The Endeavour toward Sustainable Agriculture

Growing population demands and rural development has placed significant strain on agricultural systems worldwide. While no longer the chief economic sector in developed nations, it remains an important policy arena because of the importance of food security. Developing nations heavily rely on agriculture and commodity prices for their economic activities. The environmental stresses that these activities bring can be potentially dangerous. Especially in developing nations, land resources are currently at risk. This paper will outline the over-arching trends present in agriculture and describe the various environmental risks that improper agricultural practices are causing. Then a brief discussion on current policy programs will highlight the perverse incentives that are currently being conferred. Finally, different solutions to the problems will be presented and examined.

United States and OECD Agriculture Trends

This section will highlight and discuss the current issues facing sustainable agriculture, mainly focusing on the United States and other OECD nations. Developing nations are not immune from these problems, they just lack the research. There are several overlying themes that are important to understand about the system including develops in farm size, composition, production, and use of chemical inputs. The majority of these trends have bad implications for the environment, so they will be important to consider in later sections when I consider possible policy solutions.

The first important trend to discuss is the change in size and numbers of farms that make up the industry. In general, there are fewer farms in this century than in the late 20th century. In the European Union, the average decline in the number of farms is around 4 percent. In

Australia, it was exceptionally extreme, the number of farms declined by about 1 third in 30 years (OECD, 2005, p. 37). In addition to the quantity change, the sizes of farms have experienced a shift towards larger scale. In Australia, while the number of farms has decreased, the total average area of each farm has increased by 25 percent. In the United States, the picture looks much the same. At first glance it does not seem as distorted as many might think: small farms (100 ha or less) comprise about 3 quarters of all corn farms, but they only produce 1 third of the total corn production. 4 percent of US farms are responsible for 1 fifth of all maize (OECD, 2005, p. 39). This trend is also present in other crops such as soybeans and rice. Another related trend that will have important implications is the movement to specialized farms from more diversified ones. Generally, the number of farms that mixed crops was fairly low to begin with, but they have been increasingly rare. In the European Union, the percentage of farms that specialized in mixed crops went from 12 percent in the late 1980s to 7 percent in 2000 (OECD, 2005, p. 39). Specialization is usually also associated with larger farm size. Generally, the larger the farm, the less likely they are to grow a mixture of crops. This is the result of perverse subsidies that encourage monoculturing, and this will be discussed later. These two events occurring simultaneously are important for the next section on negative agriculture practices. While this will be discussed in further detail, these conditions are not optimal for environmental sustainability or biodiversity.

There is a tendency for farms to increase production by expanding arable land. In order to achieve higher output farms have two options: they can either try to expand the total land that they are farming, or they can try and increase yields (OECD, 2005, p. 41). There will be a discussion later about current methods of increasing yields (transgenic crops), but it should be noted first that the first option is usually the more preferred choice (Mandemaker, Bakker, &

Stoorvogel, 2011). I want to make it clear that this is not just a result of the first trend already mentioned. There are a couple of important underlying mechanisms that contribute to this outcome. The first important factor regarding this choice is cost. In general, land is cheaper than the technologies used to increase yield. This is especially true in developed nations that are land-abundant like the United States and Australia, but it is also true for developing nations. Because developing nations suffer from lower education and capital levels, they are less likely to employ yield-increasing technology (Mandemaker, Bakker, & Stoorvogel, 2011). This results in much higher strain on land resources than what is environmentally sustainable. Essentially, developing nations are the most at risk for agricultural related environmental degradation and there has to be serious infrastructure changes in order to offset this natural tendency. In terms of developed nations, this trade-off will likely require subsidies and other policy tools in order to offset the drive to larger scale farms.

The last topic of importance will be the growing and prevalent use of chemical inputs, primarily fertilizers, in order to increase crop production. While these are generally more expensive than the previous option, many EU nations and countries will little land rely on these heavily. In addition, they are increasingly popular in developing nations. Over the past 35 years, the doubling of food production has been associated with almost a 7 fold increase in nitrogen and3.5 fold increase in phosphorus fertilizers (Tillman, 1999). In the United States, 98 percent of maize is treated with nitrogen and 82 percent uses phosphates (OECD, 2005, p. 47). Heavy application of fertilizers is associated with detrimental impacts on soil fertility. Because of this, in developed nations, you also see a growing demand for transgenic crops (this will be discussed more in depth later) that achieve the same result but with less of an impact on soil quality.

