The Contested Vision for Agriculture's Future:
Sustainable Intensive Agriculture and Agroecology

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Beginning Definitions

In the 1990 United States Farm Bill,[1] Congress defined sustainable agriculture as:

> an integrated system of plant and animal production practices having a site-specific application that will, over the long term: (A) satisfy human food and fiber needs; (B) enhance environmental quality and the natural resource base upon which the agricultural economy depends; (C) make the most efficient use of non-renewable resources and on-farm resources and integrate, where appropriate, natural biological cycles and controls; (D) sustain the economic viability of farm operations; and (E) enhance the quality of life for farmers and society as a whole."[2]

For purposes of this essay, the 1990 congressional definition of sustainable agriculture is a useful, satisfactory definition. Midwestern agriculture in the United States faces a future in which Congress and American society assuredly will evaluate its agricultural practices and performance by the five criteria set forth in the 1990 definition. Moreover, agriculture world-wide also will assuredly face a future in which global society will evaluate agricultural practices and performance by a very similar, if not identical, set of criteria. Agriculture in the Midwest and around the world must move in a "sustainable" direction along the lines set forth in the 1990 definition even if societal actors, domestically and internationally, modify the definition as time passes and conditions change.

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[1] Food, Agriculture, Conservation and Trade Act of 1990, P.L. 101-624.

[2] Id. at § 1603, codified at 7 U.S.C. § 3103(19) (2012).

Sustainable intensive agriculture adopts the five criteria of the 1990 congressional definition but, through the word "intensive," adds focus on how to achieve sustainable agriculture. More particularly, sustainable intensive agriculture emphasizes that modern science and modern technology are crucial components in achieving sustainable agriculture. Sustainable intensive agriculture builds upon the agricultural developments of the past century and modifies those developments to better account for advances in scientific knowledge and technological advances affecting agriculture. By so doing, sustainable intensive agriculture aims to increase agricultural productivity, reduce negative agricultural impacts on the environment, improve agricultural prosperity, and enhance societal benefits through abundant, affordable, safe, and nutritious foods, fibers, fuels, and other agricultural products.[3]

In contrast to sustainable intensive agriculture, others promote a vision for agriculture rooted in the term "agroecology." As defined by one proponent,

> Agroecology is both a science and a set of practices. It was created by the convergence of two scientific disciplines: agronomy and ecology. As a science, agroecology is the 'application of ecological science to the study, design, and management of sustainable agroecosystems,' (Fn to M. A. Altieri). As a set of agricultural practices, agroecology seeks ways to enhance agricultural systems by mimicking natural processes, thus creating beneficial biological interactions and synergies among the components of the agroecosystem."[4]

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[3] The author has previously written about sustainable intensive agriculture. D. Kershen, *Sustainable Intensive Agriculture: High Technology and Environmental Benefits*, 16 KAN. J. LAW & PUBLIC POLICY 424 (2007). This present essay again attempts to foster the adoption of sustainable intensive agriculture as the better vision for agriculture in the future.

[4] Report submitted by the Special Rapporteur on the right to food, Olivier De Schutter ¶ 12, U.N. GENERAL ASSEMBLY HUMAN RIGHTS COUNCIL (16th Sess., 20 Dec 2010).

When this author speaks of proponents of agroecology in this essay, the author is referring to those proponents cited in footnotes 4, 6 & 7. The author is aware that there are disagreements within the movement for agroecology and that not ever faction is as strongly opposed to modern science and modern technology as the proponents of agroecology cited in

In the goals for agriculture, sustainable intensive agriculture and agroecology have much in common. But in the methods, practices, and performance to achieve sustainable agriculture, these two visions for the future of agriculture are quite disparate.[5]

While sustainable intensive agriculture can adopt and be complementary to most of the practices of agroecology, the proponents of agroecology are explicit that agroecology rejects sustainable intensive agriculture with its emphasis on modern science (e.g., biology and chemistry) and modern technologies (e.g., transgenic crops and manufactured inputs).[6] Similarly, other proponents of agroecology derisively describe sustainable intensive agriculture as a modern, post-World War II techno-science culture that adopts a centralized top-down path for poverty and hunger alleviation.[7] In contrast, these same proponents support agroecology that frames poverty and hunger as social, behavioral and political, emphasizing a localized bottoms-

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those three footnotes.

[5] For a thorough discussion of the terms "sustainable agriculture," "sustainable intensive agriculture," and "agroecology," T. Garnett & C. Godfray, *Sustainable intensification in agriculture: Navigating a course through competing food system priorities,* FOOD CLIMATE RESEARCH NETWORK (2012). By reading this T. Garnett & C. Godfray document, it becomes clear how contested are terms likes "sustainable agriculture," "sustainable intensive agriculture," and "agroecology." Reading it drives home the point made in the preceding footnote that there are varying viewpoints and disagreements (often sharp) among those who would claim the mantle of each of these terms, including those who claim the term "agroecology."

[6] O. De Schutter & G. Vanloqueren, *The New Green Revolution: How Twenty-First Century Science Can Feed the World*, 2(4) SOLUTIONS 33 (Aug. 2011) (The new green revolution is agroecology as defined in De Schutter's report to the U.N. General Assembly cited in note 4 *supra*).

[7] D. Quist et al., *Hungry for innovation: pathways from GM crops to agroecology* in European Environment Authority, LATE LESSONS FROM EARLY WARNINGS: SCIENCE, PRECAUTION, INNOVATION 490-517 (2013).

up path for poverty and hunger alleviation.[8] As these authors state in their conclusion, "We find limitations to top-down innovation because of largely productivist objectives."[9]

What Is At Stake?

Why does it matter that there are competing visions of agriculture? What does it matter that sustainable intensive agriculture posits a vision that emphasizes modern science and modern technology with agricultural production as the primary goal for agriculture? What does it matter that the proponents agroecology posits a vision that emphasizes social, behavioral and political dimensions with agricultural production as, at best, a secondary goal for agriculture?

It matters because the FAO reports that in 2009 1.02 billion people were chronically hungry.[10] It matters because hundreds of millions more people today are malnourished (deficient in nutrition) even if they are not hungry. It matters because the world's population, presently at 7 billion people, will likely rise to between 9 and 10 billion people by the year 2050. (These additional people, almost all, will be citizens of developing countries, not developed, wealthy countries like Europe and North America.) As Gordon Conway says about this "chronic crisis":

> "the fundamental drivers [are] the increasing demand for food: population increase, rising per capita incomes [changing food habits to more meat, more processed foods, and higher value foods], and the competing demand for biofuel crops; and the deficiencies of supply caused by rising input prices, land and water

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[8] *Id.*

[9] Id. at p. 507. What Quist and co-authors name as "top-down innovation" is what this author calls sustainable intensive agriculture.

[10] The information in this sentence and the following several sentences comes from G. Conway, ONE BILLION HUNGRY: CAN WE FEED THE WORLD? (esp. Part I) (Cornell Univ. Press, 2012).

scarcity and deterioration, slowing productivity gains and climate change."[11]

The question thus facing the United States, Global Society, Midwestern farmers, and farmers world wide is: which vision for agriculture provides the better path forward to meet the challenges of demands for food and supply of food? This essay argues that sustainable intensive agriculture, including its complementarity with agroecology, provides the better path forward.[12]

Sustainable Intensive Agriculture

Looking back at the five criteria for sustainable agriculture as set forth in the 1990 Farm Bill,[13] does sustainable intensive agriculture fulfill these five criteria?

Satisfy human food and fiber needs

Agricultural production can rise through two methods. Farmers can expand the amount of land farmed (extensification) and by farming more land produce a greater amount of agricultural harvests. Farmers can use technological inputs (e.g., fertilizers, improved seeds, herbicides/pesticides) to increase the amount of agricultural harvests per acre (intensification).

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[11] *Id.* at p. 8.

