DEAD SEA: Agricultural runoff and hypoxia in the Gulf of Mexico

Annual oxygen-depleted “dead zones” in the Gulf of Mexico, caused in large part by fertilizer runoff from farms across the central United States, represent a significant and alarming challenge for policy makers. A basic economic analysis shows both obstacles and opportunities in the U.S. political and policy context.

Swaths of hypoxic (oxygen-starved) water in the Gulf of Mexico were first observed in the 1970s; scientists attribute this phenomenon primarily to runoff from agricultural fertilizer[1] in the Mississippi-Atchafalaya River Basin, which covers 41 percent of the contiguous U.S.[2] More than 1.6 million metric tons of nitrogen is funneled down the Mississippi and washed out to sea; about 75 percent of that is from agricultural, non-point sources;[3] other chemicals such as phosphorus also play a role. That amount of fertilizer is estimated to be triple the level in the 1950s.

The hypoxia cycle, simplified, works like this: Farmers apply fertilizer beyond their lands’ ability to absorb; rains wash excess chemicals downstream to the Gulf of Mexico where they fuel explosive algae growth (eutrophication). When the algae die or are eaten and excreted by zooplankton, aerobic bacteria feed on the waste using oxygen in the water in the process. This depletes portions of the water column of oxygen such that they can’t support other sea life.[4] Aquatic life migrates, dies or is stunted in growth. The size and persistence varies from year to year, but the hypoxic zone generally lasts from late spring to early autumn, stretching from Texas to Florida. From 2004 to 2008, it covered an average of 17,000 square kilometers, a area roughly the size of Lake Ontario.[5] For comparison, the Chesapeake Bay and its major tributaries cover only 11,000 square kilometers.

The hypoxic zone has the potential to reduce marine catch and animal size while increasing costs to the fishing industry, which represents $2.9 billion in sales and 50,000 jobs for Louisiana alone.[6] In addition, the algal growth that precedes hypoxia can cause “red tide” events where local shellfish become toxic to consumers.[7] The “dead zone” also has the potential to impact Gulf tourism industries dependent on wildlife. Various theories suggest that effects will become more pronounced over time if the hypoxic zone continues to alter ecosystems, leading to crashes in some

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[1] Malakoff, David (1998). “Death by Suffocation in the Gulf of Mexico.” *Science*. 281(5374): pp. 190-192.
[2] Mississippi River Gulf of Mexico Watershed Nutrient Task Force Web portal (2011). U.S. EPA Office of Wetlands, Oceans, and Watersheds http://water.epa.gov/type/watersheds/named/msbasin/index.cfm
[3] Rabalais, Nancy; Turner, R. Eugene; Scavia, Donald (2002). “Beyond Science Into Policy: Gulf of Mexico Hypoxia and the Mississippi River.” *Bioscience*. 52(2). pp. 129-142.
[4] Hypoxia in the Northern Gulf of Mexico Web portal (2011). Louisiana Universities Marine Consortium.
[5] Ibid.
[6] Buck, Eugene H. (2007). “Marine Dead Zones: Understanding the Problem.” Congressional Research Service. http://www.cnie.org/NLE/CRSreports/07Aug/98-869.pdf
[7] U.S. Centers for Disease Control and Prevention. Harmful Algal Blooms.

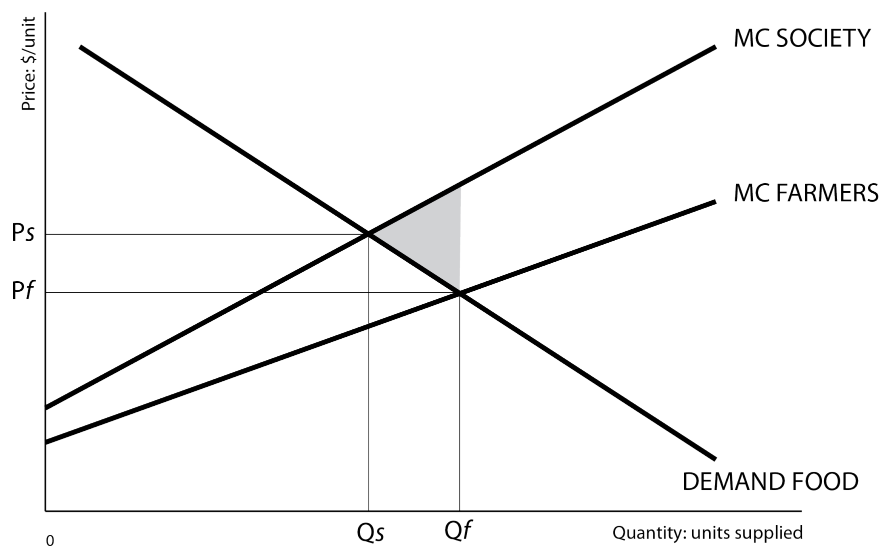
populations and even increases in pest species such as jellyfish.[8] Ecologically, that forces species migration and reduces biodiversity or critical habitat.

