How we measure biodiversity can have profound impacts on land-use

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A study led by Princeton University illustrates this challenge by using several different approaches to solve the same puzzle: Given a target amount of food, where should new croplands be put to minimize environmental or biodiversity impacts? Credit: Egan Jimenez, Princeton University

The world's human population is expanding, which means even more agricultural land will be needed to provide food for this growing population. However, choosing which areas to convert is difficult and

depends on agricultural and environmental priorities, which can vary widely.

A study led by Princeton University illustrates this challenge by using several different approaches to solve the same puzzle: Given a target amount of food, where should new croplands be put to minimize environmental or biodiversity impacts?

The researchers used the country of Zambia as a case study given that it currently harbors a significant amount of biodiversity but will likely see significant agricultural expansion. They looked at common ways of measuring biodiversity, like counting up the species present in the region, as well as factoring in the relative rarity of those species in that geographic region.

Depending on which factor they put into a model for optimizing land use , very different areas of land were suggested for agricultural development. In fact, the overlap between the recommended regions was less than 4%.

The findings, published in the journal *Ecological Applications*, indicate an urgent need for consensus: When such small differences can result in almost completely different results, contradictory models may become a roadblock to policymakers rather than a roadmap.

Conservation biologists should strive for more consistent methods for prioritizing biodiversity conservation, the researchers said, and must be more transparent in how they make and justify these decisions.

"The sheer scale of agriculture today means that we need to be strategic about where we decide to produce food into the future," said lead author Christopher Crawford, Ph.D. candidate in the Science, Technology, and Environmental Policy (STEP) Program in Princeton's School of Public

and International Affairs (SPIA). "Our paper puts the stakes for the natural world into greater context, showing that what you prioritize and how you measure it can have significant consequences on biodiversity."

Crawford's co-author David Wilcove, professor of ecology and evolutionary biology and public affairs and the High Meadows Environmental Institute, explains the effects in more detail.

"Let's say you decide which areas to protect for nature and which to convert to cropland based on where birds are, you might get a different answer than if you focused on mammals. And if you base your decision on protecting the places with the most species, you might get a different answer than if you based your decision on the places with the most endangered species," Wilcove said.

Crawford and Wilcove worked with Lyndon Estes of Clark University and Tim Searchinger, also of SPIA, whose 2016 paper provided the inspiration and model used in this study. The team compared four distinct approaches to measuring biodiversity and dug into the factors underlying these different approaches.

The analysis started by comparing four commonly used approaches to measuring biodiversity previously published in academic journals. They then identified four key methodological decisions that underlay the differences between those four published approaches and created a new set of indices specifically designed to show the impact each general decision has on the prioritization of land.

Their first approach looks at the number of vertebrates—like mammals, birds, and reptiles—and plant species in a region, as well as expert advice on habitat priorities for conservation. The second takes into account the total number of vertebrate species, measuring their importance based on their extinction risk and the rarity of the type of

ecosystem in that region. The third approach focuses on the vegetation types in the different regions, weighing them in terms of how intact they are, how rare they are, and whether or not they are threatened. The fourth approach calculates the total number of species in the different regions, weighted by the size of their geographical ranges.

After running each approach through their model, the researchers found very different regions of Zambia were recommended for agricultural development—the overlap between the areas recommended by the different methods was less than 4%, and sometimes as low as 0.3%. This shows there likely isn't a "one-size-fits-all" solution to prioritizing land use. And while some decisions, such as changing the groups of species being considered, or how they are counted, had a much bigger effect on the ultimate land-use recommendations, even small and often overlooked methodological decisions can result in notably divergent recommendations.

The findings highlight the extreme complexity policymakers face when it comes to converting land. The method chosen when making these decisions can have huge consequences for biodiversity. While the researchers focused on biodiversity, it is also only one piece of the puzzle. Land-use prioritization must also take into account the suitability of the different regions for agriculture, the amount of carbon that would be released through land conversion, and the costs of transporting crops from the would-be agricultural region to markets. Decision-making becomes complicated if even two of these factors are considered at once, let alone all of them, because of the inevitable trade-offs.

"Which species you focus on, how you count and compare them, and the spatial scale of your analysis produce strikingly different answers to the question of which places to save and which places to develop," Wilcove said. "Scientists can come up with all sorts of sophisticated algorithms for balancing conservation with development, but unless they think very

carefully about how they counted and compared the plants and animals they want to protect, their results may be meaningless."

The paper, "Consequences of under-explored variation in biodiversity indices used for land-use prioritization," first appeared online in *Ecological Applications* on June 27.

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