Current Agricultural Malpractices

This section will begin the major discussion on the specific farming techniques and practices that pose the greatest risk for environmental costs in developed nations. It will also discuss the impacts of the trends noted in the last section. The analysis will be broken down into effects of three different facets: soil, water, and air quality related impacts. The main purpose of this section is to bring about the different possible policy solutions that will be discussed in a following section – fertilizer restrictions, subsidize for diversification, and controls on greenhouse gas emissions. While this section does not necessarily draw its data from developing nations, most of those nations go through similar impacts (albeit air quality to a much lesser extent) as developed nations do. The data on OECD nations happens to be much more complete, however.

The first categories of impacts that will be discussed are those relating to the quality of the soil and its impacts on productivity. A common theme will be that the previously noted over-arching trends are causing externalities that are currently unsustainable. To begin this section, soil erosion will be highlighted. Although a bit dated, it has been estimated that each year 75 billion metric tons of soil are removed because of erosion, and the majority of it is from agricultural land (Pimentel, et al., 1995, p. 1117). Another study notes that many estimates of total erosion in the United States is particularly elusive because of the reliance on models instead of actual field-data. The importance of proper monitoring of this phenomenon, then, is stated with upmost importance (Trimble & Crosson, 2000, p. 250). While erosion has been a constant force in the Earth's natural environment, there are several factors that are influencing the occurrence in agricultural. Higher rates of erosion are the result of several factors – including increasing field size, continuous cropping, and general over-cultivation of arable lands (OECD, 2005, pp. 58-59). Growing the same crops on a piece of land usually removes vital nutrients and

natural protections that soil has from erosion. Shorter harvesting periods result in longer exposure and greater strain on the land. As previously noted, these are trends are still swelling. In general, it would be safe to associate increased erosion with the desire to increase yield. The reason that this is a serious problem is two-fold. The first problem is that erosion decreases the capacity of a particular farm because of reduced soil fertility and water availability (Pimentel, et al., 1995, p. 1118). It is estimated that the costs in the United States from erosion range from 40 million dollars to over 100 million dollars (OECD, 2005, p. 59). This leads to two serious environmental complications: first, the increased energy costs that are associated with erosion and, second, the pressure it creates to increase yields. 10 percent of current energy usage in the agricultural sector is used to offset the costs of erosion (Pimentel, et al., 1995, p. 1119). Additionally, this cost drives farmers to increase productivity through other means, usually by increasing farm size or using additional fertilizer - a common occurrence in developing nations that puts additional stresses on the land (Pimentel, et al., 1995, p. 1119). This can often create a vicious cycle for the environment where attempts to increase yield lead to decreased yield and the need to counterbalance the declining productivity.

The next important environmental concern that modern agriculture is facing is related to water use and pollution. In the EU, 60 percent of water use is for irrigation of farm land. With a heavy reliance on irrigation in order to increase the amount of arable land, farms must rely not only on extraordinary amounts of water, but also large amounts of other chemical inputs (OECD, 2005, p. 65). Because of the large amounts of water use, and the potential risk of interacting with the local water table, farms have to be concerned about their water footprint. In most OECD nations, pesticides and soil erosion sediments are the principal sources of water pollution related to agriculture (OECD, 2005, p. 66). The inefficient methods of cultivation, which include too

frequent rotation and growth cycles as well as increasing farm size, have led to a decreasing return of soil nutrients. These inefficiency concerns have manifested in droughts and widespread problems in Africa and other developing nations. While the detriments are usually associated with decreasing production from farm land (natural soil nutrients are better and more efficient than manufactured pesticides), these nutrients also seep into the water table and cause greater salinity. In the United States, pollution due to nutrients is a major source of quality deficiency in lakes and rivers. Likewise, pesticides can also enter the water supply and cause water eutrophication. Poor monitoring and maintenance of water resources will likely cause major strains on nations during this century.