[12] The author reiterates that sustainable intensive agriculture can adopt and is compatible with most of the practices of agroecology. Sustainable intensive agriculture can and will learn from and can and will adopt best management practices developed in agroecology. It is agroecology, as defined by many of its proponents, that explicitly excludes modern science, modern technology and a production orientation for agriculture. Indeed American conventional farmers already use agroecological practices, though more likely to call them conservation practices. *See e.g.*, D. Keller, *Conservation and Stewardship Showcase*, THE PROGRESSIVE FARMER 14 (February 2013); U. Lehner, *Good Stewardship = Good Profits*, THE PROGRESSIVE FARMER PF-42 (Winter Issue, 2012). Indeed, the author hopes that the discussion favoring sustainable intensive agriculture will show that it embodies the goals of agroecology by meeting the criteria of sustainable agriculture, as quoted in the first paragraph of this essay, from the 1990 U.S. farm bill.

[13] *See* notes 1-2 *supra*.

While simplified history, it is accurate to say farmers increased the amount of agricultural harvests primarily by extensification until well into the 20th century. Beginning in the early 20th century and especially since World War II, farmers have adopted technology at a very rapid rate. Since World War II, farmers have increased the amount of agricultural harvests primarily by intensification. Using the concept of total factor productivity, agricultural outputs have quadrupled since 1910 while inputs have remained relatively steady. But the inputs since 1910 have changed drastically from inputs primarily in labor to inputs based on technology (mechanization, seed, chemicals, irrigation). With this great increase in productivity, farmers have well-fed and well-clothed more people than ever before in history. Agricultural intensification based on science and technology has been the primary means by which agricultural supply has significantly increased in the past 60 years.[14]

One particular manifestation of agricultural intensification applicable to the developing world is the agricultural productivity increase called the Green Revolution.[15] With improved seeds through modern plant breeding and a package of inputs (fertilizers and irrigation), farmers in Latin American and parts of Asia greatly increased their yields in wheat and rice. Hundreds of millions did not starve because farmers produced more staple foods sold to food consumers at declining prices. After calling the Green Revolution an undisputed success, Gordon Conway summarized its achievements as " ... global production of cereals has risen from 900 million tons

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[14] The ideas expressed in this paragraph come primarily from D. Southgate, D. Graham, & L. Tweeten, THE WORLD FOOD ECONOMY, Ch. 3: *The Supply Side: Agricultural Production and Its Determinants* (Blackwell Pub., 2007).

[15] The ideas expressed in this paragraph come primarily from G. Conway, note 10 *supra*, ch. 3, *The Green Revolution*.

in 1960 to 2,500 million tons in 2009, faster than the rise in global population over the same period from 3.1 billion to 6.9 billion ... ."[16] Yet, Gordon Conway acknowledges that the Green Revolution had less impact on the poor than was expected, was more localized in its reach (especially in its reach into Africa and African farmers), had environmental problems and resource degradation effects.[17] For these reasons, Conway calls for a "Doubly Green Revolution."[18]

One facet of the "Doubly Green Revolution" will be plants and crops developed through modern breeding techniques, including genetic modification.[19] Crops created through genetic modification have been adopted widely with excellent results for increased production. Genetically modified crops have added production to global output by 275.5 million tons for the four major genetically modified crops from 1996-2010.[20] Moreover, genetically modified crops have benefitted farmers large and small, high tech or low tech, in developed or developing countries with increased production and improved economics.[21] As one research paper stated in summary,

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[16] *Id.* at 61-62.

[17] *Id.* at 61.

[18] *Id.* at 62.

[19] *Id.* at ch. 9, *Designer Crops*.

[20] G. Brookes & P. Barfoot, The global, environmental and economic impact of biotech crops 1996-2010, 3(2) WORLD AGRICULTURE 34 (2012) (Table 6).

[21] A. Mannion & S. Morse, Biotechnology in agriculture: Agronomic and environmental considerations and relfections based on 15 years of GM crops, 36 PROGRESS IN PHYSICAL GEOGRAPHY 747 (2012).

> "No evidence that GM technology benefits more developed than developing countries was found. Indeed, the agronomic and economic performance of GM crops vs conventional crops tends to be better in developing countries than for developed countries."[22]

While the studies cited in the preceding paragraph provide evidence that genetically modified crops have already benefitted farmers and food security, modern plant breeding offers much hope for the future. Modern plant breeding has not exhausted its potential for increasing agricultural production for food security. Not every improvement in plant breeders' laboratories or controlled field trials will be successful in farmers fields, yet modern plant breeding will keep developing crops – some of them being successful. Seven examples of the developments in the pipeline should be sufficient to make the point about hope for the future:

- RNAi technology for controlling insect-transmitted virus in cassava;[23]
- Selective breeding of fast-growing strains of Nile tilapia;[24]
- Wheat modified to resist aphids;[25]
- New Rice strains for Africa by modern cross-breeding of Asian and African varieties;[26]
- Pearl Millet, a grain similar to sorghum and a subsistence grain in Africa and Asia,

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[22] F. Areal et. al, GM crops, developing countries and food security, 3(2) WORLD AGRICULTURE 19 (2012).

[23] John Innes Center Press Release, *Using their genes against them: Fighting insects pests with genetic targeting* (Jan. 7, 2013).

[24] R. Dewedar, *Fast-growing fish variety could benefit Egypt and West Africa*, SciDevNet (Jan. 9. 2013)

[25] A. Driver, *Rothamsted to carry out more GM trials*, FARMERS GUARDIAN (Jan 11, 2013).

[26] N. Perkins, *Let's learn from past efforts to fight hunger*, SciDevNet (Jan 10, 2013).

developed to be resistant to ergot disease;[27] and

• Cassava in Nigeria with multiple resistance to various viruses, bacterial blights, and insects.[28]

• Plant photosynthesis for changing inefficient C3 plants (wheat, rice) into efficient C4 plants (maize, sorghum, sugarcane). This photosynthesis gene research focuses on direct yield improvement in contrast to the six earlier research projects that focus on indirect (effective) yield improvement by reduction of pests and diseases.[29]

Right at this point a crucial difference between sustainable intensive agriculture and the proponents of agroecology becomes evident. Those who favorably view sustainable intensive agriculture support the continued and expanded use of science and technology to reach every farmer in the world.[30] The proponents of agroecology call for a fundamental rethinking of agriculture specifically to reorient agriculture away from the science and technology of modern

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[27] I. Khisa, *Uganda scientists developing disease-resistant pearl millet*, THE EAST AFRICAN (Jan 19, 2013).

[28] A. el-Kurebe, *Bt will address cases of irresistibility of local crops to diseases – NRCRI*, VANGUARD (Nigeria) (Jan 18, 2013.

[29] Cornell University Press Release, *Newly discovered "scarecrow" gene might trigger big boost in food production* (Jan 24, 2013) ("Cornell University researchers have taken a leap toward meeting those needs [food supply and food security] by discovering a gene that could lead to new varieties of staple crops with 50 percent higher yields.")

[30] See e.g., C. Juma, THE NEW HARVEST: AGRICULTURAL INNOVATION IN AFRICA (Oxford Univ. Press, 2011) (esp. ch. 2 *Advances in Science, Technology, and Engineering* and ch. 3, *Agricultural Innovation Systems*); R. Paarlberg, STARVED FOR SCIENCE: R. Paarlberg, STARVED FOR SCIENCE – HOW BIOTECHNOLOGY IS BEING KEPT OUT OF AFRICA (Harvard Univ. Press, 2009); The Royal Society, REAPING THE BENEFITS – SCIENCE AND THE SUSTAINABLE INTENSIFICATION OF GLOBAL AGRICULTURE (Oct. 2009).

plant breeding.[31]

Enhance environmental quality and the natural resource base

By its activities, agriculture is "unnatural." Unlike hunters and gatherers, agriculturalists purposefully disturb the surrounding environment in order to produce food, fodder, fiber, and fuel for human uses. Thus, agriculture entails external impacts on the environment. As people grew wealthier and as people learned more about environmental interconnections, humans have begun to worry, rightly so, about the negative impacts of agriculture. Humans have begun to seek ways to practice agriculture while reducing negative impacts on the environment. As we move into the future with its food demands, agriculture needs to meet those demands while simultaneously reducing its external impacts on the environment. This is the second criterion of sustainable agriculture.

