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On the bioproductivity and land-disturbance metrics of the Ecological Footprint

ISA Research Paper 03/06, in collaboration with WWF

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Please cite this report as

Lenzen, M., C. Borgström Hansson and S. Bond (2007) On the bioproductivity and land disturbance metrics of the Ecological Footprint. *Ecological Economics* 61, 6-10.

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Date of Release: Monday, 18 September 2006

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N.S.W. 2006

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On the bioproductivity and land-disturbance metrics of the Ecological Footprint

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1 Introduction

Since the Ecological Footprint was invented, research groups around the world have adapted the concept to their particular circumstances. In particular, researchers have used different *metrics* that pertain to different research questions (Lenzen and Murray 2003). For example, while the metric used by the organisers of the Global Footprint Network (GFN) expresses *bioproductivity* requirements[1] in global hectares, an Australian approach examines *land disturbance* in weighted hectares. In short,

– bioproductivity reflects the amount of biological productivity required to renew the biotic resources humans use (food, timber etc) and to absorb their waste (mainly compensate for their CO_2 emissions from energy use). This bioproductivity is measured in "global hectares", representing an area of world-average biological productivity, including both land and water. Global hectares are calculated from actual hectares by weighting with yield factors and equivalence factors (Wackernagel *et al.* 2005, Wiedmann and Lenzen 2006);
– land disturbance reflects the current and projected future impact on land of human consumption of biotic and abiotic resources (food, timber, minerals etc), and emissions of all greenhouse gases from all sources, using as a proxy the deviation of the biodiversity of vascular plants from a pristine condition. Land disturbance is expressed in "disturbed hectares", calculated from actual areas by weighting with factors describing the degree of disturbance (Lenzen and Murray 2001; 2003).[2]

The aim of this note is to follow up on discussions at the recent Ecological Footprint Forum in Italy (2006). In particular, we will highlight a number of situations, where managing for bioproductivity alone may lead to counter-productive incentives. We conclude that in these cases, the bioproductivity metric needs to be complemented with additional information such as on land disturbance and biodiversity.

[1] The Ecological Footprint is said to describe how much of the *regenerative* capacity of the Earth is being used by humans. However, to re-generate the biosphere requires more than the regeneration of biological matter; it requires the regeneration of ecosystems, and the species relationships therein. Therefore, a more precise description would use the term *bioproductive* capacity.
[2] Consult also the LCA literature: Baitz *et al.* 1998; Ekvall 1998; Swan 1998; van Dobben *et al.* 1998; Köllner 2000; Lindeijer 2000b; a.

2 Bioproductivity and land disturbance – a few examples

2.1 Monoculture forests

The replacement of ancient woodlands[3] with monoculture forests through clear cutting is defined by the Swedish Forestry Agency as the single largest threat against biodiversity in Swedish forests (Nitare *et al.* 2004). The shrinking of these woodlands is mainly driven by the possibility to have higher yields by replacing them with monoculture forests. In Sweden's Footprint accounts the higher yields of these monocultures will increase the national biocapacity, and thus lead to a favourable comparison between Footprint and biocapacity.[4] In order to counter the current undesired trend towards high-productivity forests, the biocapacity accounts need to be combined with indicators that are sensitive to biodiversity.

2.2 Organic agriculture

Several national governments in Europe include increasing the proportion of the national area of farmland under organic agricultural practices in their strategies for sustainable development. Shifting to organic food in public procurement is also an option discussed by many local municipalities. However, bioproductivity assessments may not be in favour of organic agriculture – yields may be lower, even when including the potentially higher Footprint of conventional agricultural inputs organic farming does not need. Of course, in the long term, bioproductivity of areas with organic agriculture may be maintained or may even increase thanks to its soil-saving techniques and conservation of ecological services both from outside and within this area. But the immediate effect on national accounts of the choice to convert from conventional to organic agriculture will decrease biocapacity, due to the short-term reduction in yields from these areas. In order for the positive effects of organic agriculture to be present in the analysis of such agricultural policy choices, additional information, for example on land disturbance, would be necessary.

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[3] Ancient woodlands are defined here as woodlands that have been continuously covered with trees without significant change of tree species since year 1700.

[4] According to the Global Footprint Network, biocapacity represents the ability to provide for human demand: "A comparison of the Footprint and biocapacity reveals whether existing natural capital is sufficient to support consumption and production patterns. A country whose Footprint exceeds its biocapacity runs what we term an ecological deficit. The condition of ecological deficit is possible in two ways: imports of biocapacity from other nations (ecological trade deficit) and/or the liquidation of natural capital (ecological overshoot). We define the amount of ecological deficit (from the perspective of consumption) in global hectares as Ecological deficit (gha) = Footprint (gha) – biocapacity (gha). If a country has an ecological remainder (a negative ecological deficit)—i.e., holds more biocapacity than Footprint, and therefore has no ecological deficit—this remaining unused biocapacity may still be used for providing services that are consumed in other countries. If these services were sold to a second country, then the corresponding demand on the first country's biocapacity would be part of this first country's production Footprint, as well as part of the second country's Ecological Footprint of consumption" (Wackernagel *et al.* 2005). In principle, deficits can be reduced (or remainders increased) by reducing population, per-capita consumption, and/or per-unit Footprint intensity, or by increasing bioproductive area, and/or productivity/yield.

