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Sustainable Intensive Agriculture: High Technology and Environmental Benefits

by

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SUSTAINABLE INTENSIVE AGRICULTURE: HIGH TECHNOLOGY AND ENVIRONMENTAL BENEFITS

Drew L. Kershen[*]

I. PREFACE

In the coming decades, agriculture faces three significant challenges. While these challenges will manifest themselves in ways unique to the cultural, socio-economic, and political conditions of different countries, developed and developing nations alike will face these challenges. Moreover, for the purposes of this article, the author assumes these challenges are truisms; consequently, there is no need to cite authority to support the author's identification and assertions.[1]

Agriculture faces an agronomic challenge. Millions of people are still hungry in our world. Moreover, the world's population will continue to grow for at least several decades. Agriculture must produce the food necessary to provide the people of the world—including those who presently have the money to feel secure about their daily bread—with an adequate supply of nutritious food. Agriculture must first be about food production for the survival and health of human beings.

Agriculture faces an environmental challenge. It cannot produce the food needed for human beings if it exhausts or abuses Earth's soil, water, air, and biodiversity. Moreover, the general public, governments, and civil organizations from all societal sectors (academic, business, consumer, for-profit and non-profit, public interest, and scientific) demand that agriculture

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The author expresses appreciation to the Oklahoma Bar Association (OBA), Environmental Law Section and the Interdisciplinary Environmental Association (IEA) for allowing me to present this topic to their 2006 annual conferences. I benefited greatly from the questions and comments I received from those who attended these annual conferences. Whatever the merits or demerits of this article, it is much improved in its depth, understanding, and insights as a consequence of having been presented and discussed in PowerPoint format at the OBA and the IEA conferences.

1. The author acknowledges that others may disagree. However, the author desires to spare the reader multiple footnotes in this Preface. The author is not saying, "Trust me." Rather, the author is saying, "Let's skip thirty footnotes in order to reach the substantive parts of this article."

take responsibility for its environmental impact. As a consequence, agriculture must produce adequate food without increasing—and, more preferably, by decreasing—its geographical footprint on our natural resources.

Agriculture faces an economic challenge. In order to attract and retain people to work as farmers and livestock keepers, agriculture must provide economic returns that make their labor, managerial skills, and risk-taking worthwhile and profitable. In addition, for rural communities to thrive, agriculture must be a key economic sector. However, the economic challenge of agriculture is not limited to food and fiber—the traditional products of agriculture. The field must offer opportunities for non-traditional products such as environmental amenities, pharmaceuticals, and biofuels. Agriculture should be viewed as an economically dynamic sector.

Agriculture must face these challenges in the coming decades in a manner that creates complementary, not conflicting, synergies between and among them. As quickly as possible, agriculture must become agronomically sophisticated, environmentally protective, and economically sound.

While it would be more than presumptuous to try to prescribe answers to these agricultural challenges, the author hopes to sketch a worthwhile, sensible way forward for agriculture. To paraphrase another academic writer, this article will ask about the ways that high technology can help agriculture grow up.[2]

II. INTRODUCTION

To create a simplistic dichotomy, there are two future paths for agriculture: low technology, most easily identified with organic agriculture; and, high technology, most easily identified with agricultural biotechnology. These two paths—low technology and high technology—most often describe different techniques or approaches used in agricultural production. However, these two paths can also represent different agricultural philosophies about farmers, farming, technology, markets, resources, food, and rural life. Consequently the choice between low-tech and high-tech agriculture can present fundamental policy questions. As a society, Americans can emphasize one or the other.[3]

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2. Carol M. Rose, *Environmental Law Grows Up (More or Less), and What Science Can Do to Help*, 9 LEWIS & CLARK L. REV. 273, 281 (2005) ("This shift of focus [back to a qualitative focus in environmental regulation] is as yet incomplete. It is in this context of incomplete transformation that we need to ask about the ways that science can help environmental law to grow up.").

3. The author focuses this article on agricultural policy in the United States of America. However, European countries are debating low-tech and high-tech agriculture as well. *Compare European Ag Ministers Support Organic Farming*, ENV'T NEWS SERVICE, May 14, 2001, *available at* http://www.ens-newswire.com/ens/may2001/2001-05-14-05.asp, *and* Benoit Finck, *Germany's Organic Farming Industry Suffering in Ill Health*, AGENCE FRANCE PRESSE ENGLISH, Jan. 25, 2004 (on file with author), *with* COMM'N OF THE EUROPEAN COMTYS., TOWARDS A STRATEGIC VISION OF LIFE SCIENCE AND BIOTECHNOLOGY: CONSULTATION DOCUMENT, COM

Organic agriculture rejects many of the agricultural scientific methods adopted in the most recent sixty years,[4] but low technology agriculture is not limited to organic practices. Many practices currently used or advocated for conventional agriculture are also low technology.[5] If officials adopted these current low-tech practices of organic and conventional agriculture as public policy, our society would be choosing a low technology future for agriculture.[6]

Similarly, high technology agriculture is not limited to transgenic practices. High technology agriculture encompasses many technological[7] and

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(2001) 454 final (Aug. 4, 2001), *available at* http://ec.europa.eu/biotechnology/pdf/doc_en.pdf. *See also* CHRIS FOSTER ET AL., ENVIRONMENTAL IMPACTS OF FOOD PRODUCTION AND CONSUMPTION: A RESEARCH REPORT COMPLETED FOR THE [UK] DEPARTMENT FOR ENVIRONMENT, FOOD AND RURAL AFFAIRS ("DEFRA") (2006). In this report, the authors conclude:

> There is certainly insufficient evidence available to state that organic agriculture *overall* would have less of an environmental impact than conventional agriculture. In particular, from the data we have identified, organic agriculture poses its own environmental problems in the production of some foods, either in terms of nutrient release to water or in terms of climate-change burdens.

Id. at 141 (emphasis in original). The authors of this DEFRA report relied upon life-cycle assessments in reaching their conclusions. Their focus was on Europe where transgenic crops are hardly grown. Moreover, the references in the DEFRA report did not include R.M. Bennett, R.H. Phipps & A.M. Strange, *An Application of Life-Cycle Assessment for Environmental Planning and Management: The Potential Environmental and Human Health Impacts of Growing Genetically-Modified Herbicide-Tolerant Sugar Beet*, 49 J. ENVTL. PLAN. & MGMT. 59 (2006). In the Abstract, Bennett, Phipps & Strange wrote, "Although the overall contribution of GM sugar beet to reducing harmful emissions to the environment would be relatively small, the potential for GM crops to reduce pollution from agriculture, including diffuse water pollution, is highlighted." *Id.* at 59. *See also*, David Adam, *'Only intensive farming' will feed Britain*, GUARDIAN (Apr. 18, 2007) *available at* http://environment.guardian.co.uk/food/story/0,,2059591,00.html (last visited May 15, 2007).

4. *See, e.g.*, USDA National Organic Program, 7 C.F.R. § 205.2 (2006) (excluded methods and prohibited substances); *id.* § 205.105 (allowed and prohibited substances, methods, and ingredients in organic production and handling); *id.* § 205.272 (commingling and contact with prohibited substance prevention practice standard); *id.* § 205.600 (evaluation criteria for allowed and prohibited substances, methods, and ingredients); *see also* Harvey v. Veneman, 396 F.3d 28 (1st Cir. 2005) (considering a dispute between "true" organic farmers and "commercial" organic farmers).

5. For information on low-tech approaches to agriculture, also known as "appropriate technology" by its adherents, *see* National Center for Appropriate Technology ("NCAT"), http://www.ncat.org (last visited Feb. 24, 2007).

6. NCAT, including its subsidiary, the Appropriate Technology Transfer to Rural Areas ("ATTRA"), has had and currently has funding from the United States Department of Agriculture and the United States Department of Energy. *About NCAT: History*, http://www.ncat.org/about_history.html (last visited Feb. 24, 2007). During the Reagan Administration, NCAT lost a sponsoring agency in the federal government. *Id.*

7. *E.g.* THOMAS GODDARD ET AL., POTENTIAL FOR INTEGRATED GIS-AGRICULTURE MODELS FOR PRECISION FARMING SYSTEMS, *available at* http://www.ncgia.ucsb.edu/conf/SANTA_FE_CD-ROM/sf_papers/goddard_tom/960119.html (last visited Feb. 24, 2007) ("Precision farming aims to optimize the use of soil resources and external inputs (fertilizers and herbicides) on a site specific basis."); ENVTL. SYSTEM RESEARCH INST., INC. ("ESRI"), PRECISION AGRICULTURE AND GIS, *available at* http://www.esri.com/industries/agriculture/business/precision.html (last visited Feb. 24, 2007) ("Precision farming (PF) and variable rate

scientific[8] developments that are distinct from transgenic agriculture. In this article, however, the author will focus on transgenic practices in developing the argument for the environmental benefits of high technology agriculture.[9] More broadly, the author asserts that high technology agriculture is the best path forward to addressing agriculture's agronomic, environmental, and economic challenges in a sustainable fashion.

Sustainable intensive agriculture will be overwhelmingly high technology in nature,[10] but this does not mean that low-tech and high-tech agriculture are mutually exclusive. Both can coexist.[11] However, a tension undeniably exists, as seen in the organic movement's exclusion of transgenic agriculture as an acceptable practice.[12] The author shares the view of Dr. Brian Johnson, who, for many years, was head of English Nature, an environmental organization for agricultural technologies. Dr. Johnson recently wrote:

> This rejection of biotechnology has no scientific or rational basis, and Europeans are rejecting a potentially powerful tool for producing better agriculture. As an ecologist and environmentalist, I cannot see the sense in this, and urge you all to reconsider this position and to

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technologies (VRT) use spatial databases within field environmental and management variables with the aim of evening the application of field inputs while maximizing production across a field.").

8. Scientific breeding, using non-transgenic breeding techniques, is one such high technology. *See, e.g.*, Phil Breigitzer & Victor Raboy, *Effects of Four Independent Low-Phytate Mutations on Barley Agronomic Performance*, 46 CROP SCI. 1318, 1318 (2006) ("The seed phosphorous storage compound phytic acid . . . is poorly utilized by nonruminant animals. Low Phytate (LP) crops, in which reductions of phytate are accompanied by increases in nutritionally available P, are in development and their utility will be enhanced by competitive agronomic performance.").

9. The author has already produced one article on this topic. Drew Kershen, *Agricultural Biotechnology: Environmental Benefits for Identifiable Environmental Problems*, 32 ENVTL. L. REP. 11, 312 (2002).

10. The author first read the phrase "sustainable intensive agriculture" in David E. Adelman & John H. Barton, *Environmental Regulation for Agriculture: Towards a Framework to Promote Sustainable Intensive Agriculture*, 21 STAN. ENVTL. L.J. 3 (2002). Their phrase and article caused this author to mull the issues for four years, resulting in this effort to sketch a way forward for agriculture.

11. Coexistence among conventional, organic, and transgenic agriculture has also been contentious. Coexistence has three significant themes: good husbandry, neighborly cooperation, and farmer choice. The research *oeuvre* of Peter Barfoot and Graham Brookes—in particular their case studies of several nations about coexistence—provides an excellent source for understanding the issues and for comprehending practical solutions. This research *oeuvre* can be found on the webpage of their consultancy company, located in the United Kingdom. *See* PG Economics Home Page, http://www.pgeconomics.co.uk (last visited Feb. 24, 2007).

12. USDA National Organic Program, 7 C.F.R. § 205.2 (2006) (under "Excluded methods") ("A variety of methods used to genetically modify organisms or influence their growth and development by means that are not possible under natural conditions or processes and are not considered compatible with organic production.").

For evidence of tension between low-tech and high-tech agriculture relating to coexistence, *see* Volker Beckmann et al., *Coexistence Rules and Regulations in the European Union*, 88 AMER. J. AGRIC. ECON. 1193 (2006) (discussing the regulatory and liability rules in the various member states of the EU and their impact on farmers' decisions to adopt transgenic crops).

> campaign for more publicly funded research into the potential use of biotechnology and other new breeding methods in the search for more environmentally sustainable agriculture. . . . Let us reopen a scientifically mature debate on biotechnology in agriculture, and let us as scientists debate the subject without the distraction of campaigns against a technology that in industry, medicine and agriculture worldwide is beginning to show great promise in achieving goals that have previously eluded us.[13]

The author would amend Dr. Johnson's statement by changing "beginning to show great promise" to "already providing significant results" in achieving environmental goals that have previously eluded us.

III. ASSORTED ENVIRONMENTAL BENEFITS OF AGRICULTURAL BIOTECHNOLOGY

A. General Benefits

By its nature, agriculture creates ecological disturbance. It replaces natural landscapes with human-shaped landscapes to grow the food and fiber that human beings need or demand. Hence, the choice is not between a pristine agriculture that creates no environmental harm and a dirty agriculture that pollutes the environment. All agricultural systems harm the environment. Rather, the ecological choice is to produce food and fiber while doing the least possible environmental damage.[14] Over the past ten years, as transgenic

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13. Brian Johnson, Biotechnology in Agriculture – It May Not Be Popular, But We May Need It in Europe, http://www.gmo-safety.eu/en/debate/533.docu.html (last visited Feb. 24, 2007) (from a speech opening the 36th Annual Conference of the Ecological Society of Germany, Austria and Switzerland, in Bremen on September 14, 2006); *see also* Rhys E. Green et al., *Farming and the Fate of Wild Nature*, 307 SCI. 550, 550 (2005) ("Empirical data on such density-yield functions are sparse, but evidence from a range of taxa in developing countries suggests that high-yield farming may allow more species to persist."), *available at* http://www.sciencexpress.org.

14. Dr. Peter Raven, Director of the Missouri Botanical Garden in St. Louis, chose this theme of the ecological footprint of agriculture for a lecture he presented at the Natural History Museum of London. Dr. Raven stated,

> But the overall lesson is clear: agriculture itself is highly destructive to biodiversity, and deliberately so. We eliminate biological diversity in order to build agricultural productivity . . . .
>
> A wide variety of new approaches have been developed that will combine well to produce the more productive, sustainable agriculture of the future. . . . Organic agriculture is essentially what is practiced in sub-Saharan Africa today, and half of the people are starving; so it is clear that more is needed. To meet the real challenges of the intensive agriculture that has been deployed widely in the modern world and improve productivity and sustainability throughout, all available methods, certainly including GM [genetic modification] technology, must be applied where they will be useful.

Peter H. Raven, The Environmental Challenge (May 22, 2003), http:// www.biotech-info.net/environmental_challenge.html.

agriculture expanded rapidly across the world,[15] its environmental benefits are becoming more and more evident.

Numerous studies summarizing the environmental impacts of transgenic (biotech) agriculture have shown that it reduces the use of less environmentally-friendly herbicides in favor of more environmentally-friendly ones, reduces use of broad spectrum pesticides with concomitant benefits in human safety and the survival of non-target insects, and reduces greenhouse gases through improvements in the use of equipment and energy.[16] In addition, transgenic agriculture offers significant promise in addressing other adverse agricultural impacts on the environment.

B. Reducing the Adverse Effects of Phosphorous on Water Quality

Livestock production creates large amounts of manure, which are ultimately spread on farm fields as a fertilizer. By using manure, farmers often apply nitrogen and phosphorus at rates that exceed the nutrient needs of the plants growing on the treated land. Runoff from these fields carry the excess nitrogen and phosphorus into streams. This excess can create water quality problems that adversely affect human health, water treatment, and the

15. CLIVE JAMES, EXECUTIVE SUMMARY OF BRIEF 35 – GLOBAL STATUS OF COMMERCIALIZED BIOTECH/GM CROPS: 2006 (Int'l Serv. for the Acquisition of Agri-Biotech Applications 2006).

16. *E.g.*, H.J. Beckie et al., *A Decade of Herbicide-Resistant Crops in Canada*, 86 CAN. J. PLANT SCI. 1243, 1249, 1259-60 (2006); Graham Brookes & Peter Barfoot, *Global Impact of Biotech Crops: Socio-Economic and Environmental Effects in the First Ten Years of Commercial Use*, 9 AGBIOFORUM 139, 143 tbl. 5, 146 (2006); UNION OF THE GERMAN ACADEMIES OF SCI. & HUMANITIES & INTERACADEMY PANEL INITIATIVE ON GENETICALLY MODIFIED ORGANISMS, GENETICALLY MODIFIED INSECT RESISTANT CROPS WITH REGARD TO DEVELOPING COUNTRIES 3, http://www.interacademies.net/Object.File/Master/6/751/InsectResistCrops.pdf (last visited Feb. 24, 2007) ("These facts provide overwhelming support for the beneficial effect of *Bt*-crops cultivation, both for the environment and for the health of the farm labourers."); Jörg Romeis, Michael Meissle & Franz Bigler, *Transgenic Crops Expressing* Bacillus thuringiensis *Toxins and Biological Control*, 24 NATURE BIOTECHNOLOGY 63, 69 (2006) ("[The data] furthermore provide evidence that *Bt* crops grown today are more specific and have fewer side effects on parasitoids and predators than most insecticides currently used. . . . *Bt* technology can contribute to natural enemy conservation and be a useful tool in integrated pest management systems."); Theresa A. Brimner, Gordon James Gallivan & Gerald R. Stephenson, *Influence of Herbicide-Resistant Canola on the Environmental Impact of Weed Management*, 61 PEST MGMT. SCI. 47, 47 (2005) ("The growth of herbicide-resistant canola varieties increased from 10% of the canola area in Canada in 1996 . . . to 80% in 2000. From 1995 to 2000, the amount of herbicide active ingredient applied per hectare of canola declined by 42.8% and the Environmental Impact (EI) per hectare . . . declined 36.8%."); JANET CARPENTER ET AL., COUNCIL FOR AGRIC. SCI. & TECH., COMPARATIVE ENVIRONMENTAL IMPACTS OF BIOTECHNOLOGY-DERIVED AND TRADITIONAL SOYBEAN, CORN, AND COTTON CROPS 133 (2002); R.H. Phipps & J.R. Park, *Environmental Benefits of Genetically Modified Crops: Global and European Perspectives on Their Ability to Reduce Pesticide Use*, 11 J. ANIMAL & FEED SCI. 1 (2002).

For a general survey of the environmental benefits of ghyphosate-tolerant crops, *see* Antonio L. Cerdeira & Stephen O. Duke, *The Current Status and Environmental Impacts of Glyphosate-Resistant Crops: A Review*, 35 J. ENVTL. QUALITY 1633 (2006).

environment as a whole.[17] High-tech agriculture offers two approaches to solving problems posed by excess phosphorus from livestock production.

One approach is to reduce the amount of phosphorus in animal wastes. Plant breeders, using conventional and transgenic breeding, have developed low-phytate grains that allow animals to utilize the grain nutrition more efficiently. By doing so, the animals excrete significantly less phosphorus, and thus their manures carry less phosphorus when applied to fields.[18]

Another approach is to develop plants with improved uptake of available phosphorus. Plant molecular biologists are learning about the genes and fungi-plant interactions that enhance plant utilization of phosphorus from fertilizers and manures.[19] Simultaneously, plant breeders are working to create transgenic grasses (fescue, Russian wild rye, and wheatgrass) and transgenic alfalfa that builds upon this molecular knowledge.[20] If plants are created that better utilize phosphorus, less phosphorus will enter lakes and streams through runoff after manure applications. Less phosphorus in runoff means better water quality.

C. Aiding Cleanup of Contaminated Sites

The Environmental Protection Agency (EPA) classifies thousands of sites in the United States as contaminated and in need of remediation.[21] The

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17. *E.g.*, Douglas R. Williams, *When Voluntary, Incentive-Based Controls Fail: Structuring a Regulatory Response to Agricultural Nonpoint Source Water Pollution*, 9 WASH. U. J.L. & POL'Y 21, 44-48 (2002); J.B. Ruhl, *Farms, Their Environmental Harms, and Environmental Law*, 27 ECOLOGY L.Q. 263, 285-91 (2000).

18. *E.g.*, Victor Raboy, *Progress in Breeding Low Phytate Crops*, 132 J. NUTRITION 503S, 504S (2002)

> (These initial observations for maize and . . . barley . . . provide a proof of principal; a classical genetics approach can be used to produce hybrids or cultivars that produce seed with greatly reduced (>50%) phytic acid . . . . Still, common sense suggests that it is unlikely that this first-generation technology will represent the optimal technology, even with additional breeding efforts. . . . It, therefore, seems probable that if a low-phytate grain is desirable, a biotechnology approach might prove most successful.);

T.L. Veum et al., *Low-phytic Acid Corn Improves Nutrient Utilization for Growing Pigs*, 79 J. ANIMAL SCI. 2873, 2879 (2001) ("Formulation of swine diets with low-phytate corn containing the *lpa1-1* allele will assist the swine industry in becoming more environmentally friendly by greatly reducing the excretion of phosphorus in swine waste."); *see also* XINGEN LEI ET AL., BIOTECHNOLOGICAL APPROACHES TO MANURE NUTRIENT MANAGEMENT (Council for Agric. Sci. & Tech. 2006).

19. *E.g.*, *Knowledge of Nitrogen Transfer Between Plants and Beneficial Fungi Expands*, SCI. DAILY, June 23, 2005, http://www.sciencedaily.com/releases/2005/06/050619193216.htm; *Plant Gene Discovery Could Enhance Plant Growth, Reduce Fertilizer Needs and Phosphate Pollution*, SCI. DAILY, July 28, 2004, http://www.sciencedaily.com/releases/2004/07/040728084527.htm.

20. For information about the plant breeding research of Dr. Zengyu Wang, an associate scientist at the Samuel Roberts Noble Foundation, see Sam Roberts Noble Found., Forage Improvement Division: Genetic Transformation, http://www.noble.org/ForgBiot/GeneticTransgormation/index.html (last visited Feb. 24, 2007).

21. Philip E. Karmel, *Achieving Radical Reductions in Cleanup Costs*, *in* NEW SOLUTIONS

estimated cost for remediating these sites is in the billions of dollars per year.[22] Agriculture is one source of contamination.[23]

Biotechnology offers technology to achieve the desired cleanup at a greatly reduced cost.[24] This can be achieved through transgenic plants (flowers, shrubs, and trees) that can detoxify sites by removing heavy metals (e.g., arsenic, cadmium, or mercury) from the soil.[25] Phytoremediation, using transgenic plants, may well be a commendable high-tech approach for cleaning contaminated soils.[26]

IV. A MAJOR BENEFIT OF BIOTECHNOLOGY: REDUCING AGRICULTURAL RUNOFF

While transgenic agriculture offers the environmental benefits described previously, this article focuses on another affiliated benefit: reduced agricultural runoff. Farming and ranching are the work of a large and dispersed number of landowners who cover a vast expanse of land. Their work provides the major source of nonpoint source pollution in the United States, contributing substantial amounts of sediments, chemicals, and fertilizers to

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TO ENVIRONMENTAL PROBLEMS IN REAL ESTATE DEALS 2004, at 279, 287 (PLI Real Estate Law & Prac., Course Handbook Series No. 3152, 2004) (EPA estimate of 217,000 sites) (also cited as 511 PLI/Real 279).

22. *Id.* at 287-88.

23. Ruhl, *supra* note 17, at 314-15.

24. Bruce W. Ferguson, *Systems Agriculture: Towards a Sustainable Agricultural and Environmental Policy in* AGRICULTURAL BIOTECHNOLOGY: BEYOND FOOD AND ENERGY TO HEALTH AND THE ENVIRONMENT 93, 94 (Nat'l Agric. Biotech. Council Report No. 17, Allan Eaglesham et al. eds., 2005) [hereinafter BEYOND FOOD AND ENERGY]

> (The techniques under evaluation in this ongoing project include the planting, cultivation, treatment and harvesting of special ferns that accumulate large quantities of arsenic in their fronds. . . . For example, at some sites, phytoremediation of arsenic may cost as little as 10% of the cost of excavating and removing contaminated soil.).

25. *E.g.*, Scott A. Merkle, *Engineering Forest Trees with Heavy-Metal Resistance Genes for Phytoremediation in* BEYOND FOOD AND ENERGY, *supra* note 24, at 117; M. Cristina Romero et al., *Biosorption of Heavy Metals by* Talaromyces helicus: *A Trained Fungus for Copper and Biphenyl Detoxification*, 9 ELECTRONIC J. BIOTECH. 201 (2006), http://www.ejbiotechnology.info/content/vol9/issue3/full/11/.

26. *See also* J. SCOTT ANGLE & NICHOLAS A. LINACRE, ECOLOGICAL RISKS OF NOVEL ENVIRONMENTAL CROP TECHNOLOGIES USING PHYTOREMEDIATION AS AN EXAMPLE 21 (Int'l Food Policy Research Inst. 2005)

> (Thus, while acknowledging that there are risks associated with phytoremediation, these risks are temporary [and] last only during the process of phytoremediation. We believe that in most cases phytoremediation risks are small compared to the risks of doing nothing or the financial and engineering risks of 'dig and haul.').

Cf. generally EPA, BROWNFIELDS TECHNOLOGY PRIMER: SELECTING AND USING PHYTOREMEDIATION FOR SITE CLEANUP (2001). By publishing this primer, the EPA acknowledged that phytoremediation, in specific situations, could be an acceptable cleanup technology. However, the EPA was quite cautious in its attitude toward phytoremediation. *Id.* at 11, 19. With additional experiences in phytoremediation and advances in transgenic phytoremediation, the EPA has the opportunity to recognize phytoremediation as an ordinary, normal, useful cleanup technology.

bodies of water.[27] If the United States is to improve the quality of its waters, it must address the problems posed by agricultural runoff sensibly, efficiently, and effectively. Coincidentally and propitiously, biotechnology has arrived on the scene to assist in the cleanup.[28]

Agricultural biotechnology does not directly control runoff. By using environmentally-friendly herbicide and pest resistance, biotechnology makes agricultural runoff less harmful to receiving waters by producing a runoff with fewer chemicals. The runoff would be the same in amount—just cleaner.[29] However, biotechnology indirectly controls runoff because farmers who adopt transgenic crops are also able to adopt conservation tillage.[30] Farmers can adopt conservation tillage more easily and more readily with transgenic crops because transgenic crops provide the agronomic tools to control weeds and pests without tillage. In other words, transgenic crops allow farmers to adopt environmentally-friendly tillage practices.[31]

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27. J.B. Ruhl, *Three Questions for Agriculture About the Environment*, 17 J. LAND USE & ENVT'L L. 395, 396-402 (2002); *see also* Williams, *supra* note 17; Ruhl, *supra* note 17. For a discussion of runoff in general, see Donald J. Kochan, *Runoff and Reality: Externalities, Economics, and Traceability Issues in Urban Runoff Regulation*, 9 CHAPMAN L. REV. 409 (2006).

28. For a different, though in some respects overlapping, proposal for sensibly addressing agricultural nonpoint source pollution, see Thomas K. Ruppert, *Water Quality Trading and Agricultural Nonpoint Source Pollution: An Analysis of the Effectiveness and Fairness of EPA's Policy on Water Quality Trading*, 15 VILL. ENVTL. L.J. 1 (2004).

29. *E.g.*, David I. Gustafson, *Biotechnology Insight: How Biotech Crops Protect Water Quality*, ISB NEWS REP., July 2002, at 6, *available at* http://www.isb.vt.edu/news/2002/Jul02.pdf. Gustafson cites four studies (two using modeling techniques and two using field case studies) that predict and show significant reductions in herbicides and pesticides in water runoff from fields where farmers would plant or planted herbicide-resistant and insect-resistant transgenic crops; *id.* at 7-8. The author has read the four cited studies and confirms Mr. Gustafson's summation of their contents.

30. RICHARD FAWCETT & DAN TOWERY, CONSERVATION TECH. INFO. CTR., CONSERVATION TILLAGE AND PLANT BIOTECHNOLOGY: HOW NEW TECHNOLOGIES CAN IMPROVE THE ENVIRONMENT BY REDUCING THE NEED TO PLOW 2 (2002) (defining conservation tillage as "[a]ny tillage and planting system that covers more than 30 percent of the soil surface with crop residue, after planting, to reduce soil erosion by water").

31. *Id.* at 17

> (An analysis of surveys conducted since the introduction of herbicide-tolerant crops strongly supports the conclusion that these crops developed through plant biotechnology are facilitating the continued expansion of conservation tillage, especially no-till. As more acres are converted to conservation tillage, and especially no-till, significant environmental benefits will be derived.);

see, e.g., Cerdeira & Duke, *supra* note 16, at 1651

> (Being a broad spectrum, foliarly (sic.) applied herbicide, with little or no activity in soil, glyphosate is highly compatible with reduced- or no-tillage agriculture and has contributed to the adoption of these practices in the Western Hemisphere. This contribution to environmental quality by GRCs is perhaps the most significant one.");

see also SUJATHA SANKULA, GREGORY MARMON & EDWARD BLUMENTHAL, NAT'L CTR. FOR FOOD & AGRIC. POL'Y, BIOTECHNOLOGY-DERIVED CROPS PLANTED IN 2004: IMPACTS ON US AGRICULTURE 8 (2005) ("[C]hanges and new developments in pest management and other production practices that followed biotechnology-derived crops were also discussed in this report.

Conservation tillage may be the most sensible, efficient, and efficacious management practice to control agricultural runoff. Studies show that erosion (carrying sediment, chemicals, and nutrients) is reduced proportionally to the amount of crop residue covering the soil. Some estimate that if no-till agriculture (basically all crop residue on the soil year-round) became the predominant practice in America, erosion would decline by 90% or more.[32] Significant reduction in erosion from agricultural lands (particularly farms) means cleaner streams and lakes due to reduced loads of chemicals, fertilizers, manures, and dirt in water runoff.[33] Significant reduction in erosion also means large savings in costs caused by excessive sedimentation in stream beds and lakes.[34]

Conservation tillage will have sustainable benefits for the environment only if farmers use it. Farmers will only use conservation tillage if they can continue to control weeds and insects easily and economically through transgenic crops. Transgenic crops will easily and economically control weeds and insects only if weeds do not acquire herbicide resistance and insects do not acquire pesticide resistance, thereby undermining the beneficial traits of transgenic crops. In addition, the transgenic crops themselves must not become bothersome weeds, as volunteers, in the fields or along the roadsides of farm fields.

Many transgenic crops contain a gene from *Bacillus thuringiensis* (*Bt*) to gain better control over specific insects that damage crops. Widespread use of *Bt* crops raised the issue as to whether these insects would become resistant to the Bt gene, rendering the crop ineffective and Bt as a pest control useless. However, regarding insect-resistance to *Bt* crops, no evidence has shown increased resistance by targeted insects in the United States or elsewhere.[35] Moreover, scientists and plant breeders are developing novel strategies for transgenic plants that will increase the durability and sustainability of their pest

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One of these changes is increased adoption of no-tillage practices that has taken place subsequent to the widespread planting of herbicide-tolerant crop varieties."). Sankula et al. reported an increase of 20% in no-till acres in corn in 2004 and gave other examples of no-till adoption in relation to transgenic crops. *Id.* at 27, 33, 38-39, 50, 53, 61. In Argentina, where transgenic crops dominate agriculture, it is reported that farmers have adopted no-till on more than 50% of the acreage in grain production. Miguel Cantamutto & Monica Poverene, *Genetically Modified Sunflower Release: Opportunities and Risks*, 101 FIELD CROPS RES. 133, 135 (2007).

32. FAWCETT & TOWERY, *supra* note 30, at 4 (text and chart).

33. *Id.* at 7-9. "A summary of published natural rainfall studies comparing no-till with moldboard plowing showed that, on the average (over 32 treatment-site-years of data), no-till resulted in 70 percent less herbicide runoff, 93 percent less erosion and 69 percent less water runoff than moldboard plowing (Figure 4)." *Id.* at 8.

34. *Id.* at 4-5.

35. Bruce Tabashnik et al., *DNA Screening Reveals Pink Bollworm Resistance to* Bt *Cotton Remains Rare After a Decade of Exposure*, 99 J. ECON. ENTOMOLOGY 1525 (2006); Jeffrey Fox, *Resistance to* Bt *Toxin Surprisingly Absent from Pests*, 21 NATURE BIOTECH. 958 (2003) (describing the absence of resistance by insects in *Bt* cotton and *Bt* corn in Australia, China, and the United States).

control traits.[36] Thus, scientific evidence and field experience provide a basis for optimism that *Bt* crops are a sustainable form of non-chemical pest control for farmers.

Regarding the potential weediness of transgenic crops, this author finds no reason to believe that a transgenic crop would be weedier than any similar non-transgenic crop. However, prior to approval for commercialization, regulatory agencies consider and evaluate the potential weediness of transgenic crops.[37] Moreover, agronomic studies provide strong evidence that transgenic crops are no more likely than similar non-transgenic crops to become weeds or other forms of plant pests.[38] Finally, scientists and crop breeders are developing transgenic plants that contain a selectively unfit gene to assure that any escape from a cultivated field would be short-lived.[39] Thus, scientific evidence and field experience allow optimism that transgenic crops will not become nuisance weeds in farm fields.

Regarding weed resistance to herbicides to which plants have been bred to

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36. *E.g.*, N. Ferry et al., *Transgenic Plants for Insect Pest Control: A Forward Looking Scientific Perspective*, 15 TRANSGENIC RES. 13, 13 (2006) ("However, in order to assure durability and sustainability of resistance, novel strategies have been contemplated and are being developed. This perspective addresses a number of potentially useful strategies to assure the longevity of second and third generation insect resistant plants.").

37. *E.g.* OFFICE OF THE GENE TECH. REGULATOR (AUSTRALIA), APPLICATION DIR 021/2002 FOR COMMERCIAL RELEASE OF GENETICALLY MODIFIED CANOLA, RISK ASSESSMENT AND RISK MANAGEMENT PLAN, APPENDIX 4 ENVIRONMENTAL SAFETY WEEDINESS 74 (2003) (on file with author).

> There is no evidence to show that the introduced genes increase the potential weediness of the plants, nor do they provide these plants with an ecological advantage over conventional canola, except in the presence of glufosinate ammonium herbicide. The germination, seed dormancy and fitness traits such as herbicide sensitivity, disease resistance, stress adaptation and competitiveness are all within the range of conventionally bred canola varieties. *Id.* at 87;

see also François J. Belzile, *Transgenic, Transplastomic and Other Genetically Modified Plants: A Canadian Perspective*, 84 BIOCHIMIE 1111, 1113 (2002) (briefly discussing Canadian regulatory consideration of potential weediness).

38. *E.g.* Michael J. Horak et al., *Characterization of Roundup Ready Flex Cotton, 'MON 88913', for Use in Ecological Risk Assessment: Evaluation of Seed Germination, Vegetative and Reproductive Growth, and Ecological Interactions*, 47 CROP SCI. 268, 276 (2007) ("The results of this study support the conclusion that Roundup Ready Flex cotton MON 88913 is no more likely to pose a plant pest risk than conventional cotton."); Belzile, *supra* note 37, at 1115 ("Although such cases [multi-herbicide resistant canola] can occur, they are not frequently observed in the field. In a recent survey, 77% of Canadian growers voiced the opinion that volunteer management was equal or no more of a problem with transgenic cultivars than with conventional cultivars.").

39. *E.g.*, Hani Al-Ahmad et al., *Mitigation of Establishment of* Brassica napus *transgenes in Volunteers Using a Tandem Construct Containing a Selectively Unfit Gene*, 4 PLANT BIOTECH. J. 7, 7 (2006) ("The data clearly indicate that the *Δgai* gene greatly enhances the yield in a weed-free transgenic crop, but the dwarf plants can be eliminated when competing with non-transgenic cohorts (and presumably other species) when the selective herbicide is not used."); Hani Al-Ahmad, Shmuel Galili & Jonathan Gressel, *Poor Competitive Fitness of Transgenically Mitigated Tobacco in Competition with the Wild Type in a Replacement Series*, 222 PLANTA 372-73 (2005).

be tolerant,[40] herbicide applications kill non-resistant weeds, thereby creating selective pressures for the survival of those weeds with a genetic mutation resistant to the applied herbicide. Weeds develop resistance to herbicides—a biological fact known by farmers, agronomists, weed scientists, and herbicide manufacturers for many years.[41] The most authoritative source on weed resistance to herbicides lists twelve weeds that have become resistant to glyphosate, no weeds (thus far) that have become resistant to glufosinate, and ninety-five weeds that have become resistant to ALS inhibitors (imidazolinones are in the ALS group).[42]

Agriculture has two ways of responding to weed resistance: (1) farmers can use management techniques, such as the use of other herbicides or other cultural practices;[43] and (2) manufacturers can develop new herbicides and herbicide-tolerant plants to stay ahead of the weed resistance response.[44] Continuing conservation tillage, while depending upon transgenic crops for

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40. The three most common crops bred to be tolerant to a herbicide mode of action are glyphosate tolerant crops (transgenic, RoundUp Ready, Monsanto), glufosinate tolerant crops (transgenic, Liberty Link, Bayer Crop Science), and imidazolinoenes tolerant crops (nontransgenic, Clearfield, BASF). Stevan Z. Knezevic, *Use of Herbicide Tolerant Crops as a Component of an Integrated Weed Management Program*, NEBGUIDE g1484 (2002) (under the heading, Herbicide Tolerant Crops) *available at* http://www.ianrpubs.unl.edu/epublic/pages/publicationD.jsp?publicationId=108 (last visited May 15, 2007).

41. *See, e.g.*, Stephen R. Moss, *Herbicide Resistant Weeds*, *in* WEED MANAGEMENT HANDBOOK 225 (Robert E.L. Naylor ed., 9th ed. 2002); Ralph C. Kirkwood, *Herbicide Tolerant Crops*, *in* WEED MANAGEMENT HANDBOOK, *supra*, at 253.

42. International Survey of Herbicide Resistant Weeds, http://www.weedscience.org (last visited Feb. 24, 2007) ("The purpose of this survey is to monitor the evolution of herbicide-resistant weeds and assess their impact throughout the world. Global collaboration between weed scientists makes the survey and this web site possible.").

43. *See, e.g.*, Belzile, *supra* note 37, at 1115 ("Although such cases [multi-herbicide resistant canola] can occur, they are not frequently observed in the field. In a recent survey, 77% of Canadian growers voiced the opinion that volunteer management was equal or no more of a problem with transgenic cultivars than with conventional cultivars."); *see also* Monsanto Co., 2007 Weed Resistance Update (Jan. 2007) (on file with author) (providing information about weed resistance, management resources, and management general recommendations); Press Release, SeedQuest, Proactive Management Worth Higher Upfront Cost to Protect Against Glyphosate-Resistant Weeds (Dec. 12, 2006), *available at* http://www.seedquest.com/News/releases/2006/december/17780.htm.

44. *See, e.g.* Andrew Douglas, *Biotechnology Delivers New Traits*, FARM BUS. COMM., Dec. 21, 2006, http://www.agcanada.com/custompages/stories_story.aspx?mid=191&id=1055

> (Losing access to such a large number of acres [of soybeans] was a big blow but Syngenta is on the verge of resurrecting itself in that market. An intriguing partnership with major competitor DuPont (and Pioneer Hi-Bred) has resulted in a venture called Green Leaf Genetics, which has developed a new glyphosate-tolerant trait that also allows sulfonylurea products to be applied. It's called Optimum GAT, with GAT standing for glyphosate and ALS tolerant.);

see also e.g., David Bennett, *Ian Heap Helps Keep Tabs on Global Weed Resistance*, DELTA FARM PRESS ONLINE EDITION, Jan. 17, 2007, http://deltafarmpress.com/news/070117-weed-resistance/ (quoting Dr. Heap, who directs the International Survey of Herbicide Resistant Weeds, as speculating that herbicide manufacturers, seeing the rise of glyphosate-resistant weeds, are now working on the discovery of new herbicides and new herbicide-tolerant plants).

convenient and economical control of weeds, requires a much more cautious assessment that will depend as much upon regulatory agencies as upon any other factor in the sustainable intensive agriculture approach to agricultural runoff as nonpoint source pollution.

V. REGULATORY AGENCIES AND SUSTAINABLE INTENSIVE AGRICULTURE

When it adopted the Clean Water Act, Congress declared the development of technology to be a government goal and policy for the control of pollution.[45] Moreover, Congress mandated compliance with technological standards to control point sources of pollution.[46] Congress further offered an incentive in the Act to adopt innovative technology that significantly reduces point source pollution beyond the requirements of the mandated technological standard for a particular industry.[47]

With respect to nonpoint sources of pollution, in contrast to point sources, Congress has not mandated particular technological standards. Rather, Congress has encouraged the States and the EPA to develop best management practices for the control of nonpoint source pollution, including agricultural nonpoint sources such as agricultural runoff and return flows from irrigated agriculture.[48] While the EPA does not have authority to impose technological standards or best management practices on nonpoint sources of pollution, the EPA does have some leverage to achieve comparable pollution control through the promulgation of total maximum daily load standards (TMDLS) for particular bodies or segments of water.[49] The EPA has this leverage even

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45. 33 U.S.C. § 1251(a)(6) (2000) ("[I]t is the national policy that a major research and demonstration effort be made to develop technology necessary to eliminate the discharge of pollutants into the navigable waters . . . ."); § 1251(a)(7) (stating as a goal that "programs for the control of nonpoint sources of pollution be developed and implemented in an expeditious manner so as to enable the goals of this [Act] to be met through the control of both point and nonpoint sources of pollution").

46. 33 U.S.C. § 1311(a) (declaring the illegality of discharging any pollutant except in compliance with law); § 1311(b) (setting a timetable for achieving the objectives of the Act (clean water) through the mandated use of: best practicable control technology in subsection (b)(1)(A); best available technology economically achievable for toxic pollutants in subsection (b)(2)(A); and best conventional pollutant control technology for conventional pollutants specifically identified after 1977 in subsection (b)(2)(E)).

Congress' choice of technology standards, and the EPA's implementation of those technology standards, has resulted in significant improvement in the control of pollution from point sources. This significant improvement is a fact even though substantial debate exists among academics as to whether technology standards are the best way to control point source pollution. Thus, there is much to praise about technology standards. Wendy E. Wagner, *The Triumph of Technology-Based Standards*, 2000 U. ILL. L. REV. 83.

47. 33 U.S.C. § 1311(k) (innovative technology).

48. 33 U.S.C. §§ 1288(b)(2)(F), (b)(4)(B)-(C), (i), 1329(a)(1)(C), (b)(2)(A).

49. *Id.* § 1313 (water quality standards and implementation plans). Of the many cases litigated under section 1313, the most famous is probably Prosolino v. Marcus, 91 F. Supp. 2d 1337 (N.D. Calif. 2000), *aff'd sub nom.* Prosolino v. Nastri, 291 F.3d 1123 (9th Cir. 2002), *cert. denied*, 539 U.S. 926 (2003) (affirming EPA authority to promulgate TMDLS when states fail to do so in a timely manner and affirming that TMDLS apply to nonpoint sources of pollution). *See*

though it ultimately lacks authority to require implementation or to exercise enforcement related to TMDLS.[50]

By combining the best management practices identified in the planning processes for area-wide waste treatment management[51] and nonpoint source management programs,[52] along with the water quality standards pursued through TMDLS,[53] the EPA and the states have significant legal authority to insist that farmers engage in sustainable agriculture that reduces water pollution from nonpoint sources. More specifically, the EPA and the states should actively encourage and insist that farmers adopt conservation tillage for their agricultural lands. By so doing, the EPA and the states would combine technology-based standards (best management practices of conservation tillage) with quality-based standards (reductions in agricultural runoff to meet TMDLS related to sediments, chemicals, and nutrients) for improvements in the water quality of the lakes, rivers, streams, and wetlands.[54]

Of course, one serious objection to such a solution notes that there is an important gap between "encouraging and insisting" that farmers adopt conservation tillage and "requiring under threat of enforcement actions" that farmers do so. While the gap exists, it may not be particularly troublesome in the context of present-day farm practices. The EPA and the states should recognize that farmers are already voluntarily adopting conservation tillage in light of the rapid adoption rate of transgenic crops. American farmers appear to be adopting transgenic crops more rapidly than any crop technology ever introduced into the United States.[55] In other words, the EPA and the states can encourage and insist that farmers adopt conservation tillage, knowing that farmers will immediately translate that legal compulsion (whether soft or hard)

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generally John Bloomquist, *The Agricultural Perspective: TMDLS in the Context of a Clean and Healthful Environment*, 22 PUB. LAND & RESOURCES L. REV. 19 (2001).

50. The *Prosolino v. Nastri* appellate court discussed the EPA authority over implementation and enforcement, stating, "(i)nstead, the [Garcia River] TMDL expressly recognizes that 'implementation and monitoring' 'are state responsibilities' and notes that, for this reason, the EPA did not include implementation or monitoring plans within the TMDL." Prosolino v. Nastri, 291 F.3d at 1140. Furthermore, the court stated, "(s)tates must implement TMDLS only to the extent that they seek to avoid losing federal grant money; there is no pertinent statutory provision otherwise requiring implementation of § 303 plans or providing for their enforcement." *Id.*

The EPA did seek to gain broader authority over TMDLS with proposed regulations. *See* 65 Fed. Reg. 43,586 (July 13, 2000). However, the EPA later withdrew these proposed TMDL regulations. *See 68.* Fed. Reg. 13,608 (Mar. 19, 2003).

51. 33 U.S.C. § 1288 (2000).

52. *Id.* § 1329.

53. *Id.* § 1313.

54. For a good discussion of behavior-based (technology) regulations and quality-based (measurements of water quality) regulations, *see* Rose, *supra* note 2.

55. CLIVE JAMES, GLOBAL STATUS OF COMMERCIALIZED BIOTECH/GM CROPS: 2006, at 1 (2006) ("Adoption rates for biotech crops during the period 1996 to 2005 are unprecedented and, by recent agricultural industry standards, they are the highest adoption rates for improved crops; for example, significantly higher than the adoption of hybrid maize in its heyday in the mid-west of the USA.").

into the practical reality of growing transgenic crops. As a class, farmers are unlikely to feel terribly aggrieved at encouragement or insistence upon conservation tillage when farmers are already moving to conservation tillage[56] as they adopt transgenic crops.[57] Indeed, if the EPA and the states present conservation tillage as an affirmation of farmer stewardship of water, farmers as a class might well feel the EPA has offered a "win-win" solution that greatly reduces the tensions among the agronomic, environmental, and economic challenges they encounter in their daily lives.

The EPA can recruit one other ally to persuade farmers to adopt conservation tillage: the United States Department of Agriculture (USDA). The USDA could especially shape its conservation program[58] in order to provide financial incentives for farmers to adopt conservation tillage.[59] More precisely, the EPA and the USDA could cooperatively assist farmers who adopt conservation tillage to become eligible for financial payments under either the Environmental Quality Incentives Program (EQIP)[60] or the Conservation Security Program (CSP).[61] The EPA and the USDA could implement an environmental quality incentives program plan that makes the farmer eligible for technical assistance, cost-share payments, or incentive payments.[62] Alternatively and concurrently, the EPA and the USDA could

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56. JORGE FERNANDEZ-CORNEJO & MARGRIET CASWELL, THE FIRST DECADE OF GENETICALLY ENGINEERED CROPS IN THE UNITED STATES 13 (Econ. Research Serv., USDA 2006) ("Differences in the use of no-till between adopters and nonadopters of HT [herbicide-tolerant] soybeans are even more pronounced: 40 percent of acres planted with HT soybeans were under no-till, twice the corresponding share of acreage planted with conventional soybeans."); *id.* at 14 fig. 9.

57. For example, American farmers grew 54.6 million hectares (136.5 million acres) of biotech crops in 2006, a 10% increase in biotech crops compared to previous years. *See* James, *supra* note 55, at 12 (box). Farmers gained $12.9 billion from biotech crops for the 1996-2005 period. *Id.*

58. Congress has created several conservation program that the USDA administers: Conservation Reserve Program (CRP), 16 U.S.C.A. §§ 3831-3835a (West Supp. 2006); Wetlands Reserve Program, 16 U.S.C. §§ 3837-3837f (2000 & Supp. IV 2004); Environmental Easement Program, 16 U.S.C. §§ 3839 to 3839d (2000); Environmental Quality Incentives Program, 16 U.S.C. §§ 3839aa to 3839aa-9 (2000 & Supp. IV 2004); and the Conservation Security Program, 16 U.S.C. §§ 3838 to 3838c (2000 & Supp. IV 2004).

59. The largest conservation program that the USDA operates is the Conservation Reserve Program (CRP) which has more than 36 million acres currently enrolled. Press Release, Farm Service Agency, USDA, Conservation Reserve Program Wetlands Will Further Increase Duck Numbers (Aug. 24, 2006) (on file with author). But the CRP is for privately-owned land that the farmer removes from active farming for the contract period (ten to fifteen years) as agreed upon between the farmer and FSA. FSA Conservation Programs, http://www.fsa.usda.gov/FSA/webapp?area=home&subject=copr&topic=crp (last visited Feb. 24, 2007) (offering a brief overview of the CRP). In other words, by the nature of the program, the CRP is a conservation tillage program into which farmers voluntarily place parts or all of their farm lands.

60. 16 U.S.C. §§ 3839aa to 3838aa-9.

61. *Id.* §§ 3838 to 3838c.

62. *Id.* § 3839aa(3) (stating that a purpose of EQIP is "providing flexible assistance to producers to install and maintain conservation practices that enhance soil, water, related natural resources . . . and wildlife while sustaining production of food and fiber"). Farmers earn these benefits if they implement an "environmental quality incentives program plan . . . that describes

draft a resource management system[63] compatible with conservation tillage, so that farmers could qualify for CSP payments at either the Tier I, Tier II, or Tier III level of participation.[64] If the USDA reinforces the EPA with these financial incentives, and states encourage—if not insist—that farmers adopt conservation tillage, farmers are more likely to reduce nonpoint source pollution on their agricultural lands.

In other words, the EPA, the USDA, and the states face the fortunate coincidence that the most sensible, efficient, and effective best management practice for the control of nonpoint source pollution—conservation tillage—is precisely the tillage technique that farmers are widely and voluntarily adopting because of the high technology utilized in raising transgenic crops. From the perspective of the regulatory agencies and the regulated community, protecting the environment through conservation tillage is entirely compatible with these practices. Such use of high technology agriculture resolves any conflict between the regulatory goals for the environment and the regulated communities' self-interest for a productive, profitable agriculture.

Several other advantages exist to having the EPA, the USDA, and the states encourage and insist upon conservation tillage.

A disadvantage of TMDLS is that its implementation likely puts farmers (nonpoint sources of pollution) at odds with holders of NPDES permits (point sources of pollution).[65] If farmers adopted conservation tillage, they would bear a fairer proportion of the burden for improving water quality. Consequently, it is entirely possible that farmers and holders of NPDES permits would be able to cooperate more effectively to achieve water quality goals for particular types of bodies of water (stream segments, streams, lakes, or wetlands). Voluntary cooperation from those responsible for different sources of pollution, as opposed to antagonistic finger-pointing, bodes well for sensible, efficient, and effective control of water pollution.

TMDLS are expensive to develop and implement.[66] By encouraging and

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conservation and environmental purposes to be achieved through 1 or more practices that are approved by the Secretary [of Agriculture]." *Id.* § 3839aa-4(1).

63. *Id.* § 3838(11) ("The term 'resource management system' means a system of conservation practices and management relating to land or water use that is designed to prevent resource degradation and permit sustained use of land, water, and other natural resources, as defined in accordance with the technical guide of the Natural Resources Conservation Service.").

64. Farmers develop a conservation security plan that describes the conservation practices the farmer will implement, maintain, or improve, and the tier of contract to which the farmer commits. *Id.* § 3838a. The higher the tier to which the farmer commits, the larger the payment the farmer will earn from $20,000 for Tier I, $35,000 for Tier II, and $45,000 for Tier III. *Id.* § 3838c(2)(A).

65. *E.g.*, Ruppert, *supra* note 28, at 8 (TMDLS create a cap above which no pollution will be allowed into a specific area, thereby creating a 'fully closed' trading system . . . . This situation highlights the lack of regulatory authority over NPSs and shifts the entire burden for reduction onto already-regulated PSs. Forcing PSs to pay for NPS reductions to improve water quality implicates the equitable and distribution concerns addressed [later in the article].).

66. Based on data from around the year 2000, now considered outdated, the EPA and the

insisting that farmers adopt conversation tillage, the EPA might be able to reduce these expenses significantly. The adoption of conservation tillage might dissuade the EPA and states from developing and implementing TMDLS for particular streams or stream segments. The EPA and the states could devote the development and implementation costs of TMDLS to scientific monitoring of conservation tillage to see if tillage is achieving water quality improvements.[67] Moreover, TMDLS can lead to litigation between and among those responsible for antagonistic sources of pollution and the regulatory agencies.[68] Such litigation imposes additional costs upon administrative agencies and delays improvements in water quality. By encouraging and insisting that farmers adopt conservation tillage—a practice that manages pollution at voluntary expense to the farmer, or through conservation program payments—one can realistically hope that the need for TMDLS and their resultant litigation will be reduced.[69]

The United States subsidizes its farmers through income support and international trade incentives. However, these programs have become problematic in light of U.S. participation in the Uruguay Round of international trade agreements.[70] Indeed, the United States has already lost a

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State of Virginia estimated that the cost of each TMDLS would be in the range, on average, of $52,000 to $60,000. EPA, OFFICE OF WATER, FACT SHEET NO. 841-F-01-004, THE NATIONAL COSTS OF THE TOTAL MAXIMUM DAILY LOAD PROGRAM (DRAFT REPORT) (Aug. 1, 2001) [hereinafter EPA FACT SHEET], *available at* http://www.epa.gov/owow/tmdl/coststudy/costfact.html; VA. NATURAL RES. LEADERSHIP INST., TOTAL MAXIMUM DAILY LOADS: BALANCING WATER QUALITY AND PUBLIC SAFETY 3 (2005) (on file with author). It is estimated that states and the EPA would develop and implement approximately 36,000 TMDLS. EPA FACT SHEET, *supra*. Moreover, the EPA estimated that the implementation cost would be between $900 million and $3.2 billion per year. *Id.* For Virginia, the total estimated cleanup cost is stated as $12.5 billion. VA. NATURAL RES. LEADERSHIP INST., *supra*. Many in the regulated communities (municipalities and industries) hold the opinion that the costs for development and implementation of TMDLS will be much higher than the EPA estimates. Susan Bruninga, *Water Pollution: Costs of Implementing TMDL Regulation Underestimated in EPA Report, Groups Say*, NAT'L ENV'T DAILY, Dec. 14, 2001, at d7.

67. The EPA estimated the monitoring costs to be $17 million per year. EPA FACT SHEET, *supra* note 66. These monitoring costs are substantially less than the costs of development and implementation for TMDL programs.

68. Mo. Soybean Ass'n v. Mo. Clean Water Comm'n, 102 S.W.3d 10 (Mo. 2003) (agricultural commodity organization challenge to the listing of Missouri and Mississippi Rivers as impaired for purposes of developing TMDLS); City of Arcadia v. EPA, 265 F. Supp. 2d 1142 (N.D. Cal. 2003) (a non-agricultural challenge to the promulgation of a California TMDLS relating to trash in streams). *See generally* Ruppert, *supra* note 28, at 20-27 (Part VI, Economic Analysis: Distributional Concerns and Efficiency).

69. The EPA has not been seeking mandatory obligations for nonpoint source plans from the states. Rather, the EPA has been seeking "reasonable assurance" that nonpoint source pollution will be dealt with expeditiously, practicably, reliably, and effectively. Williams, *supra* note 17, at 82-83. By encouraging and insisting that farmers adopt conservation tillage, the EPA should have reasonable assurance that farmers are meeting the goals and results of TMDLS without incurring the costs and litigation from TMDLS.

70. Stacey Willemsen Person, Note, *International Trade: Pushing United States Agriculture Toward a Greener Future?*, 17 GEO. INT'L ENVTL. L. REV. 307, 320-25 (2005) (explaining U.S. international trade obligations in agriculture and the potential violation of these obligations in the

claim presented to the World Trade Organization by Brazil related to subsidies for cotton.[71] By encouraging and insisting that American farmers adopt conservation tillage and providing conservation payments to those who do so, the United States can create a farm bill that complies with the international trade obligations of the Uruguay Round, while also providing income support to farmers.

Congress could shift funds presently spent on income support and international trade incentives to conservation programs, such as the Environmental Quality Incentives Program and the Conservation Security Program,[72] for conservation tillage. By so doing, Congress would deal simultaneously with budget demands, international trade obligations, and the need to reduce pollution from agricultural land.[73] Moreover, if Congress funded programs for conservation tillage, and if the EPA, the USDA, and the states cooperated on programs promoting conservation tillage as the best management practice to control agricultural nonpoint source pollution, farm organizations would likely be supportive.[74] High technology transgenic crops make this scenario a sensible, efficient, and effective way forward for agriculture, trade, and the environment.

The way forward presented in this article focuses on the adoption of conservation tillage to help farmers deal with agronomic, environmental, and economic challenges. Although the way forward relies heavily upon high technology, especially through transgenic crops, to achieve a sustainable intensive agriculture, organic and conventional farmers, without disadvantage, can adopt conservation tillage as well.[75] They can develop conservation tillage techniques allowing them to handle weed and pest pressures that are acceptable to their production methods. When they do, they too become eligible for conservation payments. Hence, the way forward presented in this article is compatible with organic, conventional, and transgenic agriculture.

2002 Farm Bill).

71. Erin Morrow, *Agri-Environmentalism: A Farm Bill for 2007*, 38 TEX. TECH. L. REV. 345, 364-65 (2006) (explaining the WTO Cotton Panel ruling against the United States in Appellate Body Report, United States – *Subsidies on Upland Cotton*, 201, WT/DS267/AB/R (Mar. 3, 2005)). For a thorough discussion of the WTO Cotton Panel ruling against the United States, *see* Raj Bhala & David Gantz, *WTO Case Review 2005*, 23 ARIZ. J. INT'L & COMP. L. 107, 214-87 (2006).

72. For a brief discussion of EQIP and CSP, see *supra* text accompanying notes 60-61. *See generally*, William Evan, *Green Payments: The Next Generation of U.S. Farm Programs?* 10 DRAKE J. AGRIC. L. 173 (2005).

73. For similar ideas, *see generally* Person, *supra* note 70; Morrow, *supra* note 71.

74. *E.g.*, *ASA Releases 2007 Farm Bill Proposals*, AGWEB.COM, Feb. 12, 2007, http://www.agweb.com/get_article.aspx?src=agnews&pageid=134360 (announcing The American Soybean Association (ASA) support for "a robust Conservation Title that emphasizes conservation on working lands" through expansion of the Conservation Security Program into a national program and additional funding for the Environmental Quality Incentives Program).

75. NAT'L CTR. FOR APPROPRIATE TECH., CONSERVATION TILLAGE & WATER QUALITY, http://www.ncat.org/nutrients/hypoxia/constill.htm (last visited Mar. 6, 2007) (discussing compatibility of conservation tillage with organic farming).

VI. HURDLES FOR SUSTAINABLE INTENSIVE AGRICULTURE

The way forward for sustainable intensive agriculture, found in the recommendations presented in this article, must overcome significant hurdles to become fully-realized in the United States.

In 1986, the Office of Science and Technology Policy issued a Coordinated Framework for Regulation of Biotechnology.[76] In that policy, the agency concluded:

> Biotechnology also includes recently developed and newly emerging genetic manipulation technologies, such as recombinant DNA (rDNA) . . . and cell fusion, that are sometimes referred to as genetic engineering. While the recently developed methods are an extension of traditional manipulations that can produce similar or identical products, they enable more precise genetic modifications, and therefore hold the promise for exciting innovation and new areas of commercial opportunity.[77]

Upon examination of the existing laws available for the regulation of products developed by traditional genetic manipulation techniques, the working group concluded that, for the most part, these laws as currently implemented would address regulatory needs adequately.[78]

In 1987, the National Academy of Science studied biotechnology and its environmental impacts and concluded the following:

> *point 1*: There is no evidence that unique hazards exist either in the use of rDNA techniques or in the movement of genes between unrelated organisms.
>
> *point 2*: The risks associated with the introduction of rDNA-engineered organisms are the same in kind as those associated with the introduction of unmodified organisms and organisms modified by other methods.
>
> *point 3*: Assessment of the risks of introducing rDNA-engineered organisms into the environment should be based on the nature of the organism and the environment into which it is introduced, not on the method by which it was produced.[79]

In 2000, the National Academy of Science concluded, "(t)he present committee found the three general principles to be valid within the scope of issues considered by the 1987 paper, and the present report further clarifies and

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76. Notice for Public Comment, Coordinated Framework for Regulation of Biotechnology, 51 Fed. Reg. 23,302 (June 26, 1986).

77. *Id.*

78. *Id.* at 23,303.

79. NAT'L RESEARCH COUNCIL, GENETICALLY MODIFIED PEST-PROTECTED PLANTS: SCIENCE AND REGULATION 5-6 (2000), *available at* http://boks.nap.edu/html/gmpp/gmpp00.pdf (alterations made and citation omitted) [hereinafter PEST PROTECTED PLANTS]; *see also* NAT'L RESEARCH COUNCIL, FIELD TESTING GENETICALLY MODIFIED ORGANISMS: FRAMEWORK FOR DECISIONS 1-6 (1999) (executive summary reaching substantially the same conclusions as the 1987 NAS study).

expands on these principles."[80] Similarly, in 2002, the National Academy of Science determined,

> (b)ased on a detailed evaluation of the intended and unintended traits produced by the two approaches to crop improvement, the committee finds that the transgenic process presents no new categories of risk compared to conventional methods of crop improvement but that specific traits introduced by both approaches can pose unique risks. There is currently no formal environmental regulation of most conventionally improved crops, so it is clear that the standards being set for transgenic crops are much higher than for their conventional counterpoints . . . .[81]

While it is not possible to assess the risks of any genetically modified plant without empirical examination, the committee found that it should be possible to relatively quickly screen modified plants for potential environmental risk and then conduct detailed tests on only the subset of plants for which preliminary screening indicates potential risk.[82]

In light of these statements from 1986 through 2000, it is apparent that transgenic crops present no unique risks when compared to crops developed through other breeding techniques and should be evaluated just like any other conventional crop. However, the reality is that transgenic crops face much higher standards.[83] Within the past year, these higher standards have led federal district courts to order ever-increasing environmental reviews of transgenic crops.[84]

The higher standards of regulation present a significant hurdle for sustainable intensive agriculture due to increased costs, increased delays, and a reduction in the pace of innovation. As for costs, the estimates for a transgenic crop to traverse the regulatory process have risen from $5 million to $10

80. PEST-PROTECTED PLANTS, *supra* note 79, at 7.

81. NAT'L RESEARCH COUNCIL, ENVIRONMENTAL EFFECTS OF TRANSGENIC PLANTS: THE SCOPE AND ADEQUACY OF REGULATION 5 (2002) (emphasis omitted). (JPS: Formatting/numbering issue to tidy at the end)

82. *Id.*

83. *E.g.*, Plant-Pesticides Subject to the Federal Insecticide, Fungicide, and Rodenticide Act and the Federal Food, Drug, and Cosmetic Act, 59 Fed. Reg. 60,496 (EPA Nov. 23, 1994) (Statement of Policy). Although this EPA proposal was never formally adopted, the EPA does treat plants resistant to pests as plant-incorporated protectants (PIPs) that are subject to significantly greater scrutiny. The EPA decision to adopt this regulatory approach has been criticized by many scientific societies. *E.g.*, COUNCIL FOR AGRIC. SCI. & TECH., ISSUE PAPER NO. 10, THE PROPOSED EPA PLANT PESTICIDE RULE (Oct. 1998) ("The CAST panel [of five members of the National Academy of Sciences] agrees with the position of the EPSS [eleven professional scientific societies], as well as several governmental panels: regulating the inherited traits of plants for pest resistance because these traits were introduced by genetic engineering and not through conventional breeding is scientifically invalid.").

84. *See, e.g.*, Geertson Seed Farms v. Johanns, 439 F. Supp. 2d 1012 (N.D. Cal. 2006) (transgenic alfalfa); Int'l Ctr. For Tech. Assessment v. Johanns, No. 03-00020, 2007 U.S. Dist. LEXIS 7773, at *1 n.1 (D.C. Cir. Feb. 5, 2007) (transgenic creeping bentgrass); Ctr. For Food Safety v. Johanns, 451 F. Supp. 2d 1165 (D. Haw. 2006) (transgenic crops in test plots for pharmaceuticals).

million in the 1990s to $20 million to $30 million in 2003.[85] As for delays, the FDA voluntary consultation process required an average of 6.4 months from 1994–1999, but 13.9 months from 2000-2004. Further, the USDA approval of petitions for non-regulated status increased from an average of 5.9 months required from 1994–1999 to 13.6 months from 2000–2004.[86] As for the pace of innovation, it is widely agreed that the impact of these costs and delays, and the regulatory burdens themselves, serve as tremendous disincentives.[87] The impact is especially burdensome and nigh prohibitive for public research institutions, universities, and small-capital biotechnology firms.[88]

The more fundamental hurdle has to do with attitudes. What is the appropriate attitude towards sustainable intensive agriculture, particularly the high technology of transgenic agriculture? Dr. Norman Borlaug, the Noble Peace Prize winner whose plant-breeding efforts gave rise to the Green Revolution, is probably the most prominent of those who support sustainable intensive agriculture, including transgenic practices. In his closing comments in a speech at Tuskegee University in April 2001, Dr. Borlaug said,

> Thirty-one years ago, in my acceptance speech for the Nobel Peace Prize, I said that the Green Revolution had won a temporary success in man's war against hunger, which if fully implemented, could provide sufficient food for humankind through the end of the 20th century. But I warned that unless the frightening power of human reproduction was curbed, the success of the Green Revolution would

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85. *Compare* David McElroy, *Sustaining Agbiotechnology Through Lean Times*, 21 NATURE BIOTECH. 996, 998 (2003) *with* PEST-PROTECTED PLANTS, *supra* note 79, at 231-32 (which gives estimate for 1990s at $2.8–3.8 million).

86. GREG JAFFE, CTR. FOR SCI. IN THE PUB. INTEREST, WITHERING ON THE VINE: WILL AGRICULTURAL BIOTECH'S PROMISES BEAR FRUIT? 11-14 tbls 1-2 (2005), *available at* http://www.cspinet.org/new/pdf/withering_on_the_vine.pdf. While the author of this article cites as correct the data about the increased time to gain regulatory approval, the author generally disagrees with the analysis in the CSPI report as to the causes and the implications.

Moreover, unless federal appellate courts reverse the federal district court opinions cited *supra* note 84, the time to gain USDA approval for field trials and non-regulated status will rise by an unknown number of additional months.

87. *E.g.*, McElroy, *supra* note 85 *passim*.

88. PEW INITIATIVE ON FOOD & BIOTECH. & ANIMAL & PLANT HEALTH INSPECTION SERV., USDA, IMPACTS OF BIOTECH REG. ON SMALL BUS. AND U. RES.: POSSIBLE BARRIERS AND POTENTIAL SOLUTIONS (2004) (proceedings of a roundtable discussion held in Washington, D.C., June 2-3, 2004).

As an example of the tragic consequences for public research of regulatory costs, delays, and burdens, Golden Rice is a transgenic rice that would provide pro-vitamin A with the routine rice diet so as to save people from vitamin A malnutrition. Dr. Ingo Potrykus, one of the developers of Golden Rice, states, "We have lost 6-7 years in the preparatory adoption to regulatory requirements, which all do not make any sense scientifically." INGO POTRYKUS, THE GOLDEN RICE CASE EXEMPLIFIES THAT GREEN BIOTECHNOLOGY COULD SAVE NUMEROUS LIVES, BUT IS PREVENTED FROM DOING SO BY GMO-REGULATION (manuscript on file with author). One research study on the benefits of Golden Rice estimates that 5500 (low-impact scenario) and 39,700 (high-impact scenario) children in India would survive annually if Golden Rice were available to them. Alexander J. Stein, H.P.S. Sachdev, & Matin Qaim, *Potential Impact and Cost-Effectiveness of Golden Rice*, 24 NAT. BIOTECH. 1200, 1201 (2006).

> only be ephemeral. I now think that the world has the technology—either available or well advanced in the research pipeline—to feed on a sustainable basis a population of 10 billion people. The more pertinent question today is whether farmers and ranchers will be permitted to use it?[89]

By contrast, Mr. Frederick Kirschenmann, affiliated with the Leopold Center for Sustainable Agriculture at Iowa State University, has written,

> Ecologist Kevin McCann suggested that the lessons for conservation implicit in such networks [seal/cod] are obvious . . .
>
> - if we wish to preserve an ecosystem and its component species then we are best to proceed as if each species is sacred; and
> - species removals (that is, extinction) or species additions (that is, invasions) can, and eventually will, invoke major shifts in community structure and dynamics.
>
> The lessons for agriculture may be just as obvious. Introducing technologies that significantly modify, disrupt, or otherwise alter network architecture could severely diminish production agriculture. And altering such networks is something that can be done quite inadvertently since we *do* not, and likely *cannot*, understand the many subtle connections that link organisms together into ecosystems. Once again, it makes much more sense to use technology to increase our understanding of how natural systems function and to harness inherent strengths within those ecosystems than to invent technologies to modify components of the system to achieve single-tactic effects.[90]

The author favors Borlaug's attitude over that of Kirschenmann. Moreover, Dr. Robert Paarlberg has identified four different policy options: promotive, permissive, precautionary, and preventive.[91] The way forward for sustainable intensive agriculture is to adopt a promotive policy. Americans

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89. Norman Borlaug, Feeding the World in the 21st Century: The Role of Agricultural Science and Technology, Speech Given at Tuskegee University (Apr. 2001), *available at* http://www.highyieldconservation.org/articles/feeding_the_world.html. Two other excellent discussions of the value and importance of sustainable intensive agriculture, including biotechnology, are: NINA V. FEDOROFF & NANCY MARIE BROWN, MENDEL IN THE KITCHEN: A SCIENTIST'S VIEW OF GENETICALLY MODIFIED FOODS (2004), and AGRICULTURAL BIOTECHNOLOGY AND THE POOR (G.J. Persley & M.M. Lantin eds., 2000).

90. Frederick Kirschenmann, *Technologies for a Sustainable Future: Therapeutic Intervention Versus Restructuring the System in* BIOTECHNOLOGY: SCIENCE AND SOCIETY AT A CROSSROAD 73, 81 (Allan Eaglesham et al. eds., Nat'l Agric. Biotech. Council Report No. 15, 2003). Two other excellent discussions of the value and importance of restructuring the system are: William E. Rees, *The Eco-Footprint of Agriculture: A Far-from-(Thermodynamic)-Equilibrium Interpretation, in* AGRICULTURAL BIOTECHNOLOGY: FINDING COMMON INTERNATIONAL GOALS 87 (Allan Eaglesham et al. eds., Nat'l Agric. Biotech. Council Report No. 16, 2004), and David M. Lavigne, *Reducing the Agricultural Eco-Footprint: Reflections of a Neo-Darwinian Ecologist, in* AGRICULTURAL BIOTECHNOLOGY: FINDING COMMON INTERNATIONAL GOALS, *supra*, at 119.

91. ROBERT L. PAARLBERG, GOVERNING THE GM CROP REVOLUTION: POLICY CHOICES FOR DEVELOPING COUNTRIES 6 tbl. 1 (Int'l Food Pol'y Research Inst., 2000).

will overcome the attitudinal hurdle to the realization of sustainable intensive agriculture when the United States adopts a promotive policy towards high technology, including (and especially) agricultural biotechnology.[92]

VII. THE GULF OF MEXICO: HYPOXIA

While the initial six parts of this article have discussed sustainable intensive agriculture, high technology, and environmental benefits from a general environmental and legal perspective, Part VII focuses on a specific example—the Gulf of Mexico—to more precisely identify the way forward.

"Hypoxia is the condition in which dissolved oxygen is below the level necessary to sustain most animal life—generally defined by dissolved oxygen levels below 2 mg/l (or ppm)."[93] As mapped in 2005, the hypoxic zone (also called the "dead zone") off the coast of Louisiana in the northern Gulf of Mexico was 4564 square miles, just smaller than the state of Connecticut.[94] Since mapping began in 1985, the average size of the Gulf of Mexico hypoxic zone has been 4800 square miles.[95]

The proximate causes of the hypoxic zone in the Gulf of Mexico are eutrophication and stratification.[96] Eutrophication is the presence of excessive organic matter, fueled by excessive nutrients, in water (nitrogen in salt waters and phosphorus in fresh waters). The presence of excessive nutrients particularly gives rise to algal blooms that in growth and decomposition exhaust the dissolved oxygen in the water.[97] Without dissolved oxygen in the water, marine animal life cannot survive.

The National Science and Technology Council's Committee on

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92. For a compatible (though a permissive, rather than a promotive) attitude toward agricultural biotechnology, *see* DON S. DOERING, DESIGNING GENES: AIMING FOR SAFETY AND SUSTAINABILITY IN U.S. AGRICULTURE AND BIOTECHNOLOGY (World Resources Inst. 2004).

93. COMM. ON ENVT. & NATURAL RESOURCES, NAT'L SCI. & TECH. COUNCIL, INTEGRATED ASSESSMENT OF HYPOXIA IN THE NORTHERN GULF OF MEXICO 7 (2000).

94. Press Release, LUMCOM News, Mapping of Dead Zone Completed (July 29, 2005), *available at* http://www.lumcon.edu/Information/news/default.asp?XMLFilename=20050801 RabalaisHypoxia.xml.

95. *Id.* EPA figures are slightly larger for the Gulf of Mexico hypoxic zone; the EPA states that the Gulf of Mexico hypoxic zone for a five-year average (from 2000 through 2004) was 14,000 square kilometers (5405 square miles). *See* EPA, MISSISSIPPI RIVER BASIN & GULF OF MEXICO HYPOXIA FACT SHEET, http://www.epa.gov/msbasin/taskforce/pdf/05factsheetupdate.pdf (last visited Apr. 8, 2007). The EPA has a goal of reducing the hypoxic zone to 5000 square kilometers (1930 square miles) by 2015. EPA, MISSISSIPPI RIVER BASIS & GULF OF MEXICO HYPOXIA ACTION PLAN, http://www.epa.gov/msbasin/taskforce/actionplan.htm (last visited Feb. 25, 2007). This is a reduction from an area somewhat larger than Connecticut to an area just smaller than Delaware.

96. Stratification is the layering of saltwater into horizontal zones and depends primarily on temperature differences in the water and the lack of mixing of layers of water due to insufficient winds to generate the mixing. COMM. ON ENVT. & NATURAL RESOURCES, *supra* note 93, at 11, 12. Stratification will not be discussed further in this article.

97. *Id.* at 11-12.

Environment and Natural Resources (NSTC-CERN)[98] describes the most significant source of the excessive nutrients in the northern Gulf of Mexico as follows: "Only increased nitrogen loads from the Mississippi-Atchafalaya River system can account for the magnitude of the hypoxic zone and its increase over time. While other factors may contribute to the growth, dynamics, and decline of the hypoxic zone, none of them alone can explain its overall size and persistence."[99] NSTC-CERN lists agricultural nonpoint sources as providing 74% of nitrate and 65% of total nitrogen sources within the Mississippi-Atchafalya River basin. By contrast, NSTC-CERN assigns other nonpoint sources 16% of nitrate and 24% of total nitrogen, and municipal and industrial point sources 9% of nitrate and 11% of total nitrogen.[100] Based upon this data, it is clear that agricultural nonpoint source pollution is easily the largest source of the nitrogen overloading in the hypoxic zone of the Gulf of Mexico.

In 1998, Congress passed the Harmful Algal Bloom and Hypoxia Research and Control Act,[101] mandating that a governmental interagency task force devise an action plan for the hypoxic zone in the Gulf.[102] In accordance with that mandate, the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force determined that a 40% reduction in total nitrogen from the Mississippi River basin (MRB) would return the Gulf to its average nitrogen loads during the 1955-1970 period.[103] Furthermore, the Task Force also decided that a 20-30% reduction in nutrient loads from the MRB would increase the dissolved oxygen for the bottom water in the hypoxic zone between 15% to 50%.[104] In light of the data, the Task Force aimed for a 30% reduction in nitrogen discharges to the Gulf from the various sub-basins within the MRB.[105] More concretely, the Task Force proposed eleven implementing actions, including the voluntary implementation of best management practices by agricultural producers and other landowners.[106]

NSTC-CERN lists nine agronomic management changes that farmers within the Mississippi-Atchafalaya River Basin could adopt to control nitrogen discharges into the waters of the basin. One such change is "switching from conventional to ridge-tilling or other reduced-tillage practices."[107] Similarly,

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98. The National Science and Technology Council ("NSTC") came into existence through an Executive Order in November 1993. *Id.* at frontpage. NSTC has five committees of which the Committee on Environment and Natural Resources (CERN) is one. *Id.*

99. *Id.* at 13.

100. *Id.* at 23.

101. Title VI, Pub. L. No. 105-383, §§ 601-606, 112 Stat. 3447, 3447-50 (Nov. 13, 1998).

102. *Id.* § 604(a),(b) (assessment report by May 30, 1999 and action plan by March 30, 2000 respectively).

103. MISS. RIVER/GULF OF MEX. WATERSHED NUTRIENT TASK FORCE, ACTION PLAN FOR REDUCING, MITIGATING, AND CONTROLLING HYPOXIA IN THE NORTHERN GULF OF MEXICO 8 (2001) [hereinafter MR/GOM TASK FORCE].

104. *Id.* (sufficient dissolved oxygen to sustain much animal life).

105. *Id.* at 30.

106. *Id.* at 13-14.

107. COMM. ON ENVT. & NATURAL RESOURCES, *supra* note 93, at 38. The other eight

the MR/GoM Task Force listed as a programmatic indicator, for monitoring control of nonpoint source pollution, the tracking of "[a]cres in conservation tillage" and "[p]roducer/acres enrolled in CRP [Conservation Reserve Program] and WRP [Wetlands Reserve Program]."[108]

As previously discussed, the CTIC Conservation Tillage and Plant Biotechnology study of 2002 found that adoption of conservation tillage, particularly no-till, would reduce erosion, water runoff, chemical-fertilizer-manure loads, and sedimentation in streams, rivers, and lakes by very large percentages.[109] Both the NSCT-CERN and the MR/GoM Task Force specifically listed conservation tillage and farmland enrollment in conservation programs as desirable agronomic management changes for diminishing the Gulf's hypoxic zone.[110] Hence, the use of sustainable intensive agriculture that employs high technology—the way forward proposed in this article—dovetails comfortably with the action plans proposed for addressing this hypoxic zone. Consequently, if the EPA, the USDA, and the states encouraged and insisted that American farmers adopt conservation tillage, significant progress could be made towards the goal of the Mississippi River Basin Task Force, reducing nitrogen discharges into the Gulf by 30%.

Conservation tillage by itself is not likely to be a "magic" management practice that solves the Gulf's hypoxic-zone problems. While studies, like the CTIC study cited earlier, have shown significant reductions in erosion, water runoff, chemical-fertilizer-manure loads, and sedimentation, studies also show that conservation tillage is less effective in controlling nitrogen and phosphorus when these nutrients have become dissolved.[111] As a consequence,

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include:

- applying nitrogen fertilizer and manure at not more than agronomically recommended rates;
- switching from fall to spring application of fertilizer;
- improving management of livestock manures, whether stored or applied to the land;
- changing from row-cropping to perennial-cropping systems;
- planting cover crops for fall and winter nutrient absorption; . . .
- ensuring that the lateral spacing of subsurface tile drainage is not less than 15 meters;
- controlling water tables to promote denitrification within the soil column; and
- routing soil drainage effluent through wetlands, grass buffer strips, or riparian forest buffers.

Id. at 38-39.

108. MR/GOM TASK FORCE, *supra* note 103, at 28. The author suggests that today the Task Force would have expanded their programmatic indicators to include enrollment in the Environmental Quality Incentives Program and the Conservation Security Program, discussed at *supra* notes 58-64 and accompanying text.

109. *See supra* notes 29-34 and accompanying text.

110. *See supra* notes 106-08 and accompanying text.

111. GEORGE F. CZAPAR ET AL., EFFECTS OF EROSION CONTROL PRACTICES ON NUTRIENTS LOSSES, *available at* http://www.epa.gov/msbasin/taskforce/2006symposia/9ErosionCzapar.pdf (last visited Arp. 8, 2007). The authors discuss the effectiveness of controlling nitrogen and phosphorus through conservation tillage. *Id.* at 118-21; *see also*

the EPA rates conservation tillage as having a minor expected impact on reduction of nitrogen.[112]

Yet high technology also offers the promise of crops with increased ability to utilize the available nitrogen and phosphorus, so that less nitrogen and phosphorus remains in the soil to become dissolved.[113] If plants better utilized the available nutrients, farmers might well apply the fertilizer and manures at lesser rates that better reflect the plant utilization of the nutrients. The EPA calculates that a reduction in nitrogen fertilizer usage would have an intermediate impact in reducing nitrogen discharges to the Gulf.[114]

Conservation tillage, and the use of plants that better utilize available soil nutrients, provide reasons for optimism in treating the Gulf of Mexico's hypoxic zone. However, turning these agronomic practices into reality requires that the EPA, the USDA, and the states promote the use of high technology, sustainable intensive agriculture, especially transgenic agriculture. Moreover, Americans cannot expect that measurable water quality improvements in the Mississippi River basin and the Gulf will be seen immediately, or even for several years.[115] Reduction of the size of the hypoxic zone will be a long-term project. However, American farmers can begin the transition to improved water quality and a smaller Gulf hypoxic-zone if the EPA, the USDA, and the states encourage and insist upon conservation tillage now and upon the adoption of forthcoming high technologies. The EPA, the USDA and the state must keep focused—now and in the future—on allowing farmers to use the best available technologies and the best management practices for addressing water quality in the Mississippi River basin and the Gulf of Mexico.

VIII. CONCLUSION

Sustainable intensive agriculture using high technology already provides significant environmental benefits. It promises additional benefits in the years to come as agriculture faces foreseeable agronomic, environmental, and economic challenges. While the precise details of what will be the best available control technologies and the best management practices cannot yet be known, the way forward can be envisioned. Sustainable intensive agriculture

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CHARLES WORTMANN ET AL., AGRICULTURAL PHOSPHORUS MANAGEMENT AND WATER QUALITY PROTECTION IN THE MIDWEST (2005).

112. Attachment I at 10, Transcript of the Twelfth Meeting of the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force (Dec. 1, 2005) [hereinafter Attachment I] (PowerPoint slide titled "Conclusions," from presentation by Rick Greene) (on file with author).

113. *See supra* notes 19-20 and accompanying text.

114. Attachment I, *supra* note 112.

115. COMM. ON ENVT. & NATURAL RESOURCES, *supra* note 93, at 47 ("Further, it is clear that environmental responses to management in the MARB [Mississippi-Atchafalya River Basin] likely will be slow, possibly requiring decades of data to demonstrate statistically that remedial actions have helped the recovery of oxygen concentrations in the Gulf and have improved water quality in the Basin.").

using high technology offers sensible, efficient, and effective solutions for agriculture's agronomic, environmental, and economic challenges. American farmers have proven themselves open to this sustainable future. By choosing to promote sustainable intensive agriculture, governmental officials, regulatory agencies, and society as a whole will allow farmers to enhance the landscapes and waterscapes of America.