Stability, sustainability, and catastrophe: Applying resilience thinking to U. S. agriculture

Gigi Berardi[1]

Department of Environmental Studies
Western Washington University

Rebekah Green

Resilience Institute
Western Washington University

Bryant Hammond

Resilience Institute
Western Washington University

Abstract

Resilience is closely related to notions of sustainability, but emphasizes unpredictable, dynamic environments. As conceptualized in engineering, hazards management, and ecology literature, part of resilience is adaptive capacity, the ability to react effectively to change over time in order to maintain a desirable system state. Agricultural policy has had the effect of undermining such adaptive capacity with its emphasis on stabilization. Using a resilience framework and Hurricane Katrina as an analogy, we suggest that the emphasis on stability and efficiency degrades agricultural system resilience in two ways: through reduced diversity in size and type of production, as well as reduced ability to change production regimes based on the primary operator's judgment of social, environmental, and economic conditions; and, through the reduction of adaptive capacity by artificially stabilizing the system and eliminating feedback mechanisms that make adaptation possible. The resulting stagnation or loss of economic and political power lowers the resilience of the system and thus its long-term sustainability.

Keywords: *resilience, sustainability, adaptive capacity, agriculture, U.S. agricultural policy*

Introduction

Development of the concept of resilience in fields such as engineering, ecology, and psychology (Manyena, 2006) has complemented research using existing vulnerability frameworks that focus on the root causes of disaster (Wisner et al., 2004). In the field of hazards and disaster studies, resilience mostly has been used to refer to reducing disaster impacts, in ways very similar to Holling's (1973) original use of the concepts of stability and persistence. As Holling discussed, a resilient system would be able to absorb disturbances and eventually recover so that vital components of the system such as its plants and animals would still retain the same basic, expected functions and interactions (Walker & Salt, 2006). Resilience is necessary and desirable precisely because most environments, even those that humans attempt to stabilize and manipulate on gross scales, are dynamic, uncertain, and prone to disturbance or change.

In ecological literature, resilience describes a system's ability to remain in a distinct state, and to persist by responding adequately to and adapting to changes internal or external to the system (Carpenter et al., 2001; Gunderson et al., 2010; Holling, 1973). Matthews & Selman (2006) build on the ideas of Gunderson and Holling (2001) who wrote on the dynamics of adaptive cycles leading to changes in such distinct states (Gunderson & Holling, 2001; Matthews & Selman, 2006). Resilience also can be characteristic of socio-ecological systems (Allison & Hobbes, 2004; Langridge et al., 2006) — particularly, regarding the ability to sustain a desirable standard of living over extended periods of time (Swanson et al., 2009). Resilience, then, depends on an ability to live with change and uncertainty, and utilize a wide range of knowledge and perspectives especially regarding land use practices (Folke et al., 2003).

Resilience thinking also offers a means of expanding on ideas of system sustainability with its emphasis on unpredictable, dynamic environments and building the necessary adaptive capacity to render a system viable (Walker & Salt, 2006). Sustainability has well informed this discussion to date, with a large body of scholarship in agricultural applications.

This essay builds on approaches from disaster studies that extend to socio-economic change and can be fruitfully applied to agricultural sector resilience concerns in United States (U.S.) agriculture. Besides discussing agricultural cases, this essay highlights the consequences of a catastrophic event such as Katrina as another example of resilience thinking, with its engineered stabilization regimes similar to typical policy approaches used in constructing U.S. agricultural policy.

Sustainability and resilience

Ideas of sustainability in agriculture are not new, with usage increasing after 1987 with the Brundtland Commission's work in defining and expanding upon what was meant by "sustainable development" (Brundtland Commission, 1987; Harwood, 1990). Central to the idea of "sustainable" is that present practices should not compromise the natural resource base of future generations. However, the means by which sustainability is accomplished (and perhaps measured) is subject to much discussion and debate. Certainly, what has come to be known as conventional agriculture (high input, high yield, mono-cropped) was hoped to have been "sustainable" in the early days of the Green Revolution (Everson & Gollin, 2003).

MacRae (1990) argues that concepts of sustainability were present in English agriculture up until the repeal of the Corn Laws (import tariffs designed to protect corn prices in the United Kingdom in the early-mid 1800s). Harwood notes numerous examples of integrated farming in the 19th century U.S. that helped "shape perceptions of appropriate production practices" (1990, p. 5). Similar ideas of "appropriate" production were gaining momentum in Central Europe, following the influential Agriculture Lectures of Rudolf Steiner in 1924, which eventually grew into the biodynamic movement (Steiner, 1993). During the Dust Bowl years of the early 20th Century in the United States, the Soil Conservation Service was created in an effort to inventory and sustain the nation's soil resources (Harlow, 1994). "Organic" agriculture appeared by the 1950s, being popularized by Robert Rodale (MacRae, 1990) as a regenerative agriculture, possibly part of a larger resistance to the rapid industrialization following the Second World War (Ikerd, 2004). Such regenerative agriculture focused on the renewal of natural systems, eschewing chemical inputs that might comprise eco-biological processes within systems.

Sustainable agriculture as a system was legitimized in U.S. farm policy in the 1985 Farm Bill, or Food Security Act of 1985 (Ikerd, 2004). This bill introduced the Low-Input Sustainable Agriculture Program and was intended to increase scientific knowledge in the reduction of chemical inputs used in food and feed production. With the passage of the 1990 Farm Bill, the program was renamed as the Sustainable Agriculture Research and Education Program, the name it continues under today (Gold, 2007).

The 1990 Farm Bill defined sustainable agriculture as an integrated system of plant and animal production, one that satisfied food and fiber needs while enhancing environmental quality, promoting efficient use of natural resources, and maintaining the economic viability of farmers and community (Cibulka, 2009). This definition clearly integrates the long-term perspective of the Brundtland Commission with Rodale's emphasis on environmental health. There is an emphasis on stability and efficiency, as noted also in *Alternative Agriculture* produced by the National Research Council (1989). In a more recent report, the National Academy of Sciences focused on the dynamic nature of the agricultural environment and how a rather large, concerted effort in policy change was needed to achieve sustainability (National Research Council, 2010). Others have written eloquently on the subject of the meaning of sustainability, and raised concerns about protection of critical agro-ecosystem services (Altieri, 1995; Altieri & Anderson, 1986; Saifi & Drake, 2008; Scherr & McNeely, 2007; Warner, 2007). Saifi & Drake (2008) emphasize local interaction and interconnectedness in rural-urban contexts and also highlight the need for sustainability indicators. Other important scholarship on sustainability indicators can be found in the work of Molly Anderson and colleagues (2009) and Rao & Rogers (2006). Other researchers argue for new approaches that will integrate biological and ecological processes into food production systems (Pretty, 2008) that will inevitably lead to adaptive management (Jackson et al., 2001) — very similar to ideas of building adaptive capacity, discussed below.

