Measuring the planet to fill terrestrial data gaps

Alan Grainger[1]
School of Geography, University of Leeds, Leeds LS2 9JT, United Kingdom

How a growing world population can sustain itself on Planet Earth has been the focus of much research. Norman Borlaug (1), the "father of the Green Revolution," argued that one answer is to intensify agriculture to produce more food on the same area of land. But what he promoted as a policy strategy, others have called the "Borlaug hypothesis," aiming to add it to sustainability science theory and test it empirically. In this issue of PNAS Rudel et al. (2) follow earlier national studies (3) by testing the hypothesis at global scale. They demonstrate the existence of the general phenomenon of "land sparing," by showing that cropland area has increased more slowly than population since 1970. However, they find relatively little evidence that intensification has gone further, by shrinking cropland and generating surplus "spared land," and much of this evidence is linked to changes in trade patterns. Yet their article will prove important for introducing the concept of spared land into the literature, inspiring more research, and stimulating debate about how land sparing relates to existing theory. This commentary focuses on a key challenge they identify (the measurement of land sparing) and wider monitoring issues raised by it. It refers mainly to developing countries.

Rudel et al. (2) actually discuss two types of land sparing. The first type, which I shall call "sparing land," reduces the rate of farmland expansion. To demonstrate it requires evidence that farmland has expanded more slowly than population and (in the tropics) that deforestation rates have fallen. It can be predicted by models, e.g., using a simple model showed that if mean farm yields rose by 1–2% a^{-1} (depending on the region and scenario) deforestation rates could fall by 44–88% between 1980 and 2020, saving 59–64 ha.10^6 of forest (4). The second type, which Rudel et al. (2) term "spared land," is generated by farmland contraction. To identify it requires evidence for the latter, and that the surplus has been transferred to another land use via various routes (Fig. 1). When a time series of estimates of tropical moist forest area for 1973–2000 did not show the expected decline, it led to an hypothesis that continuing deforestation could be offset by natural reforestation elsewhere (5). Spared land is where this reforestation could occur,

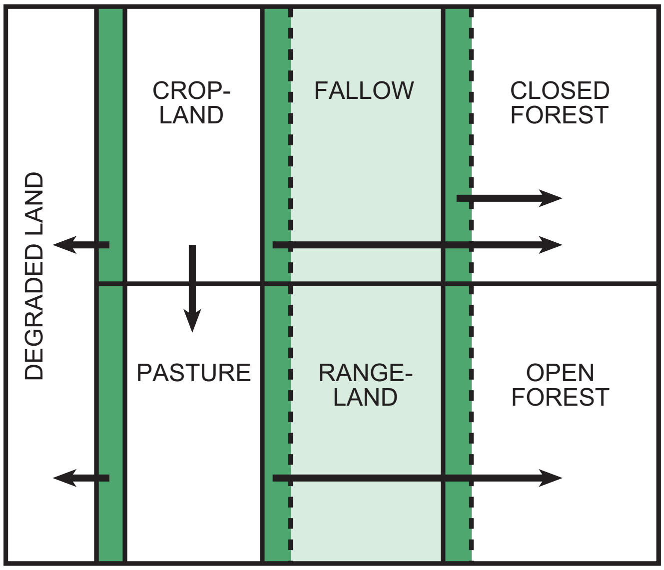

Fig. 1. A simplified portrait of principal transfer paths for spared land. Paths are shown by arrows, origins of spared land are in dark green, and overlaps between land use types are in light green. Cropland includes permanent and shifting cultivation.

and so spared land could become a new intermediate item in carbon accounting.

Both types of land sparing control deforestation, helping countries to pass through their "forest transitions" (6). But whereas sparing land depends on technological innovation, spared land can appear in any country once all highly fertile areas are identified and less fertile lands are abandoned or transferred to less intensive uses.

Rudel et al. (2) infer the existence of both types from trends in the areas of 10 major crops. This approach has limitations, which they discuss. Whether they could confirm the sparing land phenomenon in the tropics is debatable, because uncertainty about national deforestation rates makes it difficult to find convincing evidence for their decline. The main source of estimates are the Forest Resources Assessments (FRAs) of the United Nations Food and Agriculture Organization (FAO), which rely largely on government statistics, not scientific measurements (5). Two forest area data points are needed to determine a trend. Yet only half of tropical countries have had two national forest surveys, of which the latest occurred after 1980 (Table 1). The Parties to the United Nations Framework Convention on Climate Change hope to introduce a Reduced Emissions from Deforestation and Degradation (REDD) scheme to help developing countries cut deforestation rates below recent reference levels; Table 1 shows that determining these levels may be difficult.

