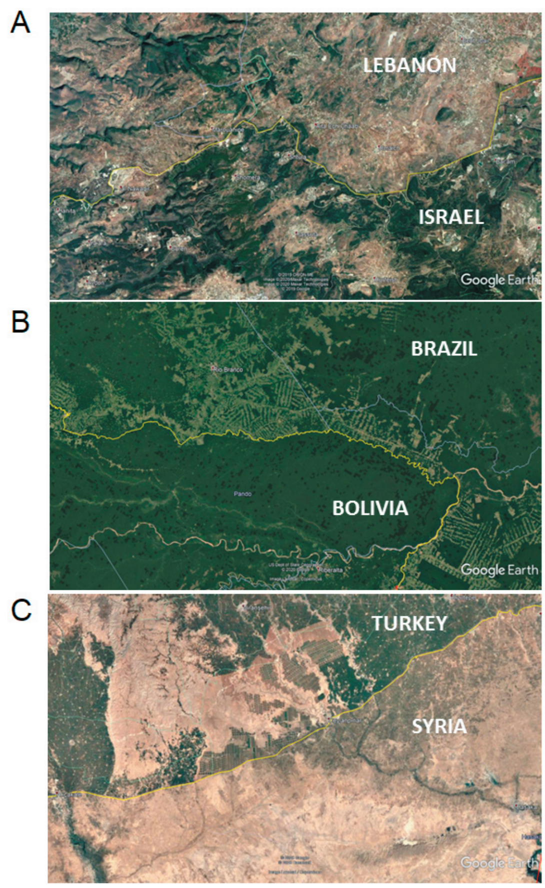

Figure 1. Examples of divergent border categories: (A) mountains, (B) tropical lowland with potential for rainfed mechanized agriculture, and (C) irrigated dryland. All the borders consider are included in the Supplementary Material (online).

Figura 1. Ejemplos de las tres categorías de límites internacionales divergentes en cobertura del territorio: (A) montañas, (B) zonas tropicales bajas con potencial para agricultura de secano, y (3) zonas áridas irrigadas. Todos los límites internacionales analizados se incluyen en el Material Suplementario (online).

