Toward the Next Generation of Agricultural Sustainability Indicators: Background Document for Expert Workshop

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Executive Summary

While essential to sustain human life, agriculture is one of the most environmentally harmful practices on the planet. It is a profound driver of deforestation, climate change, biodiversity loss, and freshwater degradation. In total, agriculture dominates global land use at 38 percent; expansion has already cleared or converted many natural terrestrial biomes, with 80 percent of new croplands replacing forests.

Intensification, in particular, has increased dramatically to provide greater yields for our growing populations. Global fertilizer use has increased by over 500 percent over the past 50 years (FAOSTAT 2012); and more than two-thirds of global freshwater withdrawals are used for irrigation (Gleick et al. 2009). Agriculture also contributes some 30 to 35 percent of global
greenhouse gas emissions, from tropical deforestation and emissions associated from livestock, rice cultivation, and fertilized soils (Foley 2011). In terms of freshwater quality, the use of fertilizers and pesticides is responsible for contamination that extends as far as fisheries, as evidenced by dead zones in the Gulf of Mexico and the Chesapeake Bay, both of which were largely the result of fertilizer runoff (Biello 2008).

How we reconcile the need to provide food for the expected 11 billion in 2100 (Gerland et al. 2014) – a much higher prediction than previous UN Population Division estimates – with the need to manage resources sustainability is perhaps the most critical issue that cross-cuts human life and the environment. Therefore, the need to design metrics that can help to understand how countries are performing with respect to addressing the environmental impacts of agriculture could not be more urgent.

Given this context, the creators of the Environmental Performance Index (EPI) seek to help design the ‘next generation’ of indicators to compare environmental performance in the agriculture sector across countries. This concept note outlines the challenges in developing rigorous, science-based metrics to rank countries in terms of their ability to mitigate the environmental impacts of agriculture. Outlining the key environmental issues with respect to agriculture, we attempt to provide an overview of data availability, gaps, and limitations. As much as possible, we aim to build upon existing efforts made in defining metrics for agriculture, including the OECD’s Compendium of Agri-Environmental Indicators (OECD 2013), an evaluation of candidate agri-environmental candidate agri-environmental indicators that WRI produced as part of its report Creating a Sustainable Food Future (Searchinger et al. 2014), Foresight’s The Future of Food and Farming report (Foresight 2011), the Sustainable Development Solutions Network’s Solutions for Sustainable Agriculture and Food Systems report (Dobermann & Nelson et al. 2013) and the Food and Agriculture Organization of the United Nations’ Targets and Indicators (FAO et al. 2014) for the post-2015 Development Agenda and Sustainable Development Goals, and UC Davis’s Sustainable Sourcing Project.

Through this concept note and workshop, we hope that expert feedback and dialogue will reveal more actionable indicators in key areas such as irrigation efficiency, greenhouse gas emissions, soil health, crop diversity, and land conversion. Current data available for these areas are imperfect, but there may be ways to bring them to scale or improve their methods so that we can use them in the near future.

Introduction

Agriculture is essential for the provision of food, crops, and fibers required for the wellbeing of humans, as well as supporting the livelihoods of those who work in the industry. The intensification and sustained inefficiencies of many agricultural processes have relied on natural,
often nonrenewable resources, namely soil, water, and energy. Skewed policies and practices in agriculture result in negative influences on the environment and human health, including deforestation (via conversion and logging), forest/land degradation (via agricultural expansion, overuse, and nutrient pollution), losses in animal and plant biodiversity (via habitat encroachment and farming of a limited number of species), decline in water quality (via nutrient pollution), decline in water quantity (via inefficient irrigation), decline in food safety (via pesticides and antibiotics), spread of invasive species (via introduction as new agricultural product or as alternative to pesticides), and depletion of fossil fuels (via energy-intensive practices), while contributing to climate change (via greenhouse gas emissions).

Sustainable agriculture policies and practices can help combat these negative impacts. Quantitative indicators for sustainability have been noted as a key prerequisite for developing legislation supporting sustainable agriculture (Senanayake 1991).

Over this past decade, advances have been made in developing improved data and indicators in several areas, including air quality and forests. Definition and data challenges, however, have persisted in some key areas, especially in the meaningful and scalable measurement of soil quality, water productivity, land conversion, greenhouse gas emissions, and other issues salient to agriculture. The informational gap is glaring when we consider the enormity of the agricultural challenge that the world’s policymakers face. Comprehensive, comparable country-level data on agricultural impacts could play an instrumental part in informing the world’s efforts to increase food production by 60% (the increase required to feed a projected 9 billion people in 2050) while sustainably managing agriculture’s impacts on natural resources (FAO 2012).

Currently, no country-level indicators aimed at capturing the environmental impacts of agriculture are backed by consistent and reliable cross-country comparative data at a global or near-global scale. The bulk of existing indicators captures the “state of” environmental conditions but are difficult to link back to agriculture as a driver and to separate out the impacts of natural endowments unrelated to environmental performance. The OECD Compendium of Agri-Environmental Indicators, released in 2013 in conjunction with Eurostat and the UN Food and Agriculture Organization (FAO), includes several indicators that capture environmental performance. It plans to update the underlying data every few years, and has so far documented positive trends in nutrient, pesticide, energy and water management from 1990–2010 in OECD countries – generally considered wealthy and developed countries (OECD 2013).

Still missing however is a comparable index or country-level data for most non-OECD countries, which encompass the developing countries including agricultural giants such as India, China, and Russia. The largest producers for vegetables, fruits, cereals, nuts, spices, and fibers are primarily non-OECD countries (FAOSTAT 2012). Developing countries are expected to provide the main source of growth for global agricultural production, consumption and trade. Demand from developing countries will be reinforced by rising per capita incomes, urbanization, and population growth, which remains nearly twice that of the OECD area (OECD/FAO 2010). If we are to
provide a comprehensive index that can catalyze real change in global agricultural practices, it must include non-OECD countries.

This concept note is intended to bring the scientific and policy communities together to provide clear direction for both groups on measuring agricultural sustainability, drawing from existing indices and data where possible. For those areas that are methodologically promising but still face tremendous data gaps, we welcome discussions around joint fundraising and collaboration to replicate the method globally and ideally at regular intervals.

Based on the success of previous work led by YCELP and CIESIN in developing indicators, the purpose of this new effort is to discuss the next generation agriculture indicators that accurately reflect the state of agricultural environmental impacts and can help guide policy and management efforts. The critical questions these indicators seek to answer are:

- What metrics can assess how a country is managing the environmental impacts of agricultural practices within its borders?
- Will current policies and management approaches enable a country to sustainably manage agricultural resources into the future?
- What are the tradeoffs between productivity and conservation? Are solutions that are sustainable both in terms of food security and environmental impact enough to close the food security gap by 2050, or is there a necessary place for less environmentally sustainable solutions to close the food yield gap?

What is the EPI?

For close to 15 years, YCELP and CIESIN have collaborated on the development of country-level sustainability and environmental performance indicators, first for the Environmental Sustainability Index (ESI) from 2000-2005 and then for the Environmental Performance Index (EPI) from 2006 to the present.