At any one point in time, there are situations where resilience and sustainability can be treated as synonymous. The element of resilience emphasized in this essay is the need for adapting to the dynamic character of the system itself.

Resilience, as a framework for understanding environmental change and response, has been gaining considerable respect and use in applications ranging from psychology (Marshall et al., 2007) and socio-ecological systems (Carpenter et al., 2001; Folke, 2003) to community development (Adger, 2000; Cumming et al., 2005). In this essay, we contend that applying resilience thinking to agricultural production systems and policy may shape important lines of inquiry regarding agricultural policy and viability. Examples considered are the case of Hurricane Katrina in the Gulf Coast (used here to show the application of resilience thinking in engineered systems, and also for Katrina's impact on agriculture), and U.S. agricultural policy itself, including an application of the National Organic Program/Organic Rule and an inevitable consequence resulting from using conventional sources of manure. Lastly, suggestions for changes in federal policy and programs, using resilience thinking, are discussed.

Resilience and adaptive capacity in agriculture

Agriculture itself represents a cultural shift from adaptation to natural seasonal fluctuations in "wild" food supply, to more intensive investment of labor and other resources for stability and predictability in caloric production via cultivation. Despite the obvious limitations of total dependence on natural cycles, exposure to extreme events historically fostered a different understanding and expectation regarding uncertainty, and an obviously greater emphasis on developing individual and group strategies for survival (Gunderson, 2008; Workman, 2009). The case of Island County, Washington, is particularly illustrative of how agricultural landscapes have evolved over time. In his classic history of environmental change in Island County, White (1980) describes how the area's agroecology changed through time, from the indigenous Salish inhabitants, through white settlers, to 20th century land use. Native ecosystems produced vast quantities of salmon, shellfish, marine mammals, deer, elk, nettles, and camas for food. This natural harvest (and cultivation of camas) was replaced with potatoes, domestic livestock, and then a more diverse crop agriculture. White's story of environmental change linked to agricultural development serves as a case study — repeated with some variation, worldwide — of resilience, and lack thereof. Island County's ecology experienced considerable reorganization over time, as the island's ecology shifted from conifer forest to intensive market agriculture, with a loss of soil fertility and sharp decreases in expected yield. An element of resilience to be gleaned from such histories, with modern relevance for protecting farm income as well as consumer prices and health, is the concept of adaptive capacity.

Current research on understanding threats or hazard events in agriculture is vigorous. Scholarship typically has focused on natural hazards such as drought and famine (Alinovi et al., 2009; Allison & Hobbes, 2004; Conway, 1993; Milestad, 2003; Myers, 2008; Ramjan & Athalye, 2008). Yet, resilience concepts as a tool for planning using ideas such as adaptive capacity have been little applied to the U.S. agricultural sector. System change may come from severe weather, but also from social or economic factors such as high energy prices, technological innovation (as with the introduction of donkey engines for hauling timber in Island County), or regional policies that encourage rapid urban sprawl (Klein & Reganold, 1997). Such changes can be understood as socioeconomic hazards, which can overwhelm community resources and coping ability to the point of a long-term decline in farm numbers, productivity, or farm acreage.

One understanding of adaptive capacity is that it is the ability to react effectively to change, cope with difficulty in novel ways, and ultimately take advantage of changing social, economic, and environmental conditions in order to manage and maintain a desirable system state; such capacity can mean the difference between disastrous change and gradual adaptation (Smit & Wandel, 2006). It incorporates ideas of adaptability, coping ability, management capacity, and flexibility (Adger & Kelly, 1999; Brooks, 2003; Fraser et al., 2003; Füssel & Klein, 2006; Jones, 2001; Smit et al., 1999; Smit & Wandel, 2006; Smithers & Smit, 1997; Tompkins & Adger, 2004).

One complex change, common in developing agricultural systems, is the emergence of market agriculture. In the case of Island County, market agriculture was introduced (1860-1900) into an existing low-intensity agricultural system. Disruption of the native ecosystems resulted from sharp increases in sheep, potatoes, and small grain production. Many social and environmental consequences resulted, such as invasive plant species management problems, and tension between Chinese, Indian, and White populations. The adaptive capacity exemplified in complex natural systems no longer provided a system buffer for disturbance.

In the early-third of the 20th century, national legislation was passed that had the same effect of reducing agricultural adaptive capacity and, thus, resilience. Farm Bills were written to address acute short-term problems such as near-starvation in the spring of 1933 and, later, the bank and farm credit crisis of the mid-1980s (due, in part, to overexpansion in the 1970s). These bills stabilized extreme economic situations but neglected to address any other underlying social and environmental factors, inevitably weakening the overall resilience of the system to disturbances such as price hikes in energy or other costly external inputs.

A dramatic instance of stability being favored over resilience — the case of New Orleans and Hurricane Katrina — well illustrates the trade-offs between stability and resilience. Engineering solutions to what was a normal and regular feature of the landscape — seasonal flooding — had the effect of stabilizing flood regimes. However, resilience decreased as a result and an extreme event (Hurricane Katrina) led to catastrophic consequences. Regional agriculture suffered as well.

Stability in socio-ecological systems: The case of Hurricane Katrina

On a larger socio-ecological scale, resilience is a measure of a community's ability to cope with stress, and includes reducing overall economic loss, even as some individuals or groups may be severely disrupted. This is well illustrated in the case of Hurricane Katrina, discussed here to show how a resilience thinking approach can be applied to the ability of New Orleans, and the region's agriculture, to cope with and recover from a major hurricane.

In terms of change to human settlement and society, stability provides an attractive concept and goal for economic and social development in the "get-back-to-normal-and-move-on" sense. Yet, focusing predominantly on enhancing the stability of a system undermines the processes by which a system adapts to changing environmental conditions. What happened in New Orleans clearly illustrates how focusing on enhancing the stability of a system (Colten, 2005; Freudenburg et al., 2010) may undermine the feedback mechanisms and information processes (provided by, in this case, the frequency and extent of flood waters) by which a system adapts to changing environmental conditions. Although a focus on stability may function as an effective response to small changes, it fails to be effective when disturbances are large. In the New Orleans case, the decreased exposure to environmental cycles and the adaptive learning (for example, in terms of selection of building materials) they typically would have stimulated contributed to exacerbating the impacts when the engineered levee systems were overwhelmed and failed. Thus, the existence of feedback mechanisms is critical in providing information so as to adapt to cyclical and evolving conditions.

