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Climate change is swiftly becoming the most important ecological issue of our time; its effects will be felt worldwide in the next few decades. For developing countries, the effects will be severe, and could include economic and political instability along with agricultural ruin (Giles, 2009). William Cline (2007) explained that developing countries will feel the most impacts of climate change, due in part to their proximity to the equator, where climatic changes will be stronger, and in part to their reliance on natural resources and rain-fed agriculture. The impacts *will* be felt in the United States, though, and will be felt intensely. This paper will address the effects that climate change will have on agriculture in America and what farmers can do to prepare.

The United States Department of Agriculture (USDA), in 2008, after completing a two year study, found that climate change is already impacting agriculture in the United States, and these impacts will only continue to increase (Hohenstein & Chapin). Weather changes and climate variability will comprise a large portion of the impacts of climate change on agriculture. Extreme weather events include hurricanes, typhoons, storms, heat waves, droughts, severe cold snaps, and floods. The incidence of these types of occurrences is predicted to rise as the climate continues to warm, and the severity of such events will also increase (National Oceanic and Atmospheric Administration [NOAA], 2008). NOAA's report explains that "abnormally hot days and nights" will become a normal occurrence. Extreme weather events are detrimental to agriculture in the areas in which they occur, completely disrupting crop production. Indeed, Eeasterling et al. (2007) determined that even a short-term "natural extreme," like a storm, if it occurs during a key point in a crop's growing cycle, can interrupt the formation of fruit or grain. In 2009, an atmospheric scientist and an economist used global climate models to conclude that, as opposed to regional incidents (the typical pattern in the past), in the future, crop yields will be lower *everywhere* (Holden, 2009). One example Holden gives is that of the heat wave that swept through France in 2003. Because temperatures were almost four degrees Celsius above normal, France's fruit and corn harvests saw a twenty-five percent decrease for that year. Climate change all but assures that such decreases will be a commonplace occurrence.

In some parts of the United States, including the Pacific Northwest and areas at high latitudes, precipitation will increase but, since more of it will fall as rain instead of snow, more of the moisture will be lost to runoff, less water will infiltrate the ground and recharge aquifers, and less water will be available during summer months (due to a lack of snowmelt) (Cline, 2007). These areas can also expect increased flooding due to excessive runoff, which can, in turn, cause soil erosion. Even if total precipitation levels remain the same, just the changing of precipitation from the majority falling in spring to the majority falling in autumn can have a "profound" effect on the types of crops that can be grown in a region and they way they must be grown (Evans, 2008).

Increasing incidences of and severity of droughts will be a major impact on the West and the Southwest. In places that already have hot summers (which can limit agricultural production), increasing temperatures spells real trouble. Easterling, et al. (2007) determined that even a slight increase in average temperature will result in lower crop yields in areas located in low latitudes or seasonally dry regions. With climate change, evaporation rates of soil moisture will increase and streamflow will decrease, further limiting production and water supplies, and the possibility of severe drought will increase (Environmental Protection Agency [EPA], 2008). The EPA reported that some areas may see as much as a twenty percent reduction in precipitation. Decreasing levels of moisture in the soil can threaten "economic viability," according to Mestre-Sanchis and Feijoo-Bello (2009). The Great Plains area of the United States is expected to suffer a significant reduction in agricultural production due to increasing heat and a significant decrease in water availability (EPA). The Intergovernmental Panel on Climate Change (IPCC, 2007) adds that this region is also at higher risk for problems with climate change due to their “unsustainable land use practices.” The EPA and IPCC expect decreases in both production and quality to be seen in crops that are currently grown in areas near “climate thresholds,” like wine grapes in Northern California. In addition, as water tables in these areas fall, it will be more expensive to pump water for irrigation purposes, causing a corresponding increase in food costs.

Changing temperatures have additional effects. Increased evaporation rates increase salt accumulation in the soil, which can affect soil fertility (Rosenzweig and Hillel, 1995). Rosenzweig and Hillel also discuss how increased temperatures increase the rate of organic decomposition and of all nutrient cycling in the soil. This, along with increased plant growth, will intensify the need for farmers to add fertilizer and other inputs. Another effect of changing temperatures is that many native species will be forced to shift northward in order to adapt, and these species shifts may throw off ecosystem balances—there is no way to predict what effect such changes could have on agricultural production.

