Land Use Policy 39 (2014) 388–389

Contents lists available at ScienceDirect

Land Use Policy

journal homepage: www.elsevier.com/locate/landusepol

Reply to Skutsch et al.

Skutsch et al. criticized the results of our recently published article, which explores the relationship between land change and land tenure in Mexico (Bonilla-Moheno et al., 2013). Specifically, they question our methodology and consequently the conclusions, which they argue are biased for the following reasons:

"(a) the use of MODIS Enhanced Vegetation Index (EVI) data to measure deforestation, because the spatial resolution of this imagery (pixel size around 250 m, or 6.25 ha) does not permit a good estimation and much deforestation would go undetected at this scale, for example small scale clearances associated with unsustainable shifting cultivation and clearance for grazing, and;

(b) inclusion in the sample of only those municipalities which have >80% of their productive land under a given tenure type".

Below we take the opportunity to explain why their interpretations of our analyses are misrepresented and erroneous.

Use of MODIS to quantify deforestation and forest recovery

At a technical level, Skutsch et al. have misrepresented the methodology we used for creating the land cover classification. First, they state: "Statistics from [MODIS] EVI are used to carry out a per-pixel land cover classification." Although the resolution of our mapping was indeed at nominal 250-m resolution, our classification analysis was not based solely on MODIS Enhanced Vegetation Index (EVI) data. As explained in our methods, and described in more detail in Clark et al. (2012), pixel-level classification was based on 120 variables derived from the MOD13Q1 MODIS satellite image product. These variables included: mean, standard deviation, minimum, maximum and range for EVI, red, NIR and MIR values for three 4-month periods, two 6-month periods, and one 12-month period for each calendar year between from 2001 to 2010. Second, they state: "The use of regression over multiple readings in any one year neatly deals with the fact that changes in the area classified as woody vegetation could reflect variation in phenology". This is inaccurate, as we do not conduct within year regressions. Instead, we perform for each municipality a linear regression of annual area of woody vegetation over 10 years of data, which is a unique contribution to the study of land change science.

Skutsch et al. also criticize our use of MODIS for detecting land use change, suggesting that medium spatial resolution imagery (e.g., SPOT or Landsat) would be more appropriate.

In principle we agree, and as co-authors state in Clark et al. (2012), "we do not advocate MODIS-based mapping as a substitute for finer-scale data analysis, which should produce better area estimates." Landsat and SPOT imagery does offer finer spatial resolution, but lack of temporal resolution means that images available without clouds often come from different seasons, where vegetation is in varying phenological states, complicating automated land-cover classification and change detection. SPOT is prohibitively expensive for a national mapping effort, while a decade of the Landsat archive has imagery with scan-line problems that cause large data gaps.

In practice, we have created an analytical sequence that is robust, comparable with detailed Landsat analyses, and most importantly is "wall-to-wall" in its spatial coverage using truly consistent image and reference datasets in space and time. An important component of our analytical sequence is the collection of training and validation data based on high-resolution images in GoogleEarth. This was done using web-based tool (Clark and Aide, 2011) that associated the land cover of more than 6000 MODIS pixels across the entire country of Mexico and across over 10 years. Another advantage of our analytical sequence is that MOD13Q1 product provides nearly two dozen16-day composite images per year. This greatly increases the number of cloud-free images, which as we previously stated is a major limitation when using Landsat images. Finally, by using the 10 years of estimates of woody vegetation cover in each municipality to determine the strength of the trend, we have developed a methodology that has been critically reviewed and accepted in a wide array of peer-reviewed journals, including those in high-impact remote sensing journals (Clark et al., 2010, 2012; Redo et al., 2012a,b, 2013; Sánchez-Cuervo et al., 2012; Aide et al., 2013; Álvarez-Berríos et al., 2013). Although not for Mexico, we compared change in forest area derived from our MODIS-based methodology with one of the most detailed analysis of forest change that exists in Latin America, the PRODES dataset for the Brazilian Legal Amazon, which used consistent processing of wall-to-wall Landsat imagery using semi-automated methods and found a significant correlation between the area of change estimated by the two datasets (Clark et al., 2012). One could argue that our approach was more complete because it included more municipalities than would otherwise be included in Landsat data owing to problems of cloud cover in the Amazon. Certainly, Landsat or SPOT classifications currently provide important land-cover change information for local studies, and new analytical and data processing techniques have the potential to produce consistent and wall-to-wall regional to global-scale data (i.e., Hansen et al., 2014), but we believe our approach is useful to highlight areas of significant change and assess broad-scale trends in a quick and consistent manner as MODIS maps were consistently produced through time and space.