In 1718, French explorers established New Orleans on the banks of the Mississippi River where easy portage to the Gulf of Mexico was found via Bayou St. John and Lake Pontchartrain. New Orleans developed into an important transportation hub where bulk goods barged from the continent's interior could be transferred to seagoing vessels (Freudenburg et al., 2010). In the 19th century, those with financial and social means crowded along the banks of the river, built up over years of flooding to be above sea level. This natural levee along the banks was both relatively high and away from the swampy "back of town" inhabited by freed slaves, indigenous peoples, and poor Cajuns (Campanella, 2006). Yet even on this natural levee, flooding plagued residents. The Mississippi River fluctuated as much as 15 feet, often spilling over its banks in spring; and summer hurricanes brought storm surges that pushed Lake Pontchartrain waters inland, into the back of town (Freudenburg et al., 2010). To reduce flood damage, traditional pre-20th century habitations were built on raised foundations several feet off the ground, allowing floodwaters to pass underneath the structures. Such architectural adaptation to seasonal variability ensured community persistence, despite frequent seasonal variability (Colten, 2005).

While historic architectural styles and settlement patterns limited seasonal flood damage, 20th century residents sought to eliminate the inconvenience of flooding altogether. City officials dredged the lake and used sediment to build a lip of high ground. Politicians and business elite acquired federal funding for large-scale water management projects — dams, levees, pumps, and shipping canals — all touted as promoting economic development. Using federal funds, the Army Corps of Engineers constructed an extensive levee system to surround the city, enclosing and draining the swampy regions north and east of the river and selling the reclaimed land to finance much of the system's construction. While these projects expanded the city's footprint into land below sea level, they also accelerated the destruction of cypress marshes that had acted as a buffer to hurricane storm surge (Colten, 2005; Freudenburg et al., 2010). In particular, shipping canals meant to benefit the economic elite sliced through predominantly African-American, middle-class neighborhoods in ways that would later expose them to heightened storm surge from hurricanes (Freudenburg et al., 2010; Green et al., 2007).

Without the need for raised housing, spatial patterns and types of development changed to take advantage of the "stabilizing" levees. Building along the raised river banks on high foundations — strategies that increased resilience — were abandoned. As the population nearly doubled over the 20th century (Campanella, 2006), single story, ranch-style housing, built directly on the ground, crowded into the newly-drained lowlands, which began subsiding without the sediment deposits that seasonal flooding brought (Campanella, 2006; Green et al., 2007). This new style of housing was particularly cost-effective for a burgeoning middle class, and, along with the collapse of "Jim Crow" (forced segregation) laws, allowed many middle class African-Americans to move out of the Ninth Ward and into newer suburban style communities away from the River's edge (Bates & Green, 2009).

New Orleans' 20th century population expansion, architecture, and settlement patterns — emerging from the elimination of seasonal flooding — resulted in a city highly vulnerable to flooding when Hurricane Katrina eventually toppled levees in August 2005. Prior to European settlement, the entire area was at or above sea level; by 2005, 49 percent was below sea level (Campanella, 2006) in housing that did not have traditional architectural features that would have reduced flood impacts (Green et al., 2007). Over 70 percent of all housing units within New Orleans Parish suffered major flood damage or severe damage and destruction due to the failure of the levee system (Office of Policy Development and Research, 2006). Historic raised houses along the river's naturally high banks remained unflooded or experienced minor, repairable flood damage, as did those at or near sea level and with raised foundations (Green et al., 2007).

It is clear that New Orleans' adaptive capacity had diminished over time. While the levee system had provided security from seasonal flooding and small storm surges, its capacity was limited. To reduce impacts from seasonal flooding and small storm surges, an engineering approach to resilience had been applied. The approach centered on reduced economic loss and rapid recovery from frequent disturbance events (Bruneau et al., 2003; Miles & Chang, 2003; Shinozuka et al., 2003 - 2004). However, for an engineering approach to resilience to be successful, it must prioritize redundancy of fallback systems and resourcefulness, two attributes that form a problem-solving strategy for achieving resilience goals and reducing risk (Bruneau et al., 2003). The levee system of New Orleans enhanced physical controls, stabilizing the area by reducing the uncertainty of frequent flooding, but undermined the adaptive capacity of residents by removing the need for non-engineered flood management strategies such as wetland maintenance, avoidance of low-lying areas, and raised foundations.

In the face of flooding and hurricanes, 19th century New Orleans was resilient. Certainly, flooding and hurricanes frequented the city, yet these events did not result in massive population loss or destruction of the majority of the housing infrastructure. Damage occurred, but it was repairable. Hence, community resilience was essentially intact — the city was able to continue functioning without extensive external support from outside sources. However, when Katrina struck, the degradation of the city's resilience was evident. Not only was the damage and loss of life extraordinary, recovery required massive federal aid in the form of emergency response, disaster aid grants, and funds for the repair and rebuilding of the levee system. Moreover, New Orleans promptly lost over half its population, and ultimately had a net loss of 110,000 in 2010 out of 455,188 residents prior to the hurricane. Ninety percent of the city's neighborhoods lost residents, including 17 neighborhoods that had not experienced flooding (Plyer, 2011). The repopulation of New Orleans that has occurred has required nearly $3 million (as of February 2011) rebuilding grants to homeowners (Road Home, 2011). Especially hard hit were the African-American neighborhoods of the Ninth Ward and East Orleans. The Ninth Ward had relatively high ground levels, but its protective levees failed due to a heightened storm surge prompted by more modification to waterways (shipping outlets) to the Gulf. When the wall of water that burst into the neighborhood swept dozens of homes off their foundations, post-Katrina recovery commissions sought to turn the neighborhood into green space or argue that it had to "prove" viability before funds would be used to assist recovery (Freudenburg et al., 2010; Green et al., 2007).

Hurricane Katrina also damaged the agricultural, aquaculture, and forestry sectors. With the degraded wetland protection, hurricane flood waters deposited salt on 35,000 acres of sugarcane cropland, causing a nine percent reduction in Louisiana's sugarcane production that year. Two sugarcane refining plants closed due to damage and the United States Department of Agriculture (USDA) reassigned quotas to Midwest sugar beet producers (Commodity Credit Corporation, 2006; Tomson, 2005). Poultry farmers lost five million chickens; dairy farmers lost 10,000 cattle (Cohn, 2005). In Louisiana, nearly all oyster beds were covered with silt and contaminants, with direct losses of $1.1 billion and an estimated two years needed for recovery (Buck, 2005). High winds caused breaking and shearing damage to over 60 percent of timber stands; timber prices plummeted overnight, and with them, the savings of tens of thousands of small-scale landowners (Cormier, 2006; Gillette, 2006; Wang & Xu, 2009).

Katrina's damage also highlighted how dependent these sectors were on external inputs and regional infrastructure. Fuel scarcity and loss of electricity for cooling, water pumps, feeding machines, and refrigeration resulted in milk dumping and egg spoilage (Clarke, 2005; Jeter, 2005). On the coast, storm surge destroyed docks, electrical systems, and processing equipment. Slow recovery of large handler-processors meant that many smaller processors had to delay opening even after they had successfully replaced their equipment. Fishers had nowhere to go to obtain ice, fuel, or sell their catch (Buck, 2005).