Evidence about sustainable intensive agriculture, especially genetically modified crops, already shows reduced impact on the environment and the natural resource base in three ways particularly worth presenting.

First, sustainable intensive agriculture, by providing farmers with herbicide-tolerant crops (bred through both classical breeding and genetic modification techniques), has allowed farmers to manage competition weeds more easily. Farmers using herbicide-tolerant crops are thus able to choose to move to reduce-tillage or no-till agriculture whereby farmers do not disturb the soil by ploughing.[32] Environmental benefits from reduced tillage systems are numerous: less erosion,

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[31] See the publications cited in notes 4, 6 & 7 *supra*.

[32] *See e.g.*, W. Givens, *Survey of Tillage Trends Following the Adoption of Glyphosate-Resistant Crops*, 23 WEED TECHNOLOGY 150 (2009) (Abstract: "Overall, producers in a crop rotation that included a GR [glyphosate-resistant] crop shifted from a relatively more tillage-

less sediment and its attached chemicals in water, rebuilt soils, reduced carbon footprint (greenhouse gas) by reduced equipment emissions, and improved water retention, water conservation on fields.[33]

Second, sustainable intensive agriculture through insect-resistant crops has reduced pesticide usage in agriculture to the benefit of the environment and to the benefit of human health.[34] Insect-resistant crops are designed so that the pesticidal impact on pests comes from the plant itself rather than through the application of external pesticide sprays. Therefore, it is not a surprise that the reduction in pesticide use in fields planted with insect-resistant crops has been impressive. Moreover, due to the reduced pesticide sprays, the environmental impact of the field has declined while the environmental quality has improved.[35] In addition, particularly in developing countries, the reduction in pesticide use and pesticide spraying has meant reduced

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intense system to reduced-till or no-till systems after implementing a GR crop into their production system.").

[33] *See e.g.*, J. Fernandez-Cornejo et al, *Conservation Tillage, Herbicide Use, and Genetically Engineered Crops in the United States: The Case of Soybeans*, 15(3) AGBIOFORUM 2312 (2012); G. Brookes & P. Barfoot, note 20 *supra*; Conservation Technology Information Center, *Facilitating Conservation Farming Practices and Enhancing Environmental Sustainability with Agricultural Biotechnology* (Purdue Univ., 2009).

[34] The author limits this paragraph to pesticides and insect-resistant crops. While herbicide-tolerant crops also have shown a beneficial environmental impact, measured by environmental impact quotient rather than quantity amount, continuous, heavy use of glyphosate raises the issue of weed evolution so that the weeds become resistant to the applied herbicide. Farmers will need careful herbicide management to handle weed resistance. Compare J. Fernandez-Cornejo, note 33 *supra*, G. Brookes & P. Barfoot, note 20 *supra*, and A. Mannion & S. Morse, note 21 *supra* with C. Benbrook, *Impacts of Genetically Engineered Crops on Pesticide Use: The First Thirteen Years* (The Organic Center, 2009) (Benbrook uses the word "pesticide" in his title but the report focuses almost exclusively on herbicides.)

[35] *See e.g.*, G. Brookes & P. Barfoot, note 20 *supra*.

pesticide exposure for farmers. Farmers health has thus also improved.[36] Finally, regulatory agencies have required that genetically-modified insect resistant crops have in place an insect-management strategy (usually a refuge approach) that reduces the risks for insects developing resistance to the insect-resistant crop.[37]

Third, sustainable intensive agriculture through the adoption of insect-resistant crops has improved the environmental impact of agriculture on beneficial insects. Insect-resistant crops lead to reduced use of broad spectrum insecticides. Insect-resistant crops carry genes that target specific crop pests. With better targeting of pests by the crops and reduced use of broad spectrum insecticides, farmers using sustainable intensive agriculture have increased the insect biodiversity in their fields.[38] Additionally, the beneficial impact from insect-resistant crops affects not only the field planted with the crop but also neighboring fields not planted to a insect-resistant crop. Due to a "halo" or "spill-over" effect, neighboring fields also have increased numbers of beneficial insects. Neighboring fields consequently gain better biological control (through extra beneficial insects) of crop pests that farmers must control to protect their plants

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[36] Pray et al., Five years of Bt cotton in China – the benefits continue, 31(4) THE PLANT JOURNAL 423 (2002) (Summary: " ... over 4 million smallholders have been able to increase yield per hectare, and reduce pesticide costs, time spent spraying dangerous pesticides, and illnesses due to pesticide poisoning.")

[37] For a brief explanation of the refuge approach, *Understanding Evolution: Refuges of genetic variation: controlling crop pest evolution*, http://evolution.berkeley.edu/evolibrary/article/agriculture_04.

[38] Lu et al., *Widespread adoption of Bt cotton and insecticide decrease promotes biocontrol services*, 487 NATURE 362 (July 2012); Chen et al., *A Critical Assessment of the Effects of Bt Transgenic Plants on Parasitoids*, 3 PloS ONE e2284 (May 2008).

and their yields.[39] Sustainable intensive agriculture is a multiple win for biodiversity with insect-resistant crops.

The three examples (reduced-till/no-till, reduced pesticide usage, and beneficial insects) of the environmental benefits of sustainable intensive agriculture serve as a reminder that sustainable intensive agriculture adopts goals of agroecology. These three examples emphasize that sustainable intensive agriculture and agroecology can be complimentary in agricultural development.

Efficient use of resources and integration of natural biological cycles and controls

A previous segment of this essay addressed the question: What Is At Stake? Criterion Three of sustainable agriculture adds another dimension to that question. To meet the food demands between now and 2050, many estimate that agriculture will have to produce between fifty and seventy per cent more food without much expanding the land base, while using fewer resources (e.g., phosphate for fertilizer and carbon-based fuels in manufacturing other agricultural inputs), and with reduced amounts of water either from irrigation or rainfall. Criterion Three is not seeking increased production per unit of land (that is Criterion One); Criterion Three seeks an increased production per input of resources – something akin to a life-cycle assessment[40] of agricultural production. Many in agricultural development phrase this

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[39] *See e.g.*, A. Mannion & S. Morse, note 21 *supra*.

[40] US-EPA defines "LCA (life cycle assessment) ... as a technique to assess the environmental aspects and potential impacts associated with a product, process, or service by: • Compiling an inventory of relevant energy and material inputs and environmental releases; • Evaluating the potential environmental impacts associated with identified inputs and releases; • Interpreting the results to help you make a more informed decision." http://www.epa.gov/nrmrl/std/lca/lca.html.

challenge by saying that agriculture will have to produce more with less or that agriculture will have to produce more with a reduced environmental footprint.[41]

Farmers around the world, but particularly in developed countries, have adopted science and technology for intensification for the past sixty years. Agricultural researchers now are able to use the life-cycle assessment to compare modern agriculture to other forms of agriculture to assess comparatively the environmental impacts. Measured by per unit of product (for example kilogram of milk or billion kilograms of beef), the comparisons are decidedly in favor of a lesser environmental impact for intensive agriculture now than for the less-intensive agricultures of yesterday.[42] The figures for a lesser environmental impact are striking and thus worth quoting:

> "Modern beef production requires considerably fewer resources than the equivalent systems in 1977, with 69.9% of animals, 81.4% of feedstuffs, 87.9% of water, and only 67.0% of the land required to produce 1 billion kg of beef. Waste outputs were similarly reduced, with modern been systems producing 81.9% of the manure, 82.3% CH4, and 88.0% N2O ... The C [carbon] footprint ... was reduced by 16.3% compared with equivalent beef production in 1977."[43]
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> "Modern dairy practices require considerably fewer resources than dairying in 1944 of animals, 23% of feedstuffs, 35% of the water and only 10% of the land required to produce the same one billion kg of milk. Waste outputs were similarly reduced with modern dairy systems producing 24% of the manure, 43% CH4 and 56% N20 ... The carbon footprint ... in 2007 was 37% of the equivalent milk

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[41] For a thoughtful review and discussion of the points presented in this paragraph, G. Conway, note 10 *supra*, especially Part IV (discussing pests, soil, water, climate change, and greenhouse gases) and ch. 17 *Conclusion*.