Skutsch et al. critique focuses heavily on discrepancies in deforestation observed between our results (from this and the parallel paper they cite Bonilla-Moheno et al., 2012) and other studies in Mexico. Four important points must be made: first, our results by no means suggest that there is no deforestation happening in Mexico, nor do we imply that. A central issue that needs to be emphasized when comparing forest change from other studies to our data is that our analysis focused on trends in "woody vegetation" change over 10 years. Our pixel-based classification included eight cover classes; the woody class included areas with over 80% trees and shrubs and excluded plantations, while the mixed woody class included areas with 20–80% woody vegetation and herbaceous, agriculture or bare ground as a background. Although we used

0264-8377/$ – see front matter
http://dx.doi.org/10.1016/j.landusepol.2013.11.012

the terms "deforestation" and "forest recovery" when describing change, we were clear throughout our paper that we were describing decreases or increases in "woody vegetation." In this sense, land cover changes are not limited to transitions from closed canopy to extensively deforested areas, but also include subtle changes like woody encroachment that goes from less woody to more woody cover. Second, the results cited as contrary to ours come from studies focused on different time periods or spatial scales. None of the studies were conducted for the time period 2001–2010 for all of Mexico. In fact, most of the cited studies rely on the same data (INEGI vegetation map series). Furthermore, we reported the same vegetation trends as some of the cited studies – Kolb and Galicia (2011) and Couturier et al., 2012 – for the comparable study regions. Third, we recognize the limitations of our data, but we question the accuracy of finer-scale change analyses that perform a per-pixel comparison of two to three dates of land-cover maps. As noted by Colditz et al. (2013), comparing two dates of INEGI maps for quantifying land change in Mexico can be problematic "due to inconsistencies in thematic class definition, spatial misalignment of polygons, differing mapping sources, and generalization to a scale of 1:250,000." As we mentioned, although our data are from coarser spatial resolution, they are consistently produced in space and time and quantified change (both loss and gain) based on linear models fit to ten years of area data aggregated over a large analytical unit (i.e., municipality). Finally, an important factor not questioned by Skutsch and colleagues, but which could explain some of the differences among results, was the increase in woody vegetation (e.g., shrub expansion) in the desert biome, a process that has been described for similar regions in south of the United States (e.g., Briggs et al., 2002, 2005, 2007). This increase is likely to be a complex interaction between regional climate and land abandonment.

The effects of tenure

A major concern of Skutsch et al. in this component of the article was that we restricted the analyses to municipalities where land tenure was dominated (>80%) by a single land tenure group (communal, ejido, or private). This filter ensured that we had a clear "treatment effect," but it reduced the samples size (i.e., number of municipalities) from 2443 to 965. Although an analysis that compared land change among the different land tenure classes within each municipality would have been optimal, the data for this level of analyses were not available. Even with these limitations, the analyses of land change and land tenure in 965 municipalities in Mexico is unprecedented. A second concern of Skutsch et al., which we noted in our article, was that land tenure classes were not uniformly distributed across biomes. This is precisely why, in an effort to not over generalize, we compared land change within each biome (Fig. 2 in Bonilla-Moheno et al., 2013).

Finally, we agree that the relationship between land cover change and land tenure is complex, and that scale plays an important role in the interpretation of results. After a thorough review of our methodology, analyses, results and interpretations, we continue to stand by our study. Nonetheless, we appreciate the comments brought forth by Skutsch et al. and believe more studies are needed at all spatial scales to better understand land change drivers. We hope this exchange will motivate the continued search for better understanding. .

References

Aide, T.M., Clark, M.L., Grau, H.R., López-Carr, D., Levy, M.A., Redo, D., Bonilla-Moheno, M., Riner, G., Andrade-Núñez, M.J., Muñiz, M., 2013. Deforestation and reforestation of Latin America and the Caribbean (2001–2010). Biotropica 45, 262–271.

Álvarez-Berríos, N.L., Redo, D.J., Aide, T.M., Clark, M.L., Grau, R., 2013. Land change in the Greater Antilles between 2001 and 2010. Land 2, 81–107.

Bonilla-Moheno, M., Aide, T.M., Clark, M.L., 2012. The influence of socioeconomic, environmental, and demographic factors on municipality-scale land-cover change in Mexico. Regional Environmental Change 12, 543–557.