Damage to the Port of New Orleans significantly blocked the flow of commodity crops out of the 33 states that ship grain exports through the Mississippi outlet (Plume, 2005). Immediately following the storm, 300 Cargill, Inc. barges on the river loaded with corn, soy, and wheat could not find a port to offload (Barrionuevo & Deutsch, 2005) and 86 ships queued at the river's entrance had to be diverted elsewhere (Frittelli, 2005). The disaster reduced the traffic on the Mississippi River by 90 percent in September 2005, leading Midwest farmers along the Mississippi to scramble for more expensive rail and road transportation alternatives to getting product to market (Walker, 2005). In November, Gulf Coast ports were operating at two-thirds capacity due to labor and housing shortages (Gallagher, 2005; Plume, 2005). Altogether, the American Farm Bureau Federation estimated that Katrina caused $1 billion in direct losses to crops and livestock, and an additional $1 billion in indirect costs associated with the degradation of the waterway shipping network and increased fuel costs (Hagstrom, 2005).

The damage to the agriculture, aquaculture, and forestry sectors was so severe that extensive federal support was needed. USDA spent $10.7 million unloading barges and provided freight subsidies for shipment out of northern ports (Plume, 2005). Direct loss was covered under USDA's federal crop insurance, non-insured crop disaster assistance program, and emergency disaster loans (Buck, 2005; Schnepf & Chite, 2005). The federal government also set up the first-ever national level, forestry-based disaster relief program (Gillette, 2006). While these sectors had impressive outputs on the national and global scale during stable periods, they needed considerable subsidies and policy support when faced with a predictable, and not infrequent hurricane disturbance, to say nothing of seasonal flooding and drought.

Stability in socio-ecological systems: Agricultural policy

Katrina provides a good example of how an emphasis on stability over resilience can result in disastrous consequences. In the context of agricultural policy and the industrial scale of agriculture it supports, protection from commodity market variability can be compared with flood protection through structural engineering projects such as dikes, seawalls, and levees. The perceived safety in stability in fact leaves those "behind the walls" ill-prepared for the next large flood (or, the next energy price spike); rather, protective, (price) stabilizing policy may compromise adaptive approaches to, for example, energy conservation. Further, New Orleans residents (or U.S. farmers) may have unreasonable expectations that the risk of catastrophic disaster is low and that government support itself is timely and reliable.

For decades, the primary emphasis in agricultural policy (and financial credit and research extension) has been in maximizing yields relative to land and labor inputs, i.e., in increasing productivity (Pimentel et al., 2008; Roberts, 2008), and in so doing, protecting U.S. agriculture from certain kinds of economic disturbances. This kind of thinking resulted in a large intervention — the agricultural adjustment acts of the 1930's (and subsequent authorizations of commodity-specific price support and supply controls, known as the U.S. Farm Bills). Such policy was in response to the most significant disturbance, arguably, to affect U.S. agriculture in the past 100 years — the 1930's disastrous "Dust Bowl," when the Great Plains suffered from years of severe drought and "black blizzards," and eroded top soil across vast swaths of the country (Worster, 2004). Possibly the worst climatological event in U.S. agricultural history coincided with the Great Depression, one of the worst economic events in the country's history.

Originally intended as a short-term, emergency measure to stop the dramatic decline of farm prices, price supports and supply management nevertheless remained a policy strategy through the 1996 Farm Bill, and continue today although the relative share for such programs continues to wane (Effland, 2000). Today, about 11% of Farm Bill annual average expenditure is for commodity programs, down significantly from the 35% in the 2002 Farm Bill (Smith, 2008).

Legislation continues to move farmers towards fewer price supports or direct payments while favoring export crop production and marketing for a global economy (Effland, 2000). The programs resulting from the Farm Bill are serving a different kind of agricultural economy, one dominated by industrial farms rather than small, independent producers. Should Farm Bills continue then to authorize direct income support tied to price fluctuations? It could be argued that the equity aspects (privileging large-scale operations, and in only a handful of commodities) negate the benefits of a high volume of production (Effland, 2000).

One of the clearest effects of U.S. agricultural policy, as best represented by the Farm Bills, was to increase and intensify inputs in production — for example, relatively-low priced chemicals. Further, the high demands for uniformity of shape and maturation time of produce resulted in an influx of breeding and machine technology, increasing production and efficiency (relative to labor and land) (Dimitri et al., 2005). At the same time, farm numbers have dropped, with U.S. farms declining from 7 million to about 2 million since the 1930s (Johnson, 2003; Keeney & Kemp, 2002).

Optimizing production relative to land and labor has consequences — on efficiency of other resources (most notably, energy) and for equity concerns. Policy raises income by raising prices so benefits accrue to those who produce the most. Thus, a relatively small number of farmers, receive benefits. This subsidy to capital intensity for larger-scale farmers is given at the expense of taxpayers, but benefits may not be sufficiently high to offset the social consequences of a decline in number of farms.

Technology, too, accounts for high production, and industrialization of agriculture, "leaving the remaining operators with little time for 'luxuries' such as biodiversity, environment, and rural development" (Keeney & Kemp, 2002, p. 7). Another change influencing the effectiveness of policies that contribute to declining farm numbers and loss of biodiversity is that, today, over 90% of farm household income is derived from off-farm sources. This is a very different environment to that of the 1930s when the program was targeted for those whose main income was derived from farming (Dimitri et al., 2005; Effland, 2000).

In terms of the ecological integrity of agricultural systems, policy programs focused on ever-greater productivity promote a lack of biodiversity by encouraging farmers to plant few varieties of seed and keep land, even marginal land, in production (Santelmann et al., 2004). The U.S. Farm Bill seeks to address such vulnerabilities with its various conservation provisions — an attempt perhaps to increase the ability to adapt to disturbances (Tompkins & Adger, 2004; Vogel et al., 2007). However, these programs remain voluntary (approximately 8% of total funds are for conservation programs, including options for land retirement and preservation, as well as to promote some best practices on working lands).

In terms of economic resilience, insurance is made more costly and more limited in scope because of uneven commodity prices and increasing losses due to various disasters (due, in part, to the low-diversity of production) (Natcher & Weaver, 2001). Overall, agricultural policy, although providing fiscal resources, emphasizes productivity relative to labor and land resources, at the expense of the efficiency of other factors such as energy, which is an increasingly significant input (Pimentel et al., 2008). More importantly, it may have the effect of reducing the range of the perceived normal operating conditions and rapid, effective response — in effect, decreasing adaptive capacity.

In short, U.S. Farm Bills have represented a major attempt to reduce historic vulnerabilities in U.S. agriculture. Given the specific conditions of the Dust Bowl years, such a response was considered a means of boosting the sustainability of U.S. agriculture. But it could hardly be interpreted as part of a coherent long-term policy focused on resilience and sustainability. Rather, it was an emergency response to aid those on the brink of economic collapse due to plummeting crop prices.

