The Ins and Outs of Organic Farming

In their Report "Soil fertility and bio-diversity in organic farming," P. Mäder *et al.* (31 May, p. 1694) downplay two factors in their discussion of the relative merits of organic and conventional farming. First, because organic farming yields (per unit of land) were 20% lower than those from conventional farming, 25% more land would be required to produce the same amount of crop biomass, offsetting some of organic farming's advantage with respect to biological diversity, inputs, and soil erosion. Allowing for an increase in cultivated land and adopting the authors' results (p. 1695), organic farming would reduce overall nutrient use by 18 to 39% (not 34 to 51%), energy use by 20 to 41% (not 20 to 56%, as indicated in the text), and pesticide use by 96%. So in terms of the environment, the issue is whether reducing nutrient, energy, and pesticide inputs and impacts on biodiversity on a smaller piece of land outweighs the impacts of increasing cropland under cultivation (*1*, *2*). The answer to this question might be different if one examines what occurs "typically." If typical cereal yields under organic farming are 60 to 70% of those of conventional farming (p. 1695), then between 43 and 67% more land would be needed to keep production constant, further diminishing the environmental and biodiversity advantages of organic farming. Similarly, organic farming might require 0 to 43% more grasslands.

Second, although Europeans—being well fed and currently running unsustainably large food surpluses—might welcome reduced crop production, it could prove disastrous for those in developing countries. A 20% reduction in production from 1997–99 levels, for instance, would reduce global crop production per capita to levels not seen since at least the early 1960s (*3*). Despite improvements during the 1960s, an estimated 37% of the inhabitants of developing countries (or 956 million people) still suffered from chronic hunger and malnourishment in 1969–71 (*4*). By 1997–99, thanks in large part to conventional agriculture, these numbers had dropped to 17% (or 777 million). Therefore, a 20% drop in production would have more than doubled their numbers to at least 1700 million in 1997–99. Clearly, there are environmental and humanitarian trade-offs that should be considered before judging the overall merits of different agricultural systems.

Curiously, the authors did not discuss the difference in yields between experimental and "typical" conditions, which, according to them was 10% compared to 30 to 40% (p. 1695, paragraphs 3 and 4), particularly because the latter is more relevant to the real world. Reducing this gap, I suspect, would be welcomed by all farmers, conventional or organic, so long as they get the same or better returns on their effort and other investments.

Image not available for online use.

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How does an organic field (left) measure up to a conventional one (right)?

CREDITS: (LEFT) GERAY SWEENEY/CORBIS (RIGHT) CHRISTINE OSBORNE/CORBIS

Indur M. Goklany*

Office of Policy Analysis, U.S. Department of the Interior, Washington, DC 20240, USA. E-mail: igoklany@ios.doi.gov

*Views expressed here are the author's and not necessarily those of any unit of the federal government.

References
1. I. M. Goklany, *Technology* **6**, 107 (1999).
2. ———, *Bioscience* **48**, 941 (1998).
3. Food and Agricultural Organization (FAO), *FAOSTAT-Database* (FAO, Rome, 2002) (available at http://apps.fao.org).
4. FAO, press release 01/69 (2001), accompanying *The State of Food Insecurity in the World 2001* (available at www.fao.org/WAICENT/OIS/PRESS_NE/PRESSENG/2001/pren0169.htm).

Response

Goklany states that 20% lower crop yields in organic farming would require 25% more land use to produce the same amount of crop biomass, offsetting some of the advantages of organic agriculture with respect to biological diversity, inputs, and soil erosion, and that the experimental yields are not typical. Furthermore, he indicates that organic farming might not be sufficient to feed the world.

Our nutrient and energy calculations in the comparison trial (known as DOK) were related to the land area. Organic systems are more efficient, both on a land unit and a crop unit base. Conventional systems clearly show highest productivity. Soil fertility and biodiversity in the organic systems of our study were significantly enhanced compared with the conventional systems, which were managed according to integrated plant production standards. In the long term, fertile soils are essential for a sustainable production. In the past three decades, agricultural yields have doubled, but worldwide, one-third of arable land has been lost to erosion (*1*), accompanied by a tremendous increase in fertilization (*2*); a dramatic decline in biodiversity of crops, weeds, birds, and insects; and immense external costs of intensive conventional agriculture (*3*). Organic farming may need more land to produce the same yield, but it maintains fertility and biodiversity of the cropped land. Conventional farming has degraded soils irreversibly in large areas of the world, and, consequently, the remaining land will be farmed as well, rather than used for ecological compensation.