ECONOMIC ANALYSIS

This represents a classic externality, where costs associated with production of a good are born by someone other than the producers (albeit with complications discussed later). The external costs of fertilizer use — runoff, eutrophication, hypoxia, marine degradation, die-off, ecological trauma and economic impacts — are not treated as costs to the farmers who apply the fertilizer; as a result, optimum crop production levels for farmers and society diverge. This stems from a lack of true exclusivity in property rights, where the actions of farmers internal to their own property have impacts beyond their fields.

Consider *FIGURE 1*[9] at the right.

FIGURE 1: AN EXTERNALITY OF PRODUCTION



The demand curve (DEMAND FOOD) represents society's willingness to pay for food production, while the marginal cost curve to farmers (MC FARMERS) includes labor, seeds, fuel, chemical fertilizer, etc. This is lower than the marginal cost of farming to society (MC SOCIETY), because society's costs include the negatives of fertilizer runoff, which is presently carried by downstream fishers, water treatment plants and people in general.

Farmers apply enough fertilizer to produce at level Q*f*, which maximizes their private producer surplus (area above MC FARMERS and below price line P*f*). However, from society's viewpoint, the optimal level of production is Q*s* because this reflects the cost of the pollution. Production at Q*f* creates a deadweight loss to society symbolized by the gray shaded triangle, while production at Q*s* would maximize net benefits (area beneath the DEMAND FOOD and above the MC SOCIETY curves).

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[8] Diaz, Robert J. and Solow, Andrew (1999). "Ecological and Economic Consequences of Hypoxia: Topic 2 Report for the Integrated Assessment on Hypoxia in the Gulf of Mexico." National Oceanic and Atmospheric Administration Coastal Ocean Program. http://oceanservice.noaa.gov/products/hypox_t2final.pdf

[9] Created by the author for demonstration

The ideal policy would harmonize and align the disparate cost curves, pushing farmers to internalize the social cost of fertilizer runoff. Note: This social optimum wouldn't mean that no fertilizer would be applied, nor does it necessarily mean that no hypoxia would occur. Some hypoxia could be expected, as runoff might still occur. However, at the social optimum of Q*s*, fertilizer application would be reduced, shrinking the hypoxic zone and its impacts over time to less drastic and lasting levels.

Note: In addition to the lack of exclusivity in property rights, the market is distorted by a basic information problem: Fertilizer application is an inexact science; farmers hedge their bets in the face of risk and over-apply.[10]

There are also multiple ecological and geographical complications. Runoff is dependent on variables including distance to waterways, rainfall, topography, crop cover, other biomass and farming practices. These factors differ from farm to farm; two farmers might apply the same amount of fertilizer with completely different results for runoff. Also, as ag runoff is a non-point pollution source, discerning which farmer is responsible for exactly how much runoff is easier said than done. In addition, the Mississippi watershed and the Gulf of Mexico are largely open access, common pool resources. Deciding who loses and by how much when property rights are not well defined is a difficult endeavor; assigning those property rights is equally challenging. Finally, as pictured in *FIGURE 1*, biological studies regarding hypoxia suggest an extra-cumulative effect of agricultural runoff — the impact of hypoxia (MC SOCIETY) rises faster than direct cost to farmers (MC FARMERS) as prolonged hypoxia leaves lasting damage.[11]

Policy makers must also note that some economic factors can exacerbate the externality and stymie attempts to deal with it. Rising food prices, rising demand for meat, rising demand for biofuels and increased population all provide incentives for farmers to grow more crops, thus using more fertilizer. Meanwhile, the discrepancy in who bears the cost of mitigation can reduce political will for solutions. The social cost of the externality is born primarily by people downstream but addressing the problem may raise prices for everyone. Those who do not directly feel the effects of the pollution — i.e. much of the U.S. not living or dependent on Gulf waters — may not be particularly interested in those higher prices.

