Agroecology: integrating a socioecological model into the mainstream agrifood system in the United States

by
Katherine Schugren-Meyer
kschugren@gmail.com

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Supervised by

Anne Jerneck
anne.jerneck@lucsus.lu.se

Cheryl Sjöström
cheryl.sjostrom@lucid.lu.se

Abstract

Agriculture in the United States can be described in terms of two competing models, one conventional and one alternative. The dominant model operates within a productivist industrial discourse. Input intensive monocultural methods have resulted in ecological and socioeconomic negative externalities. These effect not only ecosystem services and rural populations but reverberate throughout the agrifood system.

An alternative model of agricultural production, distribution and consumption systems has emerged over the past forty years as a response to the conventional model. Agroecology, the main alternative model investigated, is an emerging field of study and action. Placed within a holistic paradigm, it promotes interdisciplinary collaboration between researchers, growers, consumers and other stakeholders to work towards an agrarian sector that operates under ecological and socioeconomic principles.

This research attempts to assess the potential pathways and barriers for the development of agroecology within the conventional system in order to determine the extent to which the two competing models can coexist. The areas of possible overlap will be determined in order to contribute to a greater understanding of the evolving relationship between the two models.

An examination of reductionism and holism at a theoretical level, and a discussion of general policies, research trends and supply chain dynamics at a practical level facilitates an understanding of future trajectories in agroecological development.

The main findings show that the potential growth of agroecology is limited given paradigmatic, institutional and economic barriers. The current integration trajectory of agroecology into the conventional model is likely to result in an overlapping coexistence of the two models, aided by the development of local producer-consumer networks and the concept of ecological citizenship.

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Acronyms and abbreviations

CAFO Confined Animal Feeding Operation
CSA Community Supported Agriculture
EPA Environmental Protection Agency
GMO Genetically Modified Organism
LGU Land Grant University
NOP National Organic Program
SARE Sustainable Agriculture Research and Education Program
USDA United States Department of Agriculture

1. Introduction

There is a substantial body of literature agreeing that modern industrial agriculture is in a state of crisis with environmental, social and economic repercussions (Hanson et al. 2008, Saifi & Drake 2008, Weis 2007, Magdoff 2007, Gliessman 2007). From its initation in the U.S. in the 1930s, the industrial agricultural model has been exported throughout the developed world, and is being increasingly adopted in the developing world (Rosset & Altieri 1997). Industrial agriculture shall be defined in this paper as conventional agriculture since it is the dominant model within the U.S.

Conventional agriculture within the productivist paradigm

Agricultural development throughout the modern period of history in the U.S. has been influenced by social and political trends (Sassenrath et al. in Bohlen & House eds. 2004). It has been driven by two dominant factors[1], technology and economic growth (Thompson et al. 2007). From a productivist[2] standpoint, the development of the agricultural sector has been very successful in creating "a ready supply of cheap food that is accessible to, and affordable by, the vast majority…" (Morgan et al. 2006:2), particularly with regard to meeting the needs of an increasing population.

The productivist paradigm has shaped the shifting reality of the agrifood industry from one of connectedness to the land through farming, local markets and networks to one of increasing separation, over geographical and temporal spaces, between source and end destination (Weis 2007:14). In addition, technological and growth based development has led to a shift in human interaction with agricultural production from dealing with the farm as an integrated system to separating the system into its components and focusing on specific parts (Cochrane et al. 2007).

The rationalization of agricultural production, distribution and consumption has increasingly raised issues of environmental degradation and socioeconomic problems that have far reaching effects in relation to deteriorating rural communities and diet related health problems among consumers (Weis 2007).

Alternatives to the conventional model

In some circles there has been growing awareness of the issues related to conventional food production visible in several "response" trends of alternative agriculture (Holt-Gimenez & Patel 2009:159-164). These scientific fields, movements and hands-on experiments aim to challenge the dominant productivist paradigm in an effort to explore more sustainable methods of cultivation, distribution and consumption. The alternative models range from organic farming to local food networks to researching the interactions between species in order to use ecological processes for pest control and soil fertility in crop production. In this thesis all of the above mentioned pathways are understood to be incorporated into a wider field of study and practice known as agroecology.

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[1] Mechanization was also a necessary development since labor was a main limiting factor in production (Rosset & Altieri 1997)

[2] Defined by Lowe et al. as an "intensive, industrially driven and expansionist agriculture with state support based primarily on output and increased productivity" (1993:221). This definition refers to productivism in the post WWII period in the U.K. and it applies to the U.S. as well.

