Renewable Agriculture and Food Systems: 25(1); 3–7 doi:10.1017/S1742170509990251

Conventional research on controversial issues: an exercise in futility?

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Accepted 17 November 2009; First published online 22 December 2009 **Commentary**

Abstract

Results from research on controversial topics are often interpreted according to the world view of the reader. With conflicting results from different researchers or institutions, it is likely that vested financial interests or adherence to conventional wisdom will lead to rejection of science-based conclusions. An example from the past is the comparison of multiple cropping with monocrop systems, where clear advantages of complex systems are discounted by those committed to the monoculture paradigm. A current example is comparison of organic with conventional farming systems and food products, where food price, suspicion about certification and philosophy about perceived 'non-scientific' results cloud the technical conclusions. An emerging example is comparisons of local versus global food systems, where multiple issues including comparative advantage and food preferences obscure the key questions of energy investment, food equity and local well-being. A proposed solution to this dilemma is to instead focus scarce research funds on improving the development of alternative agroecosystems, rather than invest human energy into futile comparisons that are unlikely to convince the skeptics. In this way, more creative alternatives can be explored and greater progress made toward food equity and sufficiency.

Key words: multiple cropping, organic farming, organic food, local food systems, globalization, research priorities

Introduction

Scientists are often frustrated when their hard-earned results are not accepted by the public. An example is the continuing public controversy and lingering debate about global warming. When scientific results are contrary to the vested business interests of powerful companies, it may take decades for society to take decisive action. Such historical frustrations abound. The astronomer Galileo discounted the popular geocentric view of the universe and was indicted for this discovery. Columbus was certain to be sailing off the edge of a flat Earth according to the wine shop discussions of the day. Contemporary challenges to Darwin's work on evolution come from those who find conflict with their biblical interpretations. These scientists and innovators surely felt their efforts were futile in the face of dominant opinions in society.

Thomas Kuhn[1] described the strong adherence to current paradigms in his landmark book, *The Structure of Scientific Revolutions*. A small sector of the society finds it difficult to change public opinion—despite the evidence. Examples of resistance to change abound in agriculture, as illustrated by the relatively slow adoption of hybrid maize or the lag time between introduction of no-till planting in the Great Plains and wide farmer acceptance of the practice. *Silent Spring*, Rachel Carson's[2] critical expose of the negative impacts of pesticides, created wide controversy about chemical use. In spite of convincing scientific evidence, change away from current practice is slow to happen—due to inertia, aversion to risk, or financial and intellectual investment in the present paradigm.

Three examples in agriculture and food systems can illustrate the difficulties of major change, and perhaps demonstrate our need to pursue a different strategy in research on controversial topics. A *topic from the past* is tropical research on intercropping, where improved versions of traditional systems were often compared to monocultures, and results rarely changed anyone's mind about the potential of multiple cropping for future food production. A *topic in the present* is the comparison of organic and conventional cropping systems, where results are interpreted based on people's underlying values and philosophies rather than on the experimental results derived using the scientific method. An emerging *topic for future research* concerns the rapidly globalizing food system and local food options, where it is likely results will not convince critics of either system that alternatives have an important role to play in tomorrow's food environment.

There has been exhaustive research on the first two questions and enthusiasm with emerging research around the third. Results showing that multiple cropping has an important role for the future, or that organic cropping systems can be productive and more profitable than conventional systems, are not convincing to those who have invested heavily in the dominant monoculture and industrial agriculture paradigms. Opinions may be based on strong conventional wisdom, or on a large financial involvement potential threatened by alternatives.

What has science contributed to resolve the controversies listed above? What evidence suggests we pursue different research priorities for the long term? Finally, how do we use science to effect meaningful change in the face of controversial challenges? After discussion of the evolving foundations of science, three case studies of research on controversial issues are presented, along with conclusions and recommendations for future research priorities. A research strategy is proposed that investigators (1) carefully consider the context in which results will be applied, (2) be explicit about specific assumptions on future availability of resources and (3) emphasize the newly emerging systems, without spending inordinate time and resources on comparisons. It is proposed that this is a valuable strategy for improving food and farming systems.