The EPI is a global ranking of how well countries perform on a defined set of environmental policy issues. The index is released every two years. The 2014 EPI measures national environmental performance in two objectives, 9 policy issues, and 20 indicators. The EPI employs a proximity-to-target methodology by which to gauge how close countries are to achieving defined policy goals. Country scores are represented on a 0-100 scale, in which 100 represents “at target”, and 0 represents the worst performing country or countries. Figure 1 presents the 2014 EPI framework and indicator set.
This effort to develop the next generation of agriculture-related performance indicators is modeled on a similar effort in 2012, led by YCELP and CIESIN in partnership with the Asian Institute for Energy and Environmental Sustainability (AIEES) of Seoul National University, to identify the next generation of air quality indicators. This collaboration entailed an expert workshop in Seoul in October 2012, results of which were published in a series of articles as a special issue of *Atmospheric Environment* (Hsu et al. 2013; Hung et al. 2013; Engel-Cox et al. 2013; Pirrone et al. 2013; Bowman 2013). We focused on four major types of pollutants – particulate matter, ozone, mercury, and persistent organic pollutants (POPs) – and the experts identified opportunities for improved monitoring using ground-based and satellite measurements, better modeling, and improved indicators. The immediate result was a first-ever, satellite-derived indicator of fine-particulate matter exposure in the 2014 EPI. The workshop thus served both as a platform to develop indicators for the EPI, and an opportunity for experts to develop their own work in the area via publishable research in collaboration with others in their field.

Indicators used in past EPIs

Our pilot Environmental Performance Index, released in 2006, introduced just one agriculture indicator: the percentage of total agricultural GDP that came from *agricultural subsidies*, using
data from the World Trade Organization and the US Department of Agriculture’s Economic Research Service, with a target of 0% based on GTT and WTO agreements.

The 2008 EPI expanded the indicators in the agriculture category to include the most comprehensive agriculture indicators we have used to date – adding indicators for irrigation stress, intensive cropland, and burned land area using CIESIN calculations, as well as pesticide regulation, using the UN Environmental Programme’s Chemicals data.

To replace the irrigation stress indicator, in 2010 we introduced an indicator of agricultural water intensity, which calculated withdrawals as a percent of total available water resources, using FAO data. We set the target at an aspirational value of 10%, which was deemed sufficiently low enough that all countries could make some progress toward the ratio. This indicator was dropped by the 2012 EPI due to the quality of the water abstraction data from FAO and lack of consistent time series. In addition, the target of 10%, while based on expert opinion, was not appropriate for all cases. Water-abundant countries can use more than 10% of their water resources for agriculture with negligible impacts on the environment.

We dropped the indicator on intensive cropland in 2010 because the only available global dataset was coarse and inaccurate. We essentially had measured the percentage of agricultural areas above a certain arbitrary threshold of agricultural land per pixel. The data have not been updated since its 2000 benchmark.

We also discarded the indicator on burned land area, which looked at biomass burning in agricultural landscapes. Primarily done in the tropics, land burning is used to fertilize soils and eradicate pests. It is often an efficient way to manage the land and does not harm its productivity. However, because of the equally-significant linkages between biomass burning and air quality and climate change, we did not include the indicator in the Agriculture category in previous editions of the EPI.

The most recent editions of the EPI, released in 2012 and 2014, include just the two remaining agricultural indicators on agricultural subsidies and pesticide regulation. Together, the two indicators evaluate countries’ actions taken to reduce the harmful effects of inputs related to intensive agriculture. Due to the lack of global, consistent country-level data reflecting environmental performance of agriculture on the ground, we settled on these indicators as proxies for performance. Below, we detail the limitations of each indicator in detail and how we plan to treat them going forward.

**Agriculture subsidies.** The agricultural subsidies indicator is based on the argument that agricultural subsidies reduce environmental sustainability by creating price distortions, promoting production of input-intensive crops, wasteful

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**Agriculture subsidies indicator**

Unit of measurement: Subsidies are expressed in price of their product in the domestic market (plus any direct output subsidy) less its price at the border, expressed as a percentage of the border price (adjusted for transport costs and quality differences).
use of natural resource inputs, use of marginal and fragile lands, and rent-seeking behavior.

In the 2006 EPI, the calculation of the indicator netted out “green box” subsidies that reduce market distortions and sometimes support sustainable practices, thereby measuring only subsidies that are likely to create incentives for excessive chemical use, farming on marginal lands, and other ecologically damaging practices. The data on agricultural subsidies relied heavily on country self-reporting to the WTO, with limited coverage. Starting in 2008, the EPI team switched over to using nominal rate of assistance (NRA) data from the World Bank’s World Development Report. The later iterations no longer differentiate between subsidies unfortunately, since the World Bank dataset does not provide disaggregated data on green box subsidies.

We plan to eliminate the agricultural subsidies indicator starting with the 2016 EPI. It has become clear that while subsidies do create market distortions, their impact on the environment is less certain and our indicator is incapable of differentiating between subsidies that encourage sustainable practices. As the capacity for conservation agriculture practices such as no-till/low-till, crop rotation, and intercropping with trees gradually expands throughout developing countries, the careful use of subsidized inputs could actually help produce greater agricultural yields and alleviating poverty while also protecting ecosystems. Malawi is a case in point, where input subsidies encouraging fertilizer use among smallholders have enabled greater yields and coincided with the expansion of public programs that promote conservation agriculture practices. Conversations with an agricultural expert suggest that increasingly, governments are requiring farmers to use sustainable agriculture practices if they are to qualify for agricultural subsidies at all. Following this trend, provision of subsidies could actually be positively correlated with sustainable practices.
Table 1. History of Agriculture Indicators across Iterations of the EPI, 2006-2014.

