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Implications of Agricultural Development for Tropical Biodiversity

Jeffrey D. Brawn

Abstract

Biodiversity at tropical latitudes is notably great and increasingly threatened by habitat loss and the direct or indirect effects of climate change. Estimates vary but there is reasonably strong evidence that current rates of species extinction and local extirpations are historically high and increasing. Habitat loss and fragmentation owing to agriculture drives much of this trend and the large-scale loss of forest habitat to crops such as palm oil and soy is especially concerning. Evidence is emerging that changes in precipitation regimes at tropical latitudes may also pose a significant threat to tropical ecosystems. A trend toward more severe seasonal drought and xeric conditions is predicted for large regions of the tropics and, while data are few, this will likely challenge the viability of many animal populations and communities. Dryer conditions may be especially severe in regions where deforestation and agriculture dominant land use. These issues motivate the need for close communication and joint research agendas among conservationists, climate modelers, and agribusiness.

Keywords

agriculture, development, tropics, biodiversity, habitat fragmentation, climate change

Conserving tropical biodiversity and maintaining the integrity of tropical ecosystems is one of the most critical issues in conservation biology and a short essay on tropical biodiversity and agriculture cannot do justice to the scope and complexity of the issue. Notwithstanding, two established facts are essential. First, the level of biodiversity residing at tropical latitudes is phenomenally high as are current estimates of species' extinction rates. And second, demands on tropical lands and resources by agriculture will increase owing to population growth and the inevitable need for more food, fuel, and fiber. The challenge for resident biota is exacerbated when the expected effects of climate change at tropical latitudes are factored in. Climate-related changes in rainfall regimes, for example, are commonly predicted. In this essay, I provide a brief account of issues and offer ideas for future research that may serve to inform conservation policy. The combined effects of deforestation and land use on local and regional precipitation regimes is emerging as a critical issue for conserving tropical biodiversity.

Tropical Biodiversity and Estimated Rates of Species Loss

Excellent accounts of the global distribution of biodiversity are found in biogeography texts (Cox & Moore, 1999), illustrated in websites (http://biodiversitymapping.org/wordpress/index.php/global-visualizations/), and in a recent account by Pimm et al. (2014). For nearly all terrestrial taxa, species diversity is markedly high. For example, globally about 10,000 species of birds have been described and nearly one third of these are found in the New World or Neotropics with nearly 1,900 found in Colombia alone. The Old World or Paleotropics are also rich with bird species as illustrated by Indonesia where over 1,600 species have been observed. More generally, the Amazon Basin, southeastern Brazil, and Central Africa account for nearly 50% of the worlds' vertebrate species but only about 7% of the land area (Jenkins, Pimm, & Joppa, 2013). With few exceptions, most animal groups show similar biogeographic patterns. Importantly, the proportion of species that are endemic,

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often with restricted or small ranges, is also notably high in most tropical regions—area-restricted endemics appear to be especially vulnerable to local extirpation or extinction (Pimm et al., 2014).

Estimates of global extinction rates indicate that current and expected near-term rates far exceed estimated "background" rates of species loss as observed in the geological record (Pimm et al., 2014). Current rates may exceed 1000× the background rate and, alarmingly, this may be an underestimate since certain types of species and regions remain under sampled. Significantly, there has been an uptick in rates of species loss since 1900 and population sizes for extant species may have decreased by 50% in the past four decades (WWF, 2016). By this account, there is little evidence of abatement despite the rise of conservation-oriented science efforts to conserve habitat. Whereas these estimates are not universally accepted (McGill, Dornelas, Gotelli, & Magurran, 2015), there is widespread acceptance that comprehensive surveys are lacking for many tropical regions and far more systematic sampling is needed.

Causes of Species Loss

For tropical regions, habitat loss and fragmentation are the major threats to biodiversity and much of this is driven by agriculture (Haddad et al., 2015). In the 1980s and 1990s, the primary cause of loss in tropical forests was agricultural expansion (Gibbs et al., 2010). In Latin America, cattle pasturing increased significantly during this period with especially large losses of intact forest. More recently, increases in land devoted to crops such as oil palm and soy have intensified rates of forest loss (Laurance, Sayer, & Cassman, 2014).