2.3 Forest-to-cropland conversion

The previous two examples show how yield-increasing practices can affect biocapacity. In addition, the equivalence factors can lead to further unwanted effects: The ecological footprint has been used to raise awareness of the role of conventional palm oil in the accelerating destruction of tropical rain forests in Southeast Asia, for example Indonesia[5]. However, a possible halt to forest conversion is not rewarded by the current bioproductivity accounts. On the contrary, these accounts tend to show that converting primary forests to plantations might increase biocapacity.[6] As indicated in Table 1, standing forests are weighted by an equivalence factor of 1.4, but once cleared and turned into plantations of palm oil, they are registered as primary crop land, the equivalence factor of which is 2.2. Moreover, due to the high yields in palm oil, the local yield factor for primary cropland may be positively affected by this change. The conversion of biodiversity-rich tropical forests to monocultures of palm oil thus results in a misleading increase in biocapacity, even though the robustness and long-term regenerative capacity of ecosystems are compromised.

Biocapacity before conversion (gha)	Biocapacity after conversion (gha)
Area × 1.4 × local yield factor for forests	Area × 2.2 × local yield factor for primary cropland

Tab. 1: Effects on biocapacity of release of forest land to oil palm plantation

2.4 High-productivity animal grazing

The previous examples have in common that yield and equivalence increases affect biocapacity in the same country. The following example extends the situation to international supply chains: Beef production systems vary the world over, from highly extensive low impact grazing regimes to extremely intensive systems relying on the import of additional high-energy feeds into the system; of which soy bean oil-cake is the most widespread. Intensive systems will on average have the higher yields, which has potentially negative consequences if this method is used to inform policy as to the bioproductive capacity or biodiversity of the area under production.

For example, Welsh Black beef is grazed extensively throughout north, mid and west Wales. It is an important animal both for its meat, and for the positive effect that it has on improving pasture, increasing biodiversity and the fertility of sometimes poor upland soils. In the intensive system a high degree of external inputs is required to increase the beef yields, yet this comes at the expense of land somewhere else, which is often primary forest that is converted to soy plantation (for example in Brazil). In this case, a switch from the extensive to the intensive beef production system hence increases the biocapacity of the country of feed

[5] Between 1990 and 2000 the area of palm oil plantations in Indonesia tripled from 673,000 ha to 2,014,000 ha (FAOSTAT) and concessions have already been given for the release of another 6,000,000 ha of forest land to oil palm plantations (van Gelder 2000).

[6] Under ideal data availability, the biocapacity of a particular tract of land should not change when the land is used for a different purpose, since biocapacity should reflect its inherent potential. This point was made by Mathis Wackernagel.

origin (as in Section 2.3). Moreover, the additional feed inputs mimic a biocapacity increase for the Welsh pastures. These biocapacity increases run contrary to the positive benefits for biodiversity under the more extensive systems.

2.5 Low-productivity animal grazing

The bioproductivity metric produces the following breakdown of the Australian Ecological Footprint:

Animal grazing	15,277	11%
Fish	6,509	5%
Forest products	13,338	10%
Crops	20,302	15%
Built up area	2,967	2%
Sequestering CO_2	75,990	56%
Total Footprint	135,838	

Tab. 2: Australian Ecological Footprint in '000 gha (bioproductivity-weighted) (Global Footprint Network and ISA University of Sydney 2006)

The land disturbance metric yields

Animal grazing	99,055	71%
Fish	n.a.	n.a.
Forest products	3,136	2.3%
Crops	6,928	5%
Built up area	839	0.7%
Sequestering GHG	28,403	20%
Total Footprint	138,363	

Tab. 3: Australian Ecological Footprint in '000 ha (disturbance-weighted)

These accounts stand in stark contrast: While the bioproductivity account highlights CO_2 emissions from energy (56%) and crops (15%), the land disturbance account highlights animal grazing (71%) and greenhouse gas emissions from all sources (20%).

Landcover disturbance, soil degradation and biodiversity decline are important problems in Australia[7], and are on the mind of people, government and business representatives, and NGOs concerned about Australia's environment. In the bioproductivity metric, these issues fall by the wayside. If Australian decision makers acted only according to the bioproductivity metric, clearing and degradation of grazing lands would be paid minor attention.

[7] Glanznig 1995; Graetz *et al.* 1995; http://www.eoc.csiro.au/dest_la/www/firstup.htm.