<table>
<thead>
<tr>
<th>EPI Year</th>
<th>Category</th>
<th>Category Weight</th>
<th>Indicators</th>
<th>Indicator Weight</th>
<th>Data Source</th>
<th>Target</th>
<th>Target Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>Productive Natural Resources</td>
<td>10.00%</td>
<td>Agricultural Subsidies</td>
<td>3.33%</td>
<td>WTO, USDA-ERS</td>
<td>0%</td>
<td>GATT and WTO agreements</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Irrigation Stress</td>
<td>0.50%</td>
<td>CIESIN calculation</td>
<td>0%</td>
<td>Expert judgment</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Agricultural Subsidies</td>
<td>0.50%</td>
<td>World Bank, World Development Report</td>
<td>0%</td>
<td>Expert judgment; GATT and WTO agreements</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Intensive Cropland</td>
<td>0.50%</td>
<td>CIESIN calculation</td>
<td>0%</td>
<td>Expert judgment; GATT and WTO agreements</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Burned Land Area</td>
<td>0.50%</td>
<td>CIESIN calculation</td>
<td>0%</td>
<td>Given the large impacts of burning on human health, climate change, and tropical forest ecosystems that are not naturally regulated by fire, we assessed fires as, on balance, a negative phenomenon from a resource management perspective. Accordingly we set a burned land target of zero. Technically a target of no burning is undesirable. We were faced with data that include a large number of countries with a small proportion of total area burning, and an absence of finer level data that could indicate whether burning occurs in a biome that is naturally fire-regulated. We set the target as zero in light of these limitations.</td>
</tr>
<tr>
<td>2008</td>
<td>Agriculture</td>
<td>2.50%</td>
<td>Pesticide Regulation</td>
<td>0.50%</td>
<td>UNEP-Chemicals</td>
<td>9 banned POP chemicals and full participation in Rotterdam and Stockholm Conventions</td>
<td>Expert judgment</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Agricultural Water Intensity</td>
<td>0.80%</td>
<td>FAO</td>
<td>10% water resources</td>
<td>Aspirational value of 10%, considered low enough that all countries could make some progress toward the ratio. In hindsight, the target of 10%, while based on expert opinion, was not appropriate for all cases, particularly for water-abundant countries that can use more than 10% of their water resources for agriculture with negligible impacts on the environment.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Agricultural Subsidies</td>
<td>1.30%</td>
<td>YCELP, World Development Report, OECD</td>
<td>0 Nominal Rate of Assistance (NRA)</td>
<td>GATT and WTO agreements</td>
</tr>
<tr>
<td>2010</td>
<td>Agriculture</td>
<td>4.20%</td>
<td>Pesticide Regulation</td>
<td>2.10%</td>
<td>UNEP-Chemicals</td>
<td>22 points</td>
<td>Expert judgment</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Agricultural Subsidies</td>
<td>1.94%</td>
<td>YCELP, World Development Report, OECD</td>
<td>0%</td>
<td>GATT and WTO agreements</td>
</tr>
<tr>
<td>2012</td>
<td>Agriculture</td>
<td>5.83%</td>
<td>Pesticide Regulation</td>
<td>3.89%</td>
<td>UNEP-Chemicals</td>
<td>22 points</td>
<td>Expert judgment</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Agricultural Subsidies</td>
<td>2.50%</td>
<td>YCELP, World Development Report, OECD</td>
<td>0%</td>
<td>GATT and WTO agreements</td>
</tr>
<tr>
<td>2014</td>
<td>Agriculture</td>
<td>5.00%</td>
<td>Pesticide Regulation</td>
<td>2.50%</td>
<td>UNEP-Chemicals</td>
<td>22 points</td>
<td>Expert judgment</td>
</tr>
</tbody>
</table>
Pesticide regulation indicator

Unit of measurement: This indicator examines the adoption and legislative status of countries on one landmark agreements on POPs usage, the Stockholm Convention, and also scores the degree to which these countries have followed through on convention objectives by limiting or outlawing the use of certain toxic materials.

Pesticide regulation. Our surviving agriculture indicator assesses the status of countries’ legislation regarding the use of chemicals listed under the Stockholm Convention on persistent organic pollutants (POPs). It also scores the degree to which these countries have followed through on limiting or outlawing these chemicals. Our scoring in previous years has been based on countries’ National Implementation Plans (NIPs) submitted to the Stockholm Convention. Unfortunately, this documentation of commitments does not necessarily translate into performance on the ground. Reliance on NIPs may have led to systematic underestimates of national commitments and actions. While conducting due diligence on data reported by countries is beyond our scope, we plan to primarily use implementation data from National Reports (available online for a select number of countries) where available, and secondarily the NIPs going forward in an effort to improve the indicator. We also plan to narrow the list of POPs in our indicator to only include pesticides rather than also including industrial POPs like polychlorinated biphenyls (PCBs) and unintentional POP pollutants such as dioxins.

The policy-based indicators above represented the best available indicators at the time of previous EPI releases given the lack of more performance-based data. Acknowledging the limited ability of these indicators to capture agricultural environmental performance, we severely down-weighted them to together only constitute 5% of overall EPI scoring in the most recent EPI.

Critical considerations for the next generation of agricultural sustainability indicators

The EPI’s main thrust is comparing countries using indicators at the national level, for agriculture and other environmental issues. We believe that there is a need for country-level indicators in providing a frame of reference for national-level decisionmakers, while understanding that this means simplifying some of the complexity within a country. On the international stage, country-level performance indicators have gained appeal due to the shift toward supranational policies and synchronization of national practices (Jokinen 2004). Domestically, national policies directly or indirectly involving agriculture have a large impact on environmental sustainability at the field and farm levels (Hayati et al. 2010). Still acknowledging the value of smaller-scale analyses, we would eventually like to disaggregate our country-level indicators to include product or landscape level data, to inform more fine-tuned decisionmaking. This disaggregation would of course be contingent on data availability. Increasing attention has been paid to benchmarking agricultural yields and environmental impact at the grid (Hoekstra and Mekonnen 2013), farm (Rigby et al. 2001), and landscape levels (Piorr 2003), where impacts are most closely felt and can be more or
less accurate depending on the method of data collection (e.g., high/low-res satellite monitoring, field sampling).

In anticipation of the 2016 EPI, we are returning to the drawing board to reassess available data to see if data availability has improved since, with the following criteria in mind:

*Relevance*: The indicator tracks the environmental issue in a manner that is applicable to countries under a wide range of circumstances.

*Performance orientation*: The indicator provides empirical data on environmental conditions\(^1\) or on-the-ground results for the issue of concern, or is a “best available” proxy for such outcome measures.

*Established scientific methodology*: The indicator is based on peer-reviewed scientific data or data from the United Nations or other institutions charged with data collection.

*Data quality*: The data represent the best measure available. All potential datasets are reviewed for quality and verifiability. Those that do not meet baseline quality standards are discarded.

*Time series availability*: The data have been consistently measured across time, and there are ongoing efforts to continue consistent measurement in the future.

*Completeness*: The dataset needs to have adequate global and temporal coverage to be considered.

Of these criteria, performance orientation has been an especially sore spot for our agriculture indicators, which were solely policy (or input) based in the 2012 and 2014 EPIs and fared marginally in capturing actual environmental performance (or outputs). We are therefore prioritizing more outcome-based data (biophysical outcomes as opposed to policy intentions and practices), both to improve our existing indicators and to create new ones. We believe that outcome-based indicators provide a far stronger empirical foundation with which to influence policymaking, in providing feedback to policymakers and stakeholders on how well their agricultural policies and initiatives are working.

1. Indicator definition

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\(^1\) The “State” component of the Driving Force-Pressure-State-Impact-Response (DPSIR) framework. In some instances we resort to “Pressure” indicators, such as emissions of SO\(_2\), and in one instance we resort to a “Response” indicator, which is the regulation of certain pesticides banned under the Stockholm convention.
Agricultural sustainability

To set the stage for improved indicators, we must revisit our framework for what we mean by agricultural sustainability and what kinds of environmental performance are not only within bounds of measurement but are compelling for policymakers to act upon. With over 70 definitions of sustainable agriculture cropping up since the 1980s, it has been difficult to settle on an absolute definition that can be applied universally (Zhen and Routray 2003), particularly given that different sustainability priorities exist between developed and developing countries. The overarching trend is that definitions of sustainable agriculture encompass not just the environmental aspects of agriculture but also economic viability and socioeconomic equity. Broad definitions of agricultural sustainability such as the World Resources Institute’s define agricultural sustainability in terms of closing the food gap by both increasing food production and reducing growth in food consumption, while curbing the environmental impacts of food production (Searchinger 2014).

In the EPI, we define agricultural sustainability as striving to secure food for present and future generations, without compromising environmental performance. For the amount of extra food the world must introduce into the system to feed people, we aim to reward those that do it at the least cost to the environment. We isolate environmental solutions where possible, although there is often and ideally overlap between 'environmental' and 'productive' solutions. For example, conservation agriculture practices such as crop rotations, retention of crop stubble, and conservation tillage can improve yields while bolstering soil structure and fertility, improving water retention and providing savings to farmers in cost and labor for comparable yields (ICARDA 2014). So while our focus is on gauging performance on measures that can reduce the environmental impact of agriculture, the best case scenario would be to reward countries for implementing practices that forward both environmental and food security goals.