[42] J. Capper, *The environmental impact of beef production in the United States: 1977 compared with 2007*, 89 J. ANIMAL SCIENCE 4249 (Dec. 2011); J. Capper, R. Cady & D. Bauman, *The environmental impact of dairy production: 1944 compared with 2007*, J. ANIMAL SCIENCE (on-line March 2009) http://jas.fass.org.

[43] J. Capper, note 42 *supra* in the Abstract.

production in 1944."[44]

Studies using similar methodologies to those just quoted that compare impacts between beef production strategies (conventional, natural, and grass-fed in one study[45] and calves weaned to feedlots, calves weaned to pasture for background growth before feedlots, and calves finished on pasture in a second study[46]) determined that the least environment impact was for convention beef production and for feedlot-finished beef.

Right at this point, the proponents of agroecology would point out that the cited studies measured units of output ("the productivist objectives") and would reject these studies in favor of other metrics. Indeed, the authors of the calves study caution,

> "... we do not consider costs and benefits related to variable like job creation or quality of life, nor do we address a spectrum of proximate ecological considerations, including biodiversity impacts, or concerns such as animal welfare. Our results should therefore not be take as stand-alone metrics of the sustainability of feedlot versus pasture-finished beef production in the US Upper Midwest."[47]

Recognizing the agroecological criticism does not diminish the findings of these studies that modern agriculture (intensive) agriculture has significant environmental benefits for meeting food demand and food security for the present and future human populations. Societies can decide to value other metrics but those societies also must face the negative environmental

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[44] J. Capper, R Cady & D. Bauman, note 42 *supra* in the Abstract.

[45] J. Capper, *Is the Grass Always Greener? Comparing the Environmental Impact of Conventional, Natural and Grass-Fed Beef Production Systems*, 2 ANIMALS 127 (2012).

[46]N. Pelletier, R. Pirog & R. Rasmussen, *Comparative life cycle environmental impacts of three beef production strategies in the Upper Midwestern United States*, 103 AGRICULTURAL SYSTEMS 380 (2010).

[47] N. Pelltier, R. Pirog & R. Rasmussen note 46 *supra* at p. 388.

impacts, the reduced food supply, and the increased risk of food insecurity. Nor does recognizing the agroecological criticism diminish these findings showing that modern agriculture satisfies Criterion Three of sustainable agriculture.

If successfully developed and transferred to farmers, modern plant breeding has in the developmental pipeline several traits that would efficiently use resources and imitate natural biological systems. Five examples can serve as evidence of pipeline traits for sustainable intensive agriculture that would fulfill Criterion Three.

• Drought tolerance for plants;[48]

• Nitrogen Use Efficient Plants;[49]

• Phosphorus Efficient Plants;[50]

• Nitrogen-fixing Cereals;[51] and

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[48] Wei et al., *The pyramid of transgenes TsVP and BetA effectively enhances the drought tolerance of maize plants*, 9 PLANT BIOTECHNOLOGY J. 216 (2011); The African Agricultural Technology Foundation, Project 4: Water Efficient Maize for Africa (WEMA).

In the United States, Monsanto Corporation has a USDA-approved drought-tolerance trait in corn that farmers planted in the summer 2012 as part of large-scale on-farm field trials. Associated Press, *Monsanto Biotech Corn Tested for Release in Drought-Stricken South* (March 13, 2012).

[49] C. McAllister & P. Beatty, *Engineering Nitrogen Use Efficient Crop Plants*, ISB NEWS REPORT 4 (Sept. 2012).

[50] D Lopéz-Arredondo & L. Herrera-Estrella, *A Novel Fertilization and Weed Control System Based on Transgenic Plants that Can Metabolize Phosphate*, ISB NEW REPORT 2 (November/December 2012); S. Heuer, *Back to the Roots – A Novel Rice Protein Kinase Enhances Phosphorus Uptake*, ISB NEWS REPORT 6 (November/December 2012).

[51] John Innes Center News, *Major investment to persuade bacteria to help cereals self-fertilise* (July 15, 2012).

• Plant photosynthesis for changing C3 plants into C4 plants.[52]

Each of the developmental projects listed immediately above focus on using natural resources more efficiently and more sustainably. If these developmental plants come into existence, sustainable intensive agriculture will use less water and fertilizers (phosphorus and nitrogen) in producing the food quantity and the food security needed in coming years. Consequently, science and technology offer realistic hope that sustainable intensive agriculture will have new plants available to cope with the stresses and demands of resource limitations and climate changes, thereby fulfilling Criterion Three. The proponents of agroecology with their "productivist objection" reject all five of these research endeavors as technological fixes based on reductionist thinking.[53]

Sustain economic viability of farm operations

Criterion Four presents the question of what it means to sustain the economic viability of farm operations. If Criterion Four means that every farmer remains on the farm as a farmer, then this author suspects that both sustainable intensive agriculture and agroecology will flunk this criterion. After all, the goal of both forms of agriculture should be the alleviation of poverty through agricultural development.[54]

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[52] Cornell University Press Release, *Newly discovered "scarecrow" gene might trigger big boost in food production* (Jan. 24, 2013) ("If C4 photosynthesis is successfully transferred to C3 plants through genetic engineering, farmers could grow wheat and rice in hotter, dryer environments with less fertilizer, while possibly increasing yields by half, the researchers said."

[53] *See e.g.*, S. Neales, *An inconvenient truth*, The Australian (Jan. 18, 2013) (News story about Greenpeace's opposition to the Bill & Melinda Gates Foundation grant to the John Innes Center to study nitrogen-fixing bacteria for cereals. See fn. 51.)

[54] Two books that have influenced this author and whose themes are relevant to Criterion Four are as follows: C. Juma, note 30 *supra* and P. Collier, *The Bottom Billion: Why the Poorest*

Agricultural development entails changes in the agricultural sector. In developing countries, these changes will include social and economic transitions from a population trapped in subsistence agriculture to a population freer to adopt other occupations and lifestyles.[55] Many farmers (especially their children) assuredly will leave the agricultural sector to pursue their lives in non-farm occupations and urban locations.[56] Certainly, sustainable intensive agriculture is explicit that its goal is agricultural development for the purpose of getting rural people out of poverty.[57]

If Criterion Four means agricultural development for the purpose of getting rural people out of poverty, three measures show that sustainable intensive agriculture satisfies economic viability for farm operations.

First, many studies exist discussing the economic impact of genetically modified crops for farmers. In an on-going series of studies by PG Economics,[58] the latest report in the series

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Countries are Failing and What Can Be Done About It (Oxford Univ. Press, 2007). (While agricultural development is important for poverty alleviation, the Collier book drives home the point that agricultural development by itself will not be sufficient. Other factors – civil wars, the resource curse, geographic isolation, and bad governance – will have equal, if not more, important impacts on poverty alleviation.)

[55] See e.g., D. Southgate, D. Graham, & L. Tweeten, note 14 *supra*, especially ch. 7 *Agriculture and Economic Development*.

[56] For example, some farm children freed of daily farm labor will aspire to become professional athletes. If that dream ends, they may decide to become lawyers and law professors – a more easily attainable career goal.

