Financial competitiveness of organic agriculture on a global scale

David W. Crowder* and John P. Reganoldb

*Department of Entomology, Washington State University, Pullman, WA 99164; and bDepartment of Crop and Soil Sciences, Washington State University, Pullman, WA 99164

Edited by M. S. Swaminathan, Centre for Research on Sustainable Agricultural and Rural Development, Madras, India, and approved May 1, 2015 (received for review December 10, 2014)

To promote global food and ecosystem security, several innovative farming systems have been identified that better balance multiple sustainability goals. The most rapidly growing and contentious of these systems is organic agriculture. Whether organic agriculture can continue to expand will likely be determined by whether it is economically competitive with conventional agriculture. Here, we examined the financial performance of organic and conventional agriculture by conducting a meta-analysis of a global dataset spanning 55 crops grown on five continents. When organic premiums were not applied, benefit/cost ratios (−8 to −7%) and net present values (−27 to −23%) of organic agriculture were significantly lower than conventional agriculture. However, when actual premiums were applied, organic agriculture was significantly more profitable (22–35%) and had higher benefit/cost ratios (20–24%) than conventional agriculture. Although premiums were 29–32%, breakeven premiums necessary for organic profits to match conventional profits were only 5–7%, even with organic yields being 10–18% lower. Total costs were not significantly different, but labor costs were significantly higher (7–13%) with organic farming practices. Studies in our meta-analysis accounted for neither environmental costs (negative externalities) nor ecosystem services from good farming practices, which likely favor organic agriculture. With only 1% of the global agricultural land in organic production, our findings suggest that organic agriculture can continue to expand even if premiums decline. Furthermore, with their multiple sustainability benefits, organic farming systems can contribute a larger share in feeding the world.

Although agriculture provides growing supplies of food and other products, it is a major contributor to greenhouse gases, biodiversity loss, agrochemical pollution, and soil degradation (1–3). Concerns about the sustainability of conventional agriculture in particular have promoted interest in alternative farming systems that are more environmentally benign. These alternative systems are not widespread and include organic, integrated, conservation agriculture, mixed crop/livestock, and perennial grains (2, 4, 5). Organic agriculture is the most popular alternative farming system in the world, with global sales of organic foods and beverages growing 170% to $63 billion from 2002 to 2011 (6). The majority of these sales (90%) are concentrated in North America and Europe, with Asia, Latin America, and Africa being primarily export producers (6). Although certified organic farming is practiced in 162 countries, organic agriculture currently occupies only 1% of global cropland (6). Growth of organic agriculture is often limited by inexperience with production methods, inadequate marketing and technical infrastructure, low consumer spending power, and government policies (7, 8).

Organic agriculture is contentious, with critics arguing that it is inefficient (9, 10), relying on more land to produce the same amount of food as conventional agriculture. In turn, adopting organic agriculture on too large a scale could potentially threaten the world’s forests, wetlands, and grasslands (9, 11). Additionally, skeptics contend that organic agriculture has too many shortcomings and poor solutions to agricultural problems (9, 12) and will become less relevant in the future (10). However, recent international agricultural reports recognize organic agriculture as an innovative farming system that balances multiple sustainability goals and will be of increasing importance in global food and ecosystem security (1, 4, 5). According to a National Academy of Sciences report (5), such multiple sustainable goals for any farming system should include producing adequate amounts of high-quality food, enhancing the natural resource base and environment, contributing to the well-being of farmers and their communities, and making farming financially viable.

Reviews and meta-analyses have shown that although organic agriculture produces lower yields compared with conventional agriculture (13–15), it delivers equal or more nutritious foods (16–18) with less to no pesticide residues (17–19). Such aggregate studies generally support the perception that organic farming systems are more environmentally friendly than conventional farming systems. For example, environmental benefits include greater energy efficiency (20–22); enhanced soil carbon and quality (20–24); greater floral, faunal, and landscape diversity (21–23, 25–27); and less pesticide and nutrient pollution of ground and surface waters (20, 23, 25, 26). Although few studies have been conducted comparing the sociocultural aspects of organic and conventional agriculture, organic farming has been shown to have some sociocultural strengths, such as more humane animal production conditions (28), positive shifts in community economic development and social interactions (29, 30), and greater employment of farm workers and cooperation among farmers (31, 32).

