A Commentary on "Comparing the Yields of Organic and Conventional Agriculture" – A Study Published April 25, 2012 in Nature

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Much has already been written about the intriguing new study published in *Nature* on organic and conventional yields. The study, by Verena Seufert, Navin Ramankutty, and Jonathan Foley, will hopefully help elevate the important, ongoing discussion of the strengths and weaknesses of conventional and organic farming systems as the world charts a path toward greater food security for all.

The study reports that yields are typically lower on organic farms, compared to nearby conventional farms producing the same crop, but that there is wide variation across farms and crops, and experience and management levels. For rain-fed legumes and perennial crops grown on weak-acidic to weak alkaline soils, the difference is as low as 5%, but is as high as 34% lower yields when comparing mostly row crop and cash grain crops. Overall on average, the authors report a 25% yield advantage for specific crops, when comparing conventional systems to organic systems.

These conclusions are in line with many other studies and likely reflect accurately the average differences in yields on today's commercial organic farms in the U.S. But there is far more to the story – and challenge – in comparing the performance of organic versus conventional farming systems.

Their results are based on a careful meta-analysis of 66 studies, representing 62 locations and 316 organic-to-conventional yield comparisons, via what we have called "matched pair" studies, where the conventional and organic crops are grown on comparable soils, with comparable genetics, irrigation, harvest timing, etc.

The authors highlight nitrogen availability as a key factor limiting organic yields, an observation backed up by hundreds of studies and the experience of most organic grain farmers. They also note the likelihood of phosphorous deficiencies on many organically managed alkaline and acidic soils, where P tends to be less bioavailable. Again, this observation is consistent with experience on many organic farms. They likely should have focused more on early-season weed control challenges on organic grain farms, an area where organic farmers need help with better cultivation and planting equipment, and new technologies and practices.

Appropriately, the authors highlight that "Organic yields thus depend more on knowledge and good management practices than conventional yields." Experienced

organic farmers with healthy soils, ample nutrients cycling in their soils, and stable biointensive Integrated Pest Management (IPM) systems routinely produce higher yields than their conventional neighbors in dry years, although equally well-managed conventional systems nearby will typically out-yield the organic systems in years with ample moisture. In rain-fed row crop farming regions, well-established and expertly managed organic and conventional farms produce comparable yields when averaged over a decade or longer.

The *Nature* paper also concludes that organic yields tend to improve over time. Two factors account for such improvement—

- Experience is gained by farm managers in organic fertility and pest management systems, and
- Cropland soils and agroecosystems regain heath via increases in above- and below-ground biodiversity, increasing the supply of nutrients cycling through the system and enhancing the performance of IPM systems.

The authors report improved organic performance in studies reporting yields for at least three years under organic management. It is worth noting that in most crops and regions, the transition to a healthy organic system requires at least three rotational cycles, or nine years in a simple, three-crop rotational system. Counting the three years of transition to certified organic status, a farm needs to be certified organic for at least six years to attaint the full measure of benefits from organic farming. It takes even longer to restore farms ravaged by soil erosion, plagued with massive weed seed banks, or struggling with chemical imbalances in soil.

Undoubtedly, a small fraction of the organic systems included in the *Nature* study reflect organic yields on well-established farms under a high-level of management, whereas the conventional yields likely often came off of farms benefiting from a relatively high level of management.

Performance Beyond Crop Yields

Both in the *Nature* paper and comments to media, the authors acknowledge that crop yields are just one measure of the performance of farming systems and that other factors must be taken into account. They also stress that a comprehensive, comparative assessment of different cropping systems is a very complex and data-intensive exercise. They call for more research to develop ways to systematically evaluate performance across systems. There are many factors that can, and indeed must be taken into account.

First, as conventional crop yields have grown, the nutrient density of harvested crops has fallen. A bushel of corn harvested from a typical, high-yield row-crop farm in the American Midwest is not the same nutritionally as the corn harvested 10 years ago on that same farm, or the corn on a nearby organic farm with 25% lower yields. The protein content on the conventional farm, achieving for example a yield

of 225 bushels, would typically fall in the 6.5% to 7.5% range, while the corn grown on a nearby, equally well-managed organic farm, yielding 175 bushels, would likely contain 8% to 9% protein.

Thousands of published studies have demonstrated for dozens of crops an inverse relationship between crop yields and nutrient density, otherwise known as the "dilution effect." (See our report "Still No Free Lunch" by Brian Halweil for an overview of data on the dilution effect). The Organic Center research on the nutrient content of plant-based organic versus conventional food, and a number of published reviews have concluded that, on average across several essential nutrients, organic food is 20% to 25% more nutrient dense than conventionally grown food.