Finally, current farm policy presents a stumbling block. Tens of billions of dollars each year go to subsidy programs that reduce the cost of farming; between 1998 and 2005, an average of 37 percent of total farm produce annually came from government subsidies.[12] This lowers the MC FARMERS from *FIGURE 1*, shifting Q*f* farther to the right. Such policies then support increases in the quantity produced

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[10] Kaufman, Leslie (2011). "Chemicals in Farm Runoff Rattle States on the Mississippi." *New York Times*. http://www.nytimes.com/2011/06/03/science/earth/03runoff.html?pagewanted=all
[11] Diaz, Robert J. and Solow, Andrew (1999).
[12] Congressional Budget Office (2006). "Agricultural Trade Liberalization." http://www.cbo.gov/ftpdocs/76xx/doc7690/11-20-AgTrade.pdf

and fertilizer used; the subsidy promotes the externality. Any long-term policy response must look seriously at ending perverse subsidies that increase externalities. But given today's political climate, entrenched interests and a national, mythical affinity for farming people, this paper assumes that is unlikely.

POLICY RESPONSES

The ideal if impractical answer is a tax on fertilizer runoff. This would add an internal cost to farmers that correlates with the societal cost, shifting MC FARMERS closer to MC SOCIETY and providing an incentive for farmers to produce at Q*s*. Unfortunately, U.S. politics today make that unlikely and considering the size of the watershed and the variables of farm plots, implementing a tax on runoff, a non-point source pollution is technically difficult.

A poor alternative — though one that might seem tempting — is a fertilizer sales tax. This again shifts farmers' marginal cost curve closer to the societal cost curve, reducing production and, consequently, consumption of the input. However, this absolutely does not target the ultimate problem, which is fertilizer that runs off, not the fertilizer itself. Farmers who smartly apply fertilizer, have crops requiring more of it, or otherwise do not produce runoff would unfairly taxed at the same rate as farmers who actually generate the externality.

More broad regulation by government — fertilizer limits, application standards, application schedules, permit systems by crop type — involve careful and detailed models, monitoring and bureaucracy; such intricacy is rife with opportunity for cheating and likely cost prohibitive. Too, targeting the regulations perfectly requires the government to have substantial information about farmers and their preferences.

Though current agricultural subsidies exacerbate fertilizer runoff, other types of subsidies might be considered to reduce the externality. The most obvious option would be payments for no-fertilizer farming. Others might include tax credits for fertilizer buffer zones and farmland boundary set-asides that create non-crop greenways to absorb runoff. Subsidies for smarter irrigation systems (drip) or better practices (no-till) could reduce runoff as well. This leaves the marginal cost of farmers untouched, as the subsidy replaces the additional cost of on-farm fertilizer runoff reduction. This doesn't internalize the externality, but rather reduces it; whether the cost curve of society shifts closer to or farther from harmony with the costs of farmers depends on whether the cost of the subsidy program is cheaper or more expensive than the social costs of the fertilizer runoff.

Another option would be support for organic food production, labeling and marketing. This would provide an incentive for farmers to reduce fertilizer use by creating a new market for higher-cost farmed goods. This response would likely be hampered by the scale of production of crops and specifically by non-food crops requiring fertilizer (corn for ethanol, soy for biodiesel).

Experimental policies may be needed. The Mississippi River Basin Healthy Watersheds Initiative,[13] funded by the 2008 Farm Bill, has funneled $320 million in grant money to pilot projects across the basin to reduce runoff. Another program, the Nitrogen Control Program for the Long Island Sound, has had success with controlling point-source pollution in Connecticut. It creates nitrogen permits and trading "bubbles" based on geographic areas. Such a program could potentially be created for small, regional watersheds of non-point sources, establishing maximum nitrogen loads for a tributary, creating individual fertilizer-use quotas and then allowing farmers to trade. While not internalizing the externality, it would provide a reduction in the externality's effects (via the maximum load) and incentivize smarter consumption and fertilizer control.

Ultimately, because of all the complexity of the issue, a "first best" policy response is unlikely. A patchwork combination of the above responses is perhaps the second best option.

[13] Mississippi River Basin Healthy Watersheds Initiative Web portal (2011). U.S. Department of Agriculture. http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/programs/farmbill/initiatives/?&cid=nrcsdev11_024120