The last environmental concern is related to air quality. The nature of these problems is in a somewhat different vein than the previous concerns. Crop production, in itself, is not the source of the air pollution, but rather the vehicles and miscellaneous acts associated with agriculture like crop burning and vehicle use are the main polluters. While there is a bit of uncertainty relating to lack of data, it is known that agriculture is an important contributor to carbon dioxide, nitrous oxide, and methane (OECD, 2005, p. 69). Current tillage practices produce large amounts of greenhouse gasses including nitrous oxide and 84 percent of global human related methane (Robertson, Paul, & Harwood, 2000, p. 1922). The IPCC estimates that agriculture is responsible for 20 percent of all greenhouse gas emissions (Horrigan, Lawrence, & Walker, 2002, p. 448). In addition, fertilizers and other chemical inputs can release greenhouse gases and other dangerous compounds into the air.

Effects of Current Agricultural Policy

The aforementioned problems touched on an underlying problem with the current themes in agriculture production. Most countries, the United States especially, are deeply concerned about food security and ensuring a large food supply. As a result, it has been a long tradition to encourage farmers to produce more and to attain higher yields in order to achieve those goals. There are various mechanisms that the developed nations employ to achieve those policy objectives, this section will primarily be interested in policy choices in the United States specifically, but the general price support is a common theme in the EU and other OECD nations. While these policy mechanisms have definitely achieved the goals of increasing the food supply, they attribute to many of the environmental stresses that the system is currently suffering.

In the European Union, market price supports are usually done through trade barriers and area payments. In the United States the main policy tools are support-price provisions, marketing loans, and various payment plans. The two most common types of payments are Direct Payments and Counter-cyclical payments. Direct payments area used to subsidize farmers if the market price of a crop is below a federally set level. Essentially, the government creates a price floor and gives subsidies to farmers if the price falls below that floor. The other type, CCP, is used as a mechanism for providing year-round stability to farmers' incomes (OECD, 2005, pp. 100-105). Overtime, there has been some evolution in different types of policy options for developing nations. The EU's shift toward area-based payments and payments based on historical output that have become popular in the United States and Canada are examples of policy diversification (OECD, 2005, pp. 110-117). One particularly important type of subsidy that is common in the OECD is payments based on inputs. These outlays are of concern mainly because of their environmental impacts, "The more a payment is specific to the variable inputs necessary to

produce particular crops, the greater the incentive to increase production and the greater the impact on production, trade and environment of these commodities" (OECD, 2005, p. 118). Common payments can include offsets for fuel costs, irrigation measures, and fertilizer use.

There are several trade policies that are prevalent among developed nations. These will be divided into import and export related programs. Barriers and tariffs are important, especially in countries that also utilize high market price support. These two policies act in synergy to reduce pressure on internal farmers. Import quotas are common in the rice market; countries like Japan, Korea, and China rely heavily on import quotas for rice (OECD, 2005, pp. 122-124). The European Union and the United States are the largest users of export subsidies in the grain markets. Both systems have come under fire from the WTO and have had to reduce subsidies in the past. Programs that subsidize farmers in order to reduce the cost of production generally have significant impacts on world trade. By encouraging production, a surplus supply can lead to declining food prices worldwide and disadvantageous positions for farmers in developing nations. As discussed in the next section, biofuel mandates have generally overridden this effect and created a deficient supply, rising prices of commodities lately. This will be discussed more in-depth in the next section. It is important to note that these bloated prices have definite impacts on poor farmers in the developing world. "It is erroneous to assume that poor farmers, even those in distant and resource-poor regions, are totally isolated from agricultural markets" (Barbier & Burgess, 1992, p. 13).

