Climate Change and Food Security: Complicated Issues with Sustainable Solutions

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Abstract

Climate change and *food insecurity* are two pressing global issues with numerous negative consequences. They have a very intricate relationship which will continue to evolve. In many ways, they are conflicting: increased agricultural production can cause climate change, and the negative effects of climate change exacerbate food insecurity. Yet, this paper seeks to find common causes and opportunities for action between the two problems. As an extensive literature and research review, the ultimate goal of this paper is to establish explicit coordinated solutions to these problems.

This analysis identifies the many reasons that both of these problems persist. International discussions, treaties, and programs to combat climate change have ultimately failed and neglected to establish explicit plans to address agricultural causes and effects of climate change. Meanwhile, efforts to address food insecurity have been insufficient, as the number of hungry and undernourished people remains at near historically high levels, despite increases in agricultural production. The evolution and influence of international food aid and agricultural development is discussed to support these findings. Globalization is also identified as a driver of food inequities and environmental injustice.

Sustainable agricultural development is offered as the pathway forward to increasing agricultural yields while protecting the environment. Methods of *sustainable intensification*, including *precision farming* and *agroecology*, are discussed in detail. Yet, while potential solutions to these problems do exist, they require more than just advanced technologies. Impediments to finding solutions that include defective policies, economic inefficiencies, failed leadership, and destructive modes of development are discussed. Structural, economic, and political transformations that focus on issues of poverty and development must be undertaken. The incorporation of pro-poor solutions that emphasize environmental protection, gender equality, energy efficiency, and public health are urgently needed.

The potential of the U.S. Feed the Future program to ultimately lead the way in the new approach to addressing food security is recognized. The program must undergo some alterations in order to comprehensively address climate change as well as food insecurity, but is ultimately a very promising solution with political and societal will. The paper concludes with an analysis of the changes in perspective necessary for both food security and climate change to be addressed. These ideological changes address a more abstract root cause of these problems, and enable a sustainable pathway forward.

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Introduction

Humans require daily, nutrient-rich sustenance in order to function and live fulfilling lives. Hunger and malnourishment are undesirable to all human societies, regardless of location, culture, and level of development. Humans *need* food, but in a world with complicated food production and distribution systems and an immense human population, ensuring that every human has access to food on a daily basis is a goal yet to be achieved.

The Earth, too, has requirements for its proper functioning. Its natural cycles for water, carbon, nitrogen, and other nutrients must function properly to ensure the maintenance of its ecosystems and natural resources. Its oceans and freshwater bodies must be protected to sustain Earth's many organisms as well as to maintain temperatures and terrestrial environments. Lastly, the atmosphere in which the Earth exists is critical to each of these processes and to the reliability of natural environmental services. Changes to Earth's atmosphere implicate numerous and significant changes to life on Earth and thus are considerable causes for concern.

How can we reconcile a vital need of humans that is not fully met and a vital component of the Earth that is being altered at unprecedented rates? By analyzing the relationship between their manifestations—food insecurity and climate change, respectively—the causes of these problems may be identified, and solutions that work to address both of these problems can be established.

The relationship between food security and climate change has been widely recognized and increasingly studied in academic and research spheres in the past decade. The Consultative Group on International Agricultural Research (CGIAR) and the Earth System Science Partnership (ESSP) launched the Climate Change, Agriculture, and Food Security (CCAFS)

research initiative in 2002 to "address the increasing challenge of global warming and declining food security on agricultural practices, policies and measures through strategic collaboration," (CCAFS, 2012). This research program exists to analyze the precise focus issues of this paper. Oxfam International, the international confederation of organizations working to address global poverty and injustice, has continuously worked extensively on climate change and agricultural issues and programs. Oxfam recognizes the notable linkages between the two, especially in relation to poverty and social injustice (Oxfam, *Campaigns*, 2012). From 2004 to 2008, the World Bank worked in partnership with the FAO, GEF, UNDP, UNEP, WHO and UNESCO and representatives of governments, civil society, private sector and scientific institutions around the world to produce The International Assessment of Agricultural Knowledge, Science, and Technology for Development (IAASTD). The report evaluates the extant agricultural knowledge, research, and technology as well as the institutional arrangements and public and private sector policies in regard to agriculture "in order to reduce hunger and poverty, improve rural livelihoods, and facilitate equitable, environmentally, socially and economically sustainable development," (IAASTD, *FAQ*, 2012). The IAASTD has established many specific policy suggestions to address these issues. Notable scholars and authors in the global food governance field include Jennifer Clapp, CIGI Chair in International Governance and Professor at University of Waterloo; Eric Holt-Jimenez, Executive Director at Food First; and Bryan McDonald, Assistant Professor of Science, Technology, and Society and Fellow of the International Center for the Study of Terrorism at Pennsylvania State University. These scholars possess remarkable expertise on the food system in terms of policy, environmental science, development, and economics at local, national, and international levels, enabling them to provide a very thorough

analysis of food insecurity in relation to climate change. Their works made considerable contributions in the formation of this analysis.

These organizations and individuals have triumphed in recognizing and expanding the existing information and publications on the topic of climate change and food security. This paper seeks to identify the reasons that this knowledge is not being properly utilized to address the issue. It recognizes that, while there exists an abundance of technologies that both mitigate climate change and enhance food security, large-scale adoption of these technologies has yet to occur. The aim of this paper is to identify the problems with the global food system, the current practice of food aid and agricultural development programs, and the widespread ideologies that have inhibited a distinct recognition of the significant connection between climate change and food security. The absence of this acknowledgement has in turn hindered the widespread development of programs and solutions to address these two large problems concurrently. Ultimately, steps to move forward from this current dilemma must be identified, as well as viable pathways and programs to lead the way.

The introductory section of the paper gives an overview of the problems of interest. Climate change and food security are each clearly defined and described. Their many connections and complex relationship are then analyzed. The second section describes the barriers that international aid and food security programs have encountered in addressing food insecurity as a whole, and more specifically in tandem with the issue of climate change. The historical trajectory of food aid follows to uncover its varying motivations, effects, and evolution and provide an explanation for its current state. The contributions of globalization to both food aid and the global food production system as a whole are then considered.

The third section seeks to find solutions among these interrelated problems: food insecurity, climate change and environmental degradation, failing international aid, and an inequitable global food system. The extant agricultural technologies to mitigate or adapt to climate change while improving the ability to grow food, increase yields, and overcome poverty are discussed in detail. Yet, the technologies alone cannot fix the problem; significant changes to the structure of agricultural development, global food distribution and trade, and acquisition of natural resources are identified as the critical elements to successfully addressing these problems. The fourth and final section concludes with a commentary on the ideological roots of these problems and suggestions for a pathway forward.

Background on Recent Progression of Climate Change

"We need to stop this dangerous experiment humankind is conducting on the Earth's atmosphere."

-Thomas Loster, climate expert and Chairman of Munich Re, world's largest re-insurer

(Schneder, S., and Lane, J., 2006)

Growing scientific understanding.

The term "climate change" describes the broad range of alterations in climatic and weather conditions manifested in changes in average conditions and increased frequency and severity of extreme conditions (Beddington, et. al., 2012). Despite incessant debate and contradictory claims surrounding the issue, it indeed is occurring. In fact, 97-98% of scientists most actively publishing in the field have confirmed that climate change is happening, and that the recent substantial changes being observed are contributable to human activities (Anderegg, W., Prall, J., Harold, J., & Schneider, S., 2010). Most climate scientists also agree that these global changes are primarily due to the *greenhouse effect*: as levels of certain atmospheric gases

rise, they trap more of the heat that radiates from Earth towards space, causing global temperatures to rise. This effect is caused by an increased concentration of carbon dioxide (CO_2) and other greenhouse gases (GHGs) in the atmosphere, which have been emitted by the anthropogenic burning of fossil fuels (NASA, 2012). Human activities have essentially changed the composition of the atmosphere, altering its patterns and ultimately warming the Earth.

While shifts in climate patterns can be natural, the types of changes that have occurred in the past 100 years are unidirectional, unnatural, and destructive (CCAFS, 2012). In fact, atmospheric carbon dioxide has increased by more than 30% in the past few centuries, primarily because of the Industrial Revolution (Schneider, S., and Lane, J., 2006). Global temperature has historically experienced many fluctuations, and had a gradual decrease over the 900 years before the 20th century, in which it experienced a sharp upturn. While skeptics continue to argue that large temperature fluctuations are natural, scientists have concluded that the scale of the recent rise in temperature compared with its very short period of time is not explained by natural causes (Schneider, & Lane, 2006).

Extreme, catastrophic changes to what NASA denotes "earth's vital signs" have been observed around the globe, proving climate change's existence and force. September arctic sea ice is melting at 11.5% per year, reaching its lowest extent on record; carbon dioxide concentrations are at 392 ppms, their highest level in 650,000 years; the global average sea level has risen 4-8 inches over the past century; and the decade of 2000-2009 was the warmest on record (NASA, 2012). The effects of climate change are being seen throughout the globe, causing substantial changes in the functioning of the planet. Scientists anticipate catastrophic changes, and insurers expect natural-disaster related damages to increase exponentially in

coming years (Schneider, & Lane, 2006). Yet, substantial global action needed to avert further global warming and environmental destruction has been lacking.

International discussion and action.

The Earth's climate has long been a topic of discussion on an international scale. The Intergovernmental Panel on Climate Change (IPCC) was created by the United Nations (UN) in 1988 to provide national governments with a scientific understanding of the state of the global climate (IPCC, 2010). The United Nations Framework Convention on Climate Change (UNFCCC) was subsequently opened for signature in 1992 at the Earth Summit in Rio de Janeiro, Brazil. This international treaty established the distinct goals of stabilizing GHG concentrations in the atmosphere, limiting average global temperature increases, and addressing inevitable environmental impacts (UNFCCC, 2012). The UNFCCC developed the Kyoto Protocol in 1997 and the Copenhagen Accord in 2009 which both established emission targets for countries in order to combat climate change.

While these and other efforts have been made and emissions have successfully been reduced by many countries, total global emissions of greenhouse gases and global temperatures have continued to rise. The international treaties and agreements designed to address climate change have ultimately failed, a fact which has gone largely overlooked in the policy arena (Climate Emergency Institute, 2012). As a result, the current effects of climate change are being widely experienced, and unknown, distressing consequences are pending as time to act is running out.

Despite conclusive science supporting climate change, fervent skepticism remains and continues to hamper serious action on national and global scales. Solutions to addressing climate change would necessitate a decrease in fossil fuel use that involves the restructuring of national

and global economies. Many powerful industries, especially those of coal and oil, have perpetuated the notion that climate change is an unconfirmed theory and have successfully blocked legislation and regulations that could lead towards a more sustainable future climate scenario (McDonald, 2010). In reference to a NASA-led study published in *Science* in January 2012, Paul Hanley notes, "(It's) too bad vested interests are illegitimately blocking efforts to mitigate climate change by sowing doubt about legitimate climate science. Climate change mitigation could boost food security and saves millions of lives," (2012). Hanley's words resonate with a growing portion of the global population that go to bed hungry each night. As climate change continues, it increasingly diminishes the ability of people throughout the globe to feed themselves.