Agroecology

Agroecology, the study of agroecosystems, is an emerging field that emphasizes both ecological and socioeconomic factors in designing and maintaining sustainable food systems (Altieri 1989, Gliessman 2007:18). It addresses food production from the field level to the regional level, embracing concepts from both "hard" disciplines such as natural and economic sciences and "soft" disciplines such as cultural and social sciences (Dalgaard et al. 2003). This emphasizes the interdisciplinarity of the field of agroecology, and as well as being a field of study, agroecology is also an "action" discipline because it casts a critical eye on the conventional system and encourages the collaboration of researchers with other stakeholders to bring about change (Francis in Gliessman 2007:forward).

In relation to the agrifood system, agroecology encompasses ecological, social and economic aspects. Moreover, it views humans as existing within natural systems and working with ecosystems, rather than separate from and dominating nature (Ikard in Bohlen & House, 2009). In this regard, agroecology is understood to exist within the scientific paradigm of ecology and holism (Vanloqueren & Baret 2009), which will be defined in section 5.

The ecological agriculture productivity debate

An important argument made by proponents of the industrial model is that alternative (ie. ecological) models of agriculture do not produce as much food as the conventional model and therefore would cause global food shortages if implemented on a large scale (Paarlberg 2009). Conversely, several empirical studies show that organic and ecological cultivation methods actually do produce the equivalent to conventional methods, and models show that organic production could sustain the global population without increasing the land currently under cultivation (Badgley et al. 2007, Pretty et al. 2006, Pimental et al. 2005, Stanhill 1990). Recognizing that the sceptics of ecological based cultivation mainly operate within a strictly economic perspective, their arguments are relevant but not central to the agroecological perspective which places ecological and social wellbeing at a level of equal importance to economic gain. This study enters the debate with the assumption that agroecological practices can and do produce equivalent yields to conventional practices.

1.1 Research aim and scope

The fundamental differences between the conventional and agroecological paradigms, for instance in regards to the goal of food production systems, reveal the tensions between these competing models. Specifically, the goal of conventional production practices is to maximize yields of individual crops for maximum economic returns; while the goal of agroecology is to optimize the agroecosystem health and function as a whole, taking into account ecological and social wellbeing as well as economic benefits (Altieri 1987). This thesis attempts, in part, to discover whether the areas of potential for agroecological growth are confined to niches within the conventional system or if there is opportunity for the two models to coevolve.

Guided by the concepts reflected upon here, namely, the environmental and socioeconomic issues surrounding industrial agriculture, agroecology as an emerging alternative model and the tensions between the two, this investigation attempts to assess the potential pathways for development of agroecology within the conventional system. In so doing the extent to which the two competing models can coexist and the areas of possible overlap will be determined in order to contribute to a greater understanding of the evolving relationship between the two models.

The area of study includes the nature of agriculture policies, research and development trajectories and market channels with regard to agroecology. Specifically, federal support for sustainable agricultural practices, public and private investment and disciplinary tensions, and the phenomenon of local producer-consumer networks will be highlighted. The key opportunities as well as the major barriers to agroecological practices being adopted on a larger scale will be identified through these themes.

The scope of this study is broad but appropriate considering the aim of bringing about a discussion of agricultural and food system dynamics at the national level. The global agrifood system shall be briefly mentioned as a context in which the U.S. agricultural sector participates. However, an in depth analysis of the global food economy, for instance the issues surrounding trade regulation and food insecurity, is outside the scope of this study.

1.2 Research Questions

The following question guides the overall research aim:

To what extent is it possible to implement agroecological practices within the conventional agrifood system in the U.S.?

The following questions assist in answering the main question, and shape the results and analysis:

- What policy measures support agroecology and to what extent?
- How is agroecology prioritized in research and development?
- To what extent do local food channels support the spread of agroecology to the public?