Due to rising oil prices in the last 30 years and concern about energy security, along with an interest with reduction of greenhouse gas emissions has led to the rise of biofuel mandates prominently in the United States, the European Union, and Brazil. In the United States, for example, the 1990 Clean Air Act intended to increase the amount of oxygen in fuels – which led

to companies favoring additives like ethanol which had a higher oxygen percentage (Hertel, Tyner, & Birur, 2010, p. 77). Subsidies ranged from 40 to 60 cents per gallon of ethanol during the past 30 years. From 1984 to 2004, the United States' production of ethanol grew from .43 to 3.4 billion gallons, about 149 million gallons per year on average (Hertel, Tyner, & Birur, 2010, pp. 77-78). The growth and support of such production of ethanol and other biofuels has tremendous impacts on the international community and land use. These policies have been estimated to increase crop cover and reduce forest cover in nearly all regions around the world. In Brazil, pasture and forest lands are estimated to decline by nearly 10 percent. European policies are accountable for nearly half of the impacts in the United States, and the United States' policies are responsible for 2 thirds of the crop cover increase in Brazil (Hertel, Tyner, & Birur, 2010, p. 95). This exacerbation of deforestation and changing land use is particularly concerning given the environmental impacts and biodiversity implications. Another import concern relating to the use of biofuels is the unsustainable drive that it is creating. Agriculture production is failing to meet trends in biofuel demand, causing an increase in prices for crops worldwide (Runge & Senauer, 2007). For example, the price of tortilla flour in Mexico doubled because of the rise in United States corn prices during a period of several months. Tortillas are the source of food for a large amount of the impoverished in Mexico (Runge & Senauer, 2007). Domestic farmers that are receiving the subsidy are sheltered by the federal government, but farmers and consumers in poorer countries are devastated by the inflation.

The result of these policies can be linked to environmental concerns fairly easily. There is a "strong positive link between support and fertilizer use," (OECD, 2005, p. 177). Higher support tends to have an impact on intensification, which is detrimental to the environment because of loss of future capacity. The causal link need not lie in the relationship between profit-

maximizing producer and increased output price, but rather, "the impetus for long-term intensification and environmental deterioration … [has come] from the rapid adoption of new technologies, which have been largely triggered by sustained high support levels" (OECD, 2005, pp. 177-178). Subsidies for fertilizer can be particularly effective in developing nations. "There are indications that subsidized inorganic fertilizer artificially reduces the costs of soil erosion to farmers and, on more resource-poor lands, substitutes for – perhaps more appropriate – manure, mulches and nitrogen fixing crops" (Barbier & Burgess, 1992, p. 8). The environmental costs of fertilizer result in extremely perverse incentives for farmers resulting from these subsidies.

Possible Policy Solutions

This section will discuss numerous solutions to the previous problems and threatening trends. None of the literature that I found seriously considered reducing current agriculture production. Many authors maintain that food security is a serious enough issue to seek alternative measures. As a result, the solutions mentioned in this section will be of a few basic types. The first policy solution will discuss possible reforms of current support programs in order to reverse the perverse incentives that are being created. The second popular option is to encourage reform to the behavior and practices of farmers in order to adopt more sustainable methods. Finally, transgenic crops will be considered. It will be the objective of this section to persuade the reader that the best possible resolutions come not from subsidy reform, but rather behavior manipulation and transgenic crops, despite opposition from the underlying uncertainties.

It should be clear from the proceeding section that many of the subsidies that nations are using in order to promote production growth have many environmentally antithetical implications, especially biofuel support. One might immediately suggest that the right course of action would be to remove those price supports in order to reduce the incentives. This solution may not be so simple, however, because of uncertain responses from farmers and the industries already established by the subsidies that are unlikely to dissipate. Several authors suggest that removing the programs will likely have no impact, or the opposite of the desired effect. "Expected environmental impacts of reducing support cannot be directly inferred from simple correlations of support and environmental damage, or by assuming a simple retreat down the pathways that led to the current situation," (OECD, 2005, p. 186). In essence, the removal of the policy will not make the system revert to its state before the policy was in place, and the current infrastructure that has been developed around the subsidies will likely be adapted to fit into the new system in order to continue making returns. One model even predicted that abolishing subsidy programs will actually increase exports and output. The rationality is that farmers will produce more in the short-run in order to offset a permanent policy reform (Fisher & de Gorter, 1992, p. 267). Furthermore, the political prospects of such a policy are minimal to none. The nations that adopt production standards and limits would be limiting, "their competitiveness in these cutthroat [agricultural] markets" (May & Bonilla, 1997, p. 13). Essentially, the costs would have to be assumed by the producer instead of being shifted to the consumer. Lobbying efforts would likely result in this policy being dead on arrival. Alternative solutions to the perverse incentive problems, especially related to biofuels can include "developing a broad and balanced [energy] strategy," including promoting alternative sources of energy (Runge & Senauer, 2007). These options are more politically viable, but might not be able to reduce strain in the short-run.