Food Security

Food security is an issue whose implications are far-ranging and multi-dimensional: both powerful corporations and helpless, hungry children are affected by it. It is relevant in both discussions of economics and finance and of morality and ethics. In any circumstance, it cannot be denied that food security is a very important and desirable pursuit.

According to USAID, "Food security means having, at all times, both physical and economic access to sufficient food to meet dietary needs for a productive and healthy life. A family is food secure when its members do not live in hunger or fear of hunger," (USAID, 2010). While meeting these conditions may seem quite feasible to citizens in developed countries, in reality over one-eighth of the global population is food insecure. According to the FAO's *The State of Food Security in the World 2011,* an estimated 925 million people in the world were undernourished in 2010[1] (FAO, 2011, p. 4). This problem seems unfitting in a world with more

[1] The most recent statistic is from 2010 because the FAO is undertaking a major revision of how it estimates food security (World Hunger Education Service, 2012).

than enough food to feed every person. Yet, nearly all of these people are in developing countries and lack the income to buy or the land to grow food (World Hunger Education Service, 2012). The existence of widespread hunger—a denial of a basic human right—in a world with enough food indicates an urgent need for transformative changes to the global food system.

Although agricultural technologies are constantly being developed, increases in global population and disruptive environmental and social phenomena hamper advances in agricultural efficiency and productivity. An estimated 70 percent increase in agricultural production by 2050 is needed in order to provide sufficient food for the world's growing population (Bruinsma, 2009). With global food prices at near record levels, this will be an immense challenge that requires new methods, technologies, and perspectives. Food insecurity remains a critical global issue with no easy solutions.

> Recent projections based on population growth trends suggest that yields of food crops in Africa will have to increase by 230% by 2050 just to maintain the current insufficient food consumption level on the continent
> (Pye-Smith, 2011)

The right to food implies that food be available, accessible and adequate to human beings (De Schutter, 2010). The availability component requires a sufficient supply of food on the market to meet the demand. The global food supply actually exceeds the global demand for food. Yet, the local food supply is too low in many places, highlighting the issue of disproportionate distribution of global food supplies (McDonald, 2010). The accessibility component entails both physical and economic access, meaning that it must be both obtainable for all human demographics and affordable without compromising other basic needs. Accessibility is a considerable problem in food insecurity: various demographics are especially prone to hunger, and many people do have to compromise their basic needs in order to obtain food. Adequacy entails that food meets daily dietary needs, is safe for human consumption, is

free of adverse substances, and is culturally acceptable (De Schutter, 2010, p. 4). In many developing nations, even when there is enough food to meet demand, it lacks the nutrients necessary. This can lead to micronutrient deficiencies, or deficiencies in essential vitamins and minerals (World Hunger Education Service, 2012). Such deficiencies often go unnoticed and are widely unaddressed in food aid programs, granting them the term "hidden hunger," (Paarlberg, 2010). Preschool-aged children and nursing women and mothers are most at risk to micronutrient deficiencies, especially when living in poor, rural areas (Paarlberg, 2010). This problem calls for a new analysis of the health and hunger problems being faced in these resource and nutrient deprived regions.

Between 100 and 140 million children are Vitamin A deficient, which can cause blindness and weaken the immune system. Iron and Iodine are other common types of micronutrient deficiencies in developing countries (World Hunger Report, 2012)

Ensuring the realization of the right to food and addressing issues of availability, accessibility, and adequacy implies not only increases in agricultural yields. It is vital to look at the broader problem, the relevant issues at stake, and the policies and politics in affect.

The Nexus

The linkages between climate change and food security are numerous and complex. According to the Food and Agriculture Organization of the United Nations (FAO), climate change affects all four dimensions of food security: food availability, food accessibility, food utilization, and food systems stability. "Climate change will essentially "have an impact on human health, livelihood assets, food production, and distribution channels, as well as changing purchasing power and market floors," (FAO, 2008, p. iii). Thus, it will alter not only agricultural productivity, but also food distribution channels, affordability of food, and economic productivity that enables effective food systems, among other things.

While the connections are overlapping and contingent on one another, it is important to acknowledge and discuss the broad categories of effects so the intricate relationship between these two issues can be understood fully. The environmental and socioeconomic effects will be discussed below to provide a comprehensive understanding of the relationship between these two issues.

Environmental effects.

Climate change is by definition an environmental issue. While its essential theme is the warming of the planet's atmosphere—a topic of climatology—its environmental scope extends much further. Climate change is affecting every aspect of the global environment, from the hydrological cycle to biodiversity, from soil fertility to natural disasters. As the atmosphere is a key element in creating the conditions that allow life on Earth to exist, it is not surprising that substantial changes regarding its temperature and composition have affected essentially every component of Earth's surface.

Food security is also an environmental issue. Agriculture necessitates the abilities to grow, cultivate, and distribute food supplies, which depend on suitable and reliable environmental conditions. Food security is both affecting and affected by local, regional, and global environments.

The particular environmental effects of climate change on food security are far-ranging and problematic. All five parts of the climate system—the biosphere, the lithosphere, the atmosphere, the hydrosphere, and the cryosphere—are affected by climate change (FAO, 2008). The functioning of the environmental system has been altered and extreme weather, destruction of ecosystems, and changes in Earth's natural cycles have resulted. The IPCC projects that global temperature will rise between 1.4 and 5.8 °C by 2100, exceeding the global average rate

of temperature change sustained over the last 10,000 years (Schneider & Lane, 2006). An increase in even 3 to 4 °C will cause rising sea levels, increased flooding in some regions, and droughts in other regions that could displace at least 200,000 people (Osborne, H., 2006). The IPCC's list of likely effects that will follow include frequent heat waves, more intense storms, a surge in weather-related damage, increased intensity of food and droughts, warmer surface temperatures, more rapid spread of disease, loss of farming productivity, agricultural migration, species extinction, and loss of biodiversity (Schneider, & Lane, 2006). All of these consequences already have and will continue to affect food security directly or indirectly.

Agriculture encounters the more specific problems of increased insect infestations, crop damage from extreme heat, increased soil erosion, increased weed growth, increased plant disease, decreased herbicide and pesticide efficacy, increased moisture stress, waterlogged land, increased floods and storms, increased drought, and increased ground level ozone, among other effects (Climate Emergency Institute, 2011). Substantial research has been carried out that enables predictions to be made about the potential effects of climate change on agriculture, yet it is still quite difficult to anticipate all of the effects that could arise.

Socio-economic effects.

Climate change and food security entail a broad range of interrelated socioeconomic effects. These consequences diminish the quality of life and productive potential of countless people. As noted below, the different categories of effects form a vicious cycle of human suffering and hindered development.

Food insecurity encompasses the serious issues of hunger and malnutrition. Currently, almost one billion people suffer from hunger worldwide, and more than 3.5 million children die from under-nutrition each year (FeedTheFuture, 2012). Hunger leads to decreased economic

productivity, diminished public health, and civil unrest and insecurity. It is also a denial of a basic human right and an unjust state of human life.

Aside from lack of food distribution and resources, the largest driver of hunger is poverty. In fact, the international food crisis of 2008 was not due to a lack of food—the amount of food produced was actually 1.5 times the global demand—but rather to an inability for many impoverished people to afford food (Holt-Giménez and Patel, 2009). The rise in commodity prices then exacerbated the issue, increasing the number of hungry people from 800 million to over 1 billion worldwide (Beddington, et. al, 2012, p. 16). There are many ways that climate change will exacerbate poverty on a global scale and especially in developing countries. In fact, people who are already impoverished and food insecure are the most vulnerable to the effects of climate change (FAO, 2008). As previously mentioned, climate change will cause many environmental problems that will decrease agricultural productivity and even destroy food supplies. This will be very detrimental in developing countries, where agriculture accounts for 29% of the gross domestic product (GDP) and provides jobs for 65% of their populations (Pye-Smith, 2011). Other effects of climate change will incur non-agricultural economic losses, such as water shortages and natural disasters, which will diminish the ability for many people to meet the daily food requirements.

According to the Stern Review Report on the Economics of Climate Change, a 3°C rise in temperature would cause 150-550 million people at risk of hunger and 1-3 million more deaths from malnutrition. The Amazon Rainforest, Southern Europe, parts of Australia, and Africa will be especially vulnerable to climate change (2006).

As previously mentioned, food prices are at near-record levels, decreasing the number of people with access to food even further. The availability of oil and other energy resources is decreasing, which leads to a further increase in input costs (McDonald, 2010). As a result, many farmers are unable the costs of agricultural production, and many consumers are unable to afford

the rising costs of food. Furthermore, the unpredictability of climate change effects such as droughts, natural disasters, and salinization will hinder poor farmers from making long-term investments that could lift them out of poverty. The economic costs of climate change will not only be to the world's poor, but will in fact be felt on a global scale. According to the Stern Review on the Economics of Climate Change, unaddressed climate change could cost at least 5% of global GDP per year, and more than 20% of GDP if the more extreme projections are realized (Osboune, 2006). The global economy could eventually benefit by up to $2.5 trillion per year if a low-carbon path is instead chosen (Osborne, 2006). While it is impossible to know precisely how large the price tag of climate change will be, the economic losses and costs will undoubtedly be high. The costs that will be incurred by those who are already impoverished will be enormous, and their potential for development, or even recovery, will be diminished.

Alongside and inextricably linked with poverty is the issue of public health. An impoverished community has less resources, infrastructure, and human capital to develop medical and sanitation services. Climate change will lead to the emergence of new vector-, food-, and water-borne diseases, with which impoverished communities lack resources to cope. Furthermore, as crops are destroyed or made less productive by climate change, the percentage of under-nourished people in local populations will increase. Chronic hunger and micro-nutrient deficiencies increase susceptibility to diseases and illness, which lower levels of public health (McDonald, 2010). Also, climate change further inhibits economic growth via decreased agricultural production and increased political instability. These effects inhibit the development of necessary services—from sanitation systems to public health clinics—to ensure a healthy population. Essentially, climate change will negatively affect public health systems in numerous

ways. Resulting unhealthy populations will lead to decreased economic productivity, which will lead to decreased development and growth, which will lead to increased poverty.

Finally, an often overlooked but very significant and destructive effect of food insecurity is political and social unrest. Like any other scarce natural resource, a lack of food can become the root of political instability. When national security is threatened by food shortages, developing and implementing solutions to the aforementioned problems—poverty, disease and malnutrition, and economic stagnation—is nearly impossible. International conflicts and threats to security have seen a considerable increase in recent years. By the end of 2008, the total number of conflict-induced internally displaced persons (IDPs) worldwide reached 26 million (World Hunger Education Service, 2012). The recent Arab Spring that instigated demonstrations and protests throughout the Arab world began as angry protests over a rise in bread prices. The high prices were a result of drought and poor harvest in Russia in 2010, an event possibly attributable to climate change (Broder, 2011). Food riots have also taken place throughout Africa, Asia, Europe, and Latin America, in countries including Mexico, Morrocco, Mauritania, Burkina Faso, Cameroon, Yemen, Egypt, Haiti, and over 20 other countries (Holt-Giménez and Patel, 2009, p. 6). Promoting national stability and security is nearly impossible in countries ridden with hunger, poverty, and disease. The vicious cycle of poverty, low economic development, political instability, and poor public health that is already operating in food insecure areas will be further intensified by the effects of climate change.