Differences in crop yield of organic and conventional systems are hardly ever valid for all circumstances, because they depend on input levels and local production conditions. A satisfactory reference for productivity in system comparisons is the mean regional crop yield. Both the organic and the conventional wheat yields were similar to those of the respective farms in the region, and therefore representative (organic farms:

4.2 metric tons/ha; conventional farms: 4.8 metric tons/ha) (*4–6*). Crop yields of organic and conventional farming systems in high-intensity production regions of Europe show higher differences (*7*) than those in the United States, where yields of both systems can even be similar (*8*, *9*).

The results from our comparison trial are suitable mainly for mixed farms in central Europe. Sustainable local production is needed in developing countries to nourish the growing population. The question is whether organic or conventional farming meets this goal best. Organic farming may be applicable in developing countries because it relies mainly on local resources and combines traditional knowledge with modern agronomic techniques.

PAUL MÄDER,[1] ANDREAS FLIEßBACH,[1] DAVID DUBOIS,[2] LUCIE GUNST,[2] PADRUOT FRIED,[2] URS NIGGLI[1]

[1]Research Institute of Organic Agriculture, Ackerstrasse, CH-5070 Frick, Switzerland. [2]Swiss Federal Research Station for Agroecology and Agriculture, Reckenholzstrasse 191, CH-8046 Zürich, Switzerland.

References
1. D. C. Pimentel *et al.*, *Science* **267**, 1117 (1995).
2. D. Tilman, *Proc. Natl. Acad. Sci. U.S.A.* **96**, 5995 (1999).
3. J. Pretty *et al.*, *Agric. Syst.* **65**, 113 (2000).
4. H. P. Ryser, personal communication.
5. Agro Treuhand SO/BL, Postfach 140, CH-4533 Riedholz (Switzerland); report, data available at the Landwirtshaftliches Zentrum Ebenrain, CH-4450 Sissach/BL, P. Simon.
6. P. Mäder, A. Berner, C. Bosshard, H. R. Oberholzer, P. Fitze, paper presented at the 13th International IFOAM Scientific Conference, Basel, Switzerland, 28 to 31 August 2000.
7. F. Offermann, H. Nieberg, *Economic Performance of Organic Farms in Europe* (University of Hohenheim, Hago Druck & Medien, Karlsbad-Ittersbach, Germany, 2000), vol. 5.
8. See http://apps.fao.org/page/collections?subset=agriculture.
9. L. E. Drinkwater, P. Wagoner, M. Sarrantonio, *Nature* **396**, 262 (1998).

Organic Farming and Energy Efficiency

IN THEIR REPORT "SOIL FERTILITY AND BIOdiversity in organic farming" (31 May, p. 1694), P. Mäder *et al.* demonstrate that most organically grown crops in their study were more energy efficient per unit crop than conventionally grown crops. This is contrary to other research (*1*, *2*). In their study, organically grown winter wheat yields were only 10% below those of conventional crops of the region. How does this compare with Vaclav Smil's finding that worldwide output of grain would fall by at least half if grown without synthetic fertilizer (*3*)? Mäder *et al.* conclude that organic fertilizers generated on the farm itself are a realistic alternative to conventional farming systems. What about nutrients imported from outside fields in the form of feed for the farm animals? Alternative farming certainly deserves more attention from researchers and rural-policy makers in order to develop the healthy production systems needed for future generations. This challenge, however, may not gain much by the presentation of controversial results.

DIRK ZOEBL

Stationsstr 78, 3511 EH Utrecht, Netherlands.

References
1. S. Bonny, *Agric. Systems* **43**, 51 (1993).
2. H. E. Uhlin, *Agric. Ecosyst. Environ.* **73**, 63 (1999).
3. "Thought for food," *New Scientist* (18 May 2002), p. 34.

Response

WE AGREE WITH ZOEBL THAT ALTERNATIVE farming systems deserve more attention in order to develop healthy production systems. In fact, the environmental advantages of organic farming in comparison with intensive conventional production methods have been shown in many cases (*1*). In our study, we showed a better protection of soil fertility in organic systems compared with conventional systems.

Efficient use of fossil energy is another important topic. Organic farming has proven to be more efficient in most cases (*1*). Both articles (*2*, *3*) cited by Zoebl in support of the claim that organic farming would have a lower energy efficiency are inappropriate, because they only cover the efficiency of French and Swedish conventional agriculture between the 1960s and the 1990s and make no claims about organic farming systems. However, organic farming also makes use of modern techniques and biotechnology, improving its efficiency.

The relatively low wheat yield reduction in organic farming in our experiment is in accordance with other results from the region (*4*–*6*). Yield differences may by greater in intensive farming in Europe (*7*), or yield may be similar in extensive production areas in the United States (*8*). The supposed worldwide 50% reduction of grain output if synthetic fertilizers were not used is not substantiated by any data in the cited article (*9*). Zoebl suggests that we did not take animal feed into account, whereas in fact it was taken into account, because fertilization intensity in the organic systems (life stock units per hectare) was based on the amount of feed stuff produced in the experimental rotation, mimicking a closed system on farm level.

