Data that we provide are derived from extensive global data sets on species and PAs that are already freely available (SM). Turning these data sets into information useful for the management of individual PAs requires processing and resources that are often not easily available to park managers and decision-makers. We make our results available in an easily accessible format (table S1) (*19*), to complement other information needed for effective protected area management (e.g., on the costs of conservation actions and the value of sites for conservation of biodiversity at levels other than species, such as genes and ecosystems).

PAs are our main hope for meeting ambitious global conservation targets, such as preventing species extinctions (*3*), but the costs of ensuring their effective management are substantial, albeit affordable (*21*). We hope that the conceptual guidance and specific data provided here will support strategic reinforcement of the world's existing PAs, to improve their individual and collective effectiveness for conserving global biodiversity.

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ENVIRONMENTAL SCIENCE

What Does Zero Deforestation Mean?

Ambiguous definitions and metrics create risks for forest conservation and accountability.

Sandra Brown[1]* and Daniel Zarin[2]

Since 2005, negotiations under the United Nations Framework Convention on Climate Change (UNFCCC) have focused considerable attention on the role that reducing emissions from deforestation and forest degradation (REDD+) can play in climate change mitigation. As global interest in reducing deforestation has grown, numerous governments, corporate groups, and civil society organizations have set time-bound targets for achieving "zero deforestation." Some targets specify "net deforestation," some "gross deforestation," and some do not specify at all (see the table). Public- and private-sector policy-makers who commit to deforestation reduction targets, and those who advocate for them, are often unclear about their implications. This lack of clarity may lead to perverse outcomes, including governments celebrating reductions of deforestation when large areas of native forest have been cut down and "zero deforestation" certification of agricultural commodities produced on land recently cleared of native forest cover. Progress toward goals of forest conservation, climate change mitigation, and associated cobenefits would be better served and more readily monitored by setting separate time-bound targets for reductions in the clearing of native forests (gross deforestation) and increases in the establishment of new forests on previously cleared lands (reforestation). Net deforestation targets, inherently and erroneously, equate the value of protecting native forests with that of planting new ones.

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Net Versus Gross Deforestation

The most commonly used source of data on global deforestation is the United Nations Food and Agriculture Organization's Forest Resource Assessment (FAO-FRA) program, which publishes reports at 5-year intervals (*1*). A key metric in the FAO-FRA reports is the annualized net change in forest area. This "net deforestation" is estimated as the difference in forest area between two points in time, taking into account both losses from deforestation and gains from forest regeneration and/or tree plantations, divided by the number of years between the two time periods (*1*, *2*). For most tropical countries, this metric is generally estimated from tabular data, provided to the FAO-FRA by the countries, which are based on periodic forest inventories, land-use surveys, and/or forest area maps but rarely from interpretation of multiyear remote sensing imagery due to the lack of capacity and resources to acquire and process the imagery. Because losses in forest area generally exceed gains due to secondary forest regeneration and tree plantings in tropical countries, the FAO-FRA "net deforestation" metric for those countries is often reported simply as "tropical deforestation" (*3*).

Meanwhile, since 1988, the Brazilian Space Agency (INPE) has monitored

Illustrative Examples of Deforestation Reduction Targets from Government, Private-Sector, and Nongovernmental Organizations