In some parts of the country, like the Great Lakes region, earlier planting dates and later frost dates seem like a boon. A warmer climate means a longer growing season, which, in turn, means more crops can be harvested. This warming will increase growth in younger forests which have enough water resources (Hohenstein & Chapin, 2008). However, for agricultural crops, according to Cline (2007), warmer temperatures cause the plant to move through its growing cycle more quickly, which leaves less time and energy to devote to fruit or grain development.

Rosenzweig and Hillel (1995) also reported that hastening plants to maturity will result in a decreased yield. In addition, Easterling et al. (2007) found that, although some regions benefit from a small increase in temperature, when there is a larger increase in temperature (a rise of more than three degrees Celsius), crop yields in *all* areas will negatively impacted.

Another way that climate change impacts plants and agriculture is through increasing carbon dioxide (CO2) rates. When more CO2 is available to plants, they take in more CO2 and convert it to carbohydrates (Rosenzweig & Hillel, 1995). The EPA (2008) reported that some crops are stimulated to more growth with higher levels of CO2, including rice, wheat, soybeans, and oilseed crops. However, since this extra growth is limited by water and nutrient availability, increases in crops yields may not actually be seen. The positive effect of increased CO2 levels might be offset by a decrease in production with increased temperatures. Furthermore, slow-growing trees and mature stands of trees show little response to elevated CO2 levels (Easterling, et al., 2007). Many crops, including corn, millet, and most horticultural crops (for example, tomatoes, onions, and fruit), do not respond to more atmospheric CO2 and thus do not have increased yields under such conditions.

Livestock are also affected by climate change. According to the USDA, survival rates of livestock will improve because of shorter, warmer winters, but that gain will be more than offset by lower survival rates during longer, hotter summers (Hohenstein & Chapin, 2008). Production of livestock and dairy animals will decrease in increased temperatures. The University of Minnesota (2008) reports that the effects of climate change can create a "perfect storm," in which increased flooding and droughts create circumstances that offer pathogens the opportunity to ravage a population. Co-infections and decreased immune functions can result in catastrophic die-offs of livestock due to diseases that are usually endemic in a population, and such diseases may start to appear at higher latitudes. As ecosystems shift and invasive species move into new areas, less range is available for animals to graze, and the land that is available may no longer have the correct types of grasses for these animals to eat.

Further impacts of climate change on agriculture involve increased range and virility of a number of pests and problems. The USDA reported that insect outbreaks and increased tree mortality are already a problem in Alaska and the interior West and Southwest, and these problems are expected to increase (Hohenstein & Chapin, 2008). Rosenzweig and Hillel (1995) noted that with warmer weather, insect species like grasshoppers are able to complete more life cycles during a given year. Larvae of other insects will be able to overwinter in the warmer ground, causing an increased population the following year. Bacteria and fungi that cause diseases in plants will increase in number and will move into more northerly climes. As these opportunistic species move into new areas, they are greeted with ecosystems in which they have no natural predators, and they often experience no immediate growth limitations. The USDA further explained that some grain crops are not the only plants who will experience unprecedented growth with increased atmospheric CO2: many weed species will also experience significant growth, along with increased resistance to common herbicides and a shift northward in territory. Exotic grasses will increase their range dramatically, upsetting ecosystem balances and, in combination with decreased precipitation rates and increased temperatures, raising the risk of widespread and catastrophic fires (Hohenstein & Chapin). Another, less obvious effect of climate change on agriculture is that, as plant pests and diseases spread into more areas, so do human diseases, thus reducing the labor pool available for agricultural work (IPCC, 2007). This reduction of the labor pool also disrupts the natural flow of important agricultural know-how from one generation to the next.

One of the most discussed effects of climate change is sea level rise. This, too, will affect agriculture. According to Rosenzweig and Hillel (1995), the rising seawater could infiltrate aquifers, rendering the water unsuitable for agricultural use. Rising sea levels will also inundate low-lying coastal areas, many of which are currently being used for agricultural production.