Not only does climate change lead to food insecurity, but food insecurity also leads to increased environmental degradation and exacerbates climate change. As Sir John Beddington, the UK's chief scientific adviser, and his colleagues note, "As well as causing widespread human suffering, food insecurity contributes to degradation and depletion of natural resources,

migration to urban areas and across borders, and political and economic instability," (2012, p. 8). In food insecure conditions, unsustainable practices such as deforestation are adopted for short-term gains, but often lead to long-term losses (Osbourne, 2007). Thus, it is important to note that food security is not only an effect of this vicious cycle, but it is also a cause. Climate change is yet another component being added to this destructive pattern of social, political, environmental, and human degradation.

Agriculture's effects on climate change.

It is important to remember that the cause-effect relationship between climate change and agriculture also is not one-sided. Climate change is affecting the ability of humankind to produce and distribute food *and* the food production system is a large contributor to climate change. As noted by Holt-Giménez and Patel, "as a sector, agriculture both induces and suffers the most from climate-related hazards," (2009, p.3). The mutually influential relationship makes it especially hard to address both issues. Agriculture is an especially challenging issue to address, given its size and extent, importance to human needs, and economic and political significance.

Agriculture is a very large consumer of resources and emitter of harmful substances. Pastoral and intensive agriculture utilize about half of all useable land on the earth (Tilman, et. al., 2002). Intensive agricultural practices exploit much of this land and render it unrecoverable, if not unusable. Agriculture emits carbon dioxide through land clearance and deforestation, as well as methane, nitrous oxide, and ammonia from crops and livestock production (Pye-Smith, 2011). In fact, land use and food production account for 30% of anthropogenic GHG emissions from fertilizers, ruminant digestion, rice cultivation, deforestation, and fuel use (Beddington, et. al., 2012). It also consumes 60-70% of the world's diminishing freshwater supply (Holt-

Giménez and Patel, 2009, p. 3). The methods chosen for the future of agricultural production will be very determinative of the future of both food security and climate change. As Tilman notes, "Agriculturalists are the principle managers of global useable lands and will shape, perhaps irreversibly, the surface of the Earth in the coming decades, (Tillman, et. al, 2002).

Agricultural practices also reduce the ability of ecosystems to provide goods and services, which are essential to the functioning of the planet and human society. For example, the applications of pesticides and fertilizers can pollute groundwater and surface water, and decrease fishery values and freshwater supply. Agricultural practices degrade soil quality, causing eutrophication of aquatic ecosystems and require more agricultural inputs to make up for the loss in soil quality (Tilman, 2002). The Earth's natural services contribute greatly to economic activity and provide many services that would be very expensive to replicate. Environmental degradation from agriculture disables these services and can diminish them beyond repair, leaving humankind with even more challenges to address.

In his book, *Food Security*, Bryan McDonald enumerates four distinct categories of impacts that agriculture has on the environment. The first category is impacts on land and soil, which include soil degradation, erosion, salinization, and nutrient depletion. As land and soil regulate hydrological cycles, protect biodiversity, store carbon, and provide various other ecosystem functions, the degradation of these two resources is highly problematic (McDonald, 2010). Next is the category of impacts on water use and water quality, which are very important as less than 1% of the world's water is freshwater available directly for human uses (Schneider, & Lane, 2006), and agriculture and irrigation use 70% of that small fraction (Holt-Giménez and Patel, 2009). UN water predicts that "by 2025, 1.8 billion people will be living in countries or regions with absolute water scarcity and two-thirds of the world population could be under

conditions of water stress," (McDonald, 2010, p. 104). Agriculture pollutes water with pesticides, fertilizers, and agricultural and livestock waste products. Furthermore, oceans are greatly affected. Agriculture accelerates climate change with its greenhouse gas emissions, which causes sea-level rise in oceans. It also creates dead zones, reduces fish stocks, leads to overfishing, and destroys coastal wetland and coral reefs with runoff (McDonald, 2010). McDonald's third category of impacts relates to habitat and biodiversity loss. Forests host terrestrial biodiversity, moderate climate change, store carbon, and support local livelihoods. Unfortunately, they are often destroyed to increase land for agriculture. As animals, plants, and microorganisms lose their habitats for these purposes, ecosystem services and ecological relationships are lost as well. Some of these species are natural pest-controllers and pollinators, which have a very high cost of replacement (McDonald, 2010). The fourth category is impacts on energy use. Agriculture and food production are processes involving many steps--production, transportation, preservation, storage, preparation, and consumption--all of which are energy-consuming. When both the direct energy usage (e.g. energy used to run agricultural machinery and equipment), and indirect energy uses (e.g. energy used to produce fertilizer and pesticides) are considered, the energy used just for food production is very significant. Transportation both from farm to market and from store to consumer also consumes a great amount of energy.

Despite the many negative impacts that agriculture has on the environment, it is important to note the progress and benefits of modern agriculture. The introduction of new technologies has increased global per capita food supply, reduced hunger and malnutrition, and preserved natural ecosystems that would have otherwise been converted to cropland if productivity had not seen such increases (Tilman, et. al., 2002). If the positive aspects of modern agriculture can be accentuated and the negative impacts reduced, then agriculture can potentially

become a solution for, rather than a cause of, climate change. "Agriculture is at the nexus of three of the greatest challenges of the 21st century—achieving food security, adapting to climate change, and mitigating climate change while critical resources such as water, energy, and land become increasingly scarce," (Beddington, et. al., 2012, p. 6). Indeed, the ways in which humankind chooses to continue forward with agriculture and whether or not the industry is restructured will be very influential on the future of the planet.

The interactions and relationship between climate change and food insecurity is apparent. They cannot be addressed separately from one another, and thus solutions must be established that acknowledge and incorporate their intricate relationship. Yet, in order to establish successful solutions, the past and current programs and attempted solutions to address food insecurity and climate change must be understood. The next section will focus on international aid and action and their influence on current circumstances.

International Action

Food Aid

Addressing the issue of food insecurity has been a continuous challenge in human history. In the past 50 years, the emergence of food aid has drastically altered the ways in which the international community tackles the problems of hunger, poverty and malnutrition. While food aid has alleviated food insecurity for many people, it also involves a wide range of problems and complications that weaken its efficacy.

A brief history.

International food aid has a complex history which has shaped the current state of food security. Before 1950, international transfers of food occurred on an ad hoc basis to address food shortages in emergency situations (Clapp, 2012). The advent of formal food aid began in 1954,

with the creation of the Agricultural Trade Development Assistance Act, or Public Law 480, by President Eisenhower. This program was renamed "Food for Peace" by President John F. Kennedy in 1961, emphasizing its focus on both alleviating hunger and providing stability in developing countries (USAID, 2004). The newly formed USAID was given responsibility over the program.

Early food aid was far from pure international goodwill; it had more domestic industrial incentives than humanitarian ones. When food aid commenced in 1954, the U.S. agricultural and shipping industries as well as donor groups benefitted more financially than the aid recipients did (Lewis and Broder, 2011). During World War II, the U.S. and other industrialized countries produced additional stocks of food as a response to tight supply and high food prices. After the war, very significant surpluses posed problems for these countries—it cost money to store the stocks, and domestic food prices plummeted because supply was so high (Clapp, 2012). Thus, these countries had economic incentive to donate their food supplies to countries in need. The aid often went to countries that were geopolitically important over those with most severe food insecurity (Clapp, 2012). This pattern continued as Cold War geopolitics during the 1960s encouraged the U.S. to invest in the Green Revolution, a series of scientific and educational efforts that greatly increased agricultural yields in many developing countries. The United States' primary intentions were to build stability and counter communism in developing countries, but the ensuing achievements of the Green Revolution were very substantial in terms of food security (Wessels, 2012). The use of new plant varieties, pesticides, and herbicides allowed agricultural productivity to reach new heights and many developing countries become self-sufficient in their food supply (Biotechnology and Biological Science Research Council,

2012). Their aid helped to prevent mass starvation in Asia and Latin America with the research, development, and technology transfer that increased agricultural productivity.

After the success of the Green Revolution, U.S. aid was redirected towards short-term relief under the notion that the food crisis was over (Broder, 2011). In reality, hunger and food insecurity were still rampant. Norman Borlaug, the American agronomist who is often referred to as the "Father of the Green Revolution," received the Nobel Peace Prize 1970. In his speech, he reiterated that, despite the commendable feats in agriculture in the previous decades, the ultimate problem of hunger had not been resolved (BBSRC, 2012). Furthermore, the fertilizers, water, pesticides, equipment, and labor involved in the more intensive processes are costly, and many small farmers could not afford them. The Green Revolution was largely absent in Africa, where lacking public funds, weak governments, and lack of irrigation systems impeded investments in new technologies (Gillis, 2011). Rural impoverishment, debt, and displacement were other pressing problems that still needed to be addressed in many of the recipient countries (BBSRC). Food insecurity had not and still has not ceased to be a serious issue.

The rise of the United Nations World Food Programme (WFP) in the mid-1970s allowed a decrease in aid through U.S. PL 480, decreasing the burden on the United States. Multi-lateral food aid increased, allowing donor countries, NGOs, institutions, and private investors to collaborate (Barrett & Maxwell, 2005). While food aid was evolving to be a more global and multi-national endeavor, nations' individual interests and conflicts among donors were not put aside.

In 1970, a global food crisis emerged due to tight food supply and high food prices. This decreased supply was caused by a number of factors, including poor harvests in the Soviet Union, poor weather in Africa and North America, and high oil prices (Clapp, 2012). As a

result, donors decreased their food aid donations. Total U.S. food aid in 1974 and 1975 amounted to less than 20% of the quantities in the mid-1960s (Clapp, 2012, p. 24). This exacerbated the crisis as millions of people depended on this food aid to meet their daily dietary needs. After the food crisis 1970s, the patterns of food aid distribution came under question. The WFP established norms against the prioritization of food aid to geopolitically important countries, instead requiring that it go to countries where food insecurity was severe (Clapp, 2012). Also, principles of surplus disposal were developed to prevent the disposal of agricultural surpluses in the form of food aid from disrupting domestic production or displacing normal amounts of commercial inputs in recipient countries (Clapp, 2012). In the 1980s and 1990s, emergency food aid towards natural disasters or conflict increased while food aid programs to central governments decreased (Barrett and Maxwell, 2005).

In 1996, the World Food Summit was held by the UN, at which 185 nations signed a declaration to cut the number of hungry people in half by 2015. Yet, progress lagged for the first five years, prompting a "World Food Summit: Five Years Later" meeting to take place in the summer of 2002 (Rosset, 2002). Both meetings established goals that they are very unlikely to achieve. The UN also established the Millenium Development Goals (MDGs), a set of eight international development goals to be achieved by 2015. One of the general goals is to eradicate extreme poverty and hunger; a more specific target under this goal is to halve the proportion of people who suffer from hunger

The Millenium Development Goals have been largely unsuccessful in the region of Sub-Saharn Africa:

- Net loss of forests between 2000-2010 was 3.4 million hectares per year
- 31% people still lacked an improved sanitation facility in 2008
- In 2008, 31% of people were undernourished.
- In 2008, child mortality rate was more than double that of any other region at 174 deaths per 1000 live births. Maternal death rate was 640 deaths per 100,000 live births.
- Contraception use remained at just 22% of women ages 15-49 in 2008; 24% of women had an unmet need for family planning.
- In 2009, the youth literacy rate remained the lowest worldwide at 72%
- HIV incidence rates in 2009 remained more than 5 times any other region at .40 per 100 people (United Nations, 2011)

(UN MDG, 2012). Progress towards reaching this goal, as well as many of the other MDGs, has been very uneven—while some countries, like India and China, have seen great improvements in their quality of life, others, such as most of the sub-Saharan African countries, have seen little progress. Also, the improvements in countries like India and China are largely due to their own economic growth and are barely attributable to the MDG project. Food aid programs are in great need of many changes.