Significance

Some recognize organic agriculture as being important for future global food security, whereas others project it to become irrelevant. Although organic agriculture is rapidly growing, it currently occupies only 1% of global cropland. Whether organic agriculture can continue to expand will likely be determined by whether it is economically competitive with conventional agriculture. Accordingly, we analyzed the financial performance of organic and conventional agriculture from 40 y of studies covering 55 crops grown on five continents. We found that, in spite of lower yields, organic agriculture was significantly more profitable than conventional agriculture and has room to expand globally. Moreover, with its environmental benefits, organic agriculture can contribute a larger share in sustainably feeding the world.

Author contributions: D.W.C. and J.P.R. designed research; D.W.C. and J.P.R. performed research; D.W.C. analyzed data; and D.W.C. and J.P.R. wrote the paper.

The authors declare no conflict of interest.

This article is a PNAS Direct Submission.

1To whom correspondence should be addressed. Email: dcrowder@wsu.edu.

This article contains supporting information online at www.pnas.org/lookup/suppl/doi:10.1073/pnas.1423674112/-/DCSupplemental.
To be sustainable, organic agriculture must also be profitable (8). Moreover, whether organic agriculture can continue to expand globally will primarily be determined by its financial performance compared to conventional agriculture (7, 13). The main factors that determine the profitability of organic agriculture include crop yields, labor costs, price premiums for organic products, potential for reduced income during the organic transition period, and potential cost savings from the reduced use of nonrenewable resources and purchased inputs (33). Although individual studies have compared the financial performance of organic and conventional farms and addressed these factors, no studies have synthesized this information on a global scale. Here, we address this knowledge gap by comparing the financial performance of organic and conventional agriculture with a dataset spanning 55 crops grown on five continents. Using meta-analysis, we identified broad economic sustainability patterns not apparent in primary field research by examining total costs, variable costs, labor costs, fixed costs, gross returns, benefit/cost ratios, net present values, organic price premiums, and yields for organic and conventional agriculture.

Results and Discussion

Financial Performance of Organic and Conventional Agriculture. We conducted a literature survey and identified 129 studies that examined the financial performance of organic compared with conventional agriculture (Datasets S1–S5). Of these studies, 44 studies met our criteria for inclusion in a meta-analysis, representing 55 crops grown in 14 countries on five continents (Fig. S1). Data from these studies were used to compare financial parameters of organic and conventional agriculture using two classifications: (i) individual crops (n = 91) and (ii) cropping systems (which considered multiple crops in a rotation, n = 84) (Datasets S1–S5). Previous meta-analyses comparing yields of organic and conventional agriculture only considered individual crops, but not cropping systems (13–15, 34, 35). However, a farmer’s financial security is often based on profits from multiple crops grown over several seasons, which is reflected in our analysis of cropping systems. Therefore, we determined whether costs, gross returns, benefit/cost ratios, and net present values differed significantly between organic and conventional crops and systems.

Total costs, variable costs, and fixed costs did not differ significantly between organic and conventional crops or systems (Fig. 1A and Tables S1–S3). Labor costs, which are part of variable costs, were significantly higher for organic crops (13%) and systems (7%) (Fig. 1A and Tables S1–S3). However, the higher labor costs on organic farms were offset by the reduced use of nonrenewable resources and purchased inputs, such as synthetic fertilizers and pesticides. Organic farms often have higher labor costs because they devote more resources to mechanical pest control, have a greater diversity of enterprises, or need to develop new marketing and processing activities (36). Although one of the successes of conventional agriculture has been its ability to create more with less labor, some have found the extra labor of organic agriculture to be beneficial by helping to redistribute resources and promote rural stability in regions where the labor force is underemployed (37).

When organic premiums were not applied, gross returns, benefit/cost ratios, and net present values were significantly lower for organic crops (−10%, −7%, and −23%, respectively) and systems (−18%, −8%, and −27%, respectively) compared with their conventional counterparts (Fig. 1A and B and Tables S1–S6). Importantly, because gross returns without premiums mirror yields, our observed 10% and 18% lower yields for organic crops and systems, respectively, are similar to results from all five meta-analyses comparing organic and conventional yields (13–15, 34, 35). When actual organic premiums were applied, gross returns, benefit/cost ratios, and net present values were significantly higher for organic crops (21%, 24%, and 35%, respectively) and systems (9%, 20%, and 22%, respectively) (Fig. 1A and B and Tables S1–S6). These results show that the combination of ample organic yields, similar costs, and organic premiums allowed net present values and benefit/cost ratios to be reliably greater for organic crops and systems. Additionally, total costs, gross returns, benefit/cost ratios, and net present values for organic compared with conventional crops and systems were consistent across the 40-y study period (Fig. S2).

Organic Premiums. From the studies in our meta-analysis, we also determined price premiums that were awarded to organic crops and systems. These values were compared with breakeven premiums needed for net present values from organic agriculture to match net present values from conventional agriculture. If organic agriculture is more profitable than conventional agriculture, then actual premiums awarded are higher than breakeven premiums; if organic agriculture is less profitable, then actual premiums awarded are lower than breakeven premiums.

We found that median premiums were 32% for organically grown crops and 29% for organic systems (averaged across all crops in the system). In contrast, median breakeven premiums needed for organic crops and systems to match the net present values of their conventional counterparts were significantly lower at 5% and 7%, respectively (Fig. 1C and Table S7). Organic premiums awarded, and the difference between organic premiums and breakeven premiums, were consistent during the 40-y study period (Fig. S2). The fact that organic premiums are significantly higher than those premiums needed to break even with

Fig. 1. Financial performance of organic compared with conventional crops and systems. Shown are the median log response-ratios (RR; ±SE) for costs, gross returns, and benefit/cost (B/C) ratios (A), median Hedges d values (±SE) for net present values (B), and organic premiums awarded and breakeven premiums needed for organic net present values to match conventional net present values (C). In A and B, asterisks indicate significant differences from 0. Positive values indicate financial parameters were higher in organic agriculture compared with conventional agriculture.
conventional agriculture provides substantial financial incentives for organic growers to go through 3 y of transition expenses, acquire certification, and establish buyers and markets (36).

**Factors Affecting the Financial Performance of Organic and Conventional Agriculture.** We used mixed-effects models to examine the influence of 14 categorical variables on costs, gross returns, net present values, benefit/cost ratios, and differences in premiums for organic relative to conventional crops and systems. These 14 variables included crop type, continent, study duration, rotation length, annuals or perennials, legumes or nonlegumes, study type (experiment station, on-farm, or survey), time since conversion, organic status (transitioning or posttransition), crop diversity, nitrogen input, developed or developing country, latitude, and scale (whole-farm or plot) (Tables S8–S12).

We found that several variables (crop type, rotation length, crop diversity, annual/perennial, and legume/nonlegume) significantly affected net present values or benefit/cost ratios in organic-to-conventional crops but not systems (Fig. 2 and Tables S10 and S11). Cereals, fiber, and oil crops had the greatest organic-to-conventional net present values and benefit/cost ratios, whereas forage, vegetables, and other (meat and dairy) produced the lowest (Fig. 2). Organic-to-conventional financial performance was also higher when organic crops were grown in longer or more diverse rotations, in annual compared with perennial systems, and in leguminous compared with nonleguminous crops (Fig. 2).

Few other categorical variables significantly influenced costs, net present values, benefit/cost ratios, or differences in premiums between organic and conventional crops or systems (Tables S8 and S10–S12). Of particular note, our data indicate that organic-to-conventional gross returns without premiums, which reflect yields, did not significantly improve for crops and systems after the 3-y transition period (Fig. 3 A and B and Table S9). Additionally, organic-to-conventional gross returns without premiums were consistent across the 40-y study period for crops and systems (Fig. 3 C and D). The 3-y transition period from conventional to organic crop production is often reported as the most difficult time financially for organic farmers because their yields drop and they receive no official price premium for their crops (33, 36). Our data suggest that the lack of price premiums appears to be the major factor limiting the profitability of organic farming during the transition period.

**Externalities and Ecosystem Services.** If we also put a price on the negative externalities caused by farming, such as soil erosion or nitrate leaching into groundwater, then organic agriculture would become even more profitable because its environmental

---

*Fig. 2.* Sensitivity of net present values and benefit/cost ratios in organic (Org) compared with conventional (Conv) crops. Variables that affected net present values or benefit/cost ratios were crop type (A and B), crop diversity (C and D), length of rotation (E and F), annual or perennial crop (G and H), and leguminous or nonleguminous crop (I and J). Values shown are the median log response-ratios (±SE) comparing organic with conventional crops. In each panel, different letters indicate significant differences between values of the explanatory variables.
footprint has been shown to be less than the environmental footprint of conventional agriculture (20–27). Calculating the monetary value of ecosystem services, such as biological pest control or crop pollination, would further illustrate the financial sustainability of agricultural systems (38, 39). Although few studies have accounted for ecosystem services in comparisons of organic and conventional agriculture, conventional practices appear to decrease the ability of farms to provide some ecosystem services relative to organic practices (38, 40). For example, in a study comparing 14 organic arable fields with 15 conventional ones in New Zealand (41), the total economic value of three ecosystem services (biological pest control, soil formation, and the mineralization of plant nutrients) in the organic fields was significantly greater at US $232 ha⁻¹·y⁻¹ compared with the conventional fields at US $146 ha⁻¹·y⁻¹. Factoring in such differences in economic comparison studies would likely make up for price premiums awarded to organic products. As is, organic premiums may serve as a proxy for the monetary value of ecosystem services for those consumers who believe that organic agriculture is more environmentally friendly than conventional agriculture.

Conclusions
Despite lower yields and not accounting for externalities or ecosystem services, organic agriculture was significantly more profitable than conventional agriculture. With break-even premiums being significantly lower than actual premiums received, our findings suggest that organic agriculture can continue to expand even if premiums decline. However, making farming financially viable is vital, but is only one of four goals that must be met for agriculture to be sustainable. Equally important is enhancing the environment, producing ample crop yields of high quality, and contributing to the well-being of farmers and their communities. Conventional farming has provided increasing supplies of food and other products, but often at the expense of other sustainability goals. Although organic agriculture produces lower yields than conventional agriculture, it better unites human health, environment, and socioeconomic objectives than conventional systems. In a time of increasing population growth, climate change, environmental degradation, and rising energy costs, such agricultural systems with a more balanced portfolio of sustainability benefits are needed. With only 1% of the global agricultural land in organic production and with its multiple sustainability benefits, organic agriculture can contribute a larger share in feeding the world.

Scaling up organic and other farming systems that balance all four sustainability goals with appropriate public policies can create an enabling environment for such sustainable modes of production. The challenge facing policymakers is to develop government policies that support conventional farmers converting to organic and other more sustainable systems, especially during the transition period, often the first 3 y. In addition, such policies can be established that incorporate the value of external costs and ecosystem services of different farming approaches, such as organic agriculture, into the traditional marketplace, thereby supporting food producers for using sustainable practices. Foods would be valued based on health benefits, food security, and ecosystem services, minus any environmental and social costs, provided by the farms that produced them. Such a food system would be both farming system and technology neutral and would allow the public to choose products that push agriculture in a more sustainable direction.

Methods
Literature Survey. We searched the literature to identify studies comparing the financial performance of organic and conventional agriculture. Our search was performed in January 2013 and repeated in June 2014 using the Institute for Scientific Information Web of Knowledge Database and the search terms “conven* and organ*” and “econ* or finance*.” Our literature search yielded 3,901 studies that were reviewed. We supplemented this search by reviewing the references in three meta-analyses of conventional and organic yields (13, 14, 35). For any study containing financial data, we also reviewed the references cited to locate other sources. In total, we identified 129 studies that compared some aspects of the financial performance of organic or conventional agriculture. These studies were examined for inclusion in our meta-analysis based on six criteria: (i) studies reported gross returns and production costs for organic and conventional treatments, or these data could be calculated; (ii) studies had at least three replicates of the organic and conventional treatments; (iii) organic treatments were certified organic or following organic certification standards; (iv) conventional treatments used recommended rates of synthetic pesticides and fertilizers; (v) studies reported primary data not already included in another paper; and (vi) the spatial and

Fig. 3. Gross returns without premiums (which mirror yields) in organic compared with conventional agriculture. Log response-ratio effects (median ± SE) comparing gross returns without premiums in organic compared with conventional crops (A) and systems (B). Data are presented separately for (i) studies that only included the transition period, (ii) studies that only included the posttransition period, and (iii) studies that only included both periods. Gross returns without premiums in organic compared with conventional crops (C) and systems (D) plotted against the year studies were initiated.
temporal scales of the organic and conventional treatments were comparable. Forty-four studies met these criteria, representing 55 crops; 14 countries; and the five regions of Asia, Europe, North America, Oceania, and South America (Fig. S1 and Datasets S1–S5). None of the 44 studies had government subsidies for organic or conventional agriculture.

Calculation of Effect Sizes. From these 44 studies, we ran meta-analyses comparing financial parameters of organic and conventional agriculture using two classifications: (i) individual crops (n = 91) and (ii) cropping systems (which considered multiple crops in a rotation, n = 84) (Datasets S1–S5). For each data point, we calculated effect sizes comparing organic agriculture with conventional agriculture for the following: (i) total costs: total cost of production; (ii) variable costs: costs that vary according to the quantity of crops produced, such as labor and materials; (iii) fixed costs: costs that do not change regardless of the quantity of crops produced; (iv) labor costs: wages and benefits paid to workers; (v) and (vi) gross returns without and with premiums: the value of crops produced, calculated as price \times yield; (vii) and (viii) benefit/cost ratios; net present values without and with organic premiums, which were calculated for each study by determining net returns (gross returns – total costs) and applying a 6% discount rate according to the following formula:

\[ NPV = \frac{NR}{(1 + i)^t}, \]

where \( NPV \) is net present value, \( NR \) is net returns, \( t \) is the number of years since a study was initiated when the net returns were received, and \( i \) is the discount rate.

Values for premiums received and the year(s) premiums were awarded were taken directly from each study. Some studies did not include premiums for all years if the organic fields/plots were in the transition period; in such cases, premiums were only awarded after the transition period. Moreover, some studies did not include premiums; for these studies, premiums were listed at 0%. Thus, our calculations of premiums were conservative. Both benefit/cost ratios and net present values were calculated because they are important measures of the monetary gain of a venture relative to the costs of executing that venture, producing crops and cropping systems in this case. Net present values, gross returns, and benefit/cost ratios were positively correlated for crops and systems (Fig. S3), suggesting that each metric similarly reflected the financial performance of organic compared with conventional agriculture.

Our primary meta-analysis metric was the log response-ratio, which was calculated with and without weighting (42). Weights were the inverse of the study variance plus a common random-effects variance component (42). We calculated with and without weighting (42). Weights were the inverse of the study variance plus a common random-effects variance component (42). Weights were the inverse of the study variance plus a common random-effects variance component (42).

Unweighted effect sizes were used because weighted analyses place emphasis on highly replicated but artificial experiments at the expense of workers; (iii) of the quantity of crops produced; (iv) and (v) gross returns without and with premiums: the value of crops produced, calculated as price \times yield; (vii) and (viii) benefit/cost ratios; net present values without and with organic premiums, which were calculated for each study by determining net returns (gross returns – total costs) and applying a 6% discount rate according to the following formula:

\[ NPV = \frac{NR}{(1 + i)^t}, \]

where \( NPV \) is net present value, \( NR \) is net returns, \( t \) is the number of years since a study was initiated when the net returns were received, and \( i \) is the discount rate.

Values for premiums received and the year(s) premiums were awarded were taken directly from each study. Some studies did not include premiums for all years if the organic fields/plots were in the transition period; in such cases, premiums were only awarded after the transition period. Moreover, some studies did not include premiums; for these studies, premiums were listed at 0%. Thus, our calculations of premiums were conservative. Both benefit/cost ratios and net present values were calculated because they are important measures of the monetary gain of a venture relative to the costs of executing that venture, producing crops and cropping systems in this case. Net present values, gross returns, and benefit/cost ratios were positively correlated for crops and systems (Fig. S3), suggesting that each metric similarly reflected the financial performance of organic compared with conventional agriculture.

Our primary meta-analysis metric was the log response-ratio, which was calculated with and without weighting (42). Weights were the inverse of the study variance plus a common random-effects variance component (42). We calculated with and without weighting (42). Weights were the inverse of the study variance plus a common random-effects variance component (42). Weights were the inverse of the study variance plus a common random-effects variance component (42).

Unweighted effect sizes were used because weighted analyses place emphasis on highly replicated but artificial experiments at the expense of workers; (iii) of the quantity of crops produced; (iv) and (v) gross returns without and with premiums: the value of crops produced, calculated as price \times yield; (vii) and (viii) benefit/cost ratios; net present values without and with organic premiums, which were calculated for each study by determining net returns (gross returns – total costs) and applying a 6% discount rate according to the following formula:

\[ NPV = \frac{NR}{(1 + i)^t}, \]

where \( NPV \) is net present value, \( NR \) is net returns, \( t \) is the number of years since a study was initiated when the net returns were received, and \( i \) is the discount rate.

Values for premiums received and the year(s) premiums were awarded were taken directly from each study. Some studies did not include premiums for all years if the organic fields/plots were in the transition period; in such cases, premiums were only awarded after the transition period. Moreover, some studies did not include premiums; for these studies, premiums were listed at 0%. Thus, our calculations of premiums were conservative. Both benefit/cost ratios and net present values were calculated because they are important measures of the monetary gain of a venture relative to the costs of executing that venture, producing crops and cropping systems in this case. Net present values, gross returns, and benefit/cost ratios were positively correlated for crops and systems (Fig. S3), suggesting that each metric similarly reflected the financial performance of organic compared with conventional agriculture.

Our primary meta-analysis metric was the log response-ratio, which was calculated with and without weighting (42). Weights were the inverse of the study variance plus a common random-effects variance component (42). We calculated with and without weighting (42). Weights were the inverse of the study variance plus a common random-effects variance component (42). Weights were the inverse of the study variance plus a common random-effects variance component (42).
7. Halberg N, Sulser TB, Højh-Jensen H, Rosegrant MW, Knudsen MT (2007) Global Development of Organic Agriculture: Challenges and Prospects, eds Halberg N, Alireza H, Knudsen MT, Kristensen ES (CABI, Wallingford, UK), pp 277–322.
8. Reganold JP, et al. (2011) Agriculture. Transforming U.S. agriculture. Science 332(6030): 670–671.
9. Treswaws A (2001) Urban myths of organic farming. Nature 410(6827):409–410.
10. Pickett JA (2013) Food security: Intensification of agriculture is essential, for which current tools must be defended and new sustainable technologies invented. Food and Energy Security 2(3):167–173.
11. Avery A (2006) The Truth About Organic Foods (Henderson Communications LLC, Chesterfield, MO).
12. Kirchmann H, Thorvaldsson G (2000) Challenging targets for future agriculture. Eur J Agron 12(3-4):145–161.
13. De Ponti T, Rijk B, van Ittersum MK (2012) The crop yield gap between organic and conventional agriculture. Agric Syst 108:1–9.
14. Seufert V, Ramankutty N, Foley JA (2012) Comparing the yields of organic and conventional agriculture. Nature 485(7397):229–232.
15. Ponsio LC, et al. (2015) Diversification practices reduce organic to conventional yield gap. Proc Biol Sci 282(1799):20141396.
16. Brandt K, Leifert C, Sanderson R, Seal CJ (2011) Agroecosystem management and nutritional quality of plant foods: The case of organic fruits and vegetables. CRC Crit Rev Plant Sci 30(1-2):177–197.
17. Smith-Spangler C, et al. (2012) Are organic foods safer or healthier than conventional alternatives? A systematic review. Ann Intern Med 157(5):348–366.
18. Baranski M, et al. (2014) Higher antioxidant and lower cadmium concentrations and lower incidence of pesticide residues in organically grown crops: A systematic literature review and meta-analyses. Br J Nutr 112(5):794–811.
19. Lu C, et al. (2006) Organic diets significantly lower children’s dietary exposure to organophosphorus pesticides. Environ Health Perspect 114(2):260–263.
20. Alföldi T, et al. (2002) Organic Agriculture, Environment, and Food Security, eds Scalabba NE-H, Hattam C (FAO, Rome), Available at www.fao.org/docrep/005/y4137e/y4137e00.htm, accessed April 4, 2015.
21. Kaspercyk N, Knickel K (2006) Organic Agriculture: A Global Perspective, eds Kristiansen P, Taji A, Reganold J (Comstock, Ithaca, NY), pp 259–294.
22. Tuomisto HL, Hodge ID, Riordan P, Macdonald DW (2012) Does organic farming reduce environmental impacts? — A meta-analysis of European research. J Environ Manage 112:309–320.
23. Mondelaers K, Aertsen J, Van Huylenbroeck G (2009) A meta-analysis of the differences in environmental impacts between organic and conventional farming. Br Food J 111(10):1098–1119.
24. Gattinger A, et al. (2012) Enhanced top soil carbon stocks under organic farming. Proc Natl Acad Sci USA 109(44):18226–18231.
25. Lotter DW (2003) Organic agriculture. Journal of Sustainable Agriculture 21(4): 59–128.
26. Goepfert T, Pimentel D, Paolletti MG (2011) Environmental impact of different agricultural management practices: Conventional vs. organic agriculture. Crit Rev Plant Sci 30(1-2):95–124.
27. Crowder DW, Northfield TD, Strand MR, Snyder WE (2010) Organic agriculture promotes evenness and natural pest control. Nature 466(7302):109–112.
28. Wachter JM, Reganold JP (2014) Encyclopedia of Agriculture and Food Systems, ed Van Alfen NK (Elsevier, San Diego), Vol 4, pp 265–286.
29. MacRae RJ, Frick B, Martin RC (2007) Economic and social impacts of organic production systems. Can J Plant Sci 87:1037–1044.
30. Gruebe G, Nagarajan L, King EDIO (2009) The role of collective action in the marketing of underutilized plant species: Lessons from a case study on minor millets in South India. Food Policy 34(1):39–45.
31. Piriñanti TM, Hardjastuti S, Hartono S, Iriham (2014) Social-cultural functions of rice farming systems. Asian Journal of Agriculture and Rural Development 4(3):341–351.
32. Mendoza TC (2004) Evaluating the benefits of organic farming in rice agroecosystems in the Philippines. Journal of Sustainable Agriculture 24(2):93–115.
33. Zentner RP, et al. (2011) Effects of input management and crop diversity on economic returns and riskiness of cropping systems in the semi-arid Canadian Prairie. Renewable Agriculture and Food Systems 26(3):208–223.
34. Stanhill G (1990) The comparative productivity of organic agriculture. Agric Ecosyst Environ 30(1-2):1–26.
35. Badgley C, et al. (2007) Organic agriculture and the global food supply. Renewable Agriculture and Food Systems 22(2):86–108.
36. Padel S, Lampkin NH (1994) The Economics of Organic Farming: An International Perspective, ed Lampkin NH (CABI, Wallingford, UK), pp 201–219.
37. International Fund for Agricultural Development (2005) Organic Agriculture and Poverty Reduction in Asia: China and India Focus (IFAD, Rome).
38. Wratten S, Sandhu H, Cullen R, Costanza R (2013) Ecosystem Services in Agricultural and Urban Landscapes (Wiley-Blackwell, Oxford).
39. Dasgupta P, Ramanathan V (2014) Environment and development. Pursuit of the common good. Science 345(6203):1457–1458.
40. Porter J, Costanza R, Sandhu H, Sigggaard L, Wratten S (2009) The value of producing food, energy, and ecosystem services within an agro-ecosystem. Ambio 38(4):186–193.
41. Sandhu HS, Wratten SD, Cullen R (2010) The role of supporting ecosystem services in conventional and organic arable farmland. Ecological Complexity 7(3):302–310.
42. Hedges LV, Gurevitch J, Curtis PS (1999) The meta-analysis of response ratios in experimental ecology. Ecology 80(4):1150–1156.
43. Hedges LV, Olkin I (1985) Statistical Methods for Meta-Analysis (Academic, Orlando, FL).
44. Hillebrand H, et al. (2007) Consumer versus resource control of producer diversity depends on ecosystem type and producer community structure. Proc Natl Acad Sci USA 104(24):10904–10909.
45. SAS Institute (2014) JMP 11.0 (SAS Institute, Inc., Cary, NC).