Government	Commitment	Source
Brazil	Pledged to cut **gross** deforestation in the Legal Amazon by 80% from historic levels (1996–2005) by 2020	Ref (*4*) and http://www.planalto.gov.br/ccivil_03/_Ato2007-2010/2010/Decreto/D7390.htm
Pará State, (Brazil)	Announced at Rio+20 a target of zero **net** deforestation by 2020	http://www.loterpa.pa.gov.br/?q=node/368
Peru	Target of zero **net** deforestation of primary and natural forests by 2021	http://www.unfccc.int/files/meetings/cop_15/copenhagen_accord/application/pdf/perucphaccord_app2.pdf
European Union	Considers that significant financial support must be provided to developing countries to halt **gross** tropical deforestation by 2020 at the latest	http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:C:2010:184E:0041:0043:EN:PDF
Corporate	**Commitment**	**Source**
Asia Pulp and Paper	From 1st February 2013 all natural forest clearance has been suspended…. No further clearance of areas identified as forest will take place (**not specified**)	http://www.asiapulppaper.com/system/files/APP%20Forest%20Conservation%20Policy-ENGLISH.pdf
Consumer Goods Forum	Board of the CGF has agreed a resolution pledging to mobilize resources within the respective businesses to help achieve zero **net** deforestation by 2020	http://www.theconsumergoodsforum.com/PDF/WorkingGroups-Accordion/Sustainability/10.Board_Resolutions_on_Deforestation_and_Refrigeration.pdf
Golden Agri-Resources	GAR wants to ensure that its palm oil operations have no deforestation footprint (**not specified**)	http://www.goldenagri.com.sg/pdfs/sustain_policies/GAR_Forest_Conservation_Policy.pdf
Nestlé	Nestlé's ambition is to ensure that its products have not led to deforestation (**not specified**)	http://www.nestle.com/asset-library/documents/media/statements/2012-october/2011-nestle_commitments_on_deforestation_forest_stewardship.pdf
Nongovernment	**Commitment**	**Source**
Greenpeace	Campaigning for zero deforestation (**not specified**) globally, by 2020	http://www.greenpeace.org/usa/en/campaigns/forest/solutions-to-deforestation/
World Wildlife Fund	Call for zero **net** deforestion by 2020 supported by delegates of 67 countries at the Ninth Conference of Parties to the Convention of Biological Diversity in 2008	http://www.panda.org/zerodeforestation

Table 1. Illustrative examples of deforestation reduction targets from government, private-sector, and nongovernmental organizations. In bold, we specify whether these deforestation commitments are gross, net, or not specified.

and reported annually the amount of gross deforestation in the 59% of Brazilian territory defined as the "Legal Amazon" (*4*). INPE's analysis, methods, and data are transparent and credible. Nationally and internationally, these data are reported as deforestation, just like the FAO-FRA data, although their meaning is quite different.

In contrast to net deforestation, gross deforestation is the loss in forest area over a given time period caused by conversion of forest to nonforested land (*5*). An estimate of gross deforestation begins with an agreed-upon definition of forest (commonly based on forest cover, i.e., the proportion of ground surface covered by tree canopies) and the derivation of a map from satellite imagery for the first time period (year 1) that classifies pixels as either forest or nonforest. A second map developed for the same area at the second time period (year 2), using the identical methodology, provides the basis for comparison to identify which forest pixels in year 1 changed to nonforest pixels at year 2. The sum of the area of the pixels that were converted to nonforest in the time interval is the amount of gross deforestation. Although this methodology does not distinguish between loss of forest cover caused by intentional clearing and loss of forest due to natural disturbances, additional analysis can be used to separate the two (*6*). Tree plantations also can be identified in the imagery and mapped separately from native forests, and any harvesting of them can be excluded from estimates of gross deforestation.

With a large suite of satellites to choose from, freely available data from some providers, robust algorithms for the interpretation of the imagery, and increased computing power, monitoring changes in forest cover is no longer a technical challenge (*6*). Numerous bilateral and multilateral agreements are now providing assistance to overcome the institutional and technical capacity and resource constraints in many tropical countries (*7*).

Carbon Emissions and Cobenefits

If the intent is to reduce carbon emissions, conserve biodiversity, and protect hydrological services, then reducing gross deforestation will generally have a better outcome than reducing net deforestation. Net deforestation targets are mostly ambiguous with respect to carbon emissions, biodiversity, and hydrological services because, according to the FAO-FRA methodology, low or even negative net deforestation may be reported even when there are large losses of native forests, if those losses are offset by increases in young secondary forests or tree plantations with inferior carbon, biodiversity, and hydrological service values. For this reason, and to safeguard the customary rights to native forests of indigenous and other local people, UNFCCC negotiators agreed to prohibit counting any carbon accumulation in plantations that substitute for native forests within countries' voluntary commitments to REDD+ (*8*). Sixty-seven countries that have pledged their support to a World Wildlife Fund's (WWF) 2020 goal of zero net deforestation have adopted a definition that, in contrast to the FAO-FRA methodology, explicitly excludes plantations (see the table).