The United States is still the leading donor of food aid, but other countries, such as Brazil, Russia, India, China, Saudi Arabia, and South Korea are emerging as donors as well (Clapp, 2012). Other smaller charities, organizations, and national governments have donated vast quantities of aid, conducted endless research, and developed countless programs and strategies to address hunger and food insecurity. Their efforts have been effective, but the problem remains unsolved.

The U.S. confronts international disapproval of its decision to tie food aid to food procured within its national borders, an action deemed inefficient and less beneficial to recipients than procuring food aid closer to the recipient (Clapp, 2012). Tying food aid has been largely discontinued by EU member states and other donors. Yet, the U.S. is currently aiming to decrease food aid altogether and instead focus on developing new technologies that will increase production to promote food security (Clapp, 2012). These actions will likely resonate better with the rest of the international community.

Over the past decade, the United States has allotted $2.2 billion a year to food aid (Broder, 2011). Yet, congressional pressures have yielded a food aid target $124 million less than President Obama requested. It is estimated that for every $100 million cut in funding, 2.5 million people will not be fed (Broder, 2011). On a global scale, too, investments by both donor

countries and low-income country governments in agricultural R&D to improve agricultural productivity have also decreased (Beddington, et.al., 2012). Between mid-2010 and early 2011, rising food prices caused an additional forty-four million people to fall below the poverty line at $1.25 per day, increasing food insecurity (Clapp 2012). Thus, it is vital that the United States becomes more efficient, effective, and conscientious about addressing food security than ever before. They need a program that responds to each aspect of the issue of food insecurity and the current conditions in which it exists.

Implementation Issues

Food aid and programs suffer from various implementation issues. In *Food Aid after 50 years: Recasting its Role*, C. Barrett and D. G. Maxwell identify 5 major implementation problems common in food aid. First, the aid can "leak" to non-targeted individuals, while missing intended benefits. A second issue is timing. While food aid would ideally flow counter-cyclically to stabilize food availability, it instead flows on a budgeted monetary basis. Furthermore, delivery lags are frequent. The third problem comes in the form of disincentive effects, which include product price effects, labor supply disincentives, and government policy effects. These consequences inhibit economic development in recipient countries, which is quite contrary to the ideal result. The fourth issue is with procurement modalities. Because of the shipping premium cost, the open market shipping, the source country procurement premium, and the destination market cost, $1.00 worth of food often costs over $2.00 when all costs are included. This step in implementation is clearly very inefficient and incurs costs on those who are already in poverty, thus exacerbating the problem of food insecurity rather than solving it. The final issue that Barrett and Maxwell describe is monetization. This process generates cash flows for NGOs to cover their costs but ultimately decreases efficiency. The disincentive effects

and timing complications are worsened (Barrett & Maxwell, 2005). Thus, while the statistics regarding the generous donations that developed countries allocate to food aid appear to be very generous, the actual amount that reaches the intended recipients is much lower, and the number of unintended negative consequences is high.

Other supply issues inhibit effective implementation. At times, suppliers allow cargo preferences to get in the way of efficiency. Further restrictions on buying food from farmers in or near famine areas hinder economic growth in these areas and also decrease efficiency (Broder, 2011). Many of these regulations are accepted or unacknowledged on international discussions of best practices for food aid, although their impacts on food security are substantial.

Other problems with implementation involve failures to coordinate every level of a food aid program. While innovative ideas and admirable goals are often established at the top level, creating strategic plans to effectively carry them out on the ground level is often a neglected task. In regard to climate change, this can be especially true. Among other things, it is essential to consider ways in which climatic information is integrated within early warning systems, surveillance systems, and market information systems. Pathogen, pest, and disease effects on crop and livestock models and early warning systems are particularly important (CCAFS, 2010). The inclusion of such effects is increasing, but it is still necessary that they be expanded for food aid to be most effective.

These implementation issues support the idea that food aid is in itself not a viable solution to solving food security. The inability of developed countries to successfully respond to this intricate problem suggests that employing a top-down approach to solving a developmental problem is ineffective. Working with the nations, farmers, and citizens of food insecure countries would be a much more appropriate approach to addressing an issue that they

understand on a more day-to-day level. While the financial, technological, and informational resources of developed countries are needed, their "dumping" of food aid is not. Long-term investments that work to address the root of the problem will provide much more promising results.

Food in a Globalized World

The emergence of globalization has brought many changes to the way that individuals, communities, and nations interact. While globalization has in some ways enhanced food security—through increased communication, sharing and expansion of technologies, and better allocation of some resources—it also has brought about its own problems. To be certain, "increased interconnection has created a more complex landscape of world food problems by creating new risks and amplifying traditional sources threats and vulnerabilities that impact food security," (McDonald, 2010, p. 2). For example, the increased movement of goods and people around the globe has amplified the incidence and expansion of human, animal and plant diseases, a problem that will surely be heightened by the new diseases that climate change will introduce (Beddington, et. al., 2012).

National security, one of the key areas affected by climate change, also has been significantly affected by globalization. New and disconcerting security threats have emerged, and the interconnectedness and relationships of various countries make each threat and incident much more influential on a global scale than ever before. As previously discussed, civil and international conflict are significant impediments to attaining food security.

Increased international trade in many cases increases the disparity in power, resources, and wealth between developed and developing nations. As wealthy countries invest in and trade with developing nations, they often gain power, wealth, and economic strength while the poorer

countries often become more dependent on foreign investments and lose control over their own economies. "What is called 'free trade' today is not free but rather forced, and has yet to demonstrate any positive correlation with either reducing hunger or ensuring democratic practice. On the contrary, the ideology and discourse of free trade has been used to establish global institutions, regional agreements, and sets of rules that favor strong over weak trading partners, (Holt-Giménez and Patel, 2009, p. 49). Developing countries deserve the opportunity to develop their own economies and become self-sufficient, rather than be coerced into an inequitable trading scheme of which they are not the primary beneficiaries.

Globalization has in many ways put the fate of developing nations of the global South in the hands of the powerful and developed countries of the global North. In their book *Food Rebellions! Crisis and the Hunger for Justice,* two of the world's most prominent critics of the global food system, Eric Holt-Giménez and Raj Patel, identify "the industrial agri-foods complex" that has been built over the past half-century as the ultimate driver of food insecurity (2009). In a world with the capacity and resources to feed all human beings, there must be unnatural causes of the food crisis that has come to exist. Globalization and its effects have contributed to the current dilemma. The authors note, "Decades of skewed agricultural policies, inequitable trade, and unsustainable development have thrown the world's food system into a state of chronic malaise, in which crises are all the more severe," (2009, p.1). While mulit-national corporations and investors have acquired more wealth from this unjust agricultural system, the world's poor, consumers, and farmers bear the costs. These people are easy to neglect and overlooked in a globalized world. The actors in the agri-food complex, including multi-national grain traders, seed and chemical corporations, global processors, and supermarket trades, exercise uncontested control over the food system, dominating local markets and

controlling agricultural resources. To make matters worse, solutions offered by institutions such as the World Bank and the World Trade Organization, including increased food aid, de-regulation of commodity trade, and quick technological fixes, often exacerbate the problem. The globalized, highly centralized, industrial agri-food business produces over $6 trillion per year in wealth, and yet continues to drive global poverty and environmental degradation with its inherent risks, inequities, and externalities (Giménez and Patel, 2009, p. 20). It is evident that the global agricultural system is extremely unjust and ineffective, and that recent decisions have had detrimental effects on an international scale. Recognizing the ways that globalization has inequitably distributed power and fortressed the "industrial agri-food complex" supports the idea that food security solutions must be developed with those who are affected by them.

While globalization has undoubtedly altered the global food system and greatly increased the prevalence of large-scale agriculture, most food is still produced in the same country in which it is consumed (Paarlberg, 2010). Thus, the scope of food politics must devote more attention local food production. Paarlberg notes, "The politically managed and non-globalized quality of most food systems is also visible in nutritional outcomes, which diverge dramatically around the world (2010, p. 5). It is essential that the discussion of food security and production does not overlook the importance of local food systems and the divergent quality and quantity of resources, technology, and capacity that exists even in a very globalized world.

Localized solutions are also needed for the global problem of climate change. This is especially true in regard to agricultural methods, as the variation in agricultural conditions, resources, and environmental and economic factors is enormous. International policies regarding these issues have largely failed to take these and other considerations into account.

Failure to Act on Climate Change

A lack of substantial progress in addressing climate change is largely attributable to the fact that the global climate system is a shared resource. It is thus not in the interests of an individual country to reduce its GHG emissions in a global economy based on fossil fuels when they are not guaranteed that other countries will do the same. Effective plans of action have thus been very difficult to establish and coordinate in order to address this issue.

Adaptation (methods of coping with climate change) and mitigation (methods of decelerating or preventing climate change) are the two general categories of actions to cope with climate change as defined by the IPCC. Each one has its own working group, and the two are considered both vitally important in order to address climate change and its numerous consequences (IPCC, 2012). Yet, food security programs' plans that do incorporate climate change are designed to prepare for and deal with its effects but do little to mitigate it. Because agriculture is such a prominent global industry and contributor to global warming, this is unacceptable. Furthermore, the UNFCCC tends to handle mitigation and adaptation under separate negotiating track, limiting the potential for establishing "multiple-benefits" solutions that agriculture has the potential to provide (Beddington, et. al., p. 22).

There is not an appropriately specific focus on agriculture in climate change forums given its sizeable effect on the phenomenon. The IPCC does not explicitly list agricultural and food security risks as one of their "reasons for concern" in their assessments (Climate Emergency Institute, 2011). Furthermore, the UNFCCC (United Nations Framework Convention on Climate Change) has established programs such as REDD+ (Reducing Emissions from Deforestation and Forest Degradation), yet they have neglected to form a working group on agriculture. Members of the UNFCCC have argued that emissions from agriculture are too

difficult to measure and that food security and trade policy make agricultural-based climate change mitigation difficult (CCAFS, 2011). Yet, climate change mitigation will only be successful if it acknowledges agriculture as a driver of GHG emissions and deforestation, and addresses this relationship. While short-term economic gains and temporary hunger alleviation may result from unsustainable practices, in the long-term these actions will only exacerbate the situation. McDonald notes, "Agricultural and food production systems are linked in that food systems drive environmental changes which in turn impact food systems which leads to further environmental changes and so on," (McDonald, 2010, p. 98). It is unfitting for agriculture to be denied a working group. Members of the UNFCCC contend that the issue is too nuanced and complicated, an irresponsible and weak justification for not establishing a structured effort to focus on agriculture and climate change.

