



DISCUSSION BRIEF SUMMARY:

Sustainability Implications of Closing the Yield Gap

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Roughly 7.2 billion people now inhabit the Earth, and by 2050, that number could reach 9.6 billion. Adequately feeding them could require increasing food production by two-thirds or more. In part, this is because food is poorly distributed around the world, with widespread obesity and food waste among wealthier populations, but an estimated 870 million people undernourished. Also, as incomes rise, people tend to eat more meat, and animal feed requires a disproportionate amount of crops.

Humankind has met such a challenge before, with the Green Revolution, which dramatically reduced hunger in the last half-century even as the world population more than doubled. The approaches that raised yields before, however, cannot significantly raise them beyond current levels, and the environmental impact of agriculture is exceeding a “safe operating space” for humanity. Thus, attention is increasingly focused on closing yield gaps –the difference between potential yields, and the actual yields that farmers achieve on their fields.

Large yield gaps are most apparent in sub-Saharan Africa, which benefited very little from the Green Revolution, but significant yield gaps also remain across the low-income countries and among lower-income farmers in less-poor countries. There appears to be a particularly large untapped potential to raise yields substantially by improving water partitioning on rainfed lands. Yet decades of experience with agricultural development have shown that the approaches taken to date fall short not only on environmental sustainability, but also in terms of social sustainability, as the benefits are not distributed equitably, and access to land, technology and inputs are all major barriers for the poor.

Environmental impacts of agriculture

The substantial increase in global food production over the last half-century has been achieved, to a great extent, through the augmented use of inputs such as synthetic fertilizers, pesticides, and herbicides as well as technologies for water appropriation and distribution, plant breeding and disease control. These developments met a fundamental human need, but also exacerbated or created many sustainability concerns – e.g. groundwater depletion, water and air pollution, loss of biodiversity, and land degradation, and loss of ecosystem services. Agriculture is a major contributor to global GHG emissions – an estimated 5.9 gigatonnes (Gt) of carbon dioxide equivalent (CO₂e) in 2009, about 13% of total GHG emissions for the year, plus another 2.6 Gt CO₂e, or about 6% of global GHGs, from land use, land use change and deforestation.

Yet modern intensive agriculture also addressed an important global dimension of sustainability: the need to preserve land. Food production has increased at many times the rate of agricultural area expansion, and in industrialized countries, a great deal of farmland has even been returned to the wild. Any solution for the future will thus require striking a balance between conflicting goals.

There are many ways to arrange global agricultural production in more sustainable ways, however, and well-known effective practices, such as conservation agriculture, which minimizes or eliminates tilling to preserve soil organic matter, and thus improves soil quality and water retention capacity. Significant efforts have also been made to reduce fertilizer runoff, irrigation water waste, and other problems. And a number of “climate-smart” agricultural practices and strategies are available to make farming more resilient to climate change and also reduce GHGs and even capture carbon.

Yield and yield gaps

Within agronomy, and in national and international statistics, agricultural yield is defined as the amount of valuable (or “economic”) plant matter per unit area – e.g. tonnes of grain per hectare. Such measures can understate the value of mixed cropping systems, however, as the grain yield per hectare of a mixed system may be relatively low, but overall it may deliver substantial calories or income. Yield gaps normally refer to the difference between realized yields and either potential yield (for irrigated conditions) or water-limited yield (for rainfed conditions). A problem with this concept is that farmers are rarely aiming to maximize grain yield. Instead, they try to maximize a contribution to their income and livelihoods in relation to labour and other inputs. Many factors beyond farmers’ control can also affect yields, such as ozone and small-particle pollution, both of which reduce yields.

Another measure of yields is the land-equivalent ratio (LER), calculated by comparing the land area used to grow the crops together to the land area that would be required to grow each crop on its own. LER data suggest that intercropped systems perform about as well as sole production systems, but there is no agreement on the best way to measure the productivity of intercropped systems. The LER also fails to account for what farmers want out of their land, as the most biologically productive intercropping system may not be the one that delivers the farmer’s optimal mix of crops. One option is to use economic measures, such as a revenue-equivalent or cost-equivalent ratio.

Yet another way to measure yields is net primary production (NPP), the biomass produced in a natural ecosystem. Natural ecosystems develop over long times, and under human disturbance, ecosystems free of human activity are rare. More often are found highly managed agro-ecological systems providing humanity with food, fibres and fodder, and other products. Various assessments of NPP show that anthropogenic impacts can positively or negatively alter natural levels.

High-input vs. organic agriculture

Generally, although not always, yields under organic systems are lower than in high-input systems. Thus switching from high-input to organic agriculture would, all else remaining the same, require an increase in agricultural land area to produce the same amount of food – but it could also have environmental benefits. It is not obvious what the right balance of yield and inputs might be. Even without switching to organic agriculture, it is possible to reduce external inputs without substantial changes in yields. A more balanced productivity indicator might partly offset yield gains by increases in external inputs. It is also important to note that in some regions, adding nutrients will be essential.

Causes of yield gaps

Yields can be below potential because of insufficient or imbalanced nutrients; insufficient or excess water; pests, diseases, and weeds; soil problems; physical damage; poor seed; and suboptimal planting. They can also be low because it is not profitable for farmers to raise them further, because of resource constraints, or because of lack of knowledge. Attributing yield gaps to specific causes is challenging – it is easy to misattribute causes, and causes are often interconnected.

Ultimately, closing yield gaps is fundamentally about farmers practicing the best known management solutions for their crops and locations. Many practices that increase yields also provide environmental benefits. The value of these practices, however, may be underestimated if measures of agricultural productivity don't go beyond crop per unit of land, or crop per drop of irrigation. This is especially true in complex agro-ecosystems with mixes of crops, livestock and horticulture, where farmers are poor and have little technology. Second, closing yield gaps at the local level requires building a diverse portfolio of strategies, technologies and incentives, and then applying them in different combinations to suit specific farmers' needs.

Conclusion

While sustainable intensification promises to offer the best potential for reaping both agro-ecological and socio-economic benefits, several challenges need to be addressed to enable sustainable intensification to take hold and flourish. These include identifying appropriate land management systems; developing alternative measures of agricultural production; matching strategies to farmers' current goals and constraints; and enhancing the flow of intellectual, governance and investment resources between relevant national and international stakeholders.

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