3 Discussion

One could argue that an increase in biocapacity due to increased yield and equivalence factors is generally accompanied with an increase in the Ecological Footprint, since the products from intensive production are consumed somewhere. However, when moving to intensive production, both global biocapacity and the global Footprint will experience the same increase, while the global ecological deficit – the difference between biocapacity and Footprint – stays constant. There is hence at least no penalty in the bioproductivity metric for intensifying production.[8] These undesired effects are a direct consequence of the definition of bioproductivity in global hectares in the Ecological Footprint.

All of the above examples point to important global issues that are not covered in the bioproductivity research question and metric: landcover disturbance, soil degradation and biodiversity decline. Increasing bioproductivity can actually be *accompanied* by increasing disturbance, leading in turn to decreasing future biodiversity, biocapacity and bioproductivity (Pimentel *et al.* 1976). If used in isolation, the bioproductivity metric not only provides no "early-warning signal" for looming future problems, it may actually provide incentives that *lead* to future problems. For example, a time series of annual bioproductivity accounts for a country engaging in monoculture forest expansion could initially show a continuous biocapacity increase, but would reveal biocapacity declines only after they have already occurred. By then it may be too late for action.

The land disturbance metric is largely designed from practices within LCA[2], and – in the Australian case – based on field and satellite data[9]. This metric represents a first cut at quantifying biodiversity, but can be further refined using more ecological survey data. At present, it uses as a proxy the species density of vascular plants, because they are most readily able to be surveyed, and provide habitat and food to other species. Land disturbance is thus directly related to biodiversity decline, for example because of substitution by intensive monocultures, land clearing and other habitat loss, salinisation and other types of degradation. These factors in turn are direct precursors to biocapacity and biodiversity decline, and thus indicate future problems without ambiguity and delay. The ISA group at the University of Sydney is currently undertaking research on developing a global database underpinning the land disturbance indicator. This research is motivated by the fact that only when land disturbance weights and benchmarks are available at the global level can we assess how national policy decisions affect biodiversity in other national territories.

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[8] This problem is exacerbated at the national level: In cases where products from additional intensive production are exported, that country's biocapacity increases while its Footprint stays constant, thus improving the gap between biocapacity and Footprint, and hence encouraging intensification for export. The increase in Footprint would occur somewhere else. Similar effects can apply to biocapacity decreases: Due to WTO pressures, Switzerland decided to reduce its agricultural production subsidies and rather pay farmers for landscape maintenance. As a result, agriculture became less intensive, with lower product output, and healthier ecosystems. Yet, with Swiss consumption patterns remaining unchanged, more of the Swiss Footprint is now being imported from outside of Switzerland. All else held constant, the Swiss Footprint would stay constant under such as scenario, but its biocapacity would decrease, thus deteriorating any existing deficit. This example was provided by Mathis Wackernagel. Note however that trade considerations are not essential to support our argument, since the main point of this work holds even at the global level.

[9] http://www.eoc.csiro.au/dest_la/www/chap2b.htm.

4 Conclusions

We have shown for a number of cases that biocapacity increases can be at odds with biodiversity and ecosystem health, and that, if used on its own, the bioproductivity research question and metric of the Ecological Footprint may provide a misleading signal to decision-makers Thus, the key arguments of this work are

- that humanity has reacted to increasing human demand by increasing biocapacity, which the bioproductivity-based Ecological footprint does not penalise, and
- that this biocapacity increase has caused cost in terms of biodiversity and ecosystem health which the bioproductivity-based Ecological Footprint does not measure.

In the long term, human demand may well be limited by biodiversity and ecosystem health, rather than by bioproductivity. This is not only because biodiversity controls long-term bioproductivity, but also because biodiversity controls other ecosystem services such as resilience against disruptions (Beattie and Ehrlich 2001; Armsworth *et al.* 2004; Asnar *et al.* 2004). In many cases, ecological problems are already more related to ecosystem condition and biodiversity, and less to bioproductivity restrictions. If decision-makers only applied a bioproductivity assessment to these problems the results could be counter-intuitive, or even detrimental. If the analysis of policy decisions were restricted to the bioproductivity metric, it would not provide sufficient information and feedback to decision-makers and communities who are concerned about and affected by ecosystem degradation and biodiversity decline. An Ecological Footprint analysis that incorporates land disturbance (wherever such information is available and relevant) thus adds crucial information to policy for long-term planning.

The Ecological Footprint has had tremendous success in communicating to the public the effect of (over-)consumption on the limited biocapacity of the Earth. However, to make the tool robust for policy, issues such as those dealt with in this note and its companion note (Wiedmann and Lenzen 2006) need to be considered and resolved.

5 Acknowledgements

The authors are grateful to Mathis Wackernagel for making valuable corrections to an earlier draft of this article, thus improving the clarity of the overall message. Elizabeth Leighton from WWF Scotland contributed to the initial idea of this work.

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