Defining the concepts: Relating agroecology to sustainable agriculture

The wide use of sustainable agriculture as a blanket term can create confusion when investigating alternative agricultural models; however, the similarities encountered between definitions of agroecology and sustainable agriculture within the main sources selected to support this thesis were plentiful enough to warrant interchangeable useage. In other words, the basic tenants of agroecology from key authors match those of sustainable agriculture as found in policies and scientific platforms such as the Union of Concerned Scientists (UCS 2010). This led to the reference to sustainable agriculture in certain parts of the results and analysis section, and to agroecology in others according to the literature being used at a specific point in time, **but with the understanding that they are equated terms in the context of this investigation.**

The other concepts that are discussed in relation to agroecology are organic farming and local food systems. These practices also share the basic principles of agroecology and sustainable agriculture, but they are different from one another in specific function. For example, some certified organic products are shipped over long distances, and therefore are not considered to be locally sourced. Similarly, locally sourced food is not always produced according to organic standards. However, organic products are often sold or distributed locally, particularly among smaller organic farming operations. Thus, the two are considered to be overlapping concepts that fall under the umbrella term of agroecology.

2. Methodology

This study was carried out from a critical realist perspective. Positioned between positivism and constructivism, critical realism "recognizes the role of both agency and structural factors in influencing human behavior" (Clark 2008). Additionally, this study took an institutional analysis approach to comprehending political, economic and social dynamics within the agrifood system.

Unobtrusive methods of data collection, which were carried out without establishing contact to the original document authors (Bryman 2004:215), were undertaken in order to delineate the scope of this thesis. Data collection was mainly carried out through the internet and using library sources, although a few phone interviews were conducted.

This was paired with content analysis, the process of categorizing qualitative textual data into conceptual categories, to identify consistent patterns or themes (Julien, 2008). Three main themes; policy, research and development and civic participation in local food networks, were extracted from documents and literature for further in depth investigation.

Research process

The research process was iterative, following an emergent design. Emergent design refers to a flexible approach to data collection and analysis that allows for ongoing changes in the research design, research questions and goals in response to new information and insights (Morgan 2008). The investigation began with an exploratory literature review inspired by an interest in small scale agriculture models such as permaculture, which refers to ethically designed food production and land use systems mimicking ecosystem functions (Holmgren 2006 in King, 2008). The original line of questioning led to an investigation of agroecology as an emerging field. Holism and ecology are central to the agroecological concept, and so they were a natural theoretical framework for this study.

In terms of document analysis the 2008 Farm Bill provided an overview of the share of public spending that supports organic and sustainable agriculture. The Sustainable Agriculture Research and Education Program (SARE) and United States Department of Agriculture (USDA) websites provided definitions of organic and sustainable agriculture from the policy perspective. They also provided material for analyzing the institutional support available for experiments and transitioning to alternative agricultural methods.

In the research and development section some information on the structure and function of technology and knowledge transfer was extracted from the official land grant extension website. However, this section was more heavily weighted on findings from previous studies and articles, thus mainly secondary sources were used. Similarly, in the market section most of the results were gained from literature review, although some NGO and trade association websites were sourced.

Additionally, two expert interviews were carried out. The first was with a soil scientist from U.C. Davis who had led a collaborative project with farmers to experiment with organic production methods. The purpose of this interview was to gain more insight into the process of technology transfer and knowledge dissemination between and among researchers and agricultural producers. The other interview was with a researcher from the Center for Agroecology and Sustainable Food Systems at U.C. Santa Cruz. This interview helped to achieve a better understanding of the type of interdisciplinary work being done to integrate agroecology into local food systems, as well as to gain insight into the conventionalization of organic production.

During the investigation, the research design was continuously referred back to and revised, and the concepts and theories were redefined as more data was collected and analyzed. Thus, the iterative quality of the research process resulted in the data collection and analysis being simultaneously carried out from the very beginning of the investigation (Morgan 2008).

3. The context: the conventional model and its outcomes

This section examines the environmental and socioeconomic negative externalities resulting from the conventional agricultural model. Socioeconomic issues relating to both farmers and consumers will be discussed.

3.1 Environmental externalities

The industrial model of agriculture is relatively recent within the U.S.: prior to and even during WWII, the mainstream farm model was small in scale and many operations were family run (Rausser 2008). After the war, growers became increasingly dependent upon fossil fuel based synthetic inputs (Parr et al. 1983). The agricultural research and development focus shifted towards mechanization and chemical fertilizers, herbicides and pesticides (Warner 2008). As agricultural production developed along a structural trend of monoculture, it utilized factors associated with industrial design such as product specialization and minimization of labor (Hendrickson et al. 2008). While this has resulted in major yield increases during the past 60 years domestically and also in some limited successes internationally during the Green Revolution (Thompson & Scoones 2009), several ecological issues have arisen (Gliessman 2007:4).