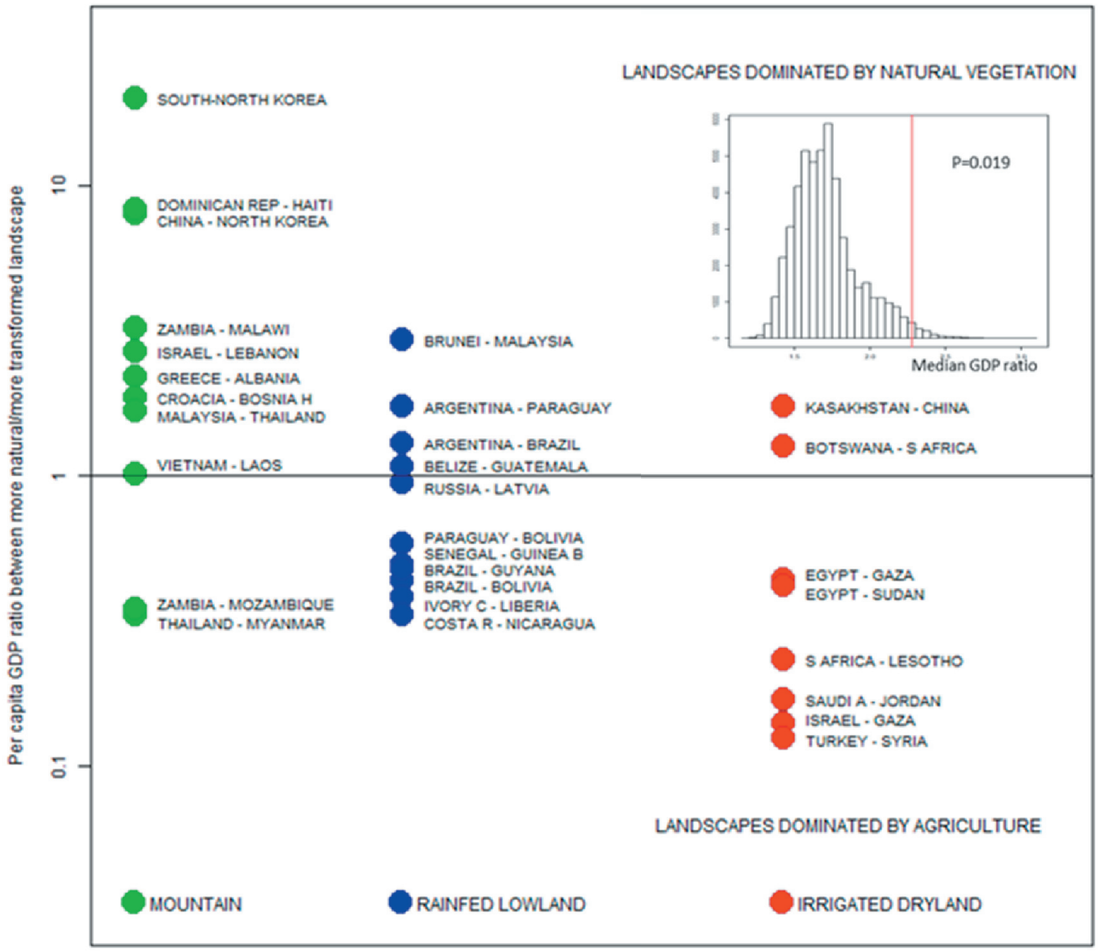

Figure 2. Ratio of per capita GDP between countries with divergent land use (more transformed/less transformed) along a portion of their international border. A value >1 implies that the wealthier country had a lower cover of agriculture in comparison to natural covers, while a value <1 implies the wealthier country had a higher cover agriculture in comparison to natural covers. 2015 GDP (Per capita Gross Domestic Product) values are from the World Bank data base for most of the countries, and from CIA Factbook for Syria and North Korea. In all cases, GDP values are expressed as Purchasing Parity Capacity and the wealthier country is listed first. The insert shows the distribution of the median ratio of per capita GDP (wealthier/poorer) of samples of 30 randomly taken from countries sharing borders across the globe (49892 pairwise transborder comparisons were conducted). For comparison, the red line shows the median value for the GDP ratio (richer/poorer) of the 30 pairs analyzed in this article.

Figura 2. Cociente entre el Producto Bruto Interno per cápita entre países con usos de cobertura divergentes en sus límites (más transformado/menos transformado). Valores >1 implican que el país más rico tiene menor cobertura de agricultura en comparación con cobertura natural, mientras que valores <1 implican que el país más rico tiene una cobertura transformada mayor que la cobertura natural. Los valores de PBI corresponden a datos de Banco Mundial para 2015 en la mayoría de los casos, y el CIA Factbook para Siria y Korea de Norte. En todos los casos, los valores de PBI se expresan como Paridad de Capacidad de Compra, y el país más rico del par se lista primero. El recuadro muestra la distribución de la mediana de la razón de PBI (más rico/más pobre) de muestras de 30 países tomadas al azar a partir de pares de países que comparten límites alrededor del mundo (se incluyeron 49892 comparaciones). A los fines comparativos, la línea roja muestra la mediana de la razón de PBI (más rico/más pobre) de los 30 pares analizados en este artículo.

conservation policies, economic growth generally results in the destruction of vast zones of tropical forests, threatening high biodiversity and high biomass ecosystems such as the Amazonian, Chaco, West African and Mesoamerican rainforests. However, three of the wealthier countries had more forest remaining than the poorer neighbor in tropical lowlands. In the case of Brunei, the economy is based largely on oil production and virtually all agricultural products are imported. The cases of Argentina (compared to Brazil and Paraguay) and Belize (compared to Guatemala), partly reflect that these countries have more productive agriculture lands in other regions (Piquer-Rodríguez et al. 2021).

The association between agriculture expansion and GDP is even more marked in irrigated drylands: in six of the eight landscape divergences associated with international borders, the wealthier country showed more land use intensification. Irrigated agriculture requires infrastructure investment which often results in large gains in productivity and job opportunities (Geist et al. 2006). Counterbalancing these benefits, irrigation agriculture could negatively affect local wetlands with increases in fertilizer and pesticide loads and reduced freshwater flows, which could result in transnational conflicts (e.g., USA-México, Turkey-Syria, Ethiopia-Sudan-Egypt). Similar to the case of Brunei in lowland rainforests, lower irrigation development in Kazakhstan compared to China may be the result of a mining-oriented economy in the former.