The following several options are primarily concerned with fixing and encouraging sustainable techniques within the current agricultural regime. The three methods will cover soil management, effecting tilling, and organic farming. Each of these solutions has difficulties and obstacles, but they are the options of least resistance and offer the potentially best results for the short term. As previously mentioned soil preservation is integral to the longevity of a farm and increasing yield. Because certain crops have different impacts on the land, diversifying the crops on a piece of land can reduce and average out the environmental risks. Corn, which is a soil-intensive crop, can be rotated with wheat in order to reduce soil erosion. In addition, crop rotations can improve "pest control, and increase nutrient – and water-use efficiency" (Tilman, Cassman, Matson, Naylor, & Polasky, 2002, p. 673). In the United States, soybeans and maize are commonly rotated together. The reason why this method is not implemented on a larger scale is related to the incentives provided by subsidize. In the United States, rotation with soybeans was less profitable for farmers because of the way deficiency payments are regulated (OECD, 2005, p. 75). In general, growing single crops is the most profitable for farmers. It is likely that subsidies would have to be given to farmers in order to diversify their lands and encourage better soil management.

The way that the soil is tilled also has a large impact on the amount of nutrients and residue left after harvesting. The larger the residue left can help fertilize the ground naturally and reduce the need for chemical inputs. Traditional tillage methods leave at most 15 percent of crop residue, but conservation methods can achieve up to 30 percent residue (OECD, 2005, p. 76). It is unlikely that better tillage methods can reduce the need for fertilizers all together, but another benefit of reduced or conservational tillage can include reduced leaching and volatilization of chemical inputs (Tilman, Cassman, Matson, Naylor, & Polasky, 2002, p. 673). Despite the

optimism, field testing has been incomplete and occasionally inconclusive. One study found that the tillage choice had minimal impact on yields for certain crops (OECD, 2005, p. 76). The good news is that adoption of these techniques has slowly been increasing over time. In the United States, where the largest portion of these methods are being used, almost 2 thirds of most crops are still not being tilled in this manner. The reasons for growing adoption are primarily due to perceived higher economic returns with newer tillage practices and some current programs in OECD that encourage it (OECD, 2005, p. 77). This then, is an example of a solution that epitomizes the economic benefits of sustainable development. The economics are not enough alone, however, to provide an impetus for large groups to change soon, there must be government nudging in order to achieve the desired effect. This is a common theme with the majority of these solutions; they will not be successful without carrots to entice producers.

Organic farming encompasses a large variety of different techniques and ideas, but it is primarily based on the want to minimize the amount of artificial chemical inputs – e.g. fertilizers, and pesticides. Organic farming "generates less stress for the environment than conventional agriculture, in terms of lower pesticide residues and soil erosion, increased biodiversity and resilience to drought," (OECD, 2005, p. 80). Successful management of the soil's ecosystems can produce plants that are "more vigorous and therefore less susceptible to pests" (Horrigan, Lawrence, & Walker, 2002, p. 452). Organic farming has gained ground in the US agricultural sector in the past decade. The number of crops being grown by an organic farming quadrupled from 1992-2001, but still remains a very small portion of the total amount of crops (OECD, 2005, p. 82).

