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Mapping the world's degraded lands

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ABSTRACT

Degraded lands have often been suggested as a solution to issues of land scarcity and as an ideal way to meet mounting global demands for agricultural goods, but their locations and conditions are not well known. Four approaches have been used to assess degraded lands at the global scale: expert opinion, satellite observation, biophysical models, and taking inventory of abandoned agricultural lands. We review prominent databases and methodologies used to estimate the area of degraded land, translate these data into a common framework for comparison, and highlight reasons for discrepancies between the numbers. Global estimates of total degraded area vary from less than 1 billion ha to over 6 billion ha, with equally wide disagreement in their spatial distribution. The risk of overestimating the availability and productive potential of these areas is severe, as it may divert attention from efforts to reduce food and agricultural waste or the demand for land-intensive commodities.

Introduction

Degraded lands are the center of much attention as global demands for food, feed and fuel continue to increase at unprecedented rates, while the agricultural land base needed for production is shrinking in many parts of the world (Bruinsma, 2003; Food and Agriculture Organization of the United Nations [FAO], 2005; Gelfand et al., 2013; Lambin et al., 2013; Lambin & Meyfroidt, 2011; Tilman et al., 2001). Indeed, projected population increases and rapidly growing meat consumption portend a projected doubling in global demand for agricultural commodities by 2050 (FAO, 2006). We expect additional pressure on the land base for fuel production as energy policies encourage more bioenergy production (World Energy Council [WEC], 2011).

Yield increases on existing croplands will be an essential component to increased food production, but by themselves will not suffice (Godfray et al., 2010; Hubert, Rosegrant, van Boekel, & Ortiz, 2010; Ray, Mueller, West, & Foley, 2013). Though inevitable, agricultural expansion into natural ecosystems leads to significant losses of ecosystem services, such as habitat necessary to maintain biodiversity, storage of carbon, flood mitigation, and soil and watershed protection, to cite a few (Foley et al., 2005; Gibbs et al., 2010; Lambin & Meyfroidt, 2011). Indeed, the full consequences of past and current agricultural expansion remain poorly understood, yet are likely to be dramatic. For example, Gibbs et al. (2010) found that during the 1980s and 1990s more than half of newly expanding agricultural areas in the tropics came at the expense of closed forests, with an additional third from disturbed forests. Others identify natural and planted grasslands as key sources for expanding row crops in the United States (Wright & Wimberly, 2013). Attention often focuses on steering crop expansion toward degraded or marginal lands in the hope of avoiding the environmental consequences of agricultural expansion into high-value ecosystems (e.g., Fargione, Hill, Tilman, Polasky, & Hawthrone, 2008; Gibbs et al., 2008).

Environmental and aid organizations, politicians, scientists, and the agricultural and energy sectors all point to various types of underutilized or degraded land as the solution to reconcile forest conservation with increasing agricultural production (e.g., Alexandratos & Bruinsma, 2012; Deininger & Byerlee, 2011; Gallagher, 2009; Gelfand et al., 2013; Gibbs, 2012; Robertson et al., 2008; Tilman, Hill, & Lehman, 2006). Clearly, there are a host of benefits to be achieved from the idealized vision of restoring degraded lands, especially when this could spare forests and avoid competition with food crops. However, this potential is often estimated using highly uncertain data sets (Field, Campbell, & Lobell, 2008; Goldewijk & Verburg, 2013; Hoogwijk et al., 2003; Meiyappan & Jain, 2012; Nijsen, Smeets, Stehfest, & Vuuren,

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2012; Ramankutty, Heller, & Rhemtulla, 2010; vanVuuren, Vliet, & Stehfest, 2009), and tends to be overstated, with little attention given to the current status and use of these degraded lands (Lambin et al., 2013; Young, 1999). The risks of overestimating the availability and productive potential of these areas is severe, as it may divert attention from efforts to reduce waste or the demand for land-intensive commodities such as beef.