Since the 1930s, technology has developed, the country has urbanized, and the economic system continues to be dynamic. Yet approaches in federal support largely has remained the same. Moreover, the long duration of these once-effective programs has produced entrenched interests and the expectation of government assistance in times of need. This results in less flexibility and willingness to change production strategies (for example, in crop rotations). This policy approach is a good example of optimizing one factor — prices. Emphasis is put on production for global markets, but not necessarily on maintaining diversity of numbers and sizes of farms within the domestic sector. Consumers may benefit through lower food prices, but they also pay for it through their tax dollars.

Non-conventional agriculture in the U.S. also is subject to stabilizing- and resilience-reducing strategies. More specifically, federal policy authorizing the National Organic Program/Organic Rule has had a broad spectrum of consequences for scale of operation. In Northwestern Washington state in 2010, suspected herbicide (aminopyralid) contamination of conventional dairy manure used on organic farms was reported (Burrows & MacConnell, 2010). Application of this contaminated manure (resulting from cattle grazing on pastures treated with the herbicide) is thought to have caused severe crop damage in broadleaf plants and continued contamination of organic fields with a potent, slow-degrading herbicide. Such contamination may have affected almost all organic farmers in the area who procured their manure from off-farm sources. Conventional sources of manure are allowed under the U.S .Department of Agriculture's National Organic Program and Rule (in fact, they may be essential given the scale of organic production across the country). Yet the "stability" represented by a readily available, concentrated source of nutrients in industrial sources of manure may have, in fact, increased vulnerabilities of producers through sharply reducing yields, as well as undermining consumer trust in "certified organic" produce. To allow for conventional sources of soil fertility results in corporate-size scales of production, but may affect producers of all scales by increasing risks as described above (Sullivan, 2011).

Further discussion: Resilience in agriculture

Large disturbances are becoming more frequent and raising questions about the sustainability of U.S. agriculture: global climate change, volatile energy markets, localized natural hazards such as flooding, and effects of regulations on technology use and labor supply (Sumner, 2007). Some areas of the country continue to lose a competitive edge to other regions with, say, more favorable climate or adequate labor supply (Stöckle et al., 2009).

While system productivity may keep the monetary cost of food low, policy may undermine or at the very least impose market disadvantages for smaller, more innovative growers (Ryden, 2007). It privileges large farms, resulting in a structure (size-distribution) of agriculture that is skewed. Diversity, thus, is compromised. Yet such diversity of scale of operations is necessary for a robust agriculture. Perhaps the innovative nature of small-farms can be seen in their disproportionately high enrollment in conservation programs and in crop diversification strategies (Berardi & Lunde, 2008). Further, smaller producers are at times better suited to respond quickly to market needs, thus adapting supply to demand (Hall et al., 2004; Wiggens, 2009). The problem arises, as argued here, when agricultural policy favors one scale of production over another. Such concerns raise questions about whether a different type of farm bill, one not tied to efficiency of land, labor, and/or production, might foster the diversity — and hence resilience — desirable in agricultural systems.

The 2002 Farm Bill marked a real change with its Conservation Security Program. This Program contained many conservation and environmental provisions to reduce pollution, protect the landscape, and support small farmer livelihoods (Keeney & Kemp, 2002). Provisions in the Bill signaled a reduced focus on commodities and intensification and more emphasis on environment and energy concerns, as well as on integrated farming systems (Keeney & Kemp, 2002). For example, the Bill specifies support for diversified resource-conserving crop rotation systems and managed rotational grazing systems, as well as conservation buffers. More recently, the Conservation Stewardship Program, authorized by the 2008 Farm Bill, has replaced the Conservation Security Program. Both programs promote diversity in operations — with commodities interspersed with resource-conserving crops in four-to-six year cycles and with livestock grazing on more pasture and feeding on more forage (and also a wider variety of feed grain: oats, barley, and wheat, rather than just soy and corn). Also required are longer periods of soil vegetative cover during the year, and use of perennials as protection for riparian zones and for loss of soil.

It should not be difficult to design a "resilience" component to be required for participation in farm *commodity* programs. Program participants currently are required to comply with Conservation and Wetland standards in return for marketing assistance loans. Yet steps to reduce vulnerability or risk could be more formalized in farm planning and plans. County or regional farm services agencies could assist. Besides showing a mere history of number of acres planted to a particular commodity crop, farmers also could show ways in which they are reducing specific risks. As an example, threats from urban sprawl, with high land rents and nuisance ordinances resulting, might invite consideration of taking advantage of new markets and higher-valued crops sought by new neighboring residents.

Threats from flooding could prompt farmers to consider a change in land use to extensive grazing systems or certain permaculture practices. Threats related to large, centralized sources of inputs (herbicide-laden dairy manure for organic farms, or large-scale, improperly-stored and aflatoxin- contaminated forage) could be addressed by diversifying sources and types of inputs. Threats involving high external energy use and extreme price spikes could prompt farmers to make a more concerted effort in on-site energy production and more self-sufficiency through energy conservation. All of these strategies could be part of a program-enrollment process and/or written into farm plans. Showing evidence of reducing vulnerability to such extreme events should be a prerequisite for participation in commodity programs, and accessing the resources they provide.

Vulnerability-reducing examples exist elsewhere, as in the case of New Zealand where subsidies were eliminated in 2009 (Federated Farmers, 2002). In this case, a major perturbation sent shock waves through the New Zealand farm sector — with a sudden elimination of farm subsidies in that country resulting. Questions regarding what scale of agriculture was able to adapt most quickly, and how — are still the subject of much discussion. Researchers MacLeod and Moller (2006) contend that there is evidence for intensification and diversification, with a complex series of adjustments resulting within livestock and crop production, but within labor markets as well (with a higher proportion of income from off-farm sources resulting). Others have commented on shifts in grazing of marginal land, which is now grazed less intensively and have reported positive changes in the structure of agriculture, in terms of diversity of size of farms (Federated Farmers, 2002).

Concluding remarks

Today, the U.S. agricultural sector continues to emphasize industrial forms of production of cereals, dairy products, and other crops for export. This emphasis on efficiency and stability (in terms of commodity production) degrades resilience in several ways: through the reduction of diversity in size, type, and style of producer, as well as through the decreased ability to change (to the extent infrastructure investments allow) among crop production systems; and, through the reduction of adaptive capacity by stabilizing cyclical variation in prices. Together, they reduce adaptive capacity (Smit & Wandel, 2006), and lock-in entrenched interests, bureaucracy, and political and economic power (Allison & Hobbes, 2004) in a cycle of stagnation that defeats the original purpose of the policy — to sustain a healthy agricultural sector.