Fossil fuel dependency

Dependency upon fossil fuels for chemical inputs as well as for operating on-farm machinary contributes to greenhouse emissions and climate change (Weis 2007:56). Transportation and distribution systems, covering long distances, further complicate the situation: the average distance fresh food travels between farm and retailer is estimated at 1500 miles (Duram & Oberholtzer 2010:102). Furthermore, reliance on a non-renewable energy source has unsustainable consequences.

Pollution

Agricultural pollution of ecosystems and nearby water sources from pesticides has negative health effects on both humans and wildlife (Pretty et al. 2001). Eutrophication from nitrogen and phosphate runoff and leakage results in the creation of algal blooms downstream such as the dead zone in the Gulf of Mexico (Gliessman 2007:12, Robertson et al. 2004).

Soil erosion

Intensive tillage practices and short rotations leave the soil uncovered at various times of the year, causing soil erosion and loss of organic matter (Gliessman 2007:3). Soil erosion is considered a major issue, to the extent that in the 1980s the USDA began a campaign to encourage conservation tillage (Uri 2001:297).

Water depletion

Irrigation is used to grow crops on land that otherwise would not receive enough water from rainfall and other natural sources. Evidence from semi-arid and arid farmland in Western states shows that groundwater extraction and water diversion from nearby lakes and streams tends to increase the soil salinity, as well as taking water from nearby ecosystems (Gliessman 2007:4).

Biological and genetic diversity loss

Monoculture has also resulted in a narrowing of the gene base of crops under production. For instance, only a handful of domesticated staple grains constitutes the majority of the crops cultivated in the U.S. and within those species only a few varieties of each are grown (Altieri 1999). The loss of genetic variation increases vulnerability to disease epidemics, as in the case of the southern corn leaf blight which caused one billion USD in damages to the national corn harvest in 1970 (Rossman 2009). Additionally, repeated use of herbicides and pesticides creates resistance among weeds and pests, requiring greater amounts of inputs and constant research for technology innovations to keep ahead of the "super pest" cycle (Weis 2007:57, Magdoff 2007).

CAFOs

Weis refers to the grain-livestock complex (2007:16) to conceptualize the industrialization of livestock farming within confined lots (Confined Animal Feeding Operations, CAFOs) and the increase of corn and soy bean production needed to provide feed to the "factory" farmed animals (ibid:59-62). The increase in demand for cheap meat and diets rich in animal products both domestically and internationally has taken a toll on the treatment of animals in CAFOs. The health effects on humans consuming antibiotic and hormone enriched meat and dairy and the environmental effects of factory farms, including huge amounts of waste generated from feeding lots, are also cause for concern (Gliessman 2007:7).

In sum, the industrial agricultural model disrupts the balance of ecosystems and has far reaching effects on the natural resources that support agriculture, as well as on human health.

3.2 Socioeconomic issues

This section will be divided into two parts: issues affecting farmers and issues affecting consumers.

The technological and production treadmill

The "treadmill of production" refers to farmers' perpetual dependence on subsidies to counter balance low prices encouraged by agribusiness lobbying (Duram 2005:13). The "technological treadmill" refers to the farmers' perpetual dependence upon fertilizers and pesticides to bolster crop production in otherwise nutrient depleted soils (Weis 2007:56). Under these complementary processes there is a consolidation of farmland as farmers are forced to "get big or get out" (Hanson et al. 2008), and producers must adopt new labor saving technology and "economies of scale" in a never ending cycle (Morgan et al. 2006:54).

The technological and production treadmills have led to a growth in the average farm size over the past 50 years, as farmers are obliged to increase the area under production to stay competitive on the market (Cochrane 1993:159). Family farms are disappearing and rural communities are shrinking as more growers either supplement their income with off farm employment or opt out of agriculture altogether. Indeed, the change in the socioeconomic composition of farming communities is quite evident: the population living on farms has decreased from 40% in 1900 to less than 2% in 1990 (Archer et al. 2008). This also suggests a widening gap between the process of food production and the general population.