The effects of habitat loss and fragmentation of tropical forests are well established—small parcels support fewer species and, for many species, only large tracts of forest can support viable populations. A recent meta-analysis indicates that habitat fragmentation reduced species richness by 13% to 75% (Haddad et al., 2015).

Climate Change, Land Use, and Precipitation

Ecologists have long known that rainfall and rainfall patterns are key elements for understanding the biology and function of tropical ecosystems (Bonebrake & Mastrandrea, 2010). Indeed, recent analyses suggest that precipitation, not temperature, may be the key climatic variable underlying global patterns of natural selection (Siepielski et al., 2017). For tropical systems, rainfall regimes (i.e., how much and when) drive nearly all ecological processes and distributional patterns. The severity of seasonal drought (largely a function of length of the dry season), for example, is a major determinant of the distribution of tropical tree species (Condit, Engelbrecht, Pino, Perez, & Turner, 2013). Moreover, there is clear evidence that prolonged droughts lead to selective mortality of trees and changes in the floristic composition of tropical forests (Hilker et al., 2014). Such changes have inevitable cascading effects on animal populations and communities since vegetation (i.e., trees, shrubs, and lianas) determine fruit, flower, nectar, and arthropod availability for vertebrates.

Tropical rainfall regimes are predicted to change over the next few decades under most greenhouse gas emission scenarios. A common prediction is that there will be regional trends toward dryer conditions, often as a result of longer dry seasons (Feng, Porporato, & Rodriguez-Iturbe, 2013; Fu, 2015). If realized, this change will lead to significant changes in the function and integrity of tropical biological systems. Distributional or range shift changes in biodiversity will have fundamental impacts on ecosystems and the availability of natural resources upon which humans depend (Pecl et al., 2017).

Whereas plausible changes in rainfall regimes owing to climate change will have large-scale and long-term effects on tropical systems, it appears that local land use also affects precipitation patterns. Several analyses indicate that the amount of deforestation can affect tropical rainfall regimes (Boers, Marwan, Barbosa, & Kurths, 2017; Chadwick, Good, Martin, & Rowell, 2016; Spracklen & Garcia-Carreras, 2015). Much of the rainfall at tropical latitudes is a function of convective heat and the proportion of local deforestation can change rainfall patterns (Lawrence & Vandecar, 2015). Relatively modest levels of deforestation or small clearings can increase local rainfall, but above 30% to 50% deforestation, a tipping point is exceeded and rainfall decreases significantly (Boers et al., 2017). The clustered nature of agricultural development may cause this tipping point to be exceeded in many tropical regions where agricultural development has occurred. Moreover, large-scale deforestation in one area of, for example, the Amazon Basin may affect precipitation patterns in other areas where intact forest still remains. One model indicates that widespread deforestation in the eastern Amazon could lead to reductions in precipitation in the western Amazon of up to 40% (Boers et al., 2017). If true, this could result in wholesale loss of moist or wet forest in a process that has been called "savannization" (Franchito, Rao, & Fernandez, 2012).

Responses of Animal Populations to Climate Change and Agriculture

The effects of forest fragmentation on tropical animal populations and communities are reasonably well known. Generally, fewer species are found in disturbed habitats and certain types of species, such as understory insectivorous birds appear to be especially sensitive (Laurance et al., 2002). Importantly, the type of agriculture and the amount of tree-cover in agro-dominated landscapes significantly influences biodiversity (Mendenhall, Shields-Estrada, Krishnaswami, & Daily, 2016). Landscapes with greater tree-cover support far more species of animals than large tracts of row-crops or treeless pasture.

How animal populations in tropical regions will respond to changes in precipitation regimes is concerning. In the long-term, a trend to more xeric conditions and altered temperature regimes (owing to climate change, land-use, or both) will alter the floristic composition and structure of forest habitat to the point where there will likely be significant changes in the distributions of numerous animal species (Chan et al., 2016).