Food continues to be abundant in the U.S., food prices are seemingly low, and there seems to be little opposition to change (indeed, it is relatively easy to organize farm operators who benefit most from the Farm Bill) — support is considerable. Yet, diversity in farms size and type results in a diverse production of food and environmental goods and services (Reidsma & Ewert, 2008; Santelmann et al., 2004). Clearly, some consumers, enjoying both rural landscapes and local produce, are willing to pay for such services in a multifunctional landscape, either through taxes or through food prices.

It is clear that U.S. agricultural policy is driven by commercialization, and vested interests. It may be that policymakers inherently desire a "resilient," "sustainable," and "stable" system, though their conception of what these entail may include the perpetuation of an industrial model of agriculture. Nevertheless, the emphasis on stability in agricultural policy and programs is an outdated conceptualization of the means to achieve a system capable of persisting — i.e., a sustainable system. We continue to live in a dynamic world of environmental, economic and social constraints that are constantly at odds with each other. Policy needs to change accordingly.

On a broader scale, a resilient agricultural sector would maintain the ability to adapt to, learn from, and recover from disturbances to normal operating conditions, while continuing to provide the goods and services that support food, feed, and fiber production. Unfortunately, many agricultural programs tend to favor stability-enhancing management strategies with little attention to resiliency. Yet tax-supported programs need not support the least resilient agriculture possible. Policy can be rewritten so that efforts are made to reduce vulnerability to disturbances. Whether the disturbance is a recurrent pest problem, high energy prices, water scarcity, or a new threat, the usual strategies are still available — technology adoption, government support. But, whither the farm resilience, personal innovation and daring, or the acknowledgement of the time necessary to develop a package of tools to better adapt to the next big hazard? How indeed will federal support manifest itself for such an effort and allow for the emergence of a less hazardous U.S. agriculture across scale and time? Certainly examples exist, as in the case of New Zealand. Now it is time for the U.S. to consider resilience thinking in farm policy.

Acknowledgements

The authors acknowledge the careful review of Jim Allaway, Peter Homann, and John McLaughlin of Huxley College, and John Tuxill of Fairhaven College, Western Washington University, in the preparation of this manuscript. Thanks also to Sam Ripley and Heather Jeffreys who provided valuable assistance in the literature review. This project was supported by the National Research Initiative of the National Institute of Food and Agriculture, USDA, Grant # 2009-55618-05083.

Endnote

1. Gigi.Berardi@wwu.edu

References

Adger, W. N. (2000). Social and ecological resilience: Are they related? *Progress in Human Geography*, 24(3), 347-364.

Adger, W. N., & Kelly, P. M. (1999). Social vulnerability to climate change and the architecture of entitlements. *Mitigation and Adaptation Strategies for Global Change*, 4, 253-256.

Alinovi, L., Mane, E., & Romano, D. (2009). *Measuring household resilience to food insecurity: Application to Palestinian households*. Rome: Food and Agriculture Organization.

Allison, H. E., & Hobbes, R. J. (2004). Resilience adaptive capacity and the "Lock-in-trap" of the western Australian agricultural region. *Ecology and Society*, 9(3).

Altieri, M. (1995). *Agroecology: The science of sustainable agriculture*. Boulder, CO: Westview Press.

Altieri, M., & Anderson, M. (1986). An ecological basis for the development of alternative agricultural systems for small farmers in the third world. *American Journal of Alternative Agriculture,* 1, 30-28.

Anderson, M., Fisk, J., Rozyne, M., Feenstra, G., & Daniels, S. (2009). *Charting growth to good food: Developing indicators and measures of good food — final project report*. Arlington, VA: Wallace Center at Winrock International.

Barrionuevo, A., & Deutsch, C. H. (2005, September 1). Port distribution system brought to knees. *New York Times*.

Bates, L., & Green, R. (2009). Housing recovery in the ninth ward: Disparities in policy, process, and prospects. In Bullard, R. (Ed.), *Race, place, and environmental justice after Hurricane Katrina* (pp. 229-245). Boulder, CO: Westview Press.

Berardi, G., & Lunde, A. (2008). Reflections of agriculture and food security, farm living and livelihoods and urban-rural encroachment: Whatcom County agriculture's biggest challenge. Unpublished manuscript, Western Washington University, Bellingham, WA. Institute for Global and Community Resilience.

Brooks, N. (2003). *Vulnerability, risk and adaptation: A conceptual framework*. Norwich, UK: Tyndall Centre for Climate Change Research.

Brundtland Commission. (1987). *Our common future*. Oxford: World Commission on Environment and Development.

Bruneau, M., Chang, S. E., Eguchi, R. T., Lee, G. C., O'Rourke, T. D., Shinozuka, M., et al. (2003). A framework to quantitatively assess and enhance the seismic resilience of communities. *Earthquake Spectra,* 19(4), 733-752.

Buck, E. (2005). *Hurricane Katrina: Fishing and agriculture industries — damage and recovery.* Retrieved from http://www.fas.org/.

Burrows, C., & MacConnell, C. B. (2010). Aminopyralid residues in compost and other organic amendments. Accessed August 2, 2010 from http://whatcom.wsu.edu/ag/aminopyralid/, Whatcom County Extension, Washington State University.

Campanella, R. (2006). *Geographies of New Orleans: Urban fabrics before the storm*. Lafayette, LA: Center for Louisiana Studies.

Carpenter, S., Walker, B., Anderies, J. M., & Abel, M. (2001). From metaphor to measurement: Resilience of what to what? *Ecosystems*, 4(8), 765-781.

Cibulka, D. A. (2009). Sustainable agricultural practices in the United States and other postindustrial countries. In Phoenix, L. E. (Ed.), *Critical food issues: Problems and state-of-the-art solutions worldwide* (Vol. 1). Santa Barbara, CA: ABC-CLIO.

Clarke, P. (2005). Katrina costs farms $2bn. *Farmers Weekly*, 143(12), 16.

Cohn, P. (2005, September 20). USDA says losses from Katrina approach $900 million. *Congress Daily*.

Colten, C. E. (2005). *The unnatural metropolis: Wresting New Orleans from nature*. Baton Rouge: Louisiana State University Press.

Commodity Credit Corporation. (2006). *2005 Louisiana sugarcane hurricane disaster assistance program*. Retrieved August 3, 2010 from http://www.epa.gov/fedrgstr/.

Conway, G. (1993). Sustainable agriculture: The trade-offs with productivity, stability and equitability. In Barbies, E. (Ed.), *Economics and ecology, new frontiers and sustainable development*. London: Chapman & Hall.

Cormier, E. (2006). Down on the farm. *Louisiana Life*, Spring, 43-47.

Cumming, G. S., Barnes, G., Perz, S., Schmink, M., Sieving, K. E., Southworth, J., et al. (2005). An exploratory framework for the empirical measurement of resilience. *Ecosystems*, 8(8), 975-987.