[57] G. Conway, note 10 *supra*, especially ch. 17 in which he states we can feed the world if ... “9. We Acknowledge the Key Role of Agriculture in Development” (p. 335) and “13. There is a Major Focus on Getting Poor Rural People Out of Poverty.” (p. 338)

[58] The entire series can be found on the PG Economics, Ltd website at http://www.pgeconomics.co.uk.

states:

> "In 2010, the direct global farm income benefit from biotech crops was $14 billion. This is equivalent to adding 4.3% to the value of global production of the soybean, maize, canola and cotton crops. Since 1996, GM technology has increased farm incomes by $78.4 billion.
> ...
> In 2010, 54.8% of the farm income benefits were earned by farmers in developing countries. The vast majority of these gains have been from GM IR cotton and GM HT soybeans. Over the fifteen years, 1996-2010, the cumulative farm income gain derived by developing country farmers was $39.24 billion, equal to 50% of the total farm income during this period."[59]

Two other recent studies confirm positive economic benefits from genetically modified crops. A 2011 report from the Ecologic Institute in Berlin concludes,

> "Due to the strong variations between regions and the additional varying factors found I the analysis that influence results on economic performance of GM crops (see above), any generalized conclusions on the economic performance of GM corps for the whole world would inevitably be misleading. However, positive economic benefits have been observed for a number of countries, which is in line with other review studies (e.g., Carpenter, 2010, Gouse et al., 2009, Bennett et al., 2004a, Fernandez-Cornejo et al., 2005, and Qaim, 2009) and explains the high adoption rates of GM crops in those countries."[60]

A 2012 report from the European Commission, Joint Research Centre made these summary points about the global economic impact of genetically modified crops:

> Economic models have been developed to estimate the global economic welfare creation of GM cultivation and the distribution of its benefits among stakeholders. The data presented in the workshop show that HT soybeans generate 3 billion USD per year, distributed between the consumer/processors (50%), the adopting farmers (28%), and the innovating biotechnology section (22%).
> ...
> In recent years a geographic shift of farmers' benefits was observed from the initial situation where benefits were concentrated in the USA, Canada, and

[59] G. Brookes & P. Barfoot, note 20 *supra* at 57-58.

[60] T. Kaphengst et al., *Assessment of the economic performance of GM crops worldwide*, Ecologic Institute (29 Mar 2011) at viii.

> Argentina to a situation where small farmers in a variety of developing countries are obtaining more benefits from the technology."[61]

Second, farmers, particularly subsistence farmers, are very sensitive to the risk of fluctuations in yield. Farmers do not want and have a difficult time surviving economically if the harvest varies greatly from one year to another. Therefore, one facet of the economic viability of farm operations is to control this risk of yield fluctuations – called in recent years resilience.[62] Studies now exist showing the genetically modified crops improve the resilience of farmers both in developed and developing countries.[63] As one study stated,

> "Moreover, another but often overlooked fact is the capacity of GM Crops to reduce variability of production and related income year on year, a characteristic which lends stability to farm incomes and facilitates planning."[64]
> ...
> "In such circumstances GM varieties can provide a degree of insurance for the farmers in that they may help to stabilize outputs in the face of environmental uncertainty given that the farmers have to commit inputs such as land and labour."[65]

Third, farmers know their own fields and know their own economic interests. Farmers are aware of the risks and benefits of the practices that each farmer adopts individually for her/his

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[61] M. Lusser et al., International workshop on socio-economic impacts of genetically modified crops co-organized by JRC-IPTS and FAO, EC-JRC SCIENTIFIC AND POLICY REPORTS (2012) at 9.

[62] G. Conway, note 10 *supra* defines resilience as "the capacity of an agricultural system to withstand or recover from stresses and shocks." Box 5.3 at 98.

[63] G. Regier et al., *Impact of Genetically Modified Maize on Smallholder Risk in South Africa*, 15(3) AGBIOFORUM 328 (2012); M. Edgerton et al., *Transgenic insect resistance traits increase corn yield and yield stability*, 30 NATURE BIOTECHNOLOGY 493 (2012); A. Mannion & S. Morse, note 21 *supra*.

[64] A. Mannion & S. Morse, note 21 *supra* at 751.

[65] *Id.* at 754.

farm. Farmers will not adopt and continue to use a farm practice that does not provide benefits. Looking at farmer adoption rates, around the world, clearly indicate that farmers, when given access to genetically modified seeds, adopt sustainable intensive agriculture in overwhelming numbers. The International Service for the Acquisition of Agri-Biotech Applications (ISAAA) publishes yearly the most comprehensive report on farmer adoption rates of genetically modified crops. In the report for 2011, ISAAA wrote:

> "A 94-fold increase in hectarage from 1.7 million hectares in 1996 to 160 million hectares in 2011 makes biotech crops the fastest adopted crop technology in the history of modern agriculture.
> The most compelling and credible testimony to biotech crops is that during the 16 year period 1996 to 2011, millions of farmers in 29 countries worldwide elected to make more than 100 million independent decisions to plant and replant an accumulated hectarage of more than 1.25 billion hectares – an area 25% larger than the total land mass of the US or China. [T]here is one principle and overwhelming reason that underpins the trust and confidence of risk-averse farmers in biotechnology – biotech crops deliver substantial, and sustainable, socio-economic and environmental benefits."[66]

Proponents of agroecology downplay these ISAAA data, ignoring that farmers are credible managers of their own lands and lives.[67] In India, where the debate between proponents of sustainable intensive agriculture and proponents of agroecology has been intense, two researchers commented on the farmers and their choice for sustainable intensive agriculture as follows:

> "Studies may disagree, but do have a centre of gravity, a central tendency. That centre of gravity is a clear refutation of the "failure of Bt cotton" narrative. But as important as formal studies is this grounded empirics of farmers trying out new ways to cope with a periodically devastating problem. Farmer adoption and

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[66] ISAAA Brief 43-2011: Executive Summary, Global Status of Commercialized Biotech/GM Crops: 2011 (February 2012) at 1.

[67] D. Quist et al., note 7 *supra* at Figures 19.1 and 19.2.

> diffusion ratify most convincingly the technology behind Bt cotton. ...
> ...
> ... There is curiously little attention given to the skill, experience and agency of farmers in assessing the new technology. In this case, their numbers – on yields, pesticide costs and income – accord with the central finding of the bulk of empirical work on Bt cotton. As farmers of necessity must count carefully, their numbers should count."[68]

ISAAA counted 16.7 million farmers who have chosen to plant genetically modified crops. Of these 16.7 million, approximately 15 million were small-scale, poor farmers in developing countries and 1.7 million farmed in developed countries. Regarding developing countries (to use two examples), ISAAA counted 7 million Indian farmers (average 1.5 hectares of land) growing Bt cotton on 10.6 million hectares of the 12.1 million cotton hectares (i.e. 88%). In China, seven million small-scale poor farmers (about 0.5 hectares of land) planted 3.9 million hectares of Bt cotton – equivalent to 71.5% of Chinese cotton.[69]

Enhance the quality of life for farmers and society

As sustainable intensive agriculture satisfies the first four criterion of sustainable agriculture, it could be argued, *ipso facto*, that sustainable intensive agricultural satisfies this fifth criterion. Satisfying human food and fiber needs, enhancing environmental quality, and making efficient use of non-renewable resources points towards enhancing the quality of life for society. Satisfying human food and fiber needs (including those of the farmers themselves), enhancing environmental quality (farmers too desire a safe, clean, and pleasing environment), and sustaining the economic viability of farms points towards enhancing the quality of life for

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[68] R. Herring & N. Rao, *On the 'Failure of Bt Cotton' – Analysing a Decade of Experience*, 47 ECONOMIC & POLITICAL WEEKLY 45, 51-52 (May 5, 2012).

[69] ISAAA note 66 *supra* at 3-4.

farmers.

Yet, this Criterion Five can also be interpreted to mean enhancing the non-material qualities of life. While neither sustainable intensive agriculture nor agroecology can or should be expected to solve the dilemmas and sorrows of human existence, agriculture should be able to provide a rewarding and satisfying life for farmers – in contrast to daily drudgery and unremitting anxiety. Is there any evidence that sustainable intensive agriculture addresses a rewarding and satisfying life?

In a study conducted by the European Commission in the year 2000, four years after genetically modified crops begin to be planted on a commercial scale, the Directorate-General for Agriculture stated the following:

> In practice, the most immediate and tangible ground for satisfaction [with genetically modified crops] appears to be the combined effect of performance (not necessarily measured by yields) and convenience of GM crops, in particular for herbicide tolerant varieties. These crops allow for a greater flexibility in growing practices and, in given cases, for reduced or more flexible labour requirements. ..."[70]

The EC-DG for Agriculture identification of performance and convenience as the primary reasons that farmers adopt genetically modified crops has been confirmed by other studies.[71] The study from the Philippines states the reasons for farmer adoption in terms that are most relevant

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[70] EC Directorate-General for Agriculture, *Economic Impacts of Genetically Modified Crops on the Agri-Food Sector*, ch. 3 at 3.1.1 (Working Doc. Rev. 2, 2000).

[71] C. Torres et al., *Adoption and Uptake Pathways of Biotechnology Crops: The Case of Biotech Corn Farmers in Selected Provinces, of Luzon, Philippines*, (U[niv.]P[hil.] Los Baños, March 2012); R. Finger, M. Hartmann, & M. Feitknecht, *Adoption Patterns of Herbicide-Tolerant Soybean in Argentina*, 12 AGBIOFORUM 494 (2009); J. Carpenter & L. Gianessi, *Herbicide Tolerant Soybeans: Why Growers Are Adopting Roundup Ready Varieties*, 2 AGBIOFORUM 65 (1999).

to Criterion Five beneath a heading "Changes in Farmers' Lives":

> During the FGD (focus group discussions) ... the farmer-respondents were asked to share the changes in their lives brought about by their adoption of biotech corn. As expected the foremost response was increased income. This was probed further by asking the farmers the concomitant changes of having higher income. Their responses, all favorable and reflective of certain improvements in their lives, were as follows:
>
> - Able to pay their loans and debts
> - Able to send their children to college
> - Acquired home appliances (e.g., TV, computers, refrigerators), vehicles, and even house and lot
> - Peace of mind (assurance of harvest as there are no more pests; lesser incidence of theft)
> - Farming activities made simpler/easier
> - Able to engage in other livelihood activities (e.g., driving public transport vehicle, livestock raising)
> - Able to engage in other productive and activities (trainings and seminars).[72]

These Filipino farmer statements about changes in their lives are powerful testimony of their enhanced quality of life, personally and for their families. In societies where many citizens are farmers, enhancing the quality of life of farmers does mean, *ipso facto*, the enhancement of the quality of life in society. Thus, the evidence indicates that farmers adopt sustainable intensive agriculture for reasons of performance and convenience. Probing these reasons shows that farmers adopting sustainable intensive agriculture enhance the lives of themselves and their families and, as a consequence, enhance the quality of life for society.

Agroecology and the Five Criteria of Sustainable Agriculture

To this point in the essay, sustainable intensive agriculture has been measured against the five criterion of sustainable agriculture and found to satisfy those five criteria. Now the essay turns towards agroecology, as described by the proponents of agroecology, and how it measures

[72] C. Torres et al., note 71 *supra* at 44.

against these five criteria.

The author again repeats that sustainable intensive agriculture is compatible with many practices of agroecology. But the question worthy of being addressed is whether agroecology, when the proponents of agroecology reject science and technology for the agricultural sector, can satisfy the five criteria of sustainable agriculture?[73] Of course the proponents of agroecology have confidence that agroecology, with its rejection (and often because of its rejection) of science and technology, can and does satisfy these five criteria.[74] This author disagrees.

<u>Satisfy human food and fiber needs</u>

Although agroecology is not identical to organic farming, the proponents of agroecology consistently invoke organic agriculture as the path forward for agricultural production.[75] In support of the claim that organic agriculture can feed the world, proponents rely heavily on three sources to support the claim – studies by Badgley,[76] Pretty,[77] and the IAASTD.[78] Good reasons

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[73] G. Conway, note 10 *supra* states that we can feed the world if "10. We Recognize the Need for a New Doubly Green Revolution" (p. 336), "12. More Attention Is Paid to Agoecological Research and Development," (p. 337) and if "15. We Accept that Biotechnology is an Essential Tool in Attaining Food Security." (p. 340)

[74] For the proponents' arguments in favor of agroecology, see the cited materials in notes 4, 6 and 7 *supra*.

[75] D. Quist et al., note 7 supra at 19.4.3.

[76] C. Badgley et al., *Organic agriculture and the global food supply*, 22 RENEWABLE AGRICLTURAL FOOD SYSTEMS 86 (2007).

[77] J. Pretty, Resource *Conserving agriculture increases yields in developing countries*, 40 ENVIRONMENTAL SCIENCE AND TECHNOLOGY 1114 (2006).

[78] IAASTD, AGRICULTURE AT A CROSSROADS: THE GLOBAL REPORT OF THE INTERNATIONAL ASSESSMENT OF AGRICULTURAL KNOWLEDGE, SCIENCE, AND TECHNOLOGY (Island Press, 2009). In support of the IAASTD report, I. Scoones, *The*

exist to doubt the credibility of the claim by these three studies.

With respect to the Badgley study, a careful analysis, focused on wheat, indicates that the Badgley study did not cite many comparative studies about organic and conventional wheat production. These uncited studies, including studies conducted by organic organizations, point to wheat yields in organic production being 30% to 50% lower. As wheat is a primary staple food, wheat production at 30 to 50 percent lower levels would mean a deficient wheat supply for the global human population now and especially in the future.[79]

With respect to the Pretty study, a commentary by a Conservation Science Group opines:

> "... While the volume and scope of data presented is impressive, we find that the analysis offers at most weak evidence for what can be achieved by these [resource-conserving] technologies.
> ...
> The analysis gives us some 'grounds for cautious optimism,' but provides only a first indication of the potential of new techniques to promote productivity and sustainability. The next step is to go further, to identify general and specific drivers of failure and success, and thereby map the most promising avenues for improving yields while reducing the environmental impact of farming."[80]

Another analysis of the Pretty study commented that the Pretty study focused on "resource-conserving" techniques (integrated pest management, integrated nutrient management, conservation tillage, agroforestry, aquaculture, water harvesting, and livestock integration into

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politics of global assessments: the case of the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD), 36 J. PEASANT STUDIES 547 (2009).

[79] The information in this paragraph comes from K. Goulding & A. Trewavas, *Special Paper: Can Organic Agriculture Feed the World?*, http://www.agbioworld.org (June 23, 2009) (accessed Feb. 1, 2013).

[80] B. Phalan, *Comment on 'Resource-Conserving Agriculture Increases Yields in Developing Countries'*, 41 ENVIRONMENTAL SCIENCE & TECHNOLOGY 1054 (2007).

farming systems) that conventional and sustainable intensive agriculture also use. Moreover, the Pretty study relied on agricultural projects that used pesticides, herbicides, inorganic fertilizers, and (likely) genetically modified soybean crops. Consequently, it can easily be argued that the Pretty study may be more supportive of sustainable intensive agriculture than of organic or agroecological farming.[81]

With regard to the IAASTD study, a good sense for its quality may be gained by quoting from three publications about the IAASTD process. The World Bank, a sponsor of the study, summarized its evaluation of the IAASTD study as follows:

> "The present [World Bank] review rates the overall outcome as moderately unsatisfactory. The IAASTD was a useful experience at the nexus of politics and science. However, agricultural technology – with its complexity, diversity, and politics – proved to be a bridge too far. For the substantial resources used, it did not offer sufficient new knowledge or conceptual frameworks for decision makers; it gave conflicting messages, and, for a 50-year timeframe, underestimated the potential of new technologies. ..."[82]

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[81] The information for this paragraph came from D. Wood & J. Lenné, *Can the ... IAASTD Approach Ensure Future Food Security?* in J. Lenné & D. Wood, AGROBIODIVERSITY FOR FOOD SECURITY (CABI, 2011), ch. 11 at 178.

[82] World Bank Independent Evaluation Group, *International Assessment of Agricultural Knowledge, Science and Technology for Development: IAASTD*, 4(2) GLOBAL PROGRAM REVIEW (2010) in the Summary.

In contrast to the IAASTD report to the World Bank and other sponsors, the International Council for Science (ICSU), in a report to the United Nations, wrote in its conclusion,

> "Progress in meeting sustainable development goals in the areas under review at the sixteenth CSD session will require substantial innovative advances in science and technology. Massive efforts will also be required: to involve farmers and other stakeholders in the S&T agenda setting, to strengthen the scientific and technological capacity in developing regions that still lack this capacity; and to get improved knowledge, approaches and technologies to the farmers – in particular small-scale farmers who could benefit most – to other natural resource managers, policy makers and development agencies." ICSU, *Discussion Paper by the Scientific and Technological Community for the 16th session of the United National Commission on Sustainable Development (CSD-16)* (10 Dec 2007).

An international affairs academic described the IAASTD process as follows:

> "The panel was launched with strong political support and high expectations, but almost everything that could go wrong did. It became a lightening rod for debates on the role of agribusiness, globalization, biotechnology, and the merits of 'science" over 'traditional' knowledge. Key governments repudiated the final report. Debate on the merits of the IAASTD still rages in agricultural circles even though the IAASTD is defunct. This article explores the reasons for this failure."[83]

Two authors with years of experience in agricultural development panned IAASTD and its recommendations as:

> "If developed countries want to follow this [IAASTD] path – and the US rejection of the IAASTD report shows that at least one does not – so be it, but it is a recipe for agricultural stagnation in most developing countries."[84]

These same two authors opined that the IAASTD was deficient because

> "... [A]s a supposedly scientific review, the IAASTD should not have attempted to foist on the world a distinctly second-hand and, we think, second-rate 'agroecology' of questionable value, nor should the IAASTD ask for respect for some decidedly anti-development and anti-science views expressed by the many social NGOs involved in the process. ..."[85]

To end this discussion of whether agroecology (as intertwined with organic agriculture) can feed the world, it is worth referring to two recently published studies using meta-datasets of published organic-conventional comparative crop yields.[86]

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[83] L. Edwards, *Food Fight: The International Assessment of Agricultural Knowledge, Science, and Technology for Development*, 15(1) AGBIOFORUM 70 (2012) in the Abstract.

[84] D. Wood & J. Lenné, note 81 *supra* at 177.

[85] *Id.* at 185.

[86] T. de Ponti, R. Rijk, M. van Ittersum, *The crop yield gap between organic and conventional agriculture*, 108 AGRICULTURAL SYSTEM 1 (2012); V. Seufert, N. Ramankutty, & J. Foley, *Comparing the yields of organic and conventional agriculture,* 485 NATURE 229 (10 May 2012).

Quoting from the Abstract for the de Ponti study:

> "... Our results show that organic yields of individual crops are on average 80% of conventional yields, but variation is substantial ... This analysis gave some support to our hypothesis that the organic-conventional yield gap increases as conventional yields increase, but this relationship was only weak. ...
> ... Our analysis was at the field and crop level. We hypothesize that due to challenges in the maintenance of nutrient availability in organic systems at crop rotation, farm and regional level, the average yield gap between conventional and organic systems may be larger than 20% at higher system levels. This relates in particular to the role of legumes in the rotation and the farming system, and to the availability of (organic) manure at the farm and regional levels."[87]

Quoting from the introductory summary in the Seufert study:

> "... Our analysis of available data shows that, overall, organic yields are typically lower than conventional yields. But these yield different are highly contextual, depending on system and site characteristics, and range from 5% lower organic yields (rain-fed legumes and perennials on weak-acidic to weak-alkaline soils), 13% lower yields (when best organic practices are used), to 34% lower yields (when the conventional and organic systems are most comparable). ..."[88]

Even if agroecology, as identified with organic agriculture, averages 80% of crop yields of conventional agriculture as the de Ponti study indicates, the global food supply and the food security of human population, at present levels, most likely cannot tolerate a 20% reduction in food production. Using the Seufert study of 34% lower yields on the most comparable farms, makes the food supply situation even worse by adopting organic farming.[89] Moreover, the caveats are strong that agroecology, closely following organic standards, will provide even less production at farm and regional levels and fall farther behind if sustainable agriculture transitions

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[87] T. de Ponti note 86 *supra* in Abstract.

[88] V. Seufert note 86 *supra* at 229.

[89] V. Seufert note 86 *supra* at 229 states, "The average organic-to-conventional yield ratio for our meta-analysis is 0.75 (with a 95% confidence interval of 0.71 to 0.79); that is, overall organic yields are 25% lower than conventional."

to sustainable intensive agriculture. Agroecology, if tied to organic agriculture, would become, as a consequence, even less likely to produce adequate food and fiber for the needs of the increased human population for the years to 2050.

It can be argued that the comparison in the preceding paragraph is agroecology to conventional or sustainable intensive agriculture in developed nations. If agroecology were adopted in developing nations, where food production on subsistence farms is very low, it could be argued that agroecology would improve agricultural production. Even assuming that point to be correct,[90] one can still ask why these subsistence farmers are being offered a second-hand and second-rate form of agriculture when agricultural development could offer them sustainable intensive agriculture. As shown in the preceding discussion of the quality of life criterion, Filipino farmers are exceedingly pleased and greatly benefitted by being offered and by adopting sustainable intensive agriculture.[91]

Agroecology, as defined by the proponents, appears to fail to satisfy Criterion One – now and more so in the future.

Enhance environmental quality and the natural resource base

As for the environmental impact of the proponents' agroecology, studies provide conflicting evidence about whether agroecology, as intertwined with organic agriculture, provides increased environmental benefits as compared to sustainable intensive agriculture. Two

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[90] V. Seufert, N. Ramankutty & J. Foley note 86 *supra* comment:
> "We cannot, therefore, rule out the claim that organic agriculture can increase yields in smallholder agriculture in developing countries. But owing to a lack of quantitative studies with appropriate controls we do not have sufficient scientific evidence to support it either." *Id.* at 231.

[91] *See*, notes 71 & 72 *supra* and accompanying text.

studies find that organic agriculture generally has positive impacts for environmental values but both caution that these benefits are in intensely managed individual fields and may not apply to farm level or the broader landscape level.[92] Moreover, organic agriculture may perform well per field, but not per unit of production – i.e., the lower production in organic fields means that the actual environmental impacts from conventional or sustainable intensive agriculture are less per bushel or pound of agricultural product.[93]

By contrast to the two studies cited in the preceding paragraph, another study is very skeptical of claims for environmental benefits from organic agriculture.[94] The author of this third study writes, "... it would be difficult to make a case for organic farming on any reasonable basis for environmental benefits compared to well-managed conventional or integrated farms."[95] The author concludes that integrated farm management, GM herbicide tolerant crops, and no-till agriculture provide environmentally superior benefits as compared to organic agriculture.[96]

While a small number (3) of studies for this Criterion Two evaluation, it appears that the proponents' agroecology may have environmental benefits at the field level but the three studies

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[92] H. Tuomisto et al., *Does organic farming reduce environmental impacts? – A meta-analysis of European research*, 112 J. ENVIRONMENTAL MANAGEMENT 309 (2012); J. Bengtsson, J. Ahnström & A. Weibull, *The effects of organic agriculture on biodiversity and abundance: a meta-analysis*, 42 J. APPLIED ECOLOGY 261 (2005).

[93] H. Tuomisto et al, note 91 *supra* at 318.

[94] A. Trewavas, *A critical assessment of organic farming-and-food assertions with particular respect to the UK and the potential environmental benefits of no-till agriculture*, 23 CROP PROTECTION 757 (2004).

[95] *Id.* at 772.

[96] *Id.* at 774-775, 777-778.

do not support the claim that agroecology benefits the environment for the broader landscape (i.e., the natural resource base) in producing the food that society needs. By contrast, sustainable intensive agriculture, using complementary practices from agroecology, does benefit the landscape at large.

Efficient use of resources and integration of natural biological cycles and controls

Going forward agriculture must produce the needed food, fodder, fiber and fuel but do so while reducing agriculture's global impact on resources. When thinking of agriculture, the most significant resource is land itself.

To produce agricultural products, crops must have adequate nutrients. Crops take nutrients from the soils in which they grow in all agricultural systems – agroecology, conventional, and sustainable intensive agriculture. When crops take nutrients, farmers must find a way to replace those nutrients or within a very few years the land is depleted and useless for agriculture. At the same time, crops need nutrients in accordance with the crop cycle so that the growing crop has the specific needed nutrient at the proper time in the growth cycle. Nutrient availability at the proper time is crucial to healthy plants and, ultimately, to crop yield.[97]

The proponents of agroecology, by rejecting science and technology and by intertwining with organic agriculture, have restricted agroecology so that it does not use synthetic fertilizers, relying instead either on cover crops (organic material plouged back into the soil – often called "green manure") or animal manures. The proponents of agroecology also reject modern breeding to develop genetically modified plants with traits to improve soil-available nitrogen use, nitrogen

[97] The comments in this paragraph come from A. Trewavas note 93 supra at ¶ *3.2 Why are organic yields lower?*.

fixation, and soil-available phosphorus use.

Whether agroecology derives plant nutrients from cover crops or animal manures, the proponents' agroecology will use larger quantities of land as compared to sustainable intensive agriculture.[98] Land must be used to grow the cover crops and land must be available for animal feed and pastures to produce animals manures.[99] Land use under the proponents' agroecology will likely be not just larger but, in fact, much larger if their agroecology must depend to any significant degree on animal manure to gain adequate nutrients for crops.[100]

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[98] K. Goulding & A. Trewavas, note 79 *supra*. (Throughout their special paper, Goulding and Trewavas make the point that organic agriculture has tremendous difficulties in providing the amount of needed nutrients and the timing of the needed nutrients for the crop cycle.)

[99] Mark Lynas Blog, *How land-inefficient is organic agriculture?* (16 July 2012), http://www.marklynas.org. In this blog post, Lynas had a very interesting dialog with Professors Seufert, Ramankutty, and Foley about organic agriculture and land use in relation to their article comparing yields between organic and conventional agriculture. See note 86 *supra* for citation.

[100] K. Goulding and A. Trewavas note 79 *supra* write,

> "... To provide 35 tonnes of manure/[hectare] requires 3.5 adult cattle/ha. There are about 4 million adult cattle in the UK and 4 million ha of arable farmland. (Respective figures in the US are 100 and 200 million.) Thus to provide sufficient anure for high wheat and other crop yields would necessitate increasing the numbers of cattle about 3.5 fold (7 fold in the USA). Their winter consumption of corn and wheat would increase by the same amount and the land devoted to food crops would have to decline. Methane production, a potent greenhouse gas, would also increase. The much larger numbers of cattle would see prices of both meat and milk drop substantially thus increasing the likelihood of increased animal fat in the diet."

And one person commenting on the Mark Lynas Blog states,

> "Hi Mark, I actually did the math on shadow land needed to get Nitrogen for the US 2009 maize crop. ... 1 cow gives 11 T of wet manure per year = 1.3 dry tonnes/cow/year. Thus, need 9 h[ectares] of pasture to get enough N for 1 ha of maize. Thus, the US 2009 maize crop would need manure from some 200 million head of cattle – just imagine the associate methane emissions! Also, to put that number in perspective, the US had 8 million dairy cows in 2010." Mark Lynas Blog, note 99 *supra*.

When focusing on land use, the evidence is very strong that the proponents' agroecology will be very land inefficient. It that occurs, agroecology will not be able to reduce agriculture's environmental footprint in the years to come and, just the opposite, will have to increase agriculture's use of land in order to meet the demands for food quantity and food security that the increased human population will require between now and the year 2050. The proponents' agroecology, as intertwined with organic agriculture, fails to satisfy Criterion Three of sustainable agriculture.

<u>Sustain the economic viability of farm operations</u>

<u>Enhance the quality of life for farmers and society</u>

Measuring the proponents' agroecology against the fourth and fifth criteria of sustainable agriculture can be combined. To the author of this essay, if the proponents' agroecology reduces agricultural production by 20 to 25 %, very likely fails to provide environmental benefits at the farm and landscape scale, and greatly expands the amount of land devoted to agriculture now and more so in the future, their agroecology fails also these fourth and fifth criteria.

The proponents' agroecology could improve the economic viability of farm operations, through premium prices for agroecology products, or could reduce the economic viability of farm operations by trapping most small-scale and resource-poor farmers in sustainable subsistence. The proponents' agroecology could enhance the quality of life for farmers who identify ideologically with their agroecology or could worsen their quality of life by failing to give them a way out of poverty.

Whatever the impact of the proponents' agroecology on individual farmers and their farm operations, society would not benefit from their agroecology under the fourth and fifth criteria because society needs agriculture to increase production, to improve its environmental performance, and to reduce its ecological footprint. From the perspective of society as a whole, by failing the initial three criteria of sustainable agriculture, the proponents' agroecology also fails the final two criteria.[101]

Conclusion

The contested vision for agriculture's future between those favoring sustainable intensive agriculture and the proponents of agroecology is a contested vision about agricultural development for developed and developing societies. The contested vision is, at root, an ideological (or belief system) contest. When one reads the documents of the proponents of agroecology, the author posits that the proponents' documents supporting agroecology are political statements having little to do with science and having the purpose of prescribing a romantic understanding of agriculture upon farmers, whether farmers want that prescribed understanding or not.[102] In this author's opinion, Mark Lynas, a well-known environmental activist and author, captured the tenor of proponents of agroecology when he wrote:

> "This [the anti-GM movement] was also explicitly an anti-science movement. ... [T]his absolutely was about deep-seated fears of scientific powers being used secretly for unnatural ends. What we [the members of the movement] didn't realize at the time was that the real Frankenstein's monster was not GM

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[101] Throughout this essay, the author uses the word "criteria" by which to measure sustainable intensive agriculture and the proponents' agroecology. The author uses the word "criteria" because lawyers often think in that term when asking whether a practice complies with a statutory definition or legal mandate. Agricultural scientists, including social scientists, are more likely to use the word "indicators" to ascertain whether a particular agricultural practice or technique is meeting defined or preferred goals. For an illustration of the use of indicators (including spider graphs), see http://www.fieldtomarket.org/report.

[102] For an article making a similar point, *cf.* P. Collier, *The Politics of Hunger – How Illusion and Greed Fan the Food Crisis*, 87(6) FOREIGN AFFAIRS 67 (2008).

technology, but our reaction against it."[103]

Sustainable intensive agriculture embraces science and technology for agricultural development. Sustainable intensive agriculture holds the belief that the threats in the years between now and 2050 are not science and technology. Sustainable intensive agriculture holds the belief that the threats are, today and until 2050, the same as for centuries – illness, famine, poverty, war, and death.[104]

Sustainable intensive agriculture does not claim and cannot deliver a complete solution to these human threats. But sustainable intensive agriculture can alleviate these threats, for individuals and societies, by providing an agricultural system that provides plentiful food, fodder, fiber and fuel and food security.

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[103] Mark Lynas Blog, *Lecture to Oxford Farming Conference*, (3 January 2013), http://www.marklynas.org.

[104] See, A. Trewavas, *The cult of the amateur in agriculture threatens food security*, 30(10) TRENDS IN BIOTECHNOLOGY 1 (2008).