PAUL MÄDER,[1] ANDREAS FLIEßBACH,[1] DAVID DUBOIS,[2] LUCIE GUNST,[2] PADRUOT FRIED,[2] URS NIGGLI[1]

[1]Research Institute of Organic Agriculture, Ackerstrasse, CH-5070 Frick, Switzerland. [2]Swiss Federal Research Station for Agroecology and Agriculture, Reckenholzstrasse 191, CH-8046 Zürich, Switzerland.

References
1. M. Stolze, A. Piorr, A. Häring, S. Dabbert, *The Environmental Impact of Organic Farming in Europe* (University of Hohenheim, Hago Druck & Medien, Karlsbad-Ittersbach, Germany, 2000), vol. 6.
2. S. Bonny, *Agric. Systems* **43**, 51 (1993).
3. H. E. Uhlin, *Agric. Ecosyst. Environ.* **73**, 63 (1999).
4. H. P. Ryser, personal communication.
5. Agro Treuhand SO/BL, Postfach 140, CH-4533 Riedholz (Switzerland); report, data available at the Landwirtschaftliches Zentrum Ebenrain, CH-4450 Sissach/BL, P. Simon.
6. P. Mäder, A. Berner, C. Bosshard, H. R. Oberholzer, P. Fitze, paper presented at the 13th International IFOAM Scientific Conference, Basel, Switzerland, 28 to 31 August 2000.
7. F. Offermann, H. Nieberg, *Economic Performance of Organic Farms in Europe* (University of Hohenheim, Hago Druck & Medien, Karlsbad-Ittersbach, Germany, 2000), vol. 5.
8. L. E. Drinkwater, P. Wagoner, M. Sarrantonio, *Nature* **396**, 262 (1998).
9. "Thought for food," *New Scientist* (18 May 2002), p. 34.

Would Title IX Help Women in Science?

AS A YOUNG WOMAN IN SCIENCE, I WAS PARticularly disturbed by Jeffrey Mervis's article "Can equality in sports be repeated in the lab?" (News Focus, 11 Oct., p. 356). The discussion concerns a proposal that universities should be forced to employ more women on their science faculty or else face a federal budget cut. The purpose of such a measure would be to increase female representation in science, as Title IX has done for female participation in sports. A fundamental difference between sports and science is presumably overlooked in this comparison. Unlike in athletics, smart, educated women can compete equally with their male counterparts. No amount of federal regulation will make the average sportswomen perform at the level of her male counterpart, but it can and does increase female participation and enjoyment in sports. Science, on the other hand, requires a high intellect, interest, opportunity, and a solid education. Lack of the latter two have restrained females of past generations, but the gender gap in education and opportunity is closing. Affirmative action may serve to broaden the pool of female scientists, but it will also weaken it—lower requirements naturally mean lower quality. As a result, the old preconception of male intellectual superiority will be reinforced, the status of women in science be reduced, and we will be back to the system that we are apparently fighting. I speak for many satisfied and successful (and therefore quieter) female scientists when I say, "Don't marginalize us!"

AGATHA M. DE BOER

Department of Oceanography, Florida State University, Tallahassee, FL 32310-4320, USA. E-mail: agathamdb@yahoo.com

JEFFREY MERVIS'S "CAN EQUALITY IN SPORTS be repeated in the lab?" (News Focus, 11

Oct., p. 356) highlights the inequitable situation of women in the natural sciences. However, unlike in sports, women in science do not need separate teams to be established to enable them to succeed. They will achieve parity once they are provided with a "level playing field" upon which they can compete directly with men. My observation is that the scientific contributions of female scientists tend to be undervalued and their opinions discounted by men. This unconscious bias among many male scientists allows the men to believe that there is no discrimination against women and that they are merely acting to "maintain academic standards." The bar is set higher for women scientists, and it continues to be raised throughout their careers. Independent objective assessment of the achievements of men and women scientists and their contributions within their institutions could help to alleviate this bias.

MARGARET L. SMITHER-KOPPERL
Smither-Kopperl Consulting, 19024 SW 191 Avenue, Williston, FL 32696, USA. E-mail: MSKConsultant@aol.com

Atacamite in Jaws and Printed Wiring Boards

IN THEIR REPORT "HIGH ABRASION RESIStance with sparse mineralization: copper biomineral in worm jaws" (11 Oct., p. 389), H. C. Lichtenegger *et al.* identify atacamite in the jaws of *Glycera dibranchiata*, list four polymorphs, and mention its formation in very arid climates and in seawater. Atacamite also forms under very specific electrochemical conditions as conductive anodic filament (CAF) in printed wiring boards (*1*). These filaments occur between conductors held at a potential difference and result from an electrochemical migration process that initiates at the anode and proceeds along separated glass fiber/epoxy interfaces. Dendritic growth differs from CAF formation. In dendritic growth, the metal ions go into solution at the anode but plate out at the cathode, forming needles or tree-like formations. In contrast, CAF forms initially at the anode and the filament extends with time to the cathode, producing an electrical short circuit. One wonders whether the conditions of this inorganic route to atacamite shed light on the biological processes used in forming atacamite as a biomineral.