To apply this definition to our treatment of indicators, we are exploring lower bounds of environmental impact that can still support production of food and other agricultural products. Particularly for any indicators on food production, it may be viewed as problematic to incentivize performance that minimizes environmental impact to zero without respect to yields – as this would implicitly mean poorer performance on the environmental health (human health) aspects of environmental performance. We welcome expert feedback on this working definition and how to translate it into robust indicators that can support the advancement of effective policies that can target environmental sustainability and food security in a more integrated way. Already, we see some progress in policies in conservation and food security being increasingly pursued together (Foresight 2011). A report by the Sustainable Development Solutions Network argues that resource efficiency targets in agriculture (e.g. 30% by 2030) should at the very least least exceed annual rates of increase in agricultural yields over that same period (Dobermann & Nelson 2013).

As we look for indicators that can help policymakers understand the scope of environmental issues in agriculture and establish policies to reduce the environmental footprint of agriculture, it is worth taking stock of the body of indicators that has accumulated over the years. Table 2 provides an inventory of the most common indicator themes on the environmental sustainability of agriculture.
Note that this breakdown may not reflect the priority placed on particular issues so much as the availability of data.

Table 2. Most common indicator themes on environmental sustainability of agriculture

<table>
<thead>
<tr>
<th>Indicator theme</th>
<th># of occurrences</th>
<th>Indicator (example)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water use</td>
<td>35</td>
<td>Total water use for ag production</td>
</tr>
<tr>
<td>Ag policy related to govt support</td>
<td>18</td>
<td>Agricultural subsidies</td>
</tr>
<tr>
<td>Climate change</td>
<td>13</td>
<td>GHG emissions from ag sources</td>
</tr>
<tr>
<td>Agricultural production</td>
<td>11</td>
<td>Crop yield</td>
</tr>
<tr>
<td>Agricultural inputs</td>
<td>10</td>
<td>Fertilizer use</td>
</tr>
<tr>
<td>Land use</td>
<td>10</td>
<td>Area of agricultural land</td>
</tr>
<tr>
<td>Environmental policy</td>
<td>10</td>
<td>Participation in UNFCCC treaties</td>
</tr>
<tr>
<td>Environmental degradation</td>
<td>7</td>
<td>Area of degraded/barren lands</td>
</tr>
<tr>
<td>Ecosystem biodiversity</td>
<td>6</td>
<td>Wild species in agricultural lands</td>
</tr>
<tr>
<td>Water quality</td>
<td>6</td>
<td>Number of dead (hypoxic) zones</td>
</tr>
<tr>
<td>Agricultural R&amp;D</td>
<td>5</td>
<td>Public ag research expenditures</td>
</tr>
<tr>
<td>Ecosystem management</td>
<td>4</td>
<td>Area of terrestrial reserves</td>
</tr>
<tr>
<td>Ag policy related to environment</td>
<td>4</td>
<td>Pesticide regulations</td>
</tr>
</tbody>
</table>


Below, we discuss the indicator areas we have identified as most relevant for measurement and data collection, based on the EPI team’s own research, consultations with experts, OECD’s Compendium of Agri-Environmental Indicators (OECD 2013), an evaluation of candidate agri-environmental indicators that WRI produced as part of its report Creating a Sustainable Food Future (Searchinger et al. 2014), Foresight’s The Future of Food and Farming report (Foresight 2011), the Sustainable Development Solutions Network’s Solutions for Sustainable Agriculture and Food Systems report (Dobermann & Nelson et al. 2013) and the Food and Agriculture Organization of the United Nations’ Targets and Indicators (FAO et al. 2014) for the post-2015
Development Agenda and Sustainable Development Goals, and UC Davis’s Sustainable Sourcing Project.

**Indicator areas**

**Irrigation stress**

Agriculture is by far the world’s largest use of “blue water” (e.g., freshwater from streams, lakes, groundwater aquifers), accounting for 70% of freshwater extraction globally and as much as 80-90% in some developing countries (Esty et al. 2008). While irrigation is a necessary part of food production in many regions of the world, it is essential to manage irrigation practices in a way that leaves enough water both for human use and ecosystem services. In some cases, water efficiency can be improved through better technology, such as drip irrigation. Appropriate crop selection is also an important factor, as non-native water intensive crops are often grown commercially that may deplete water levels.

Our 2008 EPI included an indicator for irrigation stress, which was based on a measurement of water stress developed by the University of New Hampshire Water Systems Analysis Group. By overlaying data on irrigated areas with the measure of water stress, we were able to determine spatially where measures of extreme water stress (WMO 1997) corresponded with irrigated areas. Water stress is present when rates of freshwater withdrawal exceed rates of replenishment though rainfall and natural flow. While countries can accommodate some rate of oversubscription in an isolated region via inter-basin transfer, ultimately over-drawing a water resource diminishes surface water, which degrades habitat for plants and animals. Oversubscription of groundwater for irrigation also causes land subsidence and increasing salt-water intrusion, and depletes the amount of water available for domestic consumption. The target for this indicator is for each country to experience no extreme water stress in irrigated areas. The indicator was dropped after the 2008 iteration given that it was not being measured at any regular frequency; it was more of a static risk measure rather than a performance measure.

The 2010 EPI introduced an alternative indicator on agricultural water intensity, calculating withdrawals as a percent of total available water resources using FAO data. We set the target as an aspirational value of 10%, which was considered sufficiently low enough that all countries could make some progress toward the ratio. This indicator was dropped in the 2012 EPI due to the quality of the water abstraction data from FAO and lack of consistent time series. In addition, the target of 10%, while based on expert opinion, was not appropriate for all cases, particularly given that water-abundant countries that can use more than 10% of their water resources for agriculture with negligible impacts on the environment.

In turn, we have explored creating a different indicator on water withdrawn for irrigation, where crop production per unit of water withdrawn (“crop per drop”) would be mapped against water stress levels. While FAO AQUASTAT provides data on water withdrawals for water use, the water
scarcity data we have come across only covers overall water scarcity rather than water specific to agricultural use. Even once the appropriate water scarcity data is available, there may still be problems teasing environmental performance out of the indicator to the extent that some crop types are thirstier than others or the same crop might be thirstier if grown in a different climatic zone. It is an imperfect measure, and we welcome discussion of more rigorous ways to design the indicator. Notably, a report of potential indicators to inform the post-2015 Sustainable Development Goals (SDG) agenda lists “crop per drop” as an indicator to be developed, suggesting FAO as the potential leading agency for indicator development (Leadership Council of the Sustainable Development Solutions Network 2014).

**Climate change**

Agriculture directly contributes to 14% of the world’s greenhouse gas emissions (IPCC 2007). In addition, greenhouse gas emissions from land-use change – in most countries driven by agricultural activities – account for 17% of global greenhouse gas emissions. Reducing the greenhouse gas footprint of agriculture is therefore imperative to mitigating climate change. With respect to the food security question, significant progress can be made in reducing the greenhouse gas emissions footprint of agriculture by leveraging increased efficiencies and lower costs of production without loss of productivity (Foresight 2011). On the adaptation front, there is also reason for agriculture to become more resilient as the climate changes and damages crop yields in low-latitude regions. Often, resilience measures found in climate-smart agriculture also double as mitigation measures.