Subsidies and loss of control over production

Since the mid 1990s U.S. agricultural policy has taken a "hands off" approach to market supply while providing farmers increased subsidies to counterbalance falling prices (Ray et al. 2003, Pretty et al. 2001). Essentially, neoliberal trade policies are enforced through the WTO at the international level while protectionism is practiced at the domestic level (Holt-Gimenez & Patel 2008:53-54). This has proved detrimental not only to domestic farmers by creating a dependency on subsidies but world wide as well. Excess crops produced within the U.S. have been "dumped" on the international market, resulting in widespread destruction of livelihoods, migration and hunger in developing countries (Ray et al. 2003:3 , c.f. Weis 2007, Holt-Gimenez & Patel 2008, Hendrickson et al. 2008, Friedmann & McNair 2008).

The subsidization of few staple crops and the unloading of surplus on the international market puts developing country farmers in a difficult situation but also results in a loss of control over production among domestic growers. Indeed, farmers are compelled to produce crops they can receive subsidies for, which are mainly corn and soy fed into the aforementioned livestock-grain complex, and wheat, rice and cotton (Ray et al. 2003:10). Those that live in areas with the appropriate biological and soil conditions to grow specialty crops such as fruits and vegetables may have more diversified operations, but even specialty farmers tend to follow the conventional monocrop model and take advantage of economies of scale (Guthman 2004).

Oligopsony and the hourglass model

The loss of production control experienced by farmers is further complicated by two issues: having to sell to a few powerful buyers at low prices, and the erosion of farmer's knowledge of cultivation and problem solving (Weis 2007, Mascarenhas & Busch 2006). The structure of the agricultural supply chain resembles an hourglass, as seen in Fig.1. At one end of the hourglass there are many producers and at the other end there are many consumers, and the middle is squeezed by a few consolidated corporations that control the steps in between (Weis 2007:13). This is known as **oligopsony**, when many producers sell to a few buyers (Thompson et al. 2007:9) In simple terms, producers must sell to a handful of buyers that control processing, packaging and distribution. These firms then sell to a few major retailers, at which point the product reaches the end consumer destination (Morgan et al. 2006:55). This results in an uneven distribution of each food dollar throughout the supply chain, with a much larger share going to the middlemen than to the farmers (Gliessman 2007:15).

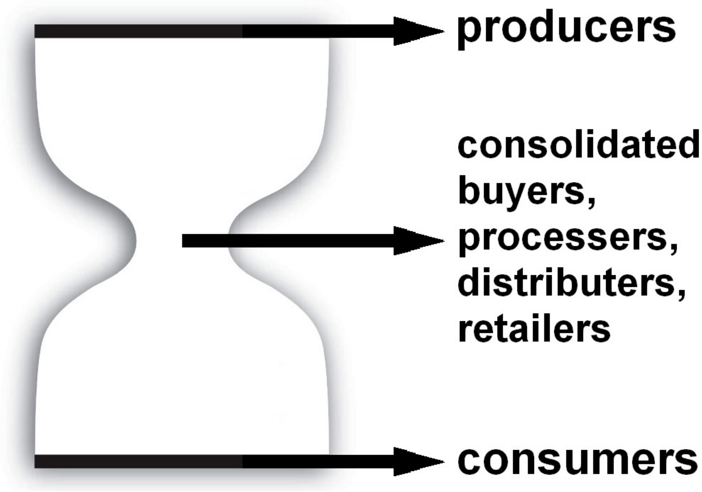

Figure 1. Hourglass model

The link between the consolidation of the food supply chain and agricultural policies bolstering crop subsidization is apparent in the indirect beneficiaries: the multi-national agribusinesses. "Upstream" corporations that produce inputs and seeds cooperate with "downstream" buyers, processors and distributors (Morgan et al. 2006:55-58) in an economic phenomenon known as **vertical integration**. For instance, the Cargill and Monsanto corporations have formed a strategic alliance, in which Monsanto supplies seeds and chemical inputs to producers, and Cargill covers the grain collection, processing, packing and distribution to retailers (Hendrickson & Heffernan 2002:351, see Fig. 2). Other alliances have also been identified such as Conagra and Novartis/ADM (Lyson & Raymer 2000). Therefore, through farm subsidies, market prices of crops are kept low and agribusiness profits are increased while the farmers lose control over who they sell to (Burmeister 2008).