Dimitri, C., Effland, A., & Conklin, N. (2005). *The 20th century transformation of U.S. Agriculture and farm policy*. Washington, DC: Economic Research Service.

Effland, A. (2000). *U.S. Farm policy: The first 200 years*. Washington, DC: Economic Research Service.

Everson, R. E., & Gollin, D. (2003). Assessing the impact of the green revolution, 1960 to 2000. *Science, 300*(5620), 758-762.

Federated Farmers. (2002). *Life after subsidies: The New Zealand farming experience 15 years later*: Federated Farmers of New Zealand, Inc., Accessed August 2, 2011 from www.fedfarm.org.nz.

Folke, C. (2003). Freshwater for resilience: A shift in thinking. *Philosophical Transactions of the Boyer Society: Biological Sciences, 358, (1440)*, 2027-2036.

Folke, C., Colding, J., & Berkes, F. (2003). Building resilience and adaptive capacity in social-ecological systems. In Berkes, F., Folke, C. & Colding, J. (Eds.), *Navigating social-ecological systems: Building resilience for complexity and change* (pp. 352-387). Cambridge: Cambridge University Press.

Fraser, E., Mabee, W., & Slaymaker, O. (2003). Mutual vulnerability, mutual dependence: The reflective notion between human society and the environment. *Global Environmental Change*, 13, 137-144.

Freudenburg, W. R., Gramling, R., Laska, S., & Erikson, K. T. (2010). *Catastrophe in the making: The engineering of Katrina and the disasters of tomorrow*. Washington, D.C.: Island Press.

Frittelli, J. (2005, September 13). *Hurricane Katrina: Shipping disruptions* (No. RL 33075): CRS Report for Congress.

Füssel, H. M., & Klein, R. (2006). Climatic change vulnerability assessments: An evolution of conceptual thinking. *Climatic Change*, 75(3), 301-329.

Gallagher, J. (2005, November 28). Rail's husky grain decline. *Traffic World*, 29.

Gillette, B. (2006). Post-Katrina timber? $1.1 billion in costs, lost dreams. *Mississippi Business Journal*, 16.

Gold, M. V. (2007). *Sustainable agriculture: Definitions and terms*. Washington, DC: Agricultural Research Service.

Green, R., Bates, L., & Smyth, A. (2007). Impediments to recovery in New Orleans' Upper and Lower Ninth Ward: One year after Hurricane Katrina. *Disasters, 31*(4), 311-335.

Gunderson, L. (2008). *Living with uncertainty and surprise*. Stockholm, Sweden: Paper Presented at Seminar in Honor of Professor CS Holling.

Gunderson, L. H., Allen, C. R., & Holling, C. S. (Eds.). (2010). *Foundations of ecological resilience*. Washington, D.C.: Island Press.

Gunderson, L. H., & Holling, C. S. (2001). *Panarchy: Understanding transformations in human and natural systems*. Washington, D.C.: Island Press.

Hagstrom, J. (2005, September 2). Farm exports could be stymied by closure of LA ports. *CongressDaily*.

Hall, D., Ehui, S., & Delgado, C. (2004). The livestock revolution, food, safety, and small-scale farmers: Why they matter to us all. *Journal of Agricultural and Environmental Ethics, 17*, 425-444.

Harlow, J. T. (1994). *History of Soil Conservation Service national resource inventories*. Fort Worth, TX: National Resources Conservation Service.

Harwood, R. (1990). A history of sustainable agriculture. In Edwards, C. A., Lal, R., Madden, P., Miller, R. & House, G. (Eds.), *Sustainable agricultural systems*. Covello, CA: Island Press.

Holling, C. S. (1973). Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics, 4*(1), 1-23.

Ikerd, J. (2004). *Twenty years of sustainable agriculture* Paper presented at the University of Vermont Center for Sustainable Agriculture Tenth Anniversary Celebration.

Jackson, J. B. C., Kirby, M. X., Berger, W. H., Bjorndal, K. A., Botsford, L. W., Bourque, B. J., et al. (2001). Historical overfishing and the recent collapse of coastal ecosystems. *Science, 293*(5530), 629-637.

Jeter, L. (2005). Storms muddy 2006 ag forecast, particularly timber. *Mississippi Business Journal*, B5.

Johnson, P. D. (2003, June 15). Big agriculture vs. sustainable production. *Denver Post*.

Jones, R. (2001). An environmental risk assessment / management framework for climate change impact assessments. *Natural Hazards, 23,* 197-230.

Keeney, D., & Kemp, L. (November 2002). A New Agricultural Policy for the United States. Paper presented at the North Atlantic Treaty Organization Advanced Research Workshop on Biodiversity Conservation and Rural Sustainability.

Klein, L., & Reganold, J. P. (1997). Agricultural changes and farmland protection in western Washington. *Journal of Soil and Water Conservation, 52*(1), 6-12.

Langridge, R., Christian-Smith, J., & Lohse, K. A. (2006). Access and resilience: Analyzing the construction of social resilience to the threat of water scarcity. *Ecology and Society, 11*(2), 18-33.

MacLeod, C. J., & Moller, H. (2006). Intensification and diversification of New Zealand agriculture since 1960: An evaluation of current indicators of land use change. *Agriculture, Ecosystems & Environment, 115*, 201-218.

MacRae, R. J. (1990). *Strategies to overcome institutional barriers to the transition from conventional to sustainable agriculture in Canada: The role of government, research institutions and agribusiness*. Montreal: McGill University.

Manyena, S. (2006). The concept of resilience revisited. *Disasters, 30*, 433-450.

Marshall, N. A., Fenton, D. M., Marshall, P. A., & Sutton, S. G. (2007). How resource dependency can influence social resilience within a primary resource industry. *Rural Sociology, 72*(3), 359-390.

Matthews, R., & Selman, P. (2006). Landscape as a focus for integrating human and environmental processes. *Journal of Agricultural Economics, 57*(2), 199-212.

Miles, S. B., & Chang, S. E. (2003). *Resilient community recovery: Improving recovery through comprehensive modeling*. Buffalo, NY: Multidisciplinary Center for Earthquake Engineering Research. Retrieved from http://mceer.buffalo.edu/publications/resaccom/03-SP01/03-SP01.pdf.

Milestad, R. (2003). *Building farm resilience: Challenges and prospects for organic farming*. Uppsala: Swedish University of Agricultural Science.

Myers, P. (2008). *Farmers' response to weather shocks and stresses in Manitoba: A resilience approach*. Unpublished Masters Thesis, University of Manitoba, Winnipeg.

Natcher, W., & Weaver, R. D. (2001). *Price volatility in the US dairy sector: Due to week-of-month effects?* Paper presented at the American Agricultural Economics Association Annual Meeting.