A drying trend may also challenge animal populations in the short term. A recent study based on long-term demographic sampling of birds populations in central Panama indicated that population growth rates are significantly lower following a longer dry season and more severe seasonal drought (Brawn, Benson, Stager, Sly, & Tarwater, 2017). Simulations based on these results suggested that even modest increases in length of dry season can lead to significant reorganization of animal communities in tropical forests—even without wholesale changes in forest structure or landcover.

Research Needs

With increasing demands on tropical land and ongoing climate change, the challenges for conserving tropical biodiversity are daunting. The effects of deforestation on local and regional precipitations patterns are becoming more apparent and this information is critical for conservation planning. Conceivably, even large tracts of undisturbed and protected habitat may be put at risk by land use and climate change if precipitation regimes are altered. Obviously, dryer conditions will also have adverse effects on agricultural productivity. These factors motivate the need for close communication and joint research agendas among conservationists, climate modelers, and agribusiness. For example, conservation biologists have suggested the need to identify ''precipitation refugia'' that will conserve biodiversity under expected climate change (Reside et al., 2014). Locating and conserving these refugia must now integrate the effects of local and regional land use on precipitation patterns.

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References

Boers, N., Marwan, N., Barbosa, H. M. J., & Kurths, J. (2017). A deforestation-induced tipping point for the South American monsoon system. *Scientific Reports*, *7*, 41489. doi:10.1038/srep41489

Bonebrake, T. C., & Mastrandrea, M. D. (2010). Tolerance adaptation and precipitation changes complicate latitudinal patterns of climate change impacts. *Proceedings of the National Academy of Sciences of the United States of America*, *107*(28): 12581–12586. doi:10.1073/pnas.0911841107

Brawn, J. D., Benson, T. J., Stager, M., Sly, N. D., & Tarwater, C. E. (2017). Impacts of changing rainfall regime on the demography of tropical birds. *Nature Climate Change*, *7*(2): 133–136. doi:10.1038/nclimate3183. Retrieved from http://www.nature.com/nclimate/journal/v7/n2/abs/nclimate3183.html#supplementary-information

Chadwick, R., Good, P., Martin, G., & Rowell, D. P. (2016). Large rainfall changes consistently projected over substantial areas of tropical land. *Nature Climate Change*, *6*(2): 177–181. doi:10.1038/nclimate2805. Retrieved from http://www.nature.com/nclimate/journal/v6/n2/abs/nclimate2805.html#supplementary-information

Chan, W.-P., Chen, I. C., Colwell, R. K., Liu, W.-C., Huang, C.-Y., & Shen, S.-F. (2016). Seasonal and daily climate variation have opposite effects on species elevational range size. *Science*, *351*(6280): 1437–1439. doi:10.1126/science.aab4119

Condit, R., Engelbrecht, B. M. J., Pino, D., Perez, R., & Turner, B. L. (2013). Species distributions in response to individual soil nutrients and seasonal drought across a community of tropical trees. *Proceedings of the National Academy of Sciences of the United States of America*, *110*(13): 5064–5068. doi:10.1073/pnas.1218042110

Cox, C. B., & Moore, P. D. (1999). *Biogeography: An ecological and evolutionary approach*. Oxford, England: Blackwell Science Ltd.

Feng, X., Porporato, A., & Rodriguez-Iturbe, I. (2013). Changes in rainfall seasonality in the tropics. *Nature Climate Change*, *3*(9): 811–815. doi:10.1038/nclimate1907

Franchito, S. H., Rao, V. B., & Fernandez, J. P. R. (2012). Tropical land savannization: Impact of global warming. *Theoretical and Applied Climatology*, *109*(1): 73–79. doi:10.1007/s00704-011-0560-3

Fu, R. (2015). Global warming-accelerated drying in the tropics. *Proceedings of the National Academy of Sciences of the United States of America*, *112*(12): 3593–3594. doi:10.1073/pnas.1503231112

Gibbs, H. K., Ruesch, A. S., Achard, F., Clayton, M. K., Holmgren, P., Ramankutty, N., & Foley, J. A. (2010). Tropical forests were the primary sources of new agricultural land in the 1980s and 1990s. *Proceedings of the National Academy of Sciences of the United States of America*, *107*(38): 16732–16737. doi:10.1073/pnas.0910275107