Ideally we would be able to include indicators that capture both climate change mitigation and adaptation efforts in agriculture. On the mitigation end, we are considering including an indicator that captures the greenhouse gas emissions from the agriculture sector against the overall economic value of agricultural output. Time series for greenhouse gas emissions data is available for the bulk of countries both from WRI’s CAIT 2.0 database (WRI 2013) and FAOSTAT. The CAIT 2.0 database draws from a mix of data from the International Energy Agency (IEA), the Carbon Dioxide Information Analysis Center (CDIAC), and the Energy Information Administration (EIA).

While the UNFCCC provides the most accurate data (reportedly directly by countries), it is not used in the CAIT 2.0 database due to the fact that the national communications on which it depends are not submitted annually, and sometimes are missing source categories (WRI 2013). The IEA data is based on emissions estimates, using IEA energy data and emission factors from IPCC guidelines; as a result, these estimates differ from countries’ official submissions for a variety of reasons. CDIAC and EIA also provide emissions estimates based on a combination of statistics by the UN, EIA, and individual researchers. The FAOSTAT emissions data is also computed. If we were to use these emissions figures, we would first do a comparison between the UNFCCC, CAIT
2.0, and FAOSTAT data to see if the data would be robust enough to provide a reasonably accurate policy signal.

Value added by agriculture as a percentage of GDP, along with GDP PPP figures, are available for most countries through the World Bank Databank. Denominating the indicator by economic value provides an indication of how agriculturally “dirty” an economy is.

Notably, a report of potential indicators to inform the post-2015 SDG agenda lists greenhouse gas emissions from the Agriculture, Forest and other Land Use (AFOLU) sector as a potential indicator to be developed, suggesting UNFCCC as the potential leading agency for indicator development (LCSDSN 2014). This proposed indicator would inform the proposed goal to “reduce non-energy related emissions of greenhouse gases through improved practices in agriculture, forestry, waste management, and industry.”

**Land conversion**

The predominant driver of land-use changes in most countries, agriculture to date occupies about 40% of global land surface (Easterling and Aggarwal et al. 2007), leaving limited remaining forest and land to be expanded for agricultural production. An estimated 80% of new croplands have been replacing tropical forests in recent decades (Gibbs et al. 2010). To combat agricultural expansion into new land, policymakers can support sustainable intensification on existing agricultural land, or expand agricultural production onto degraded land rather than clearing new forests and wetlands.

Notably, a report of potential indicators to inform the post-2015 SDG agenda lists land conversion to agricultural uses and degradation of agricultural land as indicators to be developed, suggesting FAO and UNEP as the potential leading agencies for indicator development (LCSDSN 2014). Thus far, the OECD has a data-backed indicator on conversion of natural ecosystems to agriculture, broken out by forests and wetlands to crops and pasture. It only covers eight countries however, and it is unclear when the data will be updated next. Its data is currently based on national surveys, and it could be worth exploring remote sensing techniques as a way to increase geographic coverage and updatability.

Regarding vegetative cover in agricultural landscapes, we have also considered crafting an indicator measuring the proportion of the agricultural extent that has over 30% forest/savannah cover. This threshold is based on the assumption that if the proportion of agricultural land use surpasses 70%, some correction is needed to restore and/or conserve the surrounding habitat for terrestrial and aquatic biodiversity, as well as watershed functions. This is a conservative approach, acknowledging that there is a lot of variability around the general rule of thumb that major ecosystem functions are likely to be compromised in an area where more than just 30% of the landscape is being used for intensive agriculture. Data on land use and land cover is available from
satellite images in the Pilot Assessment of Global Ecosystems: Agroecosystems (Wood et al. 2000) allowing calculation of the area under crop production relative to forest or savannah cover in a given pixel (1x1 km). We would need more regularly updated data to make this into a robust indicator.

**Wildlife in agricultural lands**
Agriculture has been considered to be possibly the largest threat to biodiversity conservation (Foresight 2011). Relating the impacts of land conversion and degradation, we have considered including an indicator measuring the number of wild bird and mammal species found on agricultural landscapes and grazing lands as a proportion of the number of wild species outside these areas, by major habitat types. The indicator would reflect relative ecological degradation in agricultural vs. non-agricultural regions within the same habitat type. It may be worth exploring the use of datasets such as those represented on the Map of Life or the Local Ecological Footprinting Tool (LEFT), which provide spatial information on the location of species, and whether they could be overlaid with agricultural land classification data to calculate species diversity on agricultural lands. As with some of the other indicators, the question of scale is crucial here. More localized indicators disaggregated from the country level could be especially helpful in supporting landscape-level planning and decisionmaking (e.g. land sparing work) that target impacts of agriculture on biodiversity and other ecosystem services (Foresight 2011).

**Agricultural crop diversity**
Diversity of agricultural crops is a measure of resilience to environmental stresses such as pest outbreaks, as well as increased pathogen transmission and floods expected to worsen through climate change (Lin 2011). At a more basic level, crop diversity supports ecosystem services, attracting a wide array of pollinators and enriching soil health. Interaction between wild and farm-grown plants can create new, hardier gene combinations. The issue has received significant attention at the international level, through the International Treaty on Plant Genetic Resources for Food and Agriculture adopted by the FAO Conference in 2011 (see Target Definition section for more details).

To date, we are unaware of global or near-global data available on agricultural crop diversity, but welcome expert consultation in this area.

**Soil health**
Unsustainable farming practices, such as the under- or overapplication of fertilizer, have led to a decline in soil quality. Land degradation, as defined by a loss of soil fertility and biological potential (Eswaran et al. 2001), has not been systematically assessed on a global basis. In the 2010 EPI report we reviewed work by the Global Land Degradation Assessment (GLADA), a partnership between the FAO and the World Soil Information System (ISRIC) to assess land
degradation using satellite data. The metric would have been percent change in net primary productivity (NPP) across agricultural land. We determined that there were still too many uncertainties in the data and methods to ensure an accurate representation of land degradation dynamics. GLADA’s methodology centered on long-term satellite records of “greenness” – the normalized difference vegetation index (NDVI). The results initially seemed promising but we were cautioned not to interpret the results as indicative of land degradation, per se. This may be because the indicator mixes in the effects of deforestation and other vegetation cover change.

Based on personal communications, it appears that net change in NPP across agricultural land may also not be the most robust measure of environmental performance given the varying level of receptiveness of different soils to disturbance. For example, even if a farmer applies too much fertilizer, soil carbon can stay high even with excess N under certain scenarios. While there are a number of indicators that capture the functional capacity of soil, few can gauge the capacity of soil to continue functioning under a range of disturbances (Herrick 2000). It would be worth doing a more exhaustive literature review to see what others have done on indicators of disturbance.

Beyond the NPP indicator, all other soil health indicators we have considered lack sufficient global coverage for us to include them in the EPI. Relevant but not globally available is data on the share of agricultural land affected by land erosion. The OECD produced data for this most recently in 2008 across 28 countries, whose data is based on modeling using the Universal Soil Loss Equation (OECD 2013). Notably, these figures are generated using estimates of soil erosion risk rather than field measurement data. It would be valuable to see what ground-truthing has been done in modeled data. If the errors are within reasonable limits, the feasibility of global or regional models may still be worth discussing.