For the purpose of climate change mitigation, it is particularly important to clarify that zero net deforestation does not mean zero net carbon emissions. For example, a zero net deforestation commitment may include conversion of 100,000 ha per year (ha $year^{-1}$) of native forest, with high carbon stocks, to agricultural commodity production and the reforestation of an equivalent area with secondary forest regrowth or new plantations that remove smaller quantities of carbon. If we assume that native forest biomass has an average carbon stock of

150 Mg C ha^{-1} (*9*) and the reforested area sequesters carbon at an annual rate of 5 Mg C ha^{-1} yr^{-1} (*10, 11*), the net annual emissions would be 14.5 Tg C yr^{-1}. Achieving zero net emissions in this example would require that for every 1 ha deforested, 30 ha would have to be reforested.

A Pragmatic Approach

At the national scale, the empirically derived "forest-transition" model has been used to classify countries into phases characterized by little loss of native forest area (pretransition), accelerating rate of forest loss (early transition), decelerating rate of forest loss (late transition), and reforestation (posttransition) (*12*). Efforts to reduce deforestation globally have prioritized the early- and late-transition countries and have helped to slow the loss of diverse, carbon-dense, "primary" forests. Brazil and Indonesia are emblematic examples of these "transition" countries, and Brazil has been the most successful at both setting and making progress toward a clear and ambitious deforestation reduction target (see the table). Pretransition countries like Gabon and Guyana may achieve their forest transitions with proportionally less deforestation, and they should be encouraged to do so. Posttransition countries like Costa Rica and India are actively reforesting, and in Costa Rica's case, this is part of a plan to reach economy-wide carbon neutrality by 2021 (*13*). Although the boundaries between these phases are porous and each country remains its own idiosyncratic case, at a general level, the phases define important differences among countries.

Deforestation in the Tesso Nilo National Park, Riau province, Indonesia, May 2013.

CREDIT: BAGUS INDAHONO/EPA/NEWSCOM

Global zero deforestation targets are particularly challenging. On the one hand, if the target is zero gross deforestation globally, as urged by the European Parliament (see the table), it cannot accommodate any expansion of infrastructure or agricultural production in native forest areas, including in pretransition countries. This seems both infeasible and inequitable. On the other hand, a global zero net deforestation target equates protecting high carbon/biodiversity/hydrologic-service–value native forests with the planting of lower-value new forests.

Ambitious targets for reductions in gross deforestation and for reforestation that take into account differences in forest-transition phases among countries are likely to prove more actionable than a one-size-fits-all approach. For example, the goal of eliminating deforestation from agricultural commodity production is possible at the global scale because big gains in productivity can be achieved by improving agricultural practices with existing technologies and because there are large expanses of previously cleared, underused land in some of the major commodity-producing countries like Brazil (*14*) and Indonesia (*15*). Hence, there are broad synergies, both globally and within these transition countries, among the goals of eliminating deforestation for commodity production, intensifying agricultural production, and restoring degraded lands. Indeed, two major commodity-producing companies with large historic responsibility for deforestation in Indonesia (Golden Agri-Resources and Asia Pulp and Paper) have announced their own zero deforestation policies (see the table) where others have not (see the figure).

In tropical countries that have little nonforested land either suitable or available for agriculture, including several in Latin America and Central Africa, zero deforestation would mean halting agricultural expansion. Without compelling economic development alternatives, this may prove difficult to sustain, especially when global demand for food, fiber, and bioenergy continues to grow (*16*). In these pre- to early-transition countries, nonzero targets for deforestation—integrated within robust land-use planning, rural development, and governance initiatives—can be both ambitious and suited to national circumstances.

As an idea, zero deforestation is compelling. It seems simple and precise, and therefore attractive. But as a global target, it means much more than what is achievable if the meaning is "gross," and much less if it is "net." Intentionally or not, these terms are being used ambiguously and sometimes interchangeably, which fosters confusion and sets the stage for perverse outcomes. Governments, corporations, and nongovernmental organizations should instead set separate, ambitious targets for reductions in gross deforestation and for reforestation. Some gross deforestation targets, including for commodity production in transition countries, could be actionable at or near zero; others could not. Until targets are clarified, and metrics agreed upon, zero may mean nothing at all.

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