Lack of understanding of the location, area, and condition of degraded land is a significant roadblock to a more reality-based strategy. Current estimates of potential production on degraded lands are greatly hindered by missing and often unreliable information (Grainger, 2009; Lewis & Kelly, 2014; Zucca, Peruta, Salvia, Sommer, & Cherlet, 2012). Indeed, no clear consensus exists as to the extent of degraded land, not only globally, but even within a particular country (Bindraban et al., 2012; FAO, 2008; Lepers et al., 2005). There are few if any routine assessments of degradation at the country level that keep track of pre-existing or changing conditions, nor is there any agreement on how to conduct such assessments (Bruinsma, 2003).

Simply to define "degradation" is challenging and likely contributes to the apparent variance in estimates. The term degradation is often used as an umbrella term that encompasses a wide variety of land conditions, such as desertification, salinization, erosion, compaction, or encroachment of invasive species. Conversely, it is sometimes used to refer to only a subset of these conditions. For example, many degradation studies focus only on drylands, so their results are difficult to compare with broader studies that include temperate and humid domains. In addition, there is disagreement between degradation data that include natural processes and those that have been induced solely through human activity (Weigmann, Hennenberg, & Fritsche, 2008), and it is often difficult to distinguish between these causes. Moreover, many of the specific circumstances behind degradation have different implications for rehabilitation, conservation, and productive potential. For example, in Indonesia a logged forest and highly eroded grassland may both be defined as degraded areas despite the clear distinctions between those land categories (Koh et al., 2010).

However, there is nearly universal consensus that degradation can be defined as a reduction in productivity of the land or soil due to human activity (Holm, Cridland, & Roderick, 2003; Kniivila, 2004; Oldeman, Hakkeling, & Sombroek, 1990). Yet studies focus on temporal and spatial scales of this process that differ, which leads to much confusion when interpreting the results. Indeed, while some estimates of degradation have focused on the end condition of the land, others consider the ongoing process of degradation itself (e.g., Bai, Dent, Olsson, & Schaepman, 2008; Cai, Zhang, & Wang, 2011), and even the perceived risk of degradation, adding more confusion to the term. Another challenge is that lands with naturally low productivity, such as heathlands or naturally saline soils, may also be described as degraded. Finally, while most seminal efforts have focused on *soil* degradation (Nijsen et al., 2012; Oldeman et al., 1990), more recent efforts have investigated the broader issue of *land* degradation from an ecosystem approach, which encompasses both soils and vegetation.

This paper takes the first step toward resolving these conflicts by compiling estimates of degraded lands at the global scale and providing the first geographically explicit and quantitative comparison across estimates. We review prominent databases and methodologies used to estimate degradation, translate these data into a common framework for comparison, and highlight reasons for discrepancies between the numbers.

Review of key datasets

The major approaches used to quantify degraded lands can be grouped into four broad categories: 1) expert opinion; 2) satellite-derived net primary productivity; 3) biophysical models; and 4) mapping abandoned cropland. Each offers a glimpse into the conditions on the ground but none capture the complete picture (Tables 1 and 2; Fig. 3).

Table 1
Benefits and limitations of major approaches used to map and quantify degraded lands.[a]

Approach	Benefits	Limitations
Expert opinion[b,c,d]	• Captures degradation in the past • Measures actual and potential degradation • Can consider both soil and vegetation degradation	• Not globally consistent • Subjective and qualitative • Actual and potential degradation sometimes combined • The state and process of degradation often combined
Satellite-derived net primary productivity[e]	• Globally consistent • Quantitative • Readily repeatable • Measures actual rather than potential changes	• Neglects soil degradation • Only captures the process of degradation occurring following 1980, rather than complete status of land • Can be confounded by other biophysical conditions
Biophysical models[f]	• Globally consistent • Quantitative	• Limited to current croplands • Does not include vegetation degradation • Measures potential, rather than actual degradation
Abandoned cropland[g,h]	• Globally consistent • Quantitative • Captures changes 1700 onward • Measures actual rather than potential changes	• Neglects land and soil degradation outside of abandonment • Includes lands not necessarily degraded

[a] Benefits and limitations refer to existing databases, not necessarily the approaches as a whole, which could be improved to overcome limitations.
[b] Oldeman et al., 1990.
[c] Dregne & Chou, 1992.
[d] Bot et al., 2000.
[e] Bai et al., 2008.
[f] Cai et al., 2011.
[g] Field et al., 2008.
[h] Campbell et al., 2009.