If the nutritional differences between high-yield conventional crops, versus nearby lower-yielding organic crops, were fully taken into account, a significant portion of the conventional farm's advantage in terms of raw yields would disappear, when comparing the nutritional value of foodstuffs harvested off one acre in contrast to another.

The studies included in the *Nature* paper analysis compared the yield of a single crop grown conventionally versus in an organic system, not the production of farming systems over the life of a rotation. Particularly in the case of row-crop and grain farms producing a single crop per year, this approach biases the results in favor of conventional production systems. This is because organic farms are almost always producing at least two crops per acre in a given season – a cover crop and the primary grain or other row crop.

Organic farmers are happy to sacrifice a bit of yield potential in return for the multiple benefits from harvesting two or three crops per year. Cover crops established soon after the harvest of grain in the fall on organic farms can produce both pasture for grazing, forage for harvest, and green manure for soil building. Regardless of how the farmer uses the cover crop, one of the most important advantages enjoyed on organic farms is the ability to utilize more fully the solar energy falling on an acre of farmland from early spring to the onset of winter.

On a typical, conventional corn-soybean farm in the Midwest, the ground is barren through corn planting in late April through mid-May. By late May, the corn is germinated and growing vigorously, and is capturing a significant share of the solar energy falling on the land. It will continue to do so through mid- to late August, when the plant stops growing and starts filling out the kernels in the corncob. Accordingly, the crop is capturing the solar energy falling on such a field for three, and at most four months. On the nearby organic farming, growing a similar rotation but planting cover crops, the solar energy falling on each acre will be utilized at least four months longer.

The two most significant advantages of long-term, well-managed organic row crop and cash grain farms arise from this fuller utilization of the solar energy falling on an acre, and the ability of soils higher in organic matter to take in and hold more moisture than the soils on nearby conventional farms. These are highly significant, natural advantages of organic systems that conventional agriculture will inevitably have to find ways to emulate in the future.

Nitrogen is a much more costly input on organic farms, whether home-grown via planting legume cover crops or applied via compost or animal manure, which is why organic farmers have no desire or economic motivation to drive yields up as high as possible. The excessive use of nitrogen on conventional farms has made it possible to squeeze a few more bushels out of each acre, but it has also contributed heavily to the loss of nitrous oxide and global warming, water pollution and the growth of dead zones, the degradation of soil organic matter, and increased farm costs of production.

The evidence is compelling that well-managed rain-fed organic farms can and routinely do achieve significantly higher levels of nitrogen uptake into corn plants, as a function of the total nitrogen available to plants, compared to nearby, intensive corn production fields. This performance measure is called "Nitrogen Use Efficiency" (NUE) and is one where advanced organic systems and practices have much to offer conventional farmers.

The authors of the *Nature* piece, in their media comments, note that more research on factors limiting yields on organic farms is needed and will lead to advances that raise organic yields. While true, many organic farmers are already harvesting yields close to what their soils and farming systems can sustain without raising their costs, diluting the nutritional quality and taste of their harvests, and contributing to local environmental degradation. The best path to more food production on both organic and conventional farms may involve producing multiple, but somewhat lower-yielding crops on each acre, a strategy that can increase productivity and reduce environmental impacts in a number of ways.

Last, this paper raises the need for hybrid farming systems combining the best of both worlds. While an appealing notion and fitting in this era of horse-trading in the political arena, both care and discipline is needed in the pursuit of hybrid farming systems. It generally does not work well to take individual practices from a well-managed organic system and place them in otherwise unchanged conventional system, and vice versa.

Organic farming systems work because of synergies across multiple design features and adherence to a set of principles grounded in basic biological and ecological realities and interactions. Organic farming systems are living, dynamic organisms that cannot be replicated without going through a series of stages and transformations. Organic farmers must learn to crawl before they walk, and walk with purpose before they run. Regaining healthy soils and farming systems is an

iterative process, where each step forward depends on masterful adherence to a series of previous steps.

Successful, intensive conventional farms rest upon specialization, large-scale equipment and ability to accomplish simplified tasks quickly, and access to off-farm inputs to meet a crop's needs. Skilled farmers learn to manage input-output relationships through purchase of inputs and become experts in material-handling and application. On such farms, it is more important to understand and have access to a fertilizer, pesticide, or animal drug that will make a problem go away, than managing the system to prevent the problem from arising.

Undoubtedly new, hybrid systems will evolve over the next several decades. The odds are, however, that they will come to function and look more like today's well-managed and established organic farms, than today's top-notch, intensive conventional farms. The rising price of energy, limits on the volume of water available to agriculture, and society's demands for steady progress toward more nutritious and safer food will inexorably push conventional agriculture toward more biologically intensive methods, likely diminishing what is today some very significant differences between these two approaches to farming.

A simple focus on crop yields as this process unfolds will assure we collectively miss the forest for the trees, and wind up with agricultural systems that serve no one's needs well.