National Research Council (Committee on Twenty-First Century Systems Agriculture) (1989). *Toward sustainable agricultural systems in the 21st century.* Washington, D.C.: National Academies Press.

Office of Policy Development and Research. (2006). *Current housing unit damage estimates: Hurricanes Katrina, Rita, Wilma*. Washington, D.C.: US Department of Housing and Urban Development.

Pimentel, D., Williamson, S., Alexander, C., Gonzalez-Pagan, O., Kontak, C., & Mulkey, S. E. (2008). Reducing energy inputs in the US food system. *Human Ecology, 36*, 459-471.

Plume, J. (2005, November 14). Grain flow bottlenecks after Katrina and Rita. *Gulf Shipper*, 7.

Plyer, A. (2011). *Population loss and vacant housing in New Orleans neighborhoods*. New Orleans: Greater New Orleans Community Data Center. http://www.gnocdc.org/PopulationLossAndVacantHousing/index.html.

Pretty, J. (2008). Agricultural sustainability: Concepts, principles and evidence. *Philisophical Transactions of the Royal Society Biological Sciences, 363*(1491), 447-465.

Ramjan, R., & Athalye, S. (2008). Drought resilience in agriculture: The role of technological options, land use dynamics, and risk perception. *Natural Resource Modeling*, 22, 437-362.

Rao, N. H., & Rogers, P. P. (2006). Assessment of agricultural sustainability. *Current Science*, 91(4), 439-448.

Reidsma, P., & Ewert, F. (2008). Regional farm diversity can reduce vulnerability of food production to climate change. Ecology and Society, 13(1): 38. [online] URL: http://www.ecologyandsociety.org/vol13/iss1/art38/

Road Home. (2011). *Weekly situation and pipeline report - week 238*. Baton Rouge: Louisiana Office of Community Development. http://www.road2la.org/Docs/pipeline/week238pipeline.pdf.

Roberts, P. (2008). *The end of food*. Boston: Mariner Books.

Ryden, R. (2007). Smallholders, organic farmers and agricultural policy: The case of Sweden compared with Denmark and Norway, from the 1970s-2003. *Scandinavian Journal of History*, 32, 63-85.

Saifi, B., & Drake, L. (2008). A coevolutionary model for promoting agricultural sustainability. *Ecological Economics,* 65(1), 24-34.

Santelmann, M. V., White, D., Freemark, K., Nassauer, J. I., Eilers, J. M., Vache, K. B., et al. (2004). Assessing alternative futures for agriculture in Iowa, U.S.A. *Landscape Ecology,* 19(4), 357-374.

Scherr, S. J., & Mcneely, J. (Eds.). (2007). *Farming with nature: The science and practice of ecoagriculture*. Washington, DC: Island Press.

Schnepf, R., & Chite, R. M. (2005, September 12). *U.S. Agriculture after Hurricane Katrina: Status and issues* (No. RL 33075): CRS Report for Congress.

Shinozuka, M., Chang, S. E., Cheng, T. C., Feng, M., O'Rourke, T. D., Saadeghvazire, A. M., et al. (2003-2004). *Resilience of integrated power and water systems: Seismic evaluation and retrofit of lifeline systems.* http://mceer.buffalo.edu/publications/resaccom/04-SP01/06_shino.pdf.

Smit, B., Burton, I., Klein, R., & Street, R. (1999). The science of adaptation: A framework for assessment. *Mitigation and Adaptation Strategies for Global Change, 4*, 199-213.

Smit, B., & Wandel, J. (2006). Adaptation, adaptive capacity, and vulnerability. *Global Environmental Change, 16*(3), 282-292.

Smith, V. (2008). Old favorites and new initiatives: Implications of the 2008 Farm Bill for the Ninth District. *Fedgazette: Regional business and economics newspaper*. 13-15. Retrieved from http://www.minneapolisfed.org/publications_papers/fedgazette/index.cfm

Smithers, J., & Smit, B. (1997). Human adaptation to climatic variability and change. *Global Environmental Change, 7*(2), 129-146.

Steiner, R. (1993). *Agriculture*. Kimberton, PA: Bio-Dynamic Farming and Gardening Association, Inc.

Stöckle, C. O., Nelson, R. L., Higgins, S., Brunner, J., Grove, G., Boydston, R., et al. (2009). *Assessment of climate change impact on eastern Washington agriculture*. Seattle, Washington: Center for Science in the Earth System, Joint Institute for the Study of the Atmosphere and Oceans, University of Washington. http://cses.washington.edu/db/pdf/wacciach5ag648.pdf.

Sullivan, D. (2011). The aminopyralid challenge continues *Biocycle*, June, 28-30.

Sumner, D. A. (2007). *Farm subsidy tradition and modern agricultural realities*. Washington, D.C.: American Enterprise Institute.

Swanson, D., Hiley, J., Venema, H. D., & Grosshans, R. (2009). *Indicators of adaptive capacity to climate change for agriculture in the prairie region of Canada*. Winnipeg, Manitoba: International Institute for Sustainable Development.

Tompkins, E., & Adger, W. N. (2004). Does adaptive management of natural resources enhance resilience to climate change? *Ecology and Society, 9*(2), 10.

Tomson, B. (2005, September 19). Crop losses are lower than feared; Katrina damaged cotton, cane, but impact on grains and soybeans was limited. *Wall Street Journal*.

Vogel, C., Moser, S. C., Kasperson, R. E., & Dabelko, G. D. (2007). Linking vulnerability, adaptation, and resilience science to practice: Pathways, players and partnerships. *Global Environmental Change, 17*(3-4), 349-364.

Walker, B., & Salt, D. (2006). *Resilience thinking: Sustaining ecosystems and people in a changing world.* Washington, D. C.: Island Press.

Walker, T. (2005). *Missouri farm exports in danger due to Hurricane Katrina*. St. Louis, MO: Missouri State Government Reporting Program.

Wang, F., & Xu, Y. J. (2009). Hurricane Katrina-induced forest damage in relation to ecological factors at landscape scale. *Environmental Monitoring and Assessment, 156*, 491-507.

Warner, K. D. (2007). *Agroecology in action: Extending alternative agriculture through social networks*. Cambridge, MA: MIT Press.

White, R. (1980). *Land use, environment, and social change: The shaping of Island County, Washington*. Seattle, WA: University of Washington Press.

Wiggens, S. (2009, July 9). *Big farms or small farms: How to respond to the food crisis?* (e-Debate Report). London: Future Agricultures Consortium.

Wisner, B., Blaikie, P., Cannon, T., & Davis, I. (2004). *At risk: Natural hazards, people's vulnerability and disasters*. New York: Routledge.

Workman, J. G. (2009). *Heart of dryness: How the last bushmen can help us endure the coming age of permanent drought*. New York: Walker and Company.

Worster, D. (2004). *Dust Bowl: The southern plains in the 1930s*. Oxford: New York.