Some of the landscape divergences may be transient conditions. For example, it is likely that if Albania or Bosnia-Herzegovina follows a predictable western-style development pathway, their hilly landscapes will become more forested and less grazed as is currently the case in neighboring Greece or Croatia. In the absence of strict protection policies, with more capital availability, Nicaragua or Bolivia may deforest their lowlands as Costa Rica, Brazil and Paraguay have done. But, in other cases, the discrepancy may be persistent due to positive feedbacks in one or both sides, as each country wants to secure its sovereignty through protected areas (Marinaro et al. 2012) or specific land use policies to reinforce national control over the area (e.g., colonization plans, infrastructure development). For example, the lowland tropical Atlantic forest of Brazil and Paraguay has been transformed into agriculture, while in Argentina, with highly productive agricultural lands in other regions, the Atlantic forest is used for conservation-based tourism and timber production (Izquierdo et al. 2008; Piquer-Rodríguez et al. 2021). National Parks can also play an important role in stabilizing some of these borders: Iguazu in Brazil/Argentina, Noel Kempf, Serra du Cutia, and Pacaas nuevos in Brazil/Bolivia, Gran Chaco in Bolivia/Paraguay, Niyik and Kasungu National Parks in Malawi/Zambia, Leina National Park (Myanmar/Thailand).

Discussion and Conclusions

Our observations show that major socioecological differences can emerge across international borders, including landscape divergences that affect biodiversity and ecosystem services. Similarly, landscape divergence could also emerge across sub-national borders, especially in countries where states or provinces have decision making autonomy (e.g., Fernández Milmanda and Garay 2019) or are subject to de-centralization devolution-related processes (Rodríguez Pose and Gill 2003). Such discontinuities, here documented across political units, have been studied from an ecological point of view, and these studies documented strong effects on wildlife population viability, animal movement and fire spread (Dallimer and Strange 2015; Fahrig 2017; Mason et al. 2020).

Our exploratory analysis highlights across border land use discontinuities and suggests that in these particular cases the outcome relates to economic asymmetries and the biophysical context (e.g., topography and water availability). These two variables are important in determining the type, extent and capital investment in agricultural activities, and imply that conservation policies in response to economic growth present contrasting challenges in mountains compared to lowlands and valleys. In mountainous regions, unsuitable for mechanized agriculture, wealthier countries tend to favor conservation or secondary forest recovery, while in deserts, wetlands, valleys and fertile tropical lowlands, apt for modern agriculture, the wealthier countries have used capital to transform these ecosystems (Figure 3).

The cases we identified represent only a small fraction of all international borders and do not imply that international borders necessarily generate abrupt discontinuities. Furthermore, divergence in land use will rarely occur along the complete length of a border. In the cases that we present, country-level GDP explain a significant part of the variation in land use divergences, but other variables such as cultural differences, geopolitical priorities or variation in within-country polices will also influence land use patterns across and along borders. The divergent patterns presented here are preliminary results based on comparable and easily accessible observational and country-wide data. More detailed analyses of transboundary divergences which included

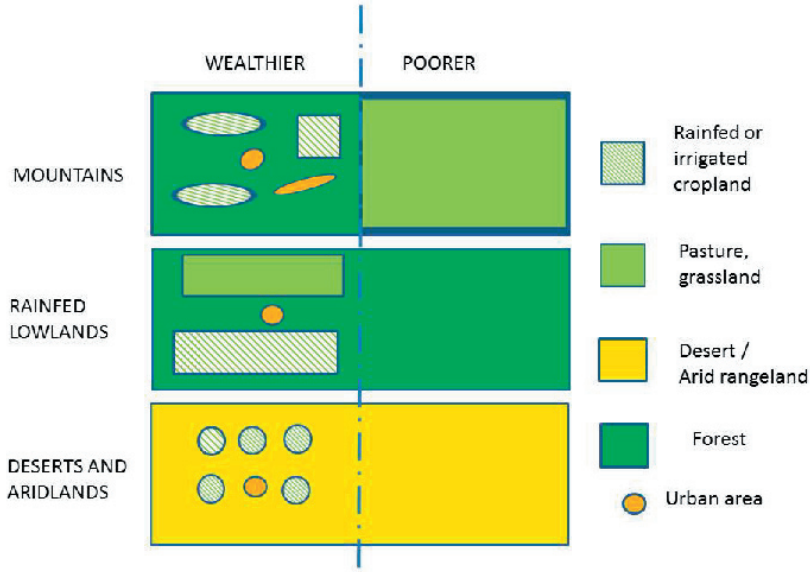

Figure 3. Schematic summary of the hypothetical patterns derived from this study. Wealthier and poorer refer to the economic characteristics of countries.