Haddad, N. M., Brudvig, L. A., Clobert, J., Davies, K. F., Gonzalez, A., Holt, R. D., . . . Townshend, J. R. (2015). Habitat fragmentation and its lasting impact on Earth's ecosystems. *Science Advances*, *1*(2): e1500052. doi:10.1126/sciadv.1500052

Hilker, T., Lyapustin, A. I., Tucker, C. J., Hall, F. G., Myneni, R. B., Wang, Y., . . . Sellers, P. J. (2014). Vegetation dynamics and rainfall sensitivity of the Amazon. *Proceedings of the National*

Academy of Sciences of the United States of America, *111*(45): 16041–16046. doi:10.1073/pnas.1404870111

Jenkins, C. N., Pimm, S. L., & Joppa, L. N. (2013). Global patterns of terrestrial vertebrate diversity and conservation. *Proceedings of the National Academy of Sciences of the United States of America*, *110*(28): E2602–E2610. doi:10.1073/pnas.1302251110

Laurance, W. F., Lovejoy, T. E., Vasconcelos, H. L., Bruna, E. M., Didham, R. K., Stouffer, P. C., . . . Sampaio, E. (2002). Ecosystem Decay of Amazonian Forest Fragments: A 22-Year Investigation Descomposición del Ecosistema en Fragmentos de Bosque Amazónico, Una Investigación de 22 Años. *Conservation Biology*, *16*(3): 605–618. doi:10.1046/j.1523-1739.2002.01025.x

Laurance, W. F., Sayer, J., & Cassman, K. G. (2014). Agricultural expansion and its impacts on tropical nature. *Trends in Ecology & Evolution*, *29*(2): 107–116. doi:10.1016/j.tree.2013.12.001

Lawrence, D., & Vandecar, K. (2015). Effects of tropical deforestation on climate and agriculture. *Nature Climate Change*, *5*(1): 27–36. doi:10.1038/nclimate2430

McGill, B. J., Dornelas, M., Gotelli, N. J., & Magurran, A. E. (2015). Fifteen forms of biodiversity trend in the Anthropocene. *Trends in Ecology & Evolution*, *30*(2): 104–113. doi:http://dx.doi.org/10.1016/j.tree.2014.11.006

Mendenhall, C. D., Shields-Estrada, A., Krishnaswami, A. J., & Daily, G. C. (2016). Quantifying and sustaining biodiversity in tropical agricultural landscapes. *Proceedings of the National Academy of Sciences of the United States of America*, *113*(51): 14544–14551. doi:10.1073/pnas.1604981113

Pecl, G. T., Araújo, M. B., Bell, J. D., Blanchard, J., Bonebrake, T. C., Chen, I.-C., . . . Williams, S. E. (2017). Biodiversity redistribution under climate change: Impacts on ecosystems and human well-being. *Science*, *355*(6332). doi:10.1126/science.aai9214

Pimm, S. L., Jenkins, C. N., Abell, R., Brooks, T. M., Gittleman, J. L., Joppa, L. N., . . . Sexton, J. O. (2014). The biodiversity of species and their rates of extinction, distribution, and protection. *Science*, *344*(6187): 1246752. doi:10.1126/science.1246752

Reside, A. E., Welbergen, J. A., Phillips, B. L., Wardell-Johnson, G. W., Keppel, G., Ferrier, S., . . . Vanderwal, J. (2014). Characteristics of climate change refugia for Australian biodiversity. *Austral Ecology*, *39*(8): 887–897. doi:10.1111/aec.12146

Siepielski, A. M., Morrissey, M. B., Buoro, M., Carlson, S. M., Caruso, C. M., Clegg, S. M., . . . MacColl, A. D. C. (2017). Precipitation drives global variation in natural selection. *Science*, *355*(6328): 959–962. doi:10.1126/science.aag2773

Spracklen, D. V., & Garcia-Carreras, L. (2015). The impact of Amazonian deforestation on Amazon basin rainfall. *Geophysical Research Letters*, *42*(21): 9546–9552. doi:10.1002/2015gl066063

WWF. (2016). *Living planet report 2016. Risk and resilience in a new era*. Gland, Switzerland: Author.