In printed wiring boards, temperatures of 75°C, 85°C, or 95°C combined with 85% relative humidity, 150 or 200 V potential difference between copper conductors (0.5- or 0.75-mm spacing), and different solder flux formulations produce CAF in printed wiring boards. A necessary condition appears to be the existence of a narrow crack along the fiber-matrix interface. The conditions for stability of reaction products are given by the Pourbaix diagram for the Cu-Cl-H_2O system (*2*).

Careful control of local ionic environment and use of organic templates or substrates have long been known as biomineralization strategies (*3*), and one wonders whether *G. dibranchiata* produces local mineral nucleation and growth conditions analogous (or at least related) to those in CAF formation.

STUART R. STOCK[1] AND LAURA J. TURBINI[2]

[1]Institute for Bioengineering and Nanoscience in Advanced Medicine, Northwestern University, Chicago, IL 60911–3008, USA. [2]Centre for Microelectronics Assembly and Packaging, University of Toronto, Toronto, ON M5S 3E4, Canada.

References

1. W. J. Ready, L. J. Turbini, *J. Electronic Mater.*, in press.
2. M. Pourbaix, *Lectures on Electrochemical Corrosion* (Plenum, New York, 1973), pp. 299–302.
3. H. A. Lowenstam, S. Weiner, *On Biomineralization* (Oxford Univ. Press, Oxford, 1989).

A National Ecological Observatory Network

IN HIS EDITORIAL "A TIGER TALE" (30 AUG., P. 1445), Donald Kennedy tells the cautionary story of the role of economic globalization in the spread of the Asian tiger mosquito, unknowingly imported in tires brought to the United States in the early 1980s on a Japanese freighter. Kennedy mentions the alien mosquito's possible relationship to the spread of West Nile virus. He says that our capacity to understand and deal with vector-borne infectious diseases such as West Nile has been limited because we have "shortchanged the science base needed by our public health infrastructure." These limitations extend far beyond holes in our public health infrastructure. They are equally driven by our failure to adequately invest in the required national scientific infrastructure to monitor, assess, and predict ecological change.

As Kennedy's "tiger tale" so vividly points out, increasing globalization and human activities can lead to unexpected consequences. These unforeseen changes can have dramatic and disruptive impacts on vegetation, climate, water supplies, and animal migration and can lead to the unexpected spread of invasive plant and animal species and infectious disease.

To realistically meet the challenges posed by globalization, we need to greatly expand our capacity to understand the relationship between humans and Earth's ecosystems. Improved understanding of the relationship will be the basis for enhanced predictions of potentially disruptive environmental changes.

The research required to develop this improved understanding must occur over a wide range of temporal and spatial scales and include all levels of biological organization from molecules to ecosystems. It will also require close coordination and excellent communication among diverse groups of researchers such as ecologists, economists, engineers, public health scientists, and policy experts.

In an effort to begin such necessary coordination, the Bush administration earlier this year proposed funding in its FY 2003 budget to begin to build a "National Ecological Observatory Network" (NEON) to be managed by the National Science Foundation. The network of ecological observatories envisioned by NEON will support ecological monitoring and research at unprecedented scales.

By providing the scientific community for the first time with the capability to formally collate long-term ecological records and data in a comprehensive and uniform manner, NEON would begin to meet the scientific infrastructure needs described above. It would also permit scientists from diverse disciplines to effectively coordinate their research efforts across scientific disciplines to achieve improved understanding of human interactions with Earth. Such a nationally coordinated and widespread data collection network would significantly enhance our ability to predict natural events such as droughts and wild- fires and mitigate the adverse impacts of unintentional disasters such as oil spills that change ecological systems and lead to economic and cultural dislocations. It could also someday even help us to predict and slow the spread of environmentally linked diseases such as West Nile virus, Lyme disease, and the Hanta virus.

For the benefit of the American people, it is critically important that Congress support the funding that the president has proposed for NEON.

JAMES A. TEERI[1] AND PETER H. RAVEN[2]

[1]Department of Ecology and Evolutionary Biology, University of Michigan, 2019 Natural Science Building, Ann Arbor, MI 48109, USA. E-mail: jateeri@umich.edu. [2]Missouri Botanical Garden, St. Louis, MO 63166, USA.

Letters to the Editor

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