Figura 3. Representación esquemática de los patrones hipotéticos derivados de este estudio. Ricos y pobres son términos referidos a las características económicas de los países.

additional variables (fire frequency, land cover types, proportion of protected areas) in South America found similar results (Piquer-Rodríguez et al. 2021). Ideally, future research will expand this approach to the global scale and incorporate quantitative and comparative analyses of land system configurations and their impacts on the environment, including trade off-analyses (Niu et al. 2021). Landscape ecologists have long seen that patterns of land cover can feedback into the biophysical driving forces (Turner 1989), for example, fire or herbivory often favor vegetation that reinforces fire- or herbivory-prone vegetation. The same concept has been extended to explain landscape-level interactions between societies where ecosystem conditions (e.g., desert versus rainforest) influence human decisions (e.g., infrastructure versus protected areas) (Willson and King 1995). Geopolitical research has developed the concept of 'borderscapes' to emphasize the specific spatially-related functioning of borders (Brambilla 2014). The patterns described here highlight the importance of using similar analytical approaches to social-ecological systems that develop self-reinforcing mechanisms, and are particularly relevant because they emphasize the interactions between land cover and land use, and countries, the most important decision-making unit at extensive geographical scales.

Despite much emphasis on globalization-related processes, the number of countries and their borders increased dramatically during the past century; this trend shows no sign of reversal and implies more international borders in the future (Khana 2016). Our preliminary observations provide an example of a relatively understudied process: country´s borders as drivers of landscape configuration and regional-scale ecological functioning. Given that the Anthropocene is an 'era' characterized by the overwhelming influence of human decisions on the biosphere´s functioning and that countries are the key geographic decision units, they deserve a greater attention, particularly in the intersection between land system and sustainability sciences.

ACKNOWLEDGEMENTS. Javier Foguet helped in organizing the Supplementary material. Two anonymous reviewers provided helpful comments on the previous manuscript. Funding was provided by PICT 2015-0521 'Globalización, teleconexiones y cambios de uso del territorio en América Latina en el siglo 21'; PUE 023 'El antropoceno en el noroeste Argentino: uso del territorio, nuevos ecosistemas, servicios ambientales, forzantes globales y gobernanza regional' to HRG; and SO_087_GeoX (Geo.X, the Research Network for Geosciences in Berlin and Potsdam) and Justus-Liebig University Giessen to MPR.

References

Aide, T. M., and H. R. Grau. 2004. Globalization, migration, and Latin American ecosystems. Science 305:1915-1916. https://doi.org/10.1126/science.1103179.

Allen, J., N. Burns, L. Garrett, R. N. Haass, G. J. Ikenberry, K. Mahbubani, S. Menon, R. Niblett, J. S. Nye Jr., S. K. O'Neil, K. Schake, and S. M. Walt. 2020. How the world will look after the Corona virus pandemic. Foreign Policy, March 20.

Brambilla, C. 2014. Exploring the critical potential of the borderscapes concept. Geopolitics 20:13-43. https://doi.org/10.1080/14650045.2014.884561.

Crespo Cuaresma, J., and M. Heger. 2019. Deforestation and economic development: evidence from national borders. Land Use Policy 84:e347-e353. https://doi.org/10.1016/jlandusepol.2018.12.039.

Diamond, J., and J. A. Robinson. 2010. Natural experiments of history. Harvard University Press.

Dallimer, M., and N. Strange. 2015. Why socio-political borders and boundaries matter in conservation. Trends in Ecology and Evolution 30:132-139. https://doi.org/10.1016/tree.2014.12.004.

Fahrig, L. 2017. Ecological responses to habitat fragmentation per se. Annual Review in Ecology, Evolution and Systematics 48:1-23. https://doi.org/10.1146/annurev-ecolsys-110316-022612.

Fernández Milmanda, B., and C. Garay. 2019. Subnational variation in forest protection in the Argentine Chaco. World Development 118:79-90. https://doi.org/10.1016/j.worlddev.2019.02.002.

Geist, H., and E. Lambin. 2002. Proximate causes and underlying driving forces of tropical deforestation. Bioscience 52:143-150. https://doi.org/10.1641/0006-3568(2002)052[0143:PCAUDF]2.0.CO;2.