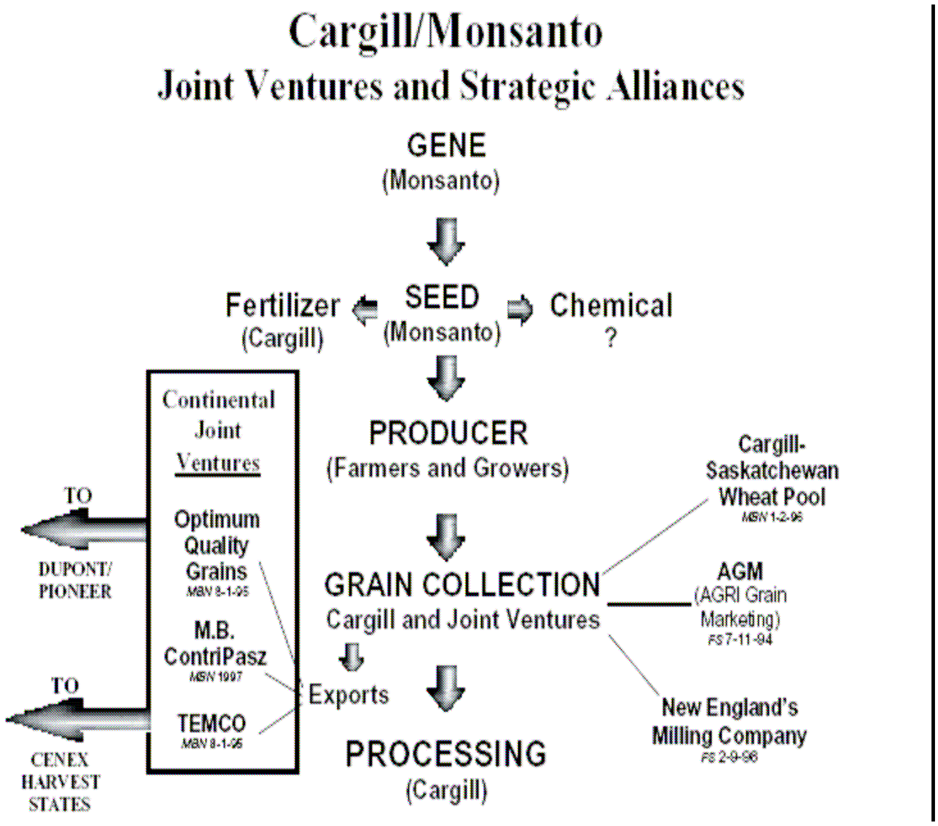

Figure 2. Vertical Integration. (Adapted from Hendrickson & Heffernan 2002:351)

This diagram illustrates the concept of vertical integration, where one corporation (Cargill in this case) owns smaller firms at each step in the supply chain, thus gaining power over the entire process from seeds to retailers (Gliessman 2007:329).

Knowledge loss

Another socioeconomic effect of the current agrifood system, loss of knowledge, stems from the specialization of production and the dependence upon external inputs for maintaining high yields (Hanson et al. 2008). Farmers rely on fertilizers and pesticides for solving production problems in a "silver bullet" techological approach. As they become dependent upon the technological treadmill, they are less able to rely upon traditional or "common sense" methods to address pest and weed issues (Weis 2007:30), thus knowledge of these practices becomes eroded. The classic example of loss of knowledge and production control lies in intellectual property rights of companies that make it illegal to save seeds from previous harvests, which has been an essential farming practice for centuries (Mascarenhas & Busch 2006). Intellectual property rights will be further discussed in section 6.2.

3.3 Consumer outcomes

This section will discuss two key issues related to the agrifood system as it relates to consumers within the U.S., namely, health and food safety.

Obesity epidemic

The consolidation of the food supply chain in an hourglass shape has negative effects on consumers as well as producers. Mirroring the producer end of the hourglass is the retail and consumer end, resulting in a similar loss of purchasing control by consumers. There is an increase in power of food and beverage corporations called **monopsony** that control the retail sales of more than half the food products sold in the U.S. (Lyson & Raymer 2000). By centering the supply chain around economies of scale and using artificial ingredients and preservatives, these corporations are able to produce food of lower nutritional quality and higher sugar, salt and fat content (Morgan et al. 2006:168-171) which results in consumer diet related health issues.