Rudel et al. (2) are severely constrained in their ability to convincingly identify or confirm the appearance of spared land because of the poor quality of data at their disposal:

(*i*) They base their analysis on international agricultural statistics, also published by FAO, which lack the 100% coverage needed to confirm land transfers within farming uses and to other uses. Until 1996 FAO listed in its *Production Yearbook* (now the *Statistical Yearbook*) series national areas of arable crops, permanent crops, permanent pastures, forests and woodlands, and other land, which combined to cover 100% of national land area. These estimates were never very reliable, but from 1996 those for permanent pastures and forests and woodlands were discontinued, and subsumed with "other land" in a "nonarable and nonpermanent crops" category, because governments were not reporting grazing land (or shifting cultivation) ar-

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[1]E-mail: a.grainger@leeds.ac.uk.

Table 1. Number of national forest surveys for 90 tropical countries by latest survey date

Recorded estimates	Latest estimate <1980	1980–1989	1990–1999	2000-	No. of countries
2	1	3	17	22	43
1	3	8	23	3	37
0	-	-	-	-	10

Source: United Nations Food and Agriculture Organization data (see ref. 5).

eas regularly. The proportion of developing countries providing statistics to FAO remains low, e.g., Africa 13%, the Americas 17%, and Asia-Pacific 32% (7). The FAOSTAT web site (http://faostat.fao.org/default.aspx) still lists the original categories (in the ResourceSTAT-Land section) but for some of them no data are available after 1996.

(*ii*) In the tropics the area of spared land could be of the same order as errors for estimates of farmland and forest areas and is made more uncertain by overlaps between them, e.g., in the humid tropics shifting cultivation fallows grow to resemble forest but remain under farming use, and in the dry tropics open forests (or savanna woodlands) are exploited for wood and grazed by livestock contiguously with less arboreal rangelands (Fig. 1). Areas of both were listed in FRA 1980 but not in later FRAs (8). By having to omit shifting cultivation and livestock raising from their tests, Rudel et al. (2) underestimate land sparing, not least because transitions from shifting cultivation to permanent cultivation generate spared land.

(*iii*) Rudel et al. (2) also omit transfers of overused farmland to degraded land, another destination for spared land. Reliable estimates of degraded land area are virtually nonexistent, and the United Nations Convention to Combat Desertification recently convened a scientific conference on how to remedy this lack of information (9).

(*iv*) FRAs list only regional estimates of natural reforestation rates, but case study evidence at lower scales is accumulating (10).

Like other scientists, sustainability scientists need their own instruments and repeated procedures (institutions) to monitor the planet to collect their global data. Yet although the instruments exist the institutions do not, hence the reliance on statistics from United Nations agencies that have robust monitoring institutions. One strategy might be for scientists to work more closely with these agencies, but the latter's flexibility is constrained because scientists demand more accurate estimates than governments, and United Nations agencies must comply with national sovereignty rules. Scientists' needs have also historically been ranked below those of governments and environmental groups (8), and even FAO admits that the quality of its agricultural statistics has declined (7).

Sustainability scientists are handicapped by a general societal inability to establish sustained earth observing systems, linked by the National Research Council to lack of connectivity between data providers, modelers, and decision makers (11). As Goward (12) argues, we still have to "make the transition from experimental land remote sensing to operational monitoring."

A new type of scientific organization, the global environmental observatory, is needed so that sustainability scientists can accurately map global changes in land cover and land use and meet the ever more complex needs of policy makers. They should be able to monitor the world's land cover and land use just as astronomers observe the universe, without restrictions of national sovereignty. This idea is catching on: proposals have been made for a global biodiversity observing system (13), a World Forest Observatory (14), a global desertification observing system (9), and a Global Land Use Observatory (15). Monitoring overall land-use change is more difficult than monitoring forest change (16), but it is vital to assess the land-use impacts of climate change and attempts to mitigate it.

Planning is most advanced for the World Forest Observatory. One design envisages a network of a small number of regional centers, comprising existing research groups who can raise their monitoring frequency to produce annual forest maps. Each would monitor a particular region, collaborating with a center in the region that would work with national forest survey bodies for ground truthing, capacity building, and incorporating local knowledge, so all stakeholders see outputs as legitimate (17). A global hub would collate and store all outputs on a common spatial database covering forest area, biodiversity, and carbon stocks and provide facilities for researchers to study them (14). A Consultative Group on Global Environmental Observatories, modeled on the Consultative Group on International Agricultural Research, could ensure compatibility between the different observatories. This compatibility is vital for monitoring overlapping categories, such as spared land.

Unless we give the same attention to measuring the land surface of our planet as we do to observing the universe, sustainability scientists in 2020 will still be in the position of Rudel et al. (2) today. They will lack the data they need to study crucial phenomena and give governments reliable information on whether humanity can indeed sustain itself on Planet Earth.

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