In addition, a one-time study conducted in 2013 provides data on organic carbon tent in topsoil in Africa based on remote sensing and field measurements (ISRIC/AfSIS 2013). The Harmonized World Soil Database, which draws upon a number of global and regional soil databases, provides the most comprehensive coverage to date of nutrient availability, nutrient retention capacity, excess salts, and toxicity, albeit with some gaps in the measured data (FAO et al. 2012). We invite any guidance on how these data could be adapted for country-level coverage and used to provide a signal on human influence, isolated from natural endowments and forces.

Another relevant indicator could look at area salinized by irrigation. However, AQUASTAT, the most complete global country-level system with water information, expects 10 years if not more between every two updates. Geographic coverage is still limited for this data.

**Nutrients**

Nutrients are instrumental for crop growth, and when short in supply, can lead to soil degradation. Yet animal manure, excess chemical fertilizer, and soil erosion also leak nutrients as pollution into
both groundwater and surface water. Excess nutrients are especially problematic, with just 10% of
global croplands covering 32% of the world’s nitrogen surplus and 40% of the phosphorus surplus
(Vitousek et al. 2009). Among the nutrients considered essential for agriculture, nitrogen and
phosphorous in particular have received heavy policy attention given the fact they can contribute
eutrophication, acidification, climate change, and contamination of soil, water and air. Nitrogen
tends to be a problem in saltwater, whereas phosphorous tends to be a problem in freshwater.

Viewed from a planetary boundaries lens, excessive levels of nitrogen and phosphorus flows may
cause negative non-linear changes in land, aquatic, and marine systems, while also functioning as
a slow driver of climate change (Rockström et al. 2009). Rockström’s team sets the planetary
boundaries at roughly 35 Mt N yr\(^{-1}\) in nitrogen flows (about 25% of current level) and phosphorus
flows beyond 10 times the natural background rate of \(\sim 1\) Mt P yr\(^{-1}\). Nutrient pollution can be
reduced through improved management of fertilizers, livestock waste and drainage water, as well
as conservation tillage and the planting of cover crops and buffers (EPA 2014). Some argue that
these N and P flow boundaries do not include social dimensions and in turn, global food security,
into account (Sutton 2012). Using indicators could nonetheless help policymakers target areas of
low nutrient efficiency for better management could help reduce the negative impacts of intensive
agriculture (Foley 2011) – ideally with food security figured into targets.

The most promising indicators identified in WRI’s scoping exercise – nutrient input balances and
fertilizer use – are both still a long way from meeting data requirements for inclusion in the EPI
due to limited geographic coverage and infrequency of update. The OECD has collected data on
nutrient input balances (the difference between nitrogen and phosphorous inputs and outputs), as
well as nutrient efficiency, but only for OECD countries. With the data most recently updated in
2008, it remains unclear when the next update will occur.

**Pesticides**

Excessive use of pesticides results in toxic runoff to waterways and chemical buildups in soil,
eventually decreasing the productivity of land and damaging ecosystems. They kill beneficial
insects, pollinators, and fauna, and human exposure to pesticides has been linked to increased rates
of neurological and reproductive disorders, endocrine disruption, and cancer (Alavanja et al. 2004). According to a report by the OECD (2004), public subsidies for agrochemical inputs
exacerbate environmental pressures through the intensification of chemical use.

As mentioned earlier, our existing agriculture indicator is policy based, assessing the status of
countries’ legislation regarding the use of chemicals listed under the Stockholm Convention on
Persistent Organic Pollutants (POPs). Specifically, the 2012 and 2014 editions of the EPI scored
whether countries allow, restrict, or ban the “dirty dozen” POPs. It uses the National
Implementation Plans (NIPs), which are essential elements for assessing policy and management
strategies and identifying priority activities to meet the requirements of the Stockholm Convention.
While ideally the POPs indicator would use the National Reports to score implementation of policies to restrict or ban POPs, many countries have not submitted these reports.

While conducting due diligence on data reported by countries is beyond our scope, we plan to primarily use implementation data from National Reports (available online for a select number of countries) where available, and secondarily the NIPs going forward in an effort to improve the indicator. We also plan to narrow the list of POPs in our indicator to only include pesticides rather than also including industrial POPs like polychlorinated biphenyls (PCBs) and unintentional POP pollutants such as dioxins.

Eventually, we would like to replace this with an indicator that better reflects the actual physical impacts of agricultural pesticides on the environment.

**Meat production and consumption**

The proliferation of industrial livestock production has created environmental concerns, including its relatively higher resource intensiveness compared to other forms of food production, increased pollution from animal waste given high livestock concentrations (Horrigan et al. 2002), nutrient overloading, methane emissions, and in some cases a buildup of arsenic and heavy metals used in livestock feed. Livestock feed also diverts crop supplies that could otherwise be used for human food.

It was recommended previously (Scherr 2008) that the EPI include an indicator on livestock concentration using the metric Livestock Head per Unit Land. We revisited the possibility this year, particularly given the recent release of livestock density data by ILRI and ULB (2014). Through our communication with the two organizations, we have reservations that livestock density is indicative of environmental performance, given its dependence on a variety of factors: production system, food/feed availability, climate/weather, and natural resource endowments and resilience. In addition, a density threshold may also depend on how we define the dimensions of impact and sustainability, which can cover a broad range of elements including nitrogen impact, greenhouse gas emissions, antibiotic usage, and animal/human health.

In light of this, we are now considering creating an indicator of meat consumption as a proxy for how environmentally damaging the diets of certain countries may be. We are currently in the process of evaluating data on domestic utilization of bovine, mutton and goat, pig, poultry, and other meat available through FAOSTAT’s food balance data. Although the indicator would be foremost focused on environmental performance, we are looking at the possibility of building in a lower bound on consumption, acknowledging that some level of meat consumption may be necessary for food security. This would hold particularly in areas where meat is a staple component of people’s diets and there are few readily accessible alternatives.
Crop yields

Inevitably, we come back to the question of how to achieve improved yields while reducing environmental impact. There are a number of recent pieces in the agricultural literature comparing actual to ideal yields, and the possibilities for closing the yield gap in a sustainable manner. The OECD has deliberately kept yield as part of the environmental discussion by including an indicator on agricultural production volume in its Compendium of Agri-Environmental indicators (OECD 2013). A major question is whether the world could close the food, crop, and fiber gap solely using conservation agriculture and other environmentally sound methods.

Foley 2011 in particular provides data for observed and potential yields covering 155 countries over the period 1997–2003. Potential yields are based on existing high-yielding areas in zones of similar climate – an approach more conservative than absolute potential yields but achievable using current technology and management techniques. It is unclear to what extent the high-yielding areas include those involving monocropping, synthetic fertilizers and pesticides, inefficient irrigation systems, and other manifestations of industrial agriculture. This is important to know if we are to understand how drastically countries would have to adjust to reach their potential targets through ‘sustainable intensification.’ In thinking about how to design an indicator about yields, the first thought is to score countries higher based on how close they are to some percentage of potential yields. However, this method raises a couple of challenges. First, we are concerned that by only looking at progress made by countries to close the yield gap, the indicator does not provide any insight into how sustainable actual farming practices are. There could be a country with high yields that scores highly one year that in fact ends up exhausting its soil and water supply over the short term. It would be inaccurate to equate those high yields with good environmental performance.