Cumulative effects of current agricultural practices will be further compounded with the added stressor of climate change. Common agricultural problems faced by farmers today, including soil salinization, erosion, overgrazing, pest resistance, loss of biodiversity, and falling groundwater tables, reduce the overall adaptability of agriculture and increase the sensitivity of modern crops to environmental changes (Easterling, et al., 2007). These modern day dilemmas add up to unpredictable complications as climate change effects accumulate.

Climate change will affect every country, not just the United States. As other countries start to feel the intense effects of a warming climate, some areas will become uninhabitable: sea water rise and increasing desertification will displace the populations of entire countries. The United States will be forced to accept large numbers of climate refugees, increasing the population of this country significantly, and, in turn, putting more pressure on farmers to find ways to feed everyone.

Agriculture will be severely impacted by climate change over the coming decades; these anticipated effects have spawned a wide variety of proposed adaptation solutions. Some are easier to accomplish than others. Some solutions require significant financial investments, and some require full scale societal change. Many solutions do not rely on newly developed technologies but, rather, on traditional agricultural practices. These are the easiest to implement quickly. As Cline (2007) explained, waiting for a new technological advance to solve these problems is the wrong choice to make—action should be taken immediately. Because climate change is such a large scale challenge, it will require many creative solutions, both the ones available now and those that may be developed in the future.

Adaptation alone is a poor solution to the challenge of climate change. A better approach incorporates mitigation efforts, also, in an attempt to reduce the concentration of CO2 presently in the atmosphere. Farmers have a distinctly unique position relating to climate change: they have the power to not only find ways to adapt to the impending changes, but to also become part of a long-term solution, through helping to slow the release of manmade greenhouse gases.

One of the most promising ways to sequester carbon from the atmosphere is simply to keep it in the soil. No-till agriculture, where plant matter is left in the fields and in the ground rather than turning the soil with plows and other farm equipment, has the possibility to sequester large amounts of carbon instead of releasing it into the atmosphere (Biello, 2007). This process requires leaving waste vegetable matter (stalks, leaves, and other plant matter) on the top of the soil and the roots in the ground, sowing new plants without tilling the soil into rows. The carbon remains in the soil, the soil is enriched and fertilized by such a practice, and farmers ultimately have to spend less money on equipment and fuel. This method may, according to Biello, result in lower crop yields for a short time, but, in the long run, this farming method can save time and money. Carbon sequestration in soil does have limits, though: each quantity of soil can only hold a certain amount of carbon and no more. No-till farming is a step towards appropriate and safe carbon sequestration, one that can be implemented now, but it is not a panacea for solving climate change. Biello stated that increasing amounts of carbon can be sequestered in agricultural soils for about thirty years or so before soils will reach their limit of carbon and be able to hold no additional carbon.

A more controversial piece of the climate change puzzle is decreasing the amount of meat that is produced. At this time, in the United States, over half of all agricultural land is used for meat production (Biello, 2007). Producing the grain to feed livestock is expensive, takes land away from the production of grain for human consumption, and is very water-intensive. Eighty percent of agricultural greenhouse gas emissions stem from livestock production (Younger, Morrow-Almeida, Vindigni, & Dannenberg, 2008). Societies all over the world are abandoning traditional, plant-based diets and turning to Americanized diets, where every meal revolves around eating meat. Meat represents both health and wealth for increasing numbers of people, despite the negative effects that high meat consumption has on both personal health and the health of the environment. If meat production were to cease or slow, less land overall would need to be farmed to produce the same amount of food, and less methane (a potent and worrisome greenhouse gas) would be produced by the livestock themselves. Reducing meat consumption and production could play a large part in the climate change solution. Methane production by livestock can also be decreased by using different types of feed and raising different breeds of livestock. The methane that is produced by livestock, instead of being released to the atmosphere, could be contained and used to produce electricity.

Other ways in which farmers can help to mitigate climate change include using inputs with less impact (substituting local manure for petroleum-based fertilizers, for example), relying on animal labor or alternative fuels to operate farm machinery (instead of fossil fuels), and finding or developing markets for agricultural products locally and regionally, instead of shipping their harvests many miles away. Integrated pest management should replace herbicides and pesticides that are made with fossil fuels; encouraging farm biodiversity offers assistance at a genetic level against pest and disease invasions.