The Global Donor Platform for Rural Development has created a Platform Working Group on Agriculture and Climate Change to work to ensure that agriculture is a major component of any post-Kyoto agreement (Global Donor Platform for Rural Development, 2012). Yet, such agreements have historically not been very successful, and any new treaty may not be established for years. It is important that the international community recognizes the importance of agriculture in climate change mitigation in current practices and programs rather than waiting to discuss it in international forums.

In climate discussions, there is great emphasis on energy usage and efficiency, yet agriculture and its global health and poverty components often remain unacknowledged. Furthermore, while many climate scientists note the intricate relationship between climate change and agriculture, it is often disregarded in popular and political discussion as a basis of solutions for climate change (McDonald, 2010). Expanding awareness

about the effects of climate change on food security, and vice-versa, is critical to establishing the most comprehensive solutions. If it is being given inadequate attention on the international stage, then it will continue to stay out of public and political spheres.

What is needed is a shift in the emphasis of international aid. While programs are continuously evolving to be more thorough and extensive in scope, many of them are failing to effectively conceptualize the entirety of the problems they tackle. The issues of food insecurity, poverty, environmental degradation, political instability, and economic development are intricately connected; they are also all increasingly affected by climate change. Whether it is in the form of humanitarian aid, the development of programs, or the establishment of international treaties, action to address these issues on a global scale must assign considerable weight to climate change and other relevant issues that may not be the specific focus.

Potential for Change and a Sustainable Solution

"Today's global food problems emerge out of a complex mix of economic, environmental, political, and social factors that impact food security, human society, and nation-states, but also, at the most basic level, determine what ends up (or doesn't end up) on people's plates,"

-Bryan McDonald, *Food Security*

(2010, p. 8).

Recognizing New Challenges

An essential element for addressing food security is identifying its root causes and employing a nuanced approach that responds to all of its dimensions. Food security no longer simply means that every person on the planet is not in a perpetual state of hunger. Rather, the issue of food security today encompasses from where a person is getting their food, how it was produced, the portion of a person's income spent on food, and how reliable a person's sources of

food will be in the future. This last concern could be greatly influenced by climate change, as well as a number of other external factors.

Since the mid-1990s, an unforeseen challenge has taken the issues of hunger and food insecurity to a more urgent level: responding to global food production has and will continue to require more than just increasing agricultural yields. In the 1960s, the Green Revolution made it possible for global crop yield to meet global crop demand, a trend that was generally able to continue until the mid-1990s (Clapp, 2012). Yet, there are limits to intensification, and a capacity for interference above which the earth's ecosystems services cannot continue to function properly. Speaking at the Cheltenham Science Festival in 2009, the UK's Chief Scientific Advisor, Professor John Beddington, said we needed a new and greener revolution, "Like the one we saw in the developing world in the 1960s, but which tackles both food security and climate change," (BBSRC, 2012). Indeed, knowledge of the changes occurring to the planet because of human activity expands the challenge to require much more than increasing agricultural yields; sustainability is a key component.

Sustainable Agriculture

In an age of resource depletion and environmental crisis, sustainability must be a key component of a successful, reliable food production system. Future investments in agricultural advancements will be much less beneficial if they are diminished by environmental exploitation, or if they cause more hunger- and poverty-related problems due to their contributions to climate change and environmental degradation. While traditional solutions may alleviate hunger initially, their net effect is either minimally beneficial or even detrimental. "Short-term gains will be offset by long-term losses if it leads to further degradation of ecosystems, threatening future ability to maintain current levels of production," (De Schutter, 2010). Applying transient

solutions is no longer an option if future generations are to have the possibility to live in a world of environmental and food security.

Sustainable agriculture entails a "set of practices that can both provide for human needs now and in the future while also nourishing and protecting earth's living systems," (McDonald, 2010, p. 118). These solutions incorporate ethics and human security in addition to environmental, economic, and food security concerns. This holistic view is necessary to ensure a successful approach to addressing complicated issues like food security, in which fragmentary solutions lead to inequitable and unethical results (McDonald, 2010). The potential for sustainable agriculture to address environmental justice issues makes it a doubly-beneficial pathway in terms of development. These methods could help to "facilitate the transition towards a low-carbon, resource-preserving type of agriculture that benefits the poorest farmers," (De Schutter, 2010, p. 4). Thus, rather than transferring the unsustainable mode of agricultural production that has degraded the environment and widened the poverty gap, a movement to work *with* natural systems to ensure long-term gains could be especially promising in developing nations. "Sustainable agriculture simulataneously increases production and income, adapts to climate change and reduces GHG emissions, while balancing crop, livestock, fisheries and agroforestry systems, increasing resource use efficiency (including land and water), protecting the environment and maintaining ecosystem services," (Beddington, et. al., 2012, p. 6).

The significance of sustainable development was acknowledged in the Rio Declaration at the UN Conference in Rio de Janeiro in 1992 (McDonald, 2010). The term is now widely recognized and discussed, yet it is often seen to be at odds with economic development and increased production. However, another concept, sustainable intensification, proves that sustainability and increased agricultural output can in fact work in conjunction with one another.

Sustainable intensification.

Sustainable intensification aims to extend the benefits of large-scale agricultural production while minimizing the negative environmental and social impacts. A global food system with a goal of sustainability could help boost soil fertility and reduce erosion, improve local water quality, and reduce runoff. It would essentially aid in efforts to mitigate and adapt to climate change by providing buffer zones, sinks to remove GHGs from the atmosphere, and energy from current biological sources in order to reduce fossil fuel GHG emissions (McDonald, 2010). Sustainable intensification encompasses the dual goals of increased productivity and reduced environmental impact through diversification and inputs management practices that foster ecological goods and services (McDonald, 2010). In a world ridden with both environmental crises and hunger, sustainable intensification is necessary.

This approach is also the only viable option in order to meet the good demand of a population projected to reach between 9 and 10 billion by 2050 (Bruinsma, 2009). Global grain demand is expected to double due to the increase in per-capita income and dietary shifts toward more meat consumption (Tilman, 2002). Meeting the global demand for food will be an even greater challenge if land and resources are not utilized in ways that will sustain them for future generations.

Precision farming.

One method of sustainable intensification is precision farming, which is a set of techniques to more precisely determine how much of an input or service is needed at a given time in agricultural production in order to prevent excessive input use, waste, and pollution (Paarlberg, 2010). By taking spatial and temporal factors into account, nutrient supply and plant demand can be matched more closely. The applications of fertilizers at certain times, such as

when crop-demand is high, or at certain location, such as the roots of plants, are ways to reduce losses and environmental impacts while sustaining or improving yields (Tilman, 2002). Precision farming technologies include: drip irrigation systems to conserve water and laser-leveled fields to minimize runoffs; the use of Geographic Information Systems (GIS) and Global Positioning Systems (GPS) to automatically steer machines and measure the amount of water needed in various parts of fields; and infrared sensors to detect the "greenness" of a crop and determine the amount of fertilizer necessary (Paarlberg, 2010, p. 115).

Creating an agricultural system where technological advancements provide enduring results and investments are able to pay themselves off requires protecting the environment in which the agricultural activities take place. One especially substantial source of environmental degradation is the release of the chemicals used in fertilizers, pesticides, and herbicides into the environment. As Tilman, et. al. note, "Crop and livestock production must increase without an increase in the negative environmental impacts associated with agriculture, which means large increases in the efficiency of nitrogen, phosphorus and water use, and integrated pest management that minimizes the need for toxic pesticides.," (2002). Precision farming solutions that limit these chemicals' negative effects on the environment will enable more sustainable and lasting advancements to be achieved.

Low-impact and precision-farming systems have been shown to lessen environmental impact in many ways, including the reduction of land used for agriculture, a decline in water use for irrigation, reductions in soil erosion by both wind and water, reduction in energy use on the farm, lower greenhouse gas emissions, decreases in herbicide, insecticide, and excessive nitrogen fertilizer use, and increased protection of biodiversity (McDonald, 2010, p. 116). Yet, many environmentalists criticize modern precision farming because it often leads to highly capitalized

agricultural production and involves training and equipment often inaccessible to small farmers (McDonald, 2010). Precision farming thus may end up primarily helping farmers in developed countries, and do little to address the struggles of small farmers in developing countries—the ones that are most in need of new resources and technology. While precision farming does have the potential to be very promising to farmers in developing countries, the costs to invest in the equipment, distribute the resources, and teach the farmers these practices must be considered.

Techniques that are developed from a first world-centric viewpoint, while often good-intentioned, often fail to lift struggling farmers up from poverty and low yields because they fail to account for high costs or challenges. For example, the establishment of carbon markets can be beneficial to climate change mitigation, but are unlikely to benefit small farmers of developing countries, who have little wealth for unreliable long-term investments (CCAFS, 2012). Strategies like these can end up extending the disparity between the world's high-yield farms and its low-yield farms, increasing what is known as the yield gap.

The yield gap.

The term "yield gap" describes the vast discrepancy between the highest and lowest yields obtained by farmers. For example, farmers in developed countries such as the United States regularly grow five times the amount of corn per acre than small farmers in Africa (Gillis, 2011). The substantial yield gap is exacerbated by the inability to successfully transfer the tools and knowledge necessary for intensification to small-scale farmers. Raising the yields of small farmers in developing countries through sustainable intensification techniques that respond to their local conditions is necessary to feeding the inhabitants of these regions. The political leadership and public investment necessary to make this possible is inadequate (Gillis, 2011).

Still, many organizations, programs[, and small-scale farmers themselves are working to expand sustainable agricultural practices in these areas.

The positive aspect of a substantial yield gap is that its presence signifies great potential to increase yields in low-yield areas. "The large yield gap for rice in many parts of south and southeast Asia, and for maize in developed and developing countries, indicates that these regions could have significant yield increases with use of appropriate technologies," (Tilman, et. al., 2002, p. 672). In sub-Saharan Africa, farmers use almost no fertilizer, and only 4% of cropland has been irrigated (Paarlberg, 2010). The implementation of sustainable irrigation and fertilization techniques could increase yields greatly.

As most of the best quality land has already been converted for agriculture, high yields will probably not be maintained on remaining, more vulnerable lands (Tilman, et. al., 2002). Thus, new technologies must also be especially sensitive to environmental conditions and prioritize efficiency. The next section describes various technologies that fit these conditions.

Technologies.

Numerous technologies have been developed, or are in the developmental process, that have great potential to advance sustainable agriculture and intensification. Increases in fertilizer and other traditional advancements alone will not only be unsustainable, but will also likely be ineffective in increasing yields singlehandedly. As Tilman notes, "Fertilizer increases are unlikely to be as effective in increasing yields as they were during their initial development because of diminishing returns," (2002). The realization that the path to yield increases in the past must be altered to fit today's environmental conditions and productive potential will promote the adoption of sustainable agricultural practices. This section does not provide an

exhaustive list of sustainable agricultural technologies, but does provide some basic information on how many of these technologies work and why they are important.