Second, some regions are clearly limited in their ability to increase crop yields – for example, up to 50% or 75% of attainable yields depending on their ability to increase irrigated area and nutrient application. We would not want to penalize countries for failing to meet the full target it is not actionable, so it would make more sense to set the indicators’ targets based on region/country. For the best definition we would need to include different targets for different crops depending on the country and then aggregate scores. Gauging country performance according to differential targets is very difficult as the EPI generally avoids a tiered approach for targets (with an exception made for the Climate and Energy category in the 2014 EPI). Consideration of suitable benchmarks for sustainable crop yields warrants further discussion.

In addition, we should discuss whether it is appropriate to always favor measures that reduce environmental impact where there is a tradeoff between improving yields and reducing environmental impacts. There may be countries that have major yield gaps or are earlier in their socioeconomic development or population growth trajectory, for instance, that could potentially warrant exemptions from being scored in this area.
Another route could be to see if there is data available on the impacts of air pollution or climate change on crop yields. In 2008, the EPI had an ozone indicator, which calculated accumulated exposure concentration of ozone over a threshold of 40 parts per billion in daylight time of growing season to get a sense of the impact of ozone pollution on crop yields. However, these data were highly modeled and the target questionable.

**Precision agriculture**

First developed in the late 1980s, precision agriculture leverages large-scale information to identify input and labor efficiencies on the farm, often providing real-time data on production variability using yield monitors, GPS, GIS, and in-field and remote sensing. Backed with this information, producers are better informed to improve agricultural yields and reduce environmental impacts, at lower costs. In particular, precision agriculture can help farmers pinpoint where and how much water, fertilizers and pesticides should be applied, cutting down on their overall use (Oliver 2013). Although increasingly associated with elaborate real-time technologies, precision agriculture is at its core the art of using computerized information to manage farm operations. It therefore also includes inexpensive and less gadget-heavy approaches, such as the free Fieldprint Calculator developed by the Field to Market group where farmers can gauge their performance against averages pulled together through publicly available data.

We are considering creating an indicator on the use of precision agriculture, potentially using data from major suppliers of precision agriculture equipment and technologies. The idea is that the use of precision agriculture would serve as a proxy for improved environmental performance on arable land. However, we recognize that countries and producers only beyond a certain net farm income will likely invest in precision agriculture. We have entertained the possibility of dividing the indicator into income buckets, for example, OECD vs. non-OECD countries. If we were to substitute an alternative fertilizer measure for countries that do not have access to precision agriculture equipment, we would still be missing out on the third of all countries that do not apply fertilizer at all. OECD has some outdated data on the share of arable land under soil conservation practices such as no-till/low-till (only 14 countries). It may be worth seeing if anyone has or can pick up this work again for a greater number of countries.

**Area of eco-verified production**

Certification has expanded as a voluntary approach to incentivizing environmentally and socially responsible practices in the food and agriculture sector. While ecolabels and sustainability certifications initially focused on environmental impacts on human health, they have grown over the years to also capture concerns about deforestation, biodiversity, and fair labor (Golden 2010).

We have considered creating an indicator for the percent of total cropped area under eco-verified production standards, which cover both certified organic production and ecological certification.
systems that account for biodiversity impacts (Scherr 2008). These would include internal standards used by companies to cover their specific supply chains, only if they meet minimum standards of verification and require that producers meet clear criteria for ecological management to protect defined ecologically important areas. There are currently 164 countries with data on certified organic agriculture as of 2012 year end (Willer & Lernoud 2014). Data on ecological certification systems are available from Rainforest Alliance and a number of other certifiers.

In our previous scoping exercise, Scherr (2008) suggested that the target for this indicator need not be 100%. The assumption was that if 10% of cropped area meets such standards, then there would be strong market and policy pressures more generally to ensure high environmental standards for agricultural production.

A potential argument against scoring countries based on this indicator is that some producers may practice sustainable agriculture without certification, for example due to the costs of verification. And in the same way that we have found that having a large extent of certified forest area is not yet a good indicator of national performance on forest conservation (for example in Brazil and Russia), the same argument might be explored for certified agricultural land area.

To use the data, we would need to make a judgment call on whether the signal provided by the indicator would be worth its limited ability to capture the state of sustainable production across countries. The data on certification is currently still more thorough than that available on the share of arable land under soil conservation practices through the OECD (only 14 countries), as mentioned in the Precision Agriculture section.

There is also the question of whether non-organic agriculture – in particular, that which draws upon genetic modification, a controversial topic – might be done without significant harm to the environment. At the heart of a rather high-profile back-and-forth earlier this year between Vandana Shiva (Shiva 2014) and writers at The New Yorker (Specter 2014, Remnick 2014) is the discussion of how to close the food gap and whether it is worth fighting for ‘natural’ crops. A major example brought up is the genetically engineered Bt cotton seed, whose use has dramatically reduced the need for toxic pesticides, while delivering huge yield gains for farmers. We welcome further discussion on how to better discern the environmental impacts of GMOs in order to provide an accurate approach to scoring country performance in this area.

**Public R&D for agriculture**

A potential indicator could look at the amount of investment in agricultural research and development as a proxy for improvements to agricultural practices. The Agricultural Science and Technology Indicators, overseen by CGIAR, provide data on total agricultural R&D spending for developing countries. OECD S&T indicators and EUROSTAT provide agricultural R&D data for many developed countries, while some countries provide data through their Department of
Agriculture, S&T, or Statistics websites. However, currently it is not possible to disaggregate the types of agricultural R&D spending to be able to identify spending committed to making agriculture more environmentally sustainable.

**Conservation areas on private lands**

Another indicator we have considered is on environmental stewardship by farm communities, including conservation trusts, short-term conservation easements, areas certified for conservation management, riparian areas conserved in natural vegetation (Scherr 2008). As of 2008, aggregate data was generally not already available within countries. It would be worth seeing if data availability has changed since then or if data can be reasonably collected.

It may be valuable to compare the results to conservation on publicly protected areas, using the same target established under the Convention on Biological Diversity for public protected areas of 10%. As of 2008, the highest proportion of privately conserved areas were in the US and Europe, with areas also emerging rapidly in countries throughout Latin America and Africa.

**Food safety**

Historically the agriculture category of the EPI has been housed in the Ecosystem Vitality half of the index, focused on the environmental impacts of agriculture. The other half of the index – Environmental Health, which measures the impact of the environment on human health – currently does not have a category dedicated to the food safety and nutrition aspects of agriculture. The inclusion of an indicator of food safety or nutrition could be something to explore further down the line, as tied to pathogen-contaminated water, pesticide residues, and other contributors to foodborne illness. The EPI’s existing indicator on pesticide regulation touches upon human health only implicitly. Once data on the actual health and environmental impacts of agriculture are globally available, we will be better able to score countries’ on-the-ground performance both in terms of Ecosystem Vitality and Environmental Health. However, for the time being, we only have the pesticide regulation as a proxy indicator that implies but does not guarantee country performance in both of these areas.