Agroforestry and appropriate forest management play a key role in the carbon solution.

The Food and Agriculture Organization of the United Nations (2007) reported that thirty-three million acres of forestland is cut down every year; since trees are a major carbon sink, this loss of forestland accounts for twenty percent of all manmade greenhouse gases released (Biello, 2007). Solving this problem is complicated. While deforestation is a serious contributor to global warming, products made from wood are actually renewable and use less petroleum than products made from plastics. In addition, the use of wood as a building material keeps some of the carbon out of the atmosphere. To complicate matters further, carbon sequestration varies greatly in different species of trees, and younger trees do not take up as much carbon as older trees do, making the planting of new trees a less-than-ideal method of mitigation. The United States Forest Service is already considering climate change when developing their National Forest Management Plans, and is instructing forest management teams how to adapt to climate change issues (Hohenstein & Chapin, 2008). The solution lies in a balanced program of retaining old growth forests, planting new trees when possible, and appropriate and ecologically sensitive ways of relying on wood as a natural and renewable resource to lessen reliance on the use of plastics.

In addition to helping mitigate the effects of global climate change, there are a number of adaptations that individual farmers can take as the effects of climate change become more pronounced. Humans have been selecting agricultural plants for specific, desired traits for thousands of years. One way to adapt to climatic changes is to select for or choose to cultivate plant species that are able to overcome some of these challenges—species that have heat, pest or drought tolerance, for example, or who mature at different times of the growing season or can tolerate high amounts of salt in the soil (Food and Agriculture Organization of the United Nations, 2007). Relying on crop forecasting for information can be valuable to farmers struggling with climate change, and changing harvest and planting dates to accommodate shifting seasons can help. The use of mulch, hedgerows, and compost assists in keeping soils fertile and also helps retain moisture, as does simply preserving topsoil through the use of cover crops. According to the Food and Agriculture Organization of the United Nations (2007), the use of mulch alone can decrease the amount of water required by a crop by as much as thirty percent. Increasing soil fertility increases both the amount of water that can be retained during drought conditions and the amount of water that can be absorbed during increased precipitation, so farmers should always continue to improve their soil (Food and Agriculture Organization of the United Nations). Water use efficiency and changing irrigation methods must play a key role, along with finding alternate ways to store water. The presence of trees on a farm brings many benefits: decreasing winds, water table regulation, and providing shade for plants and livestock (Food and Agriculture Organization of the United Nations). Areas with increasing vulnerability to wildfires must understand and use appropriate fire management techniques. Applying these relatively easy-to-implement techniques can save farmers money in the long run, along with helping them adapt to climate change.

Shifting crops northward as temperatures increase is another possibility for overcoming the effects of climate change. As southern areas become too hot and too dry to support agriculture, agriculture can and must shift. One problem with this approach, reported by Rosenzweig and Hillel (1995), is that many crops have been adapted to and selected for certain areas. Moving these crops into higher latitudes, thus exposing them to longer summers, may result in challenges to sustaining current yields.

There are many future possibilities for climate change mitigation and adaptation through agriculture, although none of them are close to being ready for implementation. One such technology is genetic modifications to increase leaf glossiness and to change canopy growth in order to reflect more solar radiation away from the earth's surface (Ridgwell, Singarayer, Hetherington, & Valdes, 2009). Another possibility is genetic manipulation to allow for improved selection, resulting in improved nutrient use and water use efficiency, according to Lea and Parry (2008). These and other such technologies may have an important role in the future, but for now, farmers will have to rely on more traditional methods of adaptation.

Evidence of climate change is undeniable, and its effects will be inescapable. Climatic changes over the coming decades will threaten the viability of agriculture in America, a very serious concern. The impacts of these changes can be lessened through aggressive mitigation and adaptation techniques, but such techniques require dedicated, labor-intensive, and often costly changes, as well as quick action. It remains to be seen whether both American farmers and the American people are willing to make the necessary changes not only to farming practices, but to their very ways of life.

References

Biello, D. (2007, May 25). Combating climate change: Farming out global warming solutions. *Scientific American* online. Retrieved March 15, 2009, from http://www.sciam.com/article.cfm?id=combating-climate-change-farming-forestry.