These practices have some major impairments and obstacles to becoming widely utilized and adopted. Top-down government regulations and policy options are likely only going to have

a minimal impact on farmers' actions. Stressing environmental concerns are not likely going to be enough to incentivize the majority of farmers. "We also need to reassure farmers that sustainable methods are economically viable," (Horrigan, Lawrence, & Walker, 2002, p. 453). Some explanation as to why current practices maintain is due to cultural and historical homogeneity. Educating farmers will be difficult because it would mean overcoming traditions and practices that have the benefit of popular. Environmentally sustainable practices are, "information- and management-intensive because a farmer is required to have a thorough understanding of how the physical characteristics associated with farming … affect crop production" (OECD, 2005, p. 83). Small farms are more likely to have undereducated and older farmers than larger farms. The implication is that it will take more effort to teach many of the farmers about these methods – policy options need to include mechanisms in order to educate about the encouraged systems. This may be easier done in developed nations than poorer countries where capacity is weak in general. The fact that this snag is not politically unfeasible gives it strength over the previous policy choice. Proper funding is the major hurdle that this solution has to overcome, and there are some definite complications. In the developed nations, the majority of current subsidies go to the few large farms that exist. About 30 percent of subsidies go to the top 2 percent of farms and 80 percent go to the top 30 percent (Horrigan, Lawrence, & Walker, 2002, p. 453). The subsidies that are required to shift farmers into sustainable agriculture are needed to go to smaller farmers rather than the large farms. This would imply a need to restructure the current farm programs, which is easier said than done. Large farms often lobby for this distribution, and it could mean greater inefficiency in the end policy result. I still find this option much more feasible and likely to have a discernable impact than an attempt to remove the subsidy programs altogether.

The last main solution that will be discussed is transgenic, or genetically engineered, crops. This solution is definitely one of the more controversial developments in agricultural technology, but may be one of the most plausible. The growth of transgenic crops has been immense: increasing from 1.7 million ha in 1996 to 67.7 million ha in 2003 (OECD, 2005, p. 84). The United States currently grows almost 1 third of the worldwide total transgenic crops by area. Transgenic crops are genetically engineered to contain traits that are typically not found in that particular crop. The most typical commercial traits to have engineered are herbicide tolerance, insect and virus resistance (OECD, 2005, p. 86). By the early 2000s, 3 fourths of all transgenic crops were herbicide tolerant. Before discussing the current problems with implementing transgenic crops, I should note the potential for sustainability. Transgenic crops can greatly reduce the need for chemical inputs such as pesticides. This reduces the risk of water pollution and biodiversity loss. Transgenic crops can also lead to higher yields and lower costs for the factors of production (OECD, 2005, p. 87). The reduction in costs can be potentially beneficial to impoverished farmers in developing nations by raising their incomes. There are some serious concerns, however, to wider implementation. Engineered traits have the potential to spread to wild crops outside of the farm, potentially leading to stronger and more resistant weeds (Horrigan, Lawrence, & Walker, 2002, p. 448). Similarly, insect resistance has the likelihood of quickening the rate of insect resistance to the pesticides. The toxin that is used to engineer the resistance might also have an effect on non-desired insects like local butterflies and other benign creatures (OECD, 2005, p. 90). There are also some serious concerns about the potential impact on human health associated with the unknown impacts of transgenic crops. There definitely has to be additional study and precaution taken with transgenic crops before they can become a useful policy solution. With that being said, the current trend of research makes it a choice of

little resistance. There should be a concern that lowering the costs of production may lead to additional strain on land resources. It would be tough to control the economic incentives associated with transgenic crops in order to ensure maximum environmental benefit. As a result, it should not be considered an immediately policy solution.

Conclusion

10,000 years from the Agricultural Revolution and in order to preserve the environment, the world may need to go through another. The growing scale of the current production has imposed environmentally stressful processes. Not only are current methods harmful and occasionally counterproductive but the current policy scene is encouraging poor farm behavior and unsustainable artificial prices. There is no easy way out of the current quagmire; all possible solutions are likely to face opposition and challenges. Removal of subsidy programs will likely be ineffective. Transgenic crops face important questions about safety and indirect effects, but will likely continue to be adopted. The brightest hope for the environment is for governments to encourage farmers to adopt sustainable practice like crop diversification, proper tillage, and crop rotation. This will require education programs and incentives for farmers to adopt en masse, but these political calculations require the least resistance.

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