**Reflections and linkages**

As far as boundaries and linkages go, we define agriculture in the EPI as encompassing crop and livestock production. Fisheries and forestry are split off as their own issues with indicators. While the issue indicators are siloed, it is vital to acknowledge linkages between issues covered in the EPI, particularly given that policymakers are often working on policies and practices that impact more than one issue. Currently, the indicators included under each issue category are not nearly exhaustive enough to support analysis of the relationship between issues, but it would be useful to move in this direction as more data becomes available. For example, Agriculture and Climate & Energy issues would be related on both the mitigation and adaptation fronts, as well as energy use.
Policies that promote climate-smart agriculture can improve the resilience of agriculture against the local impacts of climate change, while also reducing greenhouse gas emissions that contribute to global climate change. The landscape approach attempts to strike harmony between Agriculture and Forestry, given agriculture’s prevailing role as the primary driver of deforestation. The food-energy-water nexus invites us to look harder at the availability of Water Resources for Agriculture.

2. Target definition
To calculate a performance indicator we must be able to define a high performance benchmark, or target, that is derived from several sources:

- International treaties
- Agreed-upon scientific thresholds
- National-level policy goals
- Expert judgment
- Range of the available data (i.e. establishing a performance benchmark consistent with a percentile of the data)

By the same token, a poor performance benchmark needs to be established (Figure 2). This is generally defined by the worst performing country or by winsorization, that is the 5th percentile of the entire range, with any countries that fall below that threshold obtaining a “0” score.

Even granted we find datasets meet the criteria for inclusion in the EPI, it may still prove difficult to identify a sensible policy target by which to gauge country performance. For example, data on greenhouse gas emissions from the agricultural sector may exist, but identifying a globally consistent target for reducing agricultural GHG emissions may prove far more difficult.

![Diagram illustrating the proximity-to-target methodology used to calculate the EPI](image)

*Figure 2. Diagram illustrating the proximity-to-target methodology used to calculate the EPI*
Where international treaties on sustainable agriculture are concerned, there is just one dedicated treaty to date: the International Treaty on Plant Genetic Resources for Food and Agriculture. Adopted by the FAO Conference in 2001, the treaty is a legally binding, international commitment to manage the world’s agricultural biodiversity – relevant but only touching the tip of the iceberg of all of the issues relevant to sustainable agriculture. 130 countries and the European Union have signed on to the Treaty as of 2014. The objectives include the conservation and sustainable use of plant genetic resources for food and agriculture and the fair and equitable sharing of their benefits, in support of an earlier goal set by the Convention on Biological Diversity to increase the proportion of agricultural land managed to conserve plant diversity to 30% by 2010. Others have made a case for global treaties on soil conservation and sustainable farming, but these do not exist yet (Fromherz 2012).

Two of the eight high-level goals laid out in the Millennium Development Goals (MDGs), formulated by the UN in 2000 for achievement by 2015, are relevant to sustainable agriculture: “eradicating extreme poverty and hunger” and “ensuring environmental sustainability.” Agriculture is invoked in later UN documents in reference to fulfilling the MDGs (UN General Assembly 2010). In addition to stating a goal to strengthen coordination and governance for food security, they reiterate the World Trade Organization member pledge to eliminate export subsidies for agriculture across the board by the end of 2013. This particular goal informed our target-setting of 0% for the existing EPI agricultural subsidies indicator.

Proposed sustainable agriculture goals for the post-2015 Sustainable Development Goals agenda, intended to succeed the MDGs, include the following under Goal #2 to “end hunger, improve nutrition, and promote sustainable agriculture” (UNCSD 2014):

- 2.4: “by 2030 implement sustainable and resilient agricultural practices including for adaptation to climate change, extreme weather, drought and disasters, and progressively enhance soil quality”
- 2.5: “by 2020 maintain genetic diversity of seeds, cultivated plants, farmed and domesticated animals and their wild relatives, and ensure access to and fair and equitable sharing of benefits arising from the utilization of genetic resources and associated traditional knowledge as internationally agreed”
- 2.a “increase investment in rural infrastructure, agricultural research, technology development, and capable institutions, particularly in countries that are net food importers”
- 2.b. “phase out all forms of agricultural export subsidies”
- 2.d. “create and diversify seed and plant banks, including with traditional varieties, at national, regional and international levels, to safeguard seed and genetic plant diversity”

In line with these goals, the Sustainable Development Solutions Network conducted an analysis identifying gaps for proposed SDG indicators for food and agriculture, which we allude to in the previous section discussing potential indicators for greenhouse gas emissions and land conversion (UNSDSN 2014).
Water quality standards have been developed internationally to address pesticide and nitrogen/phosphorous runoff and bacteria from livestock wastes.

The Kyoto Protocol of the UN Framework Convention on Climate Change has set overall targets for emission reductions, but has not disaggregated this to include specific targets for the agricultural sector. That said, the drafted Working Group III contribution to the IPCC’s Fifth Assessment Report provides estimated economic mitigation potentials for the agriculture sector by 2030, given various carbon prices (IPCC 2014).

Actually incorporating appropriate national targets and measuring performance in the EPI remains a significant challenge, particularly given varying natural resource endowments and agricultural needs among countries. To date, indicator targets in the EPI have mostly been based on expert judgment.

3. Measurement
Going forward, the EPI team hopes to collaborate with different disciplinary communities to identify gaps in existing measurement systems and to bring to the attention of policy makers the need to invest in new systems, whether based on field measurements or remote sensing, that can help to monitor country-level management of resources.

This workshop represents an opportunity to think outside the box, and to propose novel approaches to the measurement of agricultural resources and management practices. There may also be best practices of existing measurement systems that need to be more widely diffused or funded in developing countries. The EPI offers an opportunity to publicize the need and to educate policy makers about existing guidelines. Box 1 provides some key questions that may be considered during workshop discussions.

**Box 1. Key questions related to assessing agricultural sustainability**

- How should environmental performance at the national level be defined?
- What should be monitored and measured?
  - For example: irrigation efficiency, soil quality, land conversion, nutrient pollution, greenhouse gas emissions, pesticide use, technology use
- At what scale and where should measurement take place?
  - e.g., grid, farm, watershed, landscape, national level
  - When national, how can we create a consistent indicator across countries? How can we normalize for natural endowments and economic conditions?
- What types of measurement are most scalable? Is there a “best” practice available for monitoring or collecting measurements?
  - For example, direct monitoring vs. aggregation from other data
  - What should be the mix between remote sensing and more intensive field sampling? Tradeoffs between coverage and accuracy
- Is this method adequate? Can it be applied to other regions? Can it be improved?
- How often should monitoring/measurements sites/protocols be reevaluated?
- What system will be put in place to monitor and assess quality control of measurements?
- What is the ideal time-scale for monitoring/measurements – monthly, yearly, etc.?
- What are the costs for investments for agricultural monitoring/measurements?
  - How do these costs relate to scale and population?
- Are there “best practice” guidance documents that could be more widely disseminated?
References


Horrigan, L., Lawrence, R. S., & Walker, P. (2002). How sustainable agriculture can address the environmental and human health harms of industrial agriculture. *Environmental Health*


ILRI/FAO/ULB. Livestock Geo-Wiki. International Livestock Research Institute (ILRI), Food and Agriculture Organization of the United Nations (FAO), and the Université Libre de Bruxxelles (ULB-LUBIES). Available at http://www.livestock.geo-wiki.org