There is growing awareness of the connections between diet and health problems among US citizens, visible in trends such as the obesity epidemic and other diet related diseases (Holt-Gimenez & Patel 2009). There has been a dramatic increase of obesity among the U.S. population from 15% of adults in the 1970s to 33% in 2006, as well as an increase of diet related diseases due to increased consumption of processed food, visible in studies linking cardiovascular disease risk to trans fatty acids (Malla et al. 2005) and linking sugar-sweetened beverages to type 2 diabetes and obesity risks (Hu & Malik 2010). Thus, the consolidated supply chain and economies of scale keep retail food prices low so that food and beverage corporations profit at the expense of consumer nutrition and safety.

Food safety scares

Additionally, as food travels longer geographical and temporal distances between farm and plate, the long supply chain creates a gulf between producers and consumers. The separation from food source and food consumption results in a lack of transparency of origin and content in products sold on the market (Lockie 2009). Additionally, the idea of personal accountability toward delivering a healthy and nutritious food product to the end consumer is lost along the journey between producer and retailer. This has come to the surface with the issue of food safety as a number of food safety scares have occurred over the past decade (Follet 2009). Food safety regulations can only go so far as to hold accountable manufacturing and processing facilities such as meat packing plants, and the greater the operation the greater the risk for pathogens contaminating products (Morgan et al. 2006:46).

When consumers do not have complete information, they cannot make informed decisions about where they direct their purchasing power. Indeed, "[a] food system dominated by a small handful of large corporations and governed by a small set of like-minded individuals offers consumers little real 'choice'" (Lyson & Raymer 2000:206).

The obesity epidemic and food safety scares present a powerful case for transparency and accountability among the food supply chain. Moreover, they encourage ways for producers and consumers to engage with one another directly so as to avoid the "waist" of the hourglass, which will be further discussed in section 6.3.

4. Agroecology as an alternative model

This section will provide an overview of the concept of agroecology, including a timeline of its development as a scientific field and a discussion of where it fits into the disciplinary realm.

4.1 Definitions

Recognized within the academic sphere and growing within the scientific community, agroecology has been defined as “a scientific approach used to study, diagnose and propose alternative low-input management of agroecosystems…[it] defines, classifies and studies agricultural systems from an ecological and socio-economic perspective” (Altieri 1989). Yet another definition is “the application of ecological concepts and principles to the design and management of sustainable food systems” (Gliessman 2007:18). Agroecological systems may refer to several levels of agricultural production, from the field level to the entire farm to the larger region.

The agroecological concept encompasses not only food and fiber production but it also extends to the greater food system, including in its reach supply chain dynamics and socieconomic aspects of the agrifood system such as rural quality of life and community networks (Francis et al. 2003: 101). In this respect, agroecology is also defined as “the ecology of food systems” (ibid: 100). The different conceptualizations of agroecology can be visualized in Fig. 3.

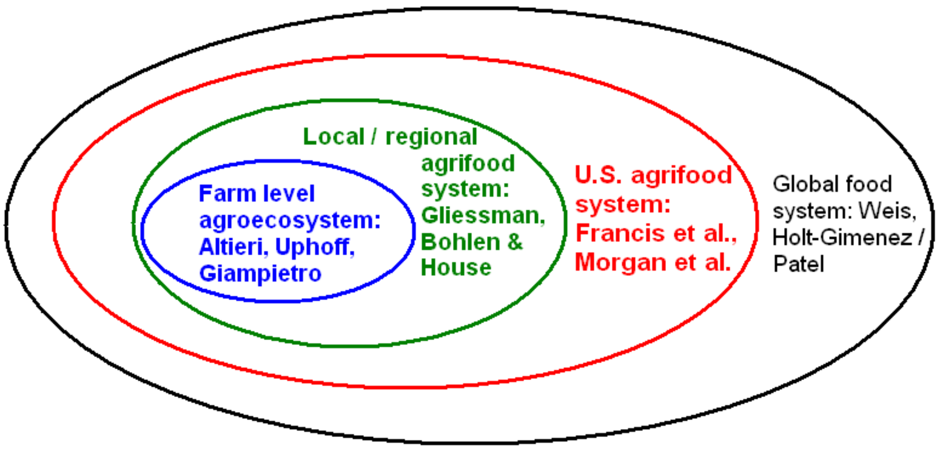

Figure 3. Conceptualization “areas” of agroecology and the agrifood system

4.2 History and development of agroecology

The concept of agroecology dates back to the 1920s with the development of crop ecology and the actual term was coined in the 1930s (Dalgaard et al. 2003). Up to and during WWII agroecological concepts were widely promoