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Resource, Environment and Energy Considerations for Maine Food Security in 2050 and Beyond

by Amanda Beal

John M. Jemison Jr.

How will we feed the world in 2050? This popular and perplexing question is being asked by policy-makers, agronomists, academics, economists, and scientists from many disciplines around the world today. As the global population continues to grow, there will be increasing pressure on the collective resources we currently depend on to produce food. Fossil fuel is one of the most talked-about food-production inputs with potential to greatly affect food prices and availability. Other critical resources, however, such as viable soil, essential nutrients, and water, are also of great concern. In the case of some inputs, scientists warn that we are now traveling on the downside of the supply curve for multiple resources on which we are heavily reliant

for conventional food production. Some have likely “peaked” in their availability, or at least easy accessibility, already. If we are to take these projections into account as we look for answers to the “2050” question, certain methods we have come to rely on for food production may not be viable in the future.

Answers and opinions differ about this complex question of feeding the world. Unfortunately, many of the proposed solutions receiving the most research dollars rely on increasing food production and distribution using means that either expedite the depletion of limited resources or degrade other resources critical to ensuring long-term food production. Some proposed solutions to the 2050 paradox are also highly reliant on the hope that new technologies can be developed in time to head off a food-supply crisis. Yet, for a growing global population with increasing energy demands, combined with current energy volatility, it is unclear how—or whether—technology-dependent solutions will be economically accessible and practical for farmers and fishermen in the future.

It is also important to recognize that it may not be forward-thinking enough to resolve how to feed the world in 2050 if it means we are not also equipped to feed the world 50 or even 250 years beyond that. If we are to meet this longer-reaching goal, we should challenge how “sustainable” our current practices are in the face of diminishing resources; further, we must strategize how to create food-production systems that conserve and recycle key resources as much as possible and are highly resilient and adaptable in the face of ongoing ecosystem changes and human population needs.

It is difficult for many people to understand that there could be a future food-security crisis. And perhaps even more difficult to imagine is how it would affect us here in Maine, a state that is currently resource rich and located in the wealthiest nation on the planet. The answer may have everything to do with how we, in Maine, prioritize our use of resources and the investments we make to develop our local food-production and -distribution capabilities over the next few decades.

What we cannot rely on in the future is the ongoing availability of abundantly cheap food. Today’s food system is dependent on intensive inputs, some of which may become too costly to extract or produce. It is also the source of many undesirable externalities that

affect watershed quality, ecosystem balance, and human health. The system is vulnerable to numerous global events, including natural disasters and economic and political events such as price spikes and export bans. For these reasons and others that will be described in greater detail in the remainder of this paper, it is in our best interest for Maine to consider its capacity to feed itself and also to contribute to a larger regional foodshed in 2050 and beyond.

In the following sections of this paper, we look more closely at the resource- and energy-related factors that must be considered, both globally and locally, as we think about the best course forward to ensure that we are able to make decisions about how to best use our own resources. In the conclusion, we emphasize the existing assets and opportunities for building a successful and resilient food system that can assure long-term food security for Maine's people.

RESOURCES

Although often talked about as isolated components, the food system relies on a web of related resource availability. Many incomplete or misleading arguments are crafted around omissions or distortions of the inter-related nature of these relationships. However, to move toward more sustainable food-production systems, we must look at the interconnection of resource issues.

We believe we must protect the wealth of already-existing "natural capital," keeping in mind both resources with quantifiable value that we rely on for economic development and income generation and resources that provide valuable ecosystem services via natural cycles such as nutrient recycling, water filtration, and erosion control. Currently, it looks as though we are on track to deplete certain types of natural capital whose depletion we could conceivably adapt to, such as fossil fuel. There are others, such as fresh water, without which it would be extremely difficult to exist. The importance of considering the value of natural capital is often overlooked in the focus on financial, physical, human, and social capital elements of the economic nexus. Although determining valuation of natural capital is a complicated process, understanding the costs of failing to protect against the degradation of these resources is of growing interest to industry and environmentalists. In global

terms, it is estimated that, overall, "the economic cost of biodiversity loss and ecosystem degradation" lies somewhere between "US\$2 and US\$4.5 trillion (3.3 – 7.5% of global GDP)" (PricewaterhouseCoopers 2010: 2). Understanding the value of natural capital will become increasingly important as key resources are depleted. Following is a brief snapshot of issues and projections pertaining to specific key resources on which we are currently reliant for food production.

Energy

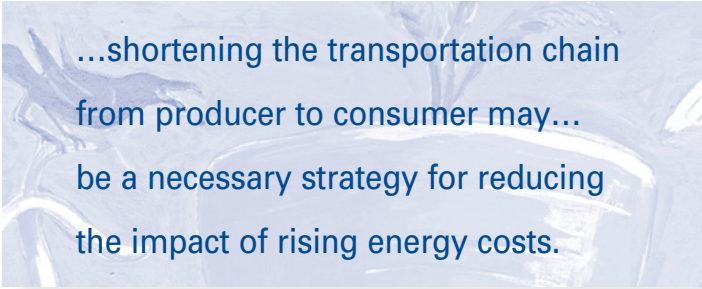
Ongoing discussion about peak oil has been driving interest in alternative-energy development to a certain degree.

However, recent reports indicate that this is an area of research and development that will need to accelerate to keep pace with overall energy demands, which are steadily increasing as some developing nations, such as China, acquire more wealth and model the energy-consumption patterns of developed nations. World oil demand is projected to grow 50 percent by 2025 (Hirsch 2005). Remaining oil reserves may be markedly lower than was once thought, further increasing the urgency to find ways to generate energy through alternative sources and to pursue concurrent strategies that could conserve energy or reduce energy usage. Researchers report that oil reserves may have been exaggerated by as much as one-third by OPEC, accused of over-reporting reserve levels since the 1980s as a strategy for securing global market share; demand for oil could begin to outpace supply by 2015 (Owen Inderwildi and Kinga 2010). The conclusions concur with Hirsch's notion that the "era of plentiful, low-cost petroleum is approaching an end" (Hirsch 2005: 1). Domestically, the U.S. Geological Survey (2010) has found that the estimated volume of undiscovered oil in

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the Alaskan National Petroleum Reserve is as much as 90 percent lower than previously released estimates.

The report by Hirsch (2005: 7–8) points out that “motor vehicles, aircraft, trains, and ships simply have no ready alternative to liquid fuels,” and that the widespread availability of alternative and renewable energy sources for “use in transportation is at best many decades in the future.” This has implications for the cost of producing and moving food around the globe in the way to which we have become accustomed. Although some researchers argue that building locally based food systems is not a cost-effective strategy for feeding people, based on these energy predictions, it is probably wise to entertain the idea that this may not always be the case, and in fact, shortening the transportation chain from producer to consumer may prove to be a necessary strategy for reducing the impact of rising energy costs.



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In the U.S., the majority of our energy comes from fossil fuels. Estimates suggest that 19 percent of our total fossil use is dedicated to food-production activities, including agricultural production and post-farm activities such as processing, packaging, distribution, and storage, corresponding to about 2,000 liters of oil per person per year (Pimentel et al. 2008). Although not the largest user of energy in the U.S., agriculture and food-production activities are areas of interest for promoting reduced use of fossil fuels and the use of renewable energy because of the certain impact increased energy prices would have on food prices.

Fishing boats today operate primarily on diesel fuel, with some gasoline and kerosene use, which ultimately accounts for about 1.2 percent of annual global oil consumption (Tyedmers, Watson and Pauly 2005). Although this translates to a relatively small percentage

of overall U.S. energy use, the increasing growth of scale and mechanization in the fishing industry leaves it quite vulnerable to rising energy costs. On the topic of scale, it has been estimated that, “small-scale fisheries employ 25 times more people and use one-quarter the fuel to catch roughly the same amount of edible fish” (Jacquet and Pauly 2008: 832). This, along with numerous other concerns related to the sustainability of this industry, is why many fisheries advocates have been calling for policies that are more supportive of small-scale, independent-operator fishing vessels and that protect the industry from further consolidation.

There is another important relationship between overall energy use and the world’s fisheries. The oceans absorb an estimated 25 percent of the CO₂ emitted from human activities annually, and as we use more energy, we produce more CO₂ (Hoegh-Guldberg et al. 2007). Increasing ocean acidity affects photosynthetic processes, dissolves coral reef structures, and inhibits the ability for shellfish to effectively access calcium carbonate to build their shells. This could potentially lead to “disturbances in the populations of shelled organisms...leading to ecosystem-wide changes” (Chai et. al 2009: 19).

Nutrients and Energy

Synthetic nitrogen is the fertilizer nutrient used most in conventional agriculture. Its availability and relationship to energy is a growing concern. More than half the nitrogen ever used as a synthetic fertilizer has been used since 1985 (McIntyre et al. 2009). And although nitrogen itself is abundant, converting it to a plant-available fertilizer form (starting with anhydrous ammonia) requires natural gas as an input in the highly energy-intensive Haber-Bosch process. The link between rising energy costs and the mechanisms we rely on to produce nitrogen fertilizer have resulted in the theory that we may be moving toward “peak nitrogen.” As Pimental et al. (2008: 462) note, “As fossil fuels become scarce, costs for the production of synthetic fertilizers will rise. This economic pressure will force farmers to seek alternative sources to meet their nitrogen, phosphorus, and potassium demands.” Fortunately, legume cover crops, the pre-World War II standby to supply nitrogen to grass crops, remain a viable alternative. This would require considerably

more land to be in production, but legumes grown as cover crops are also beneficial in terms of carbon sequestration, a goal of greenhouse-gas mitigation (Wang, Li and Alva 2010).

Intensive corn production continues to be a serious threat to water resources and coastal fisheries in many areas of the U.S., with 25 to 30 percent of the nitrogen applied at economic optimum rates leached to ground water (Jemison and Fox 1994; Toth and Fox 1998). Since ground water feeds most surface water supplies, most of the leached nitrogen ends up in coastal systems. This disrupts nutrient balance, leading to algal blooms and die-offs; bacteria that decompose the algae deplete oxygen, leaving levels too low to support fisheries in the hypoxic zones. The relationship indicates that we must adopt more sustainable fertility practices. As Maine looks to increase production of local foods, we should strive to implement more efficient food- and livestock-production systems to protect fisheries.

Phosphorus is another essential and abundantly applied nutrient in agriculture. World phosphorus use in agriculture tripled from 1960 to 1990 and continues to rise (McIntyre et al. 2009). In fact, peak phosphorus may be even closer than peak nitrogen. It is estimated that we will have depleted sources of this nutrient readily available through mining activities by 2033, after which time phosphorus is likely to become increasingly more expensive to obtain (Soil Association 2010).

Poorly timed or excess applications of phosphorus can result in nutrient loss to surface waters, contribute to eutrophication, and degrade water resources. Phosphorus added to livestock feed provides another pathway for this nutrient to be excreted and eventually leach into the watershed. Efforts to reduce the amount of phosphorus added to feed can help reduce this effect, and maintaining proper storage and application of animal wastes are key factors in mitigating nitrogen and phosphorus loss also. Approximately 90 percent of phosphorus eventually excreted by humans is never returned to the soil, suggesting the need for greater investment into systems that can safely recapture phosphorus from sewage treatment systems (Soil Association 2010).

Pesticides and Energy

Pesticide production represents another use of energy in agriculture, as synthetic pesticides used in

conventional farming are petroleum-based materials. To make one pound of the active ingredients in synthetic pesticides, it takes the equivalent of a gallon of diesel (Duffy 2001). Utilizing techniques to reduce pesticide use, such as Integrated Pest Management (IPM), and adopting alternative weed and pest management practices are part of the collection of forward-thinking strategies we will need in order to assure economically feasible and abundant food production in the future. Methods include using novel cropping sequences (e.g., double cropping wheat and short season corn to control weeds), increasing on-farm biodiversity, improving soil health and incorporating insect management methods such as interplanting crops that repels target pests and/or planting a diversion crops that attracts pests away from the crop of interest.

Water

According to the Food and Agriculture Organization Water Development and Management Unit, agriculture is responsible for 70 percent of global water use (www.fao.org). Water is one of the main limiting factors for feeding a growing population (Rosegrant, Cai and Cline 2002). By 2030, demand for water is projected to outstrip supply by 40 percent, and an estimated half the world's population is likely to live in areas of high water stress (Environmental Resources Management 2010). In some areas the rate of water use has already resulted in depleted groundwater stores and drained lakes and riverbeds, leading to conflicts over water rights, and in some cases, commodification and privatization of water access. This can ultimately lead to decreased opportunities for localized food production. In some coastal areas, excessive water drawdown has also caused salinization, as sea water encroaches into aquifers, further reducing available freshwater supply. Increasing areas of irrigation for agricultural purposes is one of the strategies proposed for increasing world food production, which clearly may not be sustainable and may actually threaten the long-term supply of water available for other essential purposes.

Water "hot-spots" in the U.S. have already been identified, mostly in the West where agriculture is highly dependent on irrigation for crop success. This area is also one that is most likely to experience reduced water availability due to population growth, increased

competition for water use, and effects of climate change (resulting in predicted shifts in precipitation and evapotranspiration) (NRDC 2010). Maine and other New England states have a lower overall risk of water shortage than other parts of the U.S., suggesting that agriculture may be less directly affected by water supply issues. Water quality, however, is of great importance. Various sources of pollution are continuously compromising freshwater sources and marine environments, and consequently affected the health of our marine and freshwater fisheries (Sumpter 2009). Human use of chemicals has a great impact on water quality, stemming from agricultural inputs such as nitrates, phosphorus and pesticides, along with chemicals used in aquaculture, discharges from other types of industry, pharmaceutical use in people and animals, stormwater runoff and overflows from sewage-treatment facilities. A recently published multi-state needs assessment estimates that the Gulf of Maine would require \$3 billion and a five-year intensive clean-up to restore water quality and overall habitat (Taylor 2010).

Land

Currently, more than half of the earth's land surface is intensively used for agricultural purposes, including cultivation, grazing, plantation forestry, and aquaculture; since 1950, it is estimated that a third of the arable land used for agriculture has been subjected to moderate to severe degradation (McIntyre et al. 2009). Five to seven million hectares of productive land is lost each year due to degradation (of physical, chemical, and biological origin) (FAO 1996). The estimated cost of global soil erosion related to agriculture is \$400 billion per year, and in the U.S., \$44 billion per year is attributed to erosion costs (Eswaran, Lal and Reich 2001).

Projections for anticipated future global land use change, which predicts an expansion of 400 million hectares, is also expected to affect land use-related air emissions and overall air quality (McIntyre et al. 2009). In the conversion of land, there are rising concerns that acquisition will be at the cost of some of the world's most economically disadvantaged. Rising food costs in 2007 and 2008 have resulted in an acceleration of "land grabbing" as more affluent countries have been making deals with landowners or government representatives to purchase large tracts of land for their own

present or future food needs. Along with significant social-justice implications, there is also the question of who will have access to water "downstream." Rarely are any legal protections available to abutting landowners, leaving them without recourse if the new landholders diverts water for their own use.

As global interest in acquiring arable land rises, here in the U.S. we are allowing viable farmland to slip away. The 2007 Natural Resources Inventory reported that between 2002 and 2007, 4,080,300 acres of active agricultural land (crop, pasture, range, and land formerly enrolled in the Conservation Reserve Program) were converted to developed uses; there was a 13,773,400-acre decline in prime farmland between 1982 and 2007 nationwide (USDA 2009). In Maine, from 1982 to 2007 cropland showed a nearly 30 percent decline while pastureland was reduced by 50 percent.

OTHER CONSIDERATIONS

Waste

Each year, as much as 40 percent of total food produced is lost to waste. In developing countries, waste takes place largely on farms or during transport or processing, primarily due to insufficient infrastructure to get food to market. However, in developed countries most food waste is produced at the foodservice, retail, or home stage of storage or preparation (Godfray et al. 2010). In considering factors leading to food waste, it is important to recognize that all of the inputs, limited and unlimited, used to produce this food are also wasted, which in the case of energy can be quantified: "The energy embedded in wasted food represents approximately 2% of annual energy consumption in the United States, which is substantial when compared to other energy conservation and production proposals" (Cuellar and Webber 2010: 6464). In addition, estimates suggest that more than one-quarter of all freshwater use is accounted for by wasted food (Hall et al. 2009). This also raises the question of how much additional food we will really need to produce by 2050, and how much of our attention should be focused on where it is produced or how it is distributed, in addition to reducing consumer food waste in developed countries.

Climate Change and Biodiversity

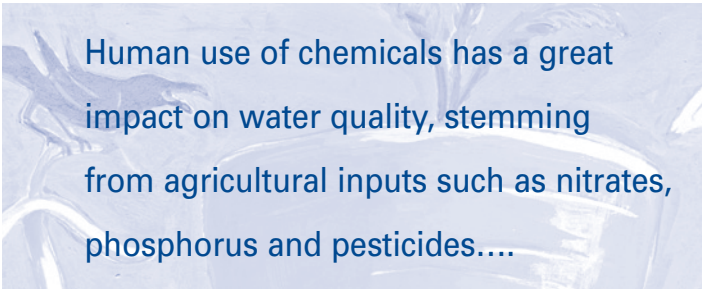
The scientific consensus on the reality of climate change is beyond debate, leaving one of the biggest questions now, “how fast should we seek to move from the status quo to a sustainable food system? The challenges of climate change and competition for water, fossil fuels, and other resources suggest that a rapid transition is essential” (Godfray et al. 2010: 814). Agriculture is a contributor to climate change. There are also a myriad of ways in which climate change may affect food production: shifting temperatures and seasonal cycles; changing hardiness zones, which could bring new agricultural opportunities along with challenges, as disease and pest patterns are altered; increasing weather events and less predictable rainfall patterns; rising water temperatures resulting in transitioning of resident aquatic species; and numerous other effects. At the same time, agriculture can play a role in mitigating climate change by using methods that increase carbon sequestration (cover cropping), absorbing greenhouse gases and reducing energy consumption.

A comprehensive 2009 University of Maine report details the potential impacts of climate change on the state’s ecosystem and economy. A crucial point is that, “...more than any other state, our social and economic well-being depends on the health and productivity of Maine’s forests, fields, lakes, rivers, and the marine waters of the Gulf of Maine. The diversity of these natural systems and the plants and animals within them result from the wide range of geologic, topographic, and climatic conditions present in the state” (Jacobson et al. 2009: 3).

To protect against the vagaries of weather, we should work to protect and/or enhance the biodiversity of plant and animal species used in food production. Although current, predominant agricultural methods rely on the widespread use of monoculture crops, we will ultimately have more options for adaptation to a changing ecosystem if we make maintaining a broader genetic profile in seed and animal stocks a priority. According to an essay in *The Economist* from October 16, 2008, “Biodiversity underpins ecosystem services. Bees can’t pollinate, nor can trees store carbon, if they have all died....Diverse systems are better at capturing carbon, storing water and preserving fisheries.”

Other Natural Shocks

The design of our food system, where we produce vast amounts of food (often the same crop or animal) in concentrated areas, provides multiple levels of vulnerability to various natural events. The past several years have seen major natural disasters in different parts of the world—earthquakes, tsunamis, floods, hurricanes, droughts—all of which have affected the food security of the regions where the shock occurred and in some cases produced a ripple effect as vulnerable countries banned exports to assure their own food supply. If any one of these events had happened—or does happen—in a region that the U.S. depends on for food production or inputs, it is quite possible that we would be affected by a notable disruption to our food system.



Human use of chemicals has a great impact on water quality, stemming from agricultural inputs such as nitrates, phosphorus and pesticides....

Consider this domestic scenario. California is home to five of the 10 top-producing agricultural counties in the U.S. (USDA NASS 2009). The area already experiences volatility in its water supply in a region highly dependent on irrigation. In addition, the San Andreas Fault passes through two of the country’s five largest agricultural counties in California (Kern and Monterey) and through counties directly adjacent to the other three (Fresno, Merced, and Tulare) (USDA ERS 2010). Simulation-based predictions suggest there is up to a 60 percent chance that a moderately intense earthquake could occur on the San Andreas Fault line within the next 25 years, which could significantly disrupt food distribution networks (Rundle et al. 2005; USGS 2008).

Currently, it is estimated that Maine citizens acquire 80 percent of their calories from food imported from outside of the state, making the state especially vulnerable to disasters elsewhere (Maine Department

Transgenic Crops and Our Vision of a Sustainable Food System

As we address the “2050 food problem,” many people are placing their money on transgenic (genetically engineered) crops as the solution. Some supporters argue that we need all options on the table; other times transgenic crops are promoted as the main solution to the problem. Those voicing opposition or questioning the crops are viewed as anti-science or luddites.

For technology to help sustain the food system, it should meet qualities mentioned previously: increase yields, reduce petroleum use, control pests effectively and safely, be safe to consume, and be profitable for farmers. Current transgenic crops have met few of these criteria. To see if a crop technology has a strong influence on yield, governmental statistics on crop yields can be analyzed. Soybean yields from 1979 to 2009 are presented in Figure 1. No one questions that yields have improved over time due to advancements in conventional plant breeding. Using National Agricultural Statistics Service data, we present 30 years of soybean yields. The data show a steady linear increase over time; however, there is no change in slope after Roundup-Ready soybeans were released in 1996. Given the rapid adoption of these soybeans, one should expect an increased slope if the technology were increasing yield. A similar analysis was done with transgenic corn and yielded similar results.

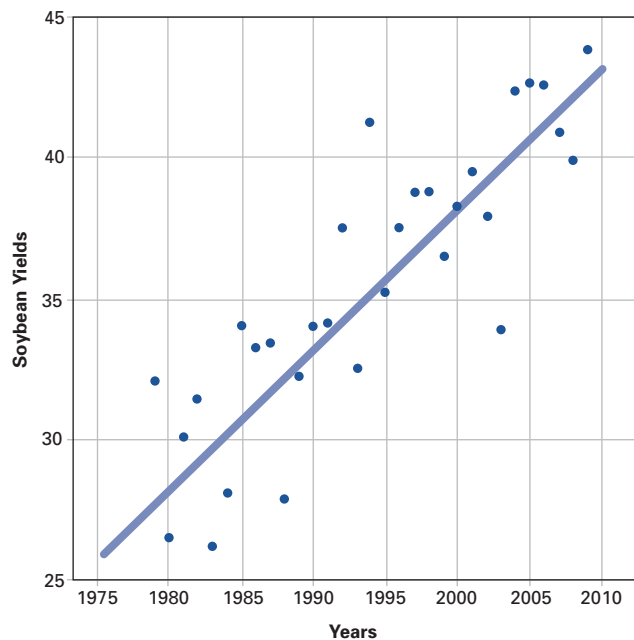
Research has been conducted in Maine to evaluate Bt corn (Jemison and Reberg-Horton 2010). In seven experiments conducted over four years, Bt corn reduced insect feeding, but yield and forage quality were not influenced. In research conducted in Pennsylvania, Bt corn benefited growers about 20 percent of the time (Dillehay et al. 2004). You may wonder then why the high adoption rate? Growers have said that they buy transgenic seed to simplify crop management, and less so for profitability (Mauro and McLaughlin 2008). A problem with simplifying management is that growers have overused Roundup on herbicide-tolerant crops and this has led to weed resistance in over 21 species (www.weedscience.org). The industry’s answer now is to make crops resistant to more than one herbicide. This can only lead to greater pesticide use. So, while the insect-tolerant corn and cotton have decreased insecticide use, herbicide use has greatly increased. Based on these reasons and the amount of herbicides used in the U.S., we support Charles

Benbrook’s assertion that transgenic crops have increased pesticide use, not decreased it (Benbrook 2009).

New drought-tolerant and nitrogen-efficient transgenic crops are more complex. Many scientists and policy leaders want to reduce barriers to release these crops. However, given the complex genetic transformations that effect drought tolerance or nitrogen efficiency, more testing should be required—not less.

Transgenic crops have been profitable to the companies that produce them and have eased crop management. While crop yield and quality continue to improve, there is little evidence that the gains have been due to herbicide- or insect-resistance technologies. Clearly, transgenic crops will remain a part of our food system. But instead of relying on industry’s claims of doubling crop yield in the next 20 years, we should be teaching farmers to improve soil quality, practice crop rotation, and rely on agroecological methods of production, which provide plants a resilient foundation to feed a growing population in an uncertain climatic future.

FIGURE 1: **Soybean Yields Over Time (USDA National Agriculture Statistics Service)**



of Agriculture 2006). While it may make sense from an economic perspective to rely on investments in area- and industry-specific infrastructure, relying on centralized, mass production of food from other places is not the best food-security strategy for Maine. Building capacity to produce and process a greater portion of the state's food needs locally or regionally is a sensible strategy, as is developing ways to obtain food-production inputs using localized, renewable resources and using more closed-loop nutrient recycling.

Biotechnology

As biotech proponents continue to push for greater public acceptance of genetically engineered food, study results cast doubt on the premise that transgenic seeds hold the answer to feeding the world. It is especially important to note that promises of increased yields and reduced pesticides use have generally not held up (see sidebar). Furthermore, the amount of money that has been spent on public and private research related to genetically modified organism (GMO) and crop research to date is staggering, yet the overall impact on global hunger is disproportional given this investment. In addition, growing concerns about long-term environmental and human health consequences for GMO use and the potential impacts on biodiversity have been largely swept aside, along with the precautionary principle, giving biotechnology firms the ability to market products without having proven that they are safe. Although GMO contamination has been reported in canola, corn, and other crops, these products are still available and the burden is most often on the farmer, who has far fewer financial and legal resources than the biotech companies, to prove s/he is the victim of this uncontained technology.

In 2010, the FDA solicited public comments as it considered an application to approve genetically engineered salmon, resulting in nearly 160,000 responses from individuals and organizations voicing concerns (Center for Food Safety 2010). In the case of fish, escapes from aquaculture pens in open ocean systems, which is not a rare occurrence, pose risk to wild populations as genetically engineered fish are not bred for survival and cross-breeding could weaken the gene pool of wild populations.

There are still many unanswered questions about the impact of genetic engineering. Given the costly yet underwhelming results so far, it may be a wiser strategy to focus more on agroecological production and regenerating wild fisheries by investing more funding in the research and development of agricultural and fishery management systems that are less reliant on this technology and more compatible with the geography, scale, and ecosystem in which they are employed.

CONCLUSION

The Food and Agriculture Organization's (FAO) 2010 price index reported that commodity food prices had risen even higher than in 2008, when global price spikes greatly affected food security throughout the world (FAO 2010). The options for building Maine's capacity to produce food for itself and others in a changing world needs to be at the forefront of policymakers' discussions right now. This is the time to be charting the course, building infrastructure, and doing so in a way that assures our most valuable resources will be prioritized and protected over the long term. If we choose to not invest considerable thought, money, and time into this process or to delay action, we will be doing a disservice to food producers and citizens. Building capacity will require ongoing and inclusive discussion with multiple farming and fishing industry stakeholders, along with continued research, innovation, and education.

Food production has never been, and likely never will be, a zero-impact activity when it comes to surrounding ecosystems. However, there are ways in which disruption can be minimized and beneficial results maximized. A 2007 FAO report stated, "Conventional agriculture production utilises more overall energy than organic systems due to heavy reliance on energy intensive fertilisers, chemicals, and concentrated feed, which organic farmers forego" (Ziesemer 2007: 4). Pimental et al. (2008: 463) add that "the reduction of pesticide use, increased use of manure, cover crops, and crop rotations can improve energy efficiency in farming systems and enhance human health." Based on the energy projections summarized previously in this article, it is clearly imperative that we employ proven strategies to reduce

petroleum-based inputs in food production, from an economic and ecological perspective.

One of the other key lessons one hopes we have learned since the days of Earl Butz and his declaration that farmers should “get big or get out” is that increasing production scale can sometimes mask inefficiencies and externalities, damage the ecosystem, and create excessive waste in a concentrated area. Maine’s geography is actually quite suitable for small- and medium-scale farms, and there are many ways in which to multiply the number of these farms without degrading the state’s collective resources. This actually poses certain advantages, as “Agricultural systems with high social and human capital are able to innovate in the face of uncertainty” (Pretty and Hine 2001: 11). With many climate and resource changes on the horizon, we believe that small- to medium-sized, diversified farms with less dependence on technology and more locally based food-production systems that can better use renewable resources will be better able to adapt to upcoming challenges.

Likewise, the marine ecology of the Gulf of Maine, on which the state is lucky to be situated, can best be used by small- and medium-scale fishing operations. Within an appropriate fishery management structure, these operations are adaptable and able to produce a tremendous diversity of marine protein in an economically sustainable manner that will contribute to both community health and a stream of high-value food for export from the state. 🐟

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