Geist, H., E. Lambin, C. Palm, and T. Tomich. 2006. Agricultural transitions at drylands and tropical forest margins: actors, scales and tradeoffs. Pp. 53-73 *in* F. Brower and B. A. Mc Carl (eds.). Agriculture and Climate Beyond 2015. Dordrecth: Springer. https://doi.org/10.1007/1-4020-4368-6_4.

Hull, V., and J. Liu. 2018. Telecoupling: a new frontier for global sustainability. Ecology and Society 23:41. https://doi.org/10.5751/ES-10494-230441.

Izquierdo, A. E., C. De Angelo, and T. M. Aide. 2008. Thirty years of human demography and land use change in the Atlantic forest of Misiones, Argentina: an evaluation of the Forest Transition model. Ecology and Society 13:3. https://doi.org/10.5751/ES-02377-130203.

Khana, P. 2016. Connectography: mapping the future of global civilization. Random House, N. York.

Laine, J. P. 2016. The multiscalar production of borders. Geopolitics 21:465-482. https://doi.org/10.1080/14650054.2016.1195132.

Mason, N., M. Ward, J. E. M. Watson, O. Venter, and R. G. Runting. 2020. Global opportunities and challenges for transboundary conservation. Nature Ecology and Evolution 4:694-701. https://doi.org/10.1038/s41559-020-1160-3.

Marinaro, S., H. R. Grau, and E. Aráoz. 2012. Extensión y originalidad en la creación de parques nacionales en relación a cambios gubernamentales y económicos de la Argentina. Ecología Austral 22:1-10.

Nanni, A. S., and H. R. Grau. 2017. Land use redistribution compensated for ecosystem services losses derived from agriculture expansion, with mixed effects on biodiversity in a NW Argentina watershed. Forests 8:303. https:/doi.org/10.3390/f8080303.

Niu, T., I. Yu, D. Yue, L. Yang, X. Mao, Y. Hu, and Q. Long. 2021. The temporal and spatial evolution of ecosystem services synergy/trade-offs based on ecological units. Forests 12(8):992. https://doi.org/10.3390/f12080992.

O´Sullivan, M. 2018. The levelling: what´s next after globalization. Hachete, N. York.

Piquer-Rodríguez, M., N. I. Gasparri, L. Zarbá, E. Aráoz, and H. R. Grau. 2021. Land system´s asymmetries across transnational ecoregions in South America. Sustainability Science 16:1519-1538. https://doi.org/10.1007/s11625-021-00967-2.

Redo, D., H. R. Grau, T. M. Aide, and M. Clark. 2012. Asymmetric forest transition driven by the interaction of socioeconomic development and environmental heterogeneity in Central America. Proceedings of the National Academy of Sciences 109:8839-8844. https://doi.org/10.1073/pnas.1201664109.

Rodríguez Pose, A., and N. Gill. 2004. The global trend towards devolution and its implications. Environment and Planning C: Politics and Space 21(3):333-351. https://doi.org/10.1068/c0235.

Rudel, T. K., O. T. Coomes, E. Morán, F. Achard, A. Angelsen, J. Xu, and E. Lambin. 2005. Forest transitions: towards a global understanding of global land use change. Global Environmental Change 15:23-31. https://doi.org/10.1016/j.gloenvcha.2004.11.001.

Turner, M. 1989. Landscape ecology: the effect of pattern on process. Annual Review in Ecology and Evolution 20: 171-197. https://doi.org/10.1146/annurev.es.20.110189.001131.

Verburg, P. H., N. Crossman, E. C. Ellis, A. Heinimann, P. Hostert, O. Mertz, H. Nagendra, T. Sikor, K.-H. Erb, N. Golubiewski, R. Grau, M. Grove, S. Konaté, P. Meyfroidt, D. C. Parker, R. R. Chowdhury, H. Shibata, A. Thompson, and L. Zhen. 2015. Land system science and sustainable development of the earth system: A global land project perspective. Anthropocene 12:19-41. https://doi.org/10.1016/j.ancene.2015.09.004.

Wilson, N., and B. W. King. 1995. Human mediated vegetation switches as processes in landscape ecology. Landscape Ecology 10:191-196. https://doi.org/10.1007/BF00129253.

Zobel, F., B. Putzenlechner, and M. Mauser. 2014. Global agricultural land resources - A high resolution suitability evaluation and its perspectives until 2100 under climate change conditions. Plos ONE 9(12):e114980. https://doi.org/10.1371/journal.pone.0107522.