Cline, W. (2007, November 19). Science: How climate change impacts agriculture. *The Washington Post* online. Retrieved March 15, 2009, from http://www.washingtonpost.com/wp-dyn/content/discussion/2007/11/16/DI2007111601638.html.

Easterling, W., Aggarwal, P., Batima, P., Brander, K., Erda, L., Howden, M., Kirilenko, A., Morton, J., Soussana, J.-F., Schmidhuber, J., & Tubiello, F. (2007). Food, fibre and forest products. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, UK, p 273-313. Retrieved May 3, 2009, from http://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4-wg2-chapter5.pdf.

Environmental Protection Agency (EPA). (2008, December 17). *Agriculture and food supply.* Retrieved March 15, 2009, from http://www.epa.gov/climatechange/effects/agriculture.html.

Evans, J. (2009, February). 21st century climate change in the Middle East. *Climatic Change*, *92*(3/4), 417-432. Retrieved March 16, 2009, doi:10.1007/s10584-008-9438-5

Food and Agriculture Organization of the United Nations. (2007). *Adaptation to climate change in agriculture, forestry, and fisheries: Perspective, framework, and priorities.* Interdepartmental Working Group on Climate Change. PDF file.

Giles, J. (2009, January 17). Climate change to stunt developing nations growth. *New Scientist*, *201*(2691), 7-7. Retrieved March 16, 2009, from Academic Search Premier database.

Hohenstein, W., & Chapin, B. (2008, May 27). *U.S. climate change science program releases reports on the effects of climate change on agriculture, land, and water resources and biodiversity.* USDA news release no. 0136.08. Retrieved March 15, 2009, from http://www.usda.gov/wps/portal/!ut/p/_s.7_0_A/7_0_1OB?contentidonly=true&contentid=2008/05/0136.xml.

Holden, C. (2009, January 9). Higher Temperatures Seen Reducing Global Harvests. *Science*, *323*(5911), 193-193. Retrieved March 16, 2009, from Academic Search Premier database.

Intergovernmental Panel on Climate Change. (2007). *Working Group II report: Impacts, adaptation, and vulnerability.* Retrieved March 15, 2009, from http://www.ipcc-wg2.org/index.html.

Lea, P., & Parry, M. (2008, December). Improving water use efficiency. *Annals of Applied Biology*, pp. 281,282. Retrieved March 16, 2009, doi:10.1111/j.1744-7348.2008.00301.x

Mestre-Sanchís, F., & Feijóo-Bello, M. (2009, January 15). Climate change and its marginalizing effect on agriculture. *Ecological Economics*, *68*(3), 896-904. Retrieved March 16, 2009, doi:10.1016/j.ecolecon.2008.07.015

National Oceanic and Atmospheric Administration. (2008, June 20). Expect more droughts, heavy downpours, excessive heat, and intense hurricanes due to global warming. *ScienceDaily*. Retrieved April 19, 2009, from http://www.sciencedaily.com/releases/2008/06/080619175522.htm

Ridgwell, A., Singarayer, J., Hetherington, A., & Valdes, P. (2009, January 27). Tackling Regional Climate Change By Leaf Albedo Bio-geoengineering. *Current Biology*, *19*(2), 146-150. Retrieved March 16, 2009, doi:10.1016/j.cub.2008.12.025

Rosenzweig, C., & Hillel, D. (1995). Potential impacts of climate change on agriculture and food supply. *Consequences: The Nature and Implications of Environmental Change (1)*2. Retrieved March 15, 2009, from http://www.gcrio.org/CONSEQUENCES/ summer95/agriculture.html.

University of Minnesota. (2008, June 25). Extreme weather events can unleash a 'perfect storm' of infectious diseases, research study says. *ScienceDaily*. Retrieved April 19, 2009, from http://www.sciencedaily.com/releases/2008/06/080625073804.htm.

Younger, M., Morrow-Almeida, H., Vindigni, S., & Dannenberg, A. (2008, November). The Built Environment, Climate Change, and Health: Opportunities for Co-Benefits. *American Journal of Preventive Medicine*, *35*(5), 517-526. Retrieved March 16, 2009, doi:10.1016/j.amepre.2008.08.017