Briggs, J.M., Knapp, A.K., Brock, B.L., 2002. Expansion of woody plants in tallgrass prairie: a fifteen year study of fire and fire-grazing interactions. American Midland Naturalist 147, 287–294.

Briggs, J.M., Knapp, A.K., Blair, J.M., Heisler, J.L., Hoch, G.A., Lett, M.S., McCarron, J.K., 2005. An ecosystem in transition: causes and consequences of the conversion of mesic grassland to shrubland. Bioscience 55, 243–254.

Briggs, J.M., Schaafsma, H., Trenkov, D., 2007. Woody vegetation expansion in a desert grassland: prehistoric human impact? Journal of Arid Environments 69, 458–472.

Clark, M., Aide, M., 2011. Virtual interpretation of earth web-interface tool (VIEW-IT) for collecting land-use/land-cover reference data. Remote Sensing 3, 601–620.

Clark, M.L., Aide, T.M., Grau, H.R., Riner, G., 2010. A scalable approach to mapping annual land cover at 250 m using MODIS time series data: a case study in the Dry Chaco ecoregion of South America. Remote Sensing of Environment 114, 2816–2832.

Clark, M., Aide, M., Riner, G., 2012. Land change for all municipalities in Latin America and the Caribbean assessed from 250-m MODIS imagery (2001–2010). Remote Sensing of Environment 126, 84–103.

Colditz, R., Llamas, R.M., Ressl, R.A., 2013. Detecting change areas in Mexico between 2005 and 2010 using 250 m MODIS. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing 99, 1404–1939.

Couturier, S., Núñez, J.M., Kolb, M., 2012. Measuring tropical deforestation with error margins: a method for REDD monitoring in South Eastern Mexico. In: Sudarshana, P., Nageswara-Rao, M.R., Soneji, J.R. (Eds.), Tropical Forests. InTech (on-line).

Kolb, M., Galicia, L., 2011. Challenging the linear forestation narrative in the neotropics: regional patterns and processes of deforestation and regeneration in Southern Mexico. Geographical Journal 178 (2), 147–161.

Hansen, M.C., Egorov, A., Potapov, P.V., Stehman, S.V., Tyukavina, A., Turubanova, S.A., Roy, D.P., Goetz, S.J., Loveland, T.R., Ju, J., Kommareddy, A., Kovalskyy, V., Forsyth, C., Bents, T., 2014. Monitoring conterminous United States (CONUS) land cover change with Web-Enabled Landsat Data (WELD). Remote Sensing of Environment 140, 466–484.

Redo, D., Aide, T.M., Clark, M.L., 2013. Vegetation change in Brazil's dryland ecoregions and the relationship to crop production and environmental factors: Cerrado, Caatinga, and Mato Grosso, 2001–2009. Journal of Land Use Science 8 (2), 123–153.

Redo, D., Aide, T.M., Clark, M.L., 2012a. The relative importance of socioeconomic and environmental variables in explaining land change in Bolivia, 2001–2010. Annals of the Association of American Geographers 102 (4), 778–807.

Redo, D., Aide, T.M., Clark, M.L., 2012b. Asymmetric forest transition driven by the interaction of socioeconomic development and environmental heterogeneity in Central America. Proceedings of the National Academy of Sciences of the United States of America 109 (23), 8839–8844.

Sánchez-Cuervo, A.M., Aide, T.M., Clark, M.L., Etter, A., 2012. Land cover change in Colombia: surprising forest recovery trends between 2001 and 2010. PLoS ONE 7 (8), e43943.

Martha Bonilla-Moheno*
Red de Ambiente y Sustentabilidad, Instituto de Ecología A.C., Carretera antigua a Coatepec 351. La Haya, Xalapa, Veracruz, Mexico

Daniel J. Redo
T. Mitchell Aide
Department of Biology, University of Puerto Rico, Río Piedras, 00931-3360 San Juan, Puerto Rico

Matthew L. Clark
Center for Interdisciplinary Geospatial Analysis, Department of Geography and Global Studies, Sonoma State University, Rohnert Park, 94928 CA, USA

H. Ricardo Grau
Instituto de Ecología Regional, Universidad Nacional de Tucumán – CONICET, Casilla de Correo 34, 4107 Yerba Buena, Tucumán, Argentina

* Corresponding author.
Tel.: +52 228 842 180x4304
E-mail addresses: martha.bonilla@inecol.mx, bonilla.moheno@gmail.com (M. Bonilla-Moheno).

7 November 2013

Available online 25 December 2013