One widely discussed and increasingly utilized method is no-till agriculture, which emerged in the late 1970s (Paarlberg, 2010). Traditional intensive tillage, which is employed to remove weeds and form soil into rows for irrigation, releases carbon accumulated in soils, leading to substantial releases of carbon into the atmosphere (U.S. DOA, 2005). Although soil erosion is a natural process, tilling accelerates rates of erosion and reverses carbon sequestration by soils, which is very detrimental in terms of climate change. Furthermore, soil loss leads to the loss of nutrients, reduced water retention, and the loss of biodiversity (McDonald, 2010). No-till agriculture avoids these damaging effects, and reduces diesel fuel consumption (Paarlberg, 2010). Other methods that increase carbon sequestration of soils include optimal nutrient management, crop rotations, and land conversions to vegetation. These techniques are very promising: "Researchers estimate that the extensive adoption of no-till agriculture, diversified rotations, cover crops, fertility management, erosion control, and irrigation management can lead to the recovery of two thirds of the carbon that has been lost from the soil due to conversions of native ecosystems to agriculture and the use of conventional management practices," (USDA, 2005). Studies have found that no-till agriculture in combination with crop rotations can actually increase production by at least 10% while also reducing input costs by 50% or more (WWF, 2010). No-till methods do require investment in certain pieces of equipment, but quickly will pay back for themselves, making the solution very financially beneficial.

Between 1987 and 2007, there was a 72-fold increase in Latin America. The technique is well-suited to the drier, hotter soils and weather conditions in this region, as it conserves water and cools soils (Farm Futures, 2012)

Other technologies have emerged to address the widespread issue of excessive water use. As previously noted, freshwater is a scarce resource, and agriculture already uses 70% of water available for human use (Holt-Giménez and Patel, 2009). It is thus vital that new crop varieties and agricultural methods be developed that require less water and are more efficient in their water use. Existing technologies include drip irrigation systems, monitoring systems that gather information about soil-moisture levels, rainfall capture systems, and the method of covering crops and substances to increase soil intake (McDonald, 2010).

Another proposal offered by Paul Hanley in his article "Fighting climate change the fast, cheap, easy way," establishes fourteen methods to target methane and black carbon emissions, which he contends are cheaper, faster, and easier ways to prompt climate change mitigation than targeting carbon dioxide emissions. All of the measures have spinoff benefits for the environment (Hanley, 2012). Approaches like Hanley's that take an alternate route to addressing climate change have the potential to be very successful in the face of struggles to switch to a carbon-neutral economy.

The emergence of "climate-friendly landscapes" and "climate-smart farming" acknowledges the importance of integrating the natural environment in human activities, rather than seeking to dominate it. Climate-friendly landscapes include those in which agricultural lands are interconnected with natural habitats to minimize GHG emissions and maximize carbon sequestration. Climate-smart farming refers more generally to agricultural practices that aim to reduce agriculture's emissions and contributions to climate change,

FAO and the European Commission are launching a project in 2012 to enhance climate-smart farming in Malawi, Zambia, and Vietnam. The project will closely study the specific ecological conditions of each country to identify opportunities for expansion and implementation of climate- smart agricultural practices (FAO-EC, 2012)

enhance its carbon sequestration and other mitigation potential, and make it more resilient to climate change (FAO-EC, 2012). Agroforestry is the inclusion of trees in a cropping system, which can improve nutrient storage and efficient usage, reduce soil erosion, and store carbon (Tilman, 2002). The area devoted to agroforestry grows each year as farmers recognize the many benefits: the tree cover yields products including fruits, fuel, timber, and resins, diversifying local diets and farmers' incomes; they increase soil fertility and crop yields through natural nitrogen fixation; and trees, as perennial crops, can cope better with floods and droughts and therefore help farmers adapt to climate change (Pye-Smith, 2011). Agroforestry and other climate-friendly landscapes also advance the idea of protecting and sustaining the environment as a mode of enhancing human progress.

Methodology	**Main technologies**
Precision Farming	Timed and targeted fertilizer application, Drip irrigation systems, GIS and GPS, infrared sensors, fetility management
Agroecology	Integrated nutrient management, agroforestry, water harvesting, integration of livestock into farming systems, push-pull pest management, on-farm fertility management
Climate-smart farming	Agroforestry, carbon sequestration, drought-resistant crop varieties, erosion control
Multiple-crop systems	Inter-cropping, diversified crop rotation, use of perennial crops, genetically modified crops
Water-use Reduction Technologies	drip irrigation, soil-moisture monitoring systems, rainfall capture systems, covering crops and substances to increase soil intake

Genetic diversity of crops is another important consideration. Multiple-crop systems may use either crop rotations or inter-cropping to reduce the incidence of pests and optimize the use of water and nutrients (Tilman, 2002). The development of crops that are drought resistant and temperature and salt tolerant are also important advancements as climate change will require

crops to be more resilient to withstand changes in the environment (McDonald, 2010). Polyculture is proven to produce higher yield than monoculture in addition to these benefits.

Another technological advancement with great potential is genetic engineering and modification of seeds and plants. Genetically modified organisms (GMOs) can be defined as "organisms in which the genetic material has been altered in a way that does not occur naturally," (WHO, 2010). They could provide a promising way to increase yields and adapt to environmental changes, but they are surrounded by controversy and have a bad reputation in modern society. In fact, they are often regarded as contrary to sustainable agriculture (McDonald, 2010). Yet, proponents argue that they could be a key component to the emergence of sustainable agriculture, and that there are more environmental and health risks of *not* introducing GMOs on a more extensive level. (McDonald, 2010) They are designed to provide a higher level of crop protection by resisting plant diseases caused by pests of viruses and offering an increased tolerance of herbicides (WHO, 2012). Potentially, GMOs could lead to higher crop and livestock yields, less damaging production, better storage and easier processing, enhanced monitoring methods, and high product quality, (McDonald, 2010, p. 120). Yet, health concerns about allergenicity, gene transfer, and outcrossing (WHO, 2012), and economic concerns about market concentration in the seed industry, intellectual property rights, and biological security remain (McDonald, 2010, p. 121). GMOs could also lead to more exploitation of farmers and expand the disparity in power held by agri-corporations and farmers. Further health, social justice, and environmental risk assessments will need to take place before GMOs are introduced on a broader scale.

Other advancements have started and will continue to contribute to sustainable agriculture and increased efficiency. The implementation of improved monitoring systems that

report weather information and soil moisture information to farmers can be very helpful in allowing them to plan agricultural processes and use resources most efficiently (McDonald, 2010). These monitoring systems would be especially helpful in rural areas of developing countries, where such information is usually absent. Also, increases in nutrient-use efficiency, or the crop production per added unit of nitrogen, phosphorus, and water, allow resources to be utilized to their maximum potentials (Tilman, 2002). The U.S. has had improvements in nitrogen-fertilizer efficiency because of improved timing of fertilizer application, covered crops, reduced tillage, and applying livestock wastes to close the nitrogen and phosphorus cycles (Tilman, 2002). These and other technologies should be expanded to small, low-yield farms, along with the introduction of fertilizer if it is not already present.

One particularly promising agricultural approach, especially for developing countries, is agroecology. In the *Report submitted by the Special Rapporteur on the right to food*, a document developed for 16th session of the UN Human Rights Council, Olivier De Schutter discusses the concept of "agroecology" as the potential path of realization of the human right to adequate food on a global scale. The approach has the potential not only to enable this and other human rights to flourish, but also to bolster economic growth, alleviate rural poverty, empower minority groups, and improve nutritional value of food. De Schutter contends that agroecology embodies both the science and policy aspects of this issue, as it discusses both the agricultural techniques and policy actions to be successful. He offers a largely bottom-up approach, emphasizing the importance of investments in social organization to encourage

Agroforestry in Sub-Saharan Africa
The incorporation of multifunctional trees into the agricultural land in the Western Tanzanian provinces of Shinyanga and Tabora has rehabilitated over 350,000 hectares of land in Tanzania (De Schutter, 2010).
In Niger, the regeneration of a native tree has improved soil fertility and increased sorghum yields and farmers' incomes (Pye-Smith, 2011).

partnerships and innovation, public infrastructure and extension systems, and on-the-ground agricultural research. Agroecology seeks to empower food-insecure groups to help design and implement policies, share knowledge and best practices in farmer unions and workshops, and establish partnerships with research organizations.

Agroecology recognizes the importance of incorporating climate change adaptation and mitigation into agricultural techniques, acknowledging the agricultural losses due to salinization, freshwater scarcity, droughts, and floods. De Schutter notes, "By 2080, 600 million additional people could be at risk of hunger, as a direct result of climate change," (2011, p. 5). The methods of agroecology protect and enhance biodiversity, improve soil infiltration, and decrease GHG emissions, providing ways to lessen this number. If these methods are expanded, another future scenario could emerge. Rather than "replicating the model of industrial processes in which external inputs serve to produce outputs in a linear model of production," the agroecology approach "seeks ways to enhance agricultural systems by mimicking natural processes, thus creating beneficial biological interactions and synergies among the components of the agroecosystem," (p. 6). Agroecology and other technologies have the capacity to not only establish new and sustainable techniques, but also to change the ways in which people conceptualize agriculture and its relationship with nature.

While sustainable agriculture technologies are prevalent, political will and coordination is not. International, national, and local policies are required to ensure that sustainable agriculture practices continue to be developed and implemented. Policies are also necessary to address other issues of food insecurity that affect resource allocation, finances and profits, and agricultural trade. It is vital to confront the social and political factors that limit the expansion of sustainable agriculture technologies and food security, rather than simply aim to develop more innovative

technologies. The food production system itself is flawed, and needs to undergo significant structural changes to lead towards food security.

Structural Changes

As noted before, the global food system has some critical defects that have created a situation with almost a billion hungry people in a world with enough food to feed everyone. These faults are tied to inequitable power distribution, flawed economic policies, poor developmental planning, and a disregard of the environment.

The ways in which developed or donor countries have approached the problem of food security has been largely flawed. Food aid indeed has seen many improvements over time, but donors are still largely focused on their own interests and gains, and are failing to make long-term advancements. Currently, 150-200 million people depend on food aid, a number that would ideally be zero (Clapp, 2012). While food aid can be effective in alleviating hunger, it is not the appropriate method to do so since it addresses one aspect of food security (hunger), while others aspects—poverty, political dependence, instability, and public health—often remain unaltered or are exacerbated.

Food aid itself complicates the problem of food insecurity. It creates an unreliable and dependence-inducing source of food while doing little to enhance the ability of hungry people to feed themselves. As climate change and other global issues complicate the barriers to food insecurity further, food aid will be an even weaker option. "The trend of food aid donations to be procyclical with supply and counter-cyclical with prices will only be exacerbated by greater volatility in prices meaning that amounts actually provided by donors are likely to spike and trough in concert with the sharps ups and down of food prices (Clapp, 2012, p. 169). Food aid is ineffective and even detrimental when it causes economic problems in addition to failing to

respond to the needs of recipients. While food aid is more recipient-focused than it was at its start, further advancements to respond to the needs of food insecure populations must be employed, or alternatives to food aid should be adopted.