Evolving Foundations in Science

Most scientists in agriculture were educated, or more likely trained, in the contemporary model of discipline-bound science: agronomy, soils, entomology, animal science and agricultural economics. There have been limited opportunities to consider holistic strategies that depart from reductionist orthodoxy to explain the world through science. For those few fortunate to have taken a course in history of science or for other reasons to have challenged the dominant mechanistic paradigm of 'hard science', it is a small step to embrace a wider vision of how the scientific method can be applied to current questions that involve environmental and social dimensions in addition to production and economics. Agroecology, defined as *the ecology of food systems*[3], covers this broad approach.

In *The Web of Life—a New Scientific Understanding of Living Systems*, physicist Fritzof Capra[4] documents the historical 'tension between mechanism and holism ... as an inevitable consequence of the ancient dichotomy between substance (matter, structure, quantity) and form (pattern, order, quality)'. He further describes how Aristotle 'distinguished between matter and form but at the same time linked the two through a process of development'. In chapter 2, From the Parts to the Whole, Capra[4] details the radical changes that challenged Aristotle's concept of wholeness. The mechanistic and reductionist foundation of the Scientific Revolution grew from the brilliant work of Galileo Galilei, René Descartes, Isaac Newton and others in an array of technical fields. From cell theory to embryology and microbiology, then to understanding heredity, the belief prevailed that systems would be explained by aggregating their components. Although the effects of environment were recognized and quantified, the search to explain mechanisms was relatively devoid of context. Assumptions were that the future would resemble the past in most ways, especially in dogma of science. Early proponents of alternative thinking included Sir Albert Howard and Lady Evelyn Balfour in the UK, among others. It was only with the emergence of ecology and systems thinking, and such creative advances as the Gaia hypothesis[5], that serious challenges to mechanistic thinking began.

In dealing with broad and complex issues, research results are rarely conclusive and often inadequate to convince anyone who has invested in the opposing paradigm. Three case studies are presented that represent controversial issues in the food system and the argument is made for intensive research on the emerging alternatives. There is no question about the need for research on controversial issues, but in the context of global food needs and growing negative impacts of agriculture it is important to seek near-term and creative answers.

Multiple Cropping Systems versus Monoculture

Agriculture began with mixtures of species, as early farmers emulated the natural biodiversity, and then gradually selected individual plants and plant species that most suited their food needs. Early small grain mixtures in northern Europe gave way to cereal monocultures that were predecessors to our current systems in the US Midwest. Maize/bean/squash systems in Central America were replaced by monocultures on favored lands well suited for mechanized technology. Yet complex systems persisted where farmers had limited land resources and limited access to fertilizers and pesticides. Some researchers in the 1970s began to explore the potentials of multiple cropping systems[6].

Most multiple cropping researchers were trained in reductionist science and began to look at components of systems. Research at the *Centro Internacional de Agricultura Tropical* (CIAT) in Colombia focused on maize and bean genotypes for intercropping, relative densities and planting dates, and physical orientation of different maize and bean combinations[7,8]. Important to these breeding programs was the study of genotype by system interactions, since unique adaptation of intercropping would signal the need for separate breeding or at least testing programs in complex systems[9].

Prevalent thinking during these evaluations emphasized comparisons of intercrop and monocrop system performance. The multiple crop system often 'overyielded' monocultures, measured by the Land Equivalent Ratio (LER)[10] or Area-Time Equivalent Ratio (ATER)[11]—which compare total crop yield of mixtures with the yields of monocultures of the component species. Net incomes from the two systems showed greater returns to intercrops, and this could be considered a more integrative and valuable measure of performance to the farmer[12].

In a quest for technical credibility, peer acceptance and convincing evidence that multiple cropping systems indeed were at least equal to conventional monocultures, scientists included single crop 'check plots' for comparisons. This allowed calculation of the land efficiency indicators described above. Discoveries of LER values greater than 1.0 only confirmed the conventional wisdom of those doing the research that multiple cropping systems had great potential for the future. These same results did little to persuade people committed to the monoculture paradigm to seriously consider alternatives, because they focused on such complications as harvesting crops growing together, or because the alternative system did not stir their vision of future agriculture. Another shortcoming of early multiple cropping research on component technologies was the narrow focus on production and economics, with little or no attention to environmental or social implications of the systems. From today's perspective, we conclude that much of this research on a controversial topic did little to change the direction of mainstream research, nor to influence regulations or farm supports to encourage more production in complex systems. Some practical recommendations for farmers emerged, but much of the replicated field work for publishing results could be called 'agronomic trivial pursuit'.

Organic versus Conventional Farming and Foods

Over the past two decades greater attention has been focused on alternative farming systems. Demand for organic food has grown for reasons associated with food safety, nutrition, environmental quality and social justice. In 2006, there were over 30 million ha managed organically, and global sales of organic foods were near US$30 billion[13]. A number of scientists have compared systems' productivity and food quality of products between the two systems and results have been mixed.

Comparisons of organic and conventional production systems have been conducted by two groups, each considering their approach objective. Some conventional researchers, who would like to prove that organic systems have little to offer, merely cut out chemical weed control and/or fertilizer application, and as expected, the organic systems yields are much lower. There are limited numbers of these experiments today, yet they are used to support the contention that organic farming cannot feed the world or that much more marginal land would be required for production to meet global food demand, increasing the negative impacts of farming on the environment[14]. Perceptive scientists do not take these studies seriously.

Research frequently is conducted on components of systems—weed management methods, sources of nutrients to maintain soil fertility, timing of cultural practices and comparisons of alternative crops. As with conventional industrial agriculture, there is continuous search for a magic bullet, a productive system that will fit in many field niches, one that allows simplicity in management by providing the correct menu for varieties, fertility, weed control and other practices. Most research including organic is directed at improving efficiency of current systems or substituting one input for another, the first two steps in the complexity hierarchy described by MacRae et al.[15]. There is little research that looks at redesign of the whole system.

The first challenge is identifying the most important components that should be changed to create an organic system that will outperform—agronomically or economically—a nearby conventional system. Conventional statistics are valuable to conduct comparisons on one- to three-factor experiments, yet less valuable in comparing whole systems that differ in a larger number of components. Often intent on ferreting out the effects of individual components, even though these are completely confounded in the large systems comparisons, frustration mounts when scientists try to explain why one system is superior to another. Complicating the comparisons are the relatively singular goals of conventional systems—production and economics, while the multiple economic, environmental and social goals of farmers using organic systems require a wider suite of indicators. These complexities add to the difficulty of designing, analyzing and interpreting results of systems comparisons.

Results of conventional and organic systems research are open to wide interpretations, often clouded by the assumptions of the researchers and those who read the results. Interpretations are further confused by conflicting world views of scientists, differences between authors and reviewers, priorities of researchers and administrators and perceived utility by clients. Consequences may be more confusion, less communication and lost opportunity cost of improving an emerging alternative system called organic farming.

Local versus Global Food Systems

The emergence of local food production as an alternative to food produced from a globalized industrial system has generated significant recent debate[16]. Many of us enjoy coffee every morning and would find it hard to abandon the banana with our granola. We participate in a global food system that assures we can buy that banana any day of the year in food markets of any size. Observing the produce section in most US food markets reveals apples from New Zealand, kiwi and grapes from Chile and oranges from Mexico. In markets in the Midwest and the eastern two-thirds of the US we find lettuce, broccoli and other vegetables from the west coast, even during the season when local production is possible. For half a century, foods have moved widely into and across the US, but only recently have we begun to seriously calculate the impacts of this massive transportation complex[16,17].

Economic and climatic factors compel us to specialize fresh fruit and vegetable production at sites where a comparative advantage of favorable climate, adequate labor and available transportation make this system profitable. For example, tomatoes can be grown in glass house facilities in southern British Columbia, but the energy cost is 17 times higher than producing the same tomatoes in the field[17]. The average food travel distance required to put a meal on a dinner plate in Iowa is currently about 2500 km[16]. Although fluctuations in price of fossil fuels will change the food transportation equation on an almost daily basis, there is no doubt that there will be adjustments toward more local foods in the near future.

In typical reductionist research thinking, we focus on one pet indicator ... whether this is food kilometers, comparative climatic production advantage of different locations, large differences in labor costs, specialization versus diversity in local production systems, or local food security. Serious evaluation of global versus local requires attention to all these factors and many more.

New questions emerge from these studies. What is the impact of outsourcing a high percent of food production to other countries in a world with volatile petroleum prices, differing food safety standards and levels of enforcement, and political instability? What about equity and access to food by local people in countries where these prime products are grown for export? To what extent do the financial benefits of food exportation trickle down to the poor who are hungry? The poorest people, who often live in rural areas and are involved in food production, may be those who suffer most. Food is recognized as a basic human right in the International Declaration of Human Rights by the UN, but this has gone virtually unheeded for six decades. With the publication of the Bruntland Report, *Our Common Future*[18] attention was once again drawn to the tragedy of undernutrition in many countries.

How do we objectively compare local with global food systems, and what impact would the results of such research have on people's food decisions and on government food policies? It would be highly relevant to look at the whole food system from capture and use of natural resources through the farm production process to processing, marketing and consumption, as well as to the disposal or recycling of non-consumed waste. Life-cycle accounting has become commonplace in evaluation of production efficiency in a number of industries. Such evaluation often includes materials and economic indices, and should incorporate environmental impacts of alternative systems at each step of the process. Often neglected in such analyses are the social impacts and long-term implications of different systems, including the distribution of benefits. Although this becomes nearly impossible to calculate for individual food items, much less for entire food systems, appreciation of the fact that there are social dimensions that should be taken into account is a great step forward. If these analyses are carefully and thoughtfully done, it will be possible to get some idea of the relative costs and efficiencies of local foods versus those from a global industry.

How is such information used and does it have an impact? Proponents of local foods point to problems in today's global system, such as food kilometers, insecurity of long supply lines, lax environmental regulations and perhaps use of pesticides banned in the US and poor treatment of labor. Those invested in the global system will point to its advantages in efficiency of scale, appropriateness of growing food where the crops or animals are most adapted and labor is least expensive, and benefits of having a highly diverse food supply available every day of the year. Both groups would probably use some of the same research data to support their conclusions. Neither would acquire the convincing evidence to impact national policies, nor would they likely influence all but the most concerned consumers. Most food decisions appear to be made in the US based on price, on appearance, and perhaps on nutritional quality from the label or previous experience. Few people really care where the food came from or how it was produced. Thus, the research turns out to be interesting, perhaps publishable, but another exercise in academic trivial pursuit.

There is little doubt that tomorrow's food systems will combine local and imported food. The debate about what is considered local will continue. Is there a role for research to inform the debate, to educate the consumer and to influence policy? One strategy is to forego the research comparisons of local versus global foods, and concentrate on improving local food alternatives. Promoting diverse systems and appropriate practices that allow farmers to grow more foods for local consumers is part of this strategy. Education on the costs and implications of imported foods, when there are local options of foods in season, is another part of the puzzle. Supporting local farmers adds to the local economy.

How do we bring this information together through credible analysis in the current economic context to decide what type of balance is in the best interest for all people in the food system? It is unlikely that conventional component research approaches, and even larger system-wide analysis of alternative food systems, will provide clear answers. We need holistic methods for addressing these complex issues, yet the impacts of research may still be less than convincing.

Conclusions

From this discussion of three cases in agricultural research—multiple cropping systems versus monoculture, organic versus conventional farming and food, and local versus global food systems—it is clear that research on complex issues is difficult. We have the experiment designs and statistical procedures that work well with single- and two-factor issues in agriculture, but less confidence in how to analyze the results of whole systems—on the farm, in a region, or at the national level. When most changes in cropping systems or food systems are made by adjusting or changing single components, one at a time, the confounded results of systems research make it difficult to pinpoint where to tweak the system. Thus our scientific methods appear to be less than adequate to answer large questions. This is especially notable when factors related to environmental sustainability or social impacts of research are involved.

What can we do to improve the relevance of research on difficult topics? Or should we spend scarce research funds on projects that will not lead to change? Recommendations for research on controversial topics may be summarized as follows:

- Research goals should be clearly defined, with specific hypotheses and methods or focus on a practical question to be explored.
- Scope of inquiry, including spatial context and time frame, need to be carefully thought out and articulated, with no intent to extend results beyond the frame of reference.
- Assumptions about the future are essential, especially with regard to natural resources, human population and vital need for ecosystem services.
- Expectations should not be too high, with regard to the publication or widespread use of results, since these are also likely to be controversial.
- Broad scope of reference should be used when appropriate, to include production, economics, environment and social impacts of research results.

Even more critical in the decision to work on controversial issues is to anticipate whether research will have an impact on the farming or food systems, on local or national policy, or on human well being. When there are production, economic, environmental and social questions all coming to bear on farmer decisions as well as on those made by others in the food web, the results of research can be ambiguous at best. Often the data can be used to support just about any side of complex arguments. In the study of controversial alternatives, one option is to thoughtfully invest available research funds on innovative new directions, build alliances with other groups that will help finance research as well as diffuse results, and trust in economics and an educated public to sort out complexity and make rational decisions. Such a strategy would be preferable to wasting inordinate time and energy doing comparison-type research that will not provide convincing results.

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