While technologies are present, the main challenge of food insecurity is a lack of appropriate policies—at every level—to promote and enable sustainable modes of production on a wide scale. It is vital to develop policies that allocate investments in public spending to public goods, in lieu of the policies that provide input subsidies and invest in private goods (De Schutter, 2010). Subsidies ultimately encourage farmers to use excessive amounts of fertilizers, pesticides, and water because they will receive artificially high prices for their yields (Paarlberg, 2010). The resulting environmental effects are substantial. "Some of the nitrogen volatilizes into a major greenhouse gas, and some of it washes into rivers and helps create dead zones where the rivers meet the ocean", (Gillis, 2011). Financial investments by the private sector and governments of developed countries would be much more beneficial than subsidies, food aid donations, and private investments. There is insufficient investment in rural economies and production systems in developing countries, which often cater to their urban-based governments and more wealthy urban populations (Paarlburg, 2010). The lack of infrastructure, communication and transport systems, and access to information disables rural farmers from entering markets and lifting themselves and their small communities out of poverty

A shift to bottom-up approaches to addressing food insecurity and its causes, like those mentioned in the discussion of agroforestry, can help to ensure that these investments are most effective. Food aid can make up a very large portion of the budget of least developed countries, yet these nations have little control over the aid they receive. As Jennifer Clapp notes, "While recipient country governments are acutely aware of the impacts of donor policies on their own

food security situations, they have had only a marginal voice in most international forums on the issue," (2012, p. 13). Ground-level engagement and empowerment of individuals in developing countries in food security discussions is vital to their eventual self-sufficiency and sustainability. Already established alliances between farmers, businesses, farm-laborers, agroecologists, environmentalist, human rights advocates, and indigenous movements have helped to advance sustainable and equitable approaches to food production (Giménez and Patel, 2009). An expansion of these types of relationships would be beneficial to economic development and food security, as well as environmental protection.

USAID and The Mountain Institute are partnering with agrarian communities to enhance adaptation to the glacial melt along the Santa River due to climate change. They work together to identify threats and establish adaptation measures such as restoration and protection of grasslands and forests to limit their vulnerability (USAID, 2012).

The idea of food sovereignty, which was introduced at the World Food Summit in 1996 by La Via Campesina, acknowledges people's right to produce food in order to have sovereignty over their lives (Stedile and Martins de Carvalho, 2012). By focusing not just on having enough food but also being able to produce it, the concept reaches to the core of the problem of food insecurity. "Control of production is fundamental for population in order to have guaranteed access to their own food for the entire year. And so they can guarantee that this food is appropriate for the environment in which they live, for their nutritional needs and their food habits (Stedile and Martins de Carvalho, 2012, p. 23). The food sovereignty movement has continued to expand in both the global North and South, fostering both local community initiatives as well as annual conferences like the U.S. Community Food Security Coalition. "The growth of webs of smallholder food producers and community-based food initiatives over the past few years is fundamental, since the energy, inventiveness, know-how, and self-

determination they express is, without doubt, the indispensable basis for any successful efforts to change food systems (McKeon, 2012, p. 261). This movement towards creating food systems that are socially and environmentally responsible is vital to addressing the main causes of hunger and exploitation.

Bryan McDonald enumerates various components of empowering and protecting individuals and communities. First, conditions must be established in which people have the capacity and freedom to take part in choosing and pursuing their options. Next, threats in the food system must be tackled by working with populations in sub-political areas whose concerns and priorities often go unaddressed. Finally, increasing consumer information by educating these populations about their food choices and implications will enable informed agriculture and consumption choices to be made (McDonald, 2010, p. 158). The empowerment of marginalized groups has historically been of critical importance to advancements in population control, economic growth, educational advancements, and improvements in public health; the issue of food security, too, would benefit greatly by enabling those most affected by food insecurity but with little power to make decisions and gain control over the problem.

In Ethiopia, the Productive Safety Net Programme has helped to lift 1.3 million people out of poverty and into food security through household and community asset building. Activities such as small-scale irrigation and watershed development become community-owned to enhance pro-poor empowerment and economic development while creating conditions to increase food security (Black, 2012).

By identifying possible trade-offs between mitigation efforts and poverty dimensions of farmers and consumers in developing countries, the most effective strategies to both combat climate change and increase food security can be established. It is vital that particular attention be paid to "the trade-offs and synergies of mitigation, food security, and poverty alleviation,

while ensuring the health of water, land and ecosystems at different scales," (CCAFS, 2012). This shift to strategic planning based on the interests of developing countries will lead to both developmental and environmental advances, rather than further disparities between the developed and developing world.

Another important challenge to be considered is the fact that global population is increasing at an unprecedented rate. As populations increase, incomes expand, and diets change, meeting the global demand for food supply will be more difficult than ever before. While innovations in technology have improved crop yields and enabled many countries to be agriculturally self-sufficient, it will be impossible for technological advancements to increase yields enough to meet the demand for food if agricultural lands and other natural resources are destroyed in the process. Advancements on the supply side—sustainable intensification, better distribution of food supplies, greater agricultural and trade efficiency—will make drastic differences. Yet, changes on the demand side**,** in terms of the number of people who need to be fed and the food that they are demanding, must occur as well. Population stabilization is also a vital component to attaining food security because population growth increases society's exposure to environmental stresses and reduces the amount of resources available per person.

In order to stabilize populations and break cycles of poverty, the implementation of family planning services is necessary. Family planning not only reduces the negative social and environmental impacts of overpopulation, but also enhances economic development, female empowerment, and public health. These services would be especially beneficial to food insecure regions, where poverty, lack of education, and disease are often considerable problems. Yet, there are many cultural barriers to the implementation of family planning in countries where large families are desired for economic, social, and cultural reasons. Programs must emphasize

income growth, increased child survival, education, and employment opportunities for females, while being sensitive of the norms and ideals of individual cultures (Paarlberg, 2010). It is critical to focus especially on women, who have little power in patriarchal societies and are often illiterate, undernourished, and unaware of their options. Also, seven out of every ten people who suffer from hunger are women, a startling statistic given that women are responsible for 50% of global food production (Holt-Giménez and Patel, 2009). Women are particularly vulnerable to the effects of climate change, both as consumers with fewer resources of economic value and as producers who are vulnerable to food price volatility. Female empowerment is not only important to stabilizing population, but also to addressing the root causes of poverty and food insecurity. Lowering the rate of population growth is not easy, and it will not solve the issue of food insecurity; yet, it will be a critical step in making that goal more attainable.

The current approach to food insecurity and agricultural issues employs outdated methods that fail to respond to the current global environmental situation. While programs have developed extensive plans to adapt to and even attempt to mitigate climate change, they do not address the core issue at stake. Agriculture is a large factor in development; and it is through unsustainable development the current environmental crisis was created. While alternative methods have potential to be helpful, the only hope to prevent catastrophic, irreversible climate change is to revamp the entire system of development as soon as possible. The International Energy Agency (IEA) warns that "anything built from now on that produces carbon will do so for decades, and this "lock-in" effect will be the single factor most likely to produce irreversible climate change… If this is not rapidly changed within the next 5 years, the results are likely to be disastrous," (Deep Green Resistance, 2011). Thus, sustainable agriculture should not be seen simply as a commendable advancement or an eco-friendly option; rather, it should be *the*

direction pursued in all technological advancements if reversing climate change and averting future food insecurity are to be achieved.

Despite what relative global inaction would suggest, addressing both climate change and food security would bring many economic gains in the long run. These problems both have underlying causes in imperfect markets and economic inefficiencies that fail to reflect their true cost to global society.

Economic mechanisms.

The current agricultural and food production system is inherently economically flawed and inefficient. Climate change is also a large economic problem that is lacking the market recognition that its very costly consequences call for. Hilary Osbourne notes, "Climate change is the greatest and widest ranging market failure ever seen," (2006). The system should maximize the net benefit to society when all costs and benefits of the practices are considered, a goal that implies the idea of sustainability (Tilman, 2002). Most costs to the environment are not accounted for in the market, emerging as negative externalities which distort the cost of a product as it does not reflect its cost to the environment. The failure to include environmental costs and the value of ecosystem goods and services—which are often quite difficult to calculate and incorporate—has brought about many current environmental problems. In the case of agriculture and food production, a critical decision has to be made throughout the globe: either agricultural economics must undergo significant changes to account for these costs, or the current system can proceed, creating inefficiencies and vicious cycles of environmental degradation and food insecurity. If the former option is in fact chosen, many aspects of food production and distribution must be reevaluated. Efficiency measures would also help to reduce loss and waste in supply chains and decrease net emissions of food both per unit of food

consumed and in absolute terms (Beddington, et. al., 2009). With greater efficiency, the ability of food supply to meet demand can be drastically increased, and environmental consequences can be reduced.

One often overlooked environmental cost of food is transportation. Transportation of food is a very significant consumer of energy, emitter of GHGs, polluter of air and water, and driver of habitat loss. The environmental and energy costs of food transportation should be incorporated into the costs of the food products, rather than remaining externalities. Food transported by air, truck, or car uses far more energy than transporting it by rail or ship (McDonald, 2010, p.111). These energy and environmental costs are rarely considered, creating another way in which the food system exacerbates, rather than helps to address, climate change.

Food prices should also reflect the differences in energy input and environmental impacts among different types of food. For example, meat production uses significantly more energy and emits more GHGs than vegetables or commodity crops. Currently, nearly half of global cereal production is used for animal feed, a pattern that lessens the ability to meet the increasing demand for food worldwide (FAO, 2006). A 2006 report by the FAO found that meat consumption can emit more CO2, methane, and nitrous oxide than either transportation or industry, can require 80 times as much water as crops (McDonald, 2010). Furthermore, while agriculture in general pollutes water with pesticides, fertilizers, and wastes, livestock wastes pollute water substantially further (McDonald, 205). Meat consumption has increased greatly in develeoping countries such as China and India in recent years, and will likely continue here and in other countries that experience economic development (Clapp, 2012). However, if prices begin to reflect the energy and environmental costs, more sustainable levels meat consumption could be established.

Another important issue in terms of energy is the emergence of agrofuels, such as corn-based ethanol. "Not until the dramatic displacement of food crops by fuel crops in 2006 did the FAO begin to warn of impending food shortages," (Holt-Giménez and Patel, 2009, p. 10). Yet, rather than stark food shortages, it was food price inflation that resulted from the diversion of crops toward agriculture rather than food supply. By 2008, a quarter of the U.S. corn harvest was being diverted toward ethanol (Hol-Gemenez and Patel, 2009). Ethanol not only increases food security, but has dubious environmental benefits. It has been portrayed as a clean alternative to fossil fuels, but actually requires a very energy intensive production process that includes fossil fuel consumption and increases agricultural carbon emissions.

The rise of agrofuels concentrates corporate monopoly power over both the fuel and food production industries "under one giant industrial roof," (Holt-Giménez and Patel, 2009, p. 71). It also inflates the value of overproduced commodities like corn and sugarcane, increasing the total amount of grain being produced and traded and leading to further environmental destruction and unsustainable practices. Climate change is predicted to substantially reduce corn production and exports in the coming decades (Nelson, et. al., 2011). Thus, in order to adapt to climate change, agrofuel production must be limited considerably so that corn production can go towards food, not fuel.

Specific economic policies have exacerbated the issues of food security and climate change. According to Peter Rosset from the *Institute for Policy Studies*, "Research carried out by our Institute reveals that since 1996, governments have presided over a set of policies that have conspired to undercut peasant, small, and family farmers, and farm cooperatives in nations both North and South," (2002). He notes the policy of runaway trade liberalization, which requires small farmers in developing countries to compete with subsidized corporate farms in the

North. Eventually, the developing countries cope with "eliminating price supports and subsidies for food producers, the privatization of credit, the excessive promotion of exports to the detriment of food crops, the patenting of crop genetic resources by corporations who charge farmers for their use, and a bias in agricultural research toward expensive and questionable technologies like genetic engineering while virtually ignoring pro-poor alternatives like organic farming and agroecology," (2002).

The global economy is controlled by developed nations, and many economic mechanisms favor them over those most in need of economic development. Developing countries could benefit from "strategic decoupling from global networks and creation of sustainable local food systems," which would allow them to pursue economic growth without impediments by the global food production system (McDonald, 2010, p. 121). This step would help to avoid the externalities created by inefficient large-scale trade. Trade would thus be based on necessity and geographical conditions rather than financial gains.

Structural changes to the food system are necessary for sustainable agriculture to flourish and meet the global demand for food. Specific programs and actions must lead the way in realizing these changes. One existing program that does succeed in incorporating other global issues into their strategy is the U.S. Feed the Future Program. While it indeed highlights considerations such as climate change, public health, and economic development, further analysis is necessary to determine just how comprehensively the program will address these issues.

The Feed the Future Program

The Feed the Future program was launched in spring 2009 by the U.S. government. The program focuses on employing the strengths of the private sector and advanced research in order

to improve agricultural productivity, enhance economic growth, and advance global stability and prosperity (FeedTheFuture, 2012). Twenty countries were selected that face major challenges in food security, but have economic and political resolve to work towards progress. The countries were chosen based on the following five criteria: level of need, opportunity of partnership, potential for agricultural growth, opportunity for regional sovereignty, and resource availability (FeedTheFuture, 2012). By choosing countries that have both serious challenges and great capacity for progress, the program maximizes its potential for establishing examples of success that can serve as a model for more difficult scenarios. The program centers upon country-led plans and donor-coordination, with great emphasis on agricultural research (FeedTheFuture, 2011). By synthesizing research and development, donor resources and expertise, and recipient-led planning, the program distributes power and utilizes knowledge appropriately and effectively.

The emphasis on research highlights the program's aim to be comprehensive through attention to details, consideration of relevant issues, and situation specific analysis. Distinctive areas of research include advancing productivity, transforming production systems, enhancing nutrition and food safety, and building institutional and human capacity (Nicholson, 2012). These areas address the various scientific, social, and political barriers to developing effective food security solutions. The program also has the necessary support and leadership to make is successful. According to Simon Nicholson in his paper "Feeding 10 billion: A Dialogue between Feed the Future and the International Research Community," Feed the Future could potentially be a very promising endeavor in that "the collaborative intent of the initiative, the widespread support it is garnering in the United States and abroad, and the clear commitment of key actors in the US government to its success offer reason for considerable optimism," (2011, p.

18). Indeed, the program could effectively overcome the aforementioned structural, implementation, and leadership issues often encountered in developmental assistance.

It is valid to postulate that Feed the Future will be an effective program, and that it should be commended for the attention it pays to a wide range of developmental issues in addition to food security. Its attention to climate change is unmatched by other food security initiatives. It uses a "sustainable intensification approach," as it seeks to increase agricultural yields while avoiding long-term environmental degradation (Nicholson, 2011). The emphasis on sustainable intensification is critical to the program's potential to mitigate and adapt to climate change while enhancing food security. In their 2011 research strategy, the program acknowledges the importance of climate change in their planning. It notes that long-term sustainability is a key component of modern agriculture and considers the ways in which agricultural practices and products can be made to be more efficient and sustainable. The strategy notes, "Environmentally and economically sustainable agricultural productivity gains will be generated from a range of innovations, including resource use efficiency, genetic improvement, integrated pest management, reduced post-harvest losses, risk management strategies, and reduced marketing costs (FeedTheFuture, 2011, p. 3). These methods address various aspects that affect both the socio-economic and environmental issues involved with climate change.

Of the program's six "focus areas," environment-sensitive development is the one that most directly addresses the issue of climate change. Under this focus, the program will "encourage sustainable and equitable management of land, water, fisheries and other resources," and "take advantage of opportunities in effective resource management and proactive adaptation to environmental challenges," (FeedtheFuture, 2011). Also considered in its research are: methods to increase stress tolerance in plants, deployment of genetic diversity of crop plants and

livestock, modeling of climate production systems, improvements in resource use efficiency (and in turn, reduce GHG emissions), and increases in water capacity, carbon sequestration, soil fertility, and crop yields (FeedTheFuture, 2011). The research has clearly been completed regarding important factors to address in order to effectively adapt to and mitigate climate change. However, the more specific techniques and programs to carry out these plans have not been enumerated.

The Feed the Future program is considering and incorporating climate change into their research, planning, and implementation at levels that have not been paralleled by other food programs. Yet, because climate change is such an unpredictable and multidimensional phenomenon, further steps must be taken to ensure that it effectively addresses and responds to this issue. As noted by Nora McKeon in her chapter "Now's the time to make it happen: The UN Committee on Food Security," the emergence of people's movements throughout the world demanding alternatives to the corporate-controlled food system. Their influence can be seen in the success of prominent activist groups, such as La Via Campesina, as well as small, localized civil engagement of farmers in the most remote agricultural communities. These actions have advanced the food sovereignty movement and altered the international conversation about food security and the future of agricultural production (McKeon, 2012). Simultaneously, "cracks" are developing in the global food system that draw attention to its inability to provide affordable and accessible food to all global citizens. Climate change and the global energy crisis highlight its unsustainable approach to food production and distribution. These factors enable appropriate international attention to be drawn to the state and causes of food insecurity and the need for transformative changes that focus upon food sovereignty.

The six main pillars to food sovereignty respond to the barriers to food insecurity that exist throughout the world. The first is that it focuses on food for the people, "putting the right to food at the center of food, agriculture, livestock, and fisheries policies." The second is to value food providers by respecting their rights and protecting them against exploitation. The third pillar is to localize food systems by favoring consumer-producer interaction and rejecting inequitable international trade and corporate profits. The fourth pillar localizes control over resource inputs and rejects the privatization of natural resources. The fifth pillar is to build knowledge and skills that help to advance local food production and harvesting systems. The sixth and final pillar is to work with natural through agroecolocial methods that both improve resilience and adaptation and minimize environmental damage (McKeon, 2012, p. 261-262). International policies and programs that focus upon these pillars would maximize the ability for the global food system to become more sustainable, equitable, and efficient. Programs such as the Feed the Future program that draw upon these pillars offer the best potential for addressing climate change and food insecurity.

Conclusion: Global Solutions to Global Issues

"But man is a part of nature, and his war against nature is inevitably a war against himself. [We are] challenged as mankind has never been challenged before to prove our maturity and our mastery, not of nature, but of ourselves."

— Rachel Carson, Author of *Silent Spring*

The ongoing relationship between food insecurity and climate change can generally be described as a zero-sum game. In order to work towards achieving global food security, it has been necessary to increase GHG emissions and further degrade the environment, thus exacerbating climate change. Similarly, in order to work towards decelerating climate change, it

has been necessary to use economic and political mechanisms that limit GHG emitting activities, such as agriculture, leading to further food insecurity. Yet, not doing anything about climate change has an even higher price for food insecurity, as its impacts will increase the number of hungry and impoverished people and decrease the supply of nutritious food. In any business as usual scenario, food insecurity will increase whether climate change is halted or not. Thus, a great transformation is needed in the global food system in order to address the issue of food insecurity through solutions that also work to limit and prevent climate change.

There is a pervasive conception of human and nature as separated, as two opposed and powerful forces that work against one another. This view is objectively flawed and misleading. In reality, the natural environment and its goods and services are that which allow humanity to exist and advance. The trends that aim to dominate and manipulate the Earth for human gains are often ultimately destructive to humanity. It is vital to establish a perspective that values nature to promote human and environmental health, security, and well-being.

Rather than allowing the current vicious cycle of environmental degradation, poverty and hunger, and unsustainable agriculture to continue, a "virtuous cycle that enhances environmental quality, promotes human security, and ensures food security" should be developed (McDonald, 2010, p. 99). The idea of a virtuous cycle builds upon a very different approach to international relations and global problem-solving. Currently, global issues exist in the fields of economics, development, ecology, health, human rights, national security, education, and international politics. These problems and challenges are very interdependent and interrelated and thus must be tackled as a whole, instead of as intricate parts. This is not to suggest that developmental or international programs should simply aim to "save the world" and have no specific goal. It is impossible for any singular program to address rural poverty, child malnutrition, terrorism,

melting ice caps, the AIDS epidemic, gender inequality, illiteracy, and genocide, for example. The purpose of developmental and international initiatives must be more narrowly defined in order to be effective. However, these programs should strive to incorporate considerations about other pressing global issues into their strategies. Such a transformation would eliminate the need for causes to compete against one another and to make global progress a cost-benefit analysis. Programs can no longer deny the "inseparability of economic organization, technology, equity, sustainability, and democracy," (Holt-Giménez and Patel, 2009, p. x). Problems in these areas are intricately connected, and innovative solutions that find common ground between two or three of them can lead to increasingly beneficial solutions. Progress in one area can facilitate progress in another, creating a self-perpetuating path towards advancement in multiple, or even all, of the areas.

The initial research question was: How can we reconcile a vital need of humans that is not fully met and a vital need of the Earth that is being altered at unprecedented rates? The concluding response goes along with this paper's theme of transformations in thinking. The question must be rephrased. What really needs to be asked is how humans can coexist with the functioning systems of and other organisms on the planet. This is a "how" that must be determined if humans are to exist at all, because humankind cannot survive without these systems and organisms. Achieving a stable, nurturing relationship with the planet will breed human progress, as the benefits and services we receive by exploiting the planet beyond its capacity pale in comparison to those we receive when conserving its resources to sustainable levels.

Thomas Malthus, the famous economic and demography scholar and theorist, posited that overpopulation was the key driver and cause of societal problems. Because population increases

geometrically, and food supply can only increase arithmetically (he presumed), population will eventually outgrow food supply and available resources, leading to hunger and poverty. In his view, problems such as food security are attributable to one thing—overpopulation, which would lead to starvation and death until the population was back to carrying capacity. An opposing theory by Danish economist Ester Boserup asserted that population size and growth were a result of agricultural methods and food supply in a society. She argued that rather than widespread death in times of pressure on a resource like food, human innovation will find ways to overcome the issue through innovation. This paper takes a Boserupian stance on the situation of food insecurity and climate change. Now is a time for innovation in a time of pressure. While responding to a growing population is one goal of this innovative effort, the more general goal is adapting to the changes taking place to the planet and to human systems, and taking responsibility for those actions for which humans are accountable. While many natural resources that enable human existence are finite, human innovation is infinite; problems such as food insecurity and climate change can be overcome.

The pathway forward very well could be initiated through the Feed the Future program. The scope and comprehensiveness of the program offers great potential to effectively address solutions to the global problems being faced along with food insecurity. However, one program or initiative is not enough to solve these issues; the economic, structural, and ideological changes that have been enumerated are critical elements. Yet, the solutions do exist; their fulfillment depends on the presence of active adoption, implementation, and leadership. The technologies, economic and structural transformations, and considerations needed to developing solutions have been noted. Innumerable individuals, research groups, organizations, and programs are working to address these problems and can contribute to future advancements to improve the quality of

life of earth's inhabitants both now and in the future. However, the question becomes whether we can find a way to align, coordinate and act with urgency or have loosely coordinated pockets of progress. The most promising pathway forward must include not only verified options for success, but also a widespread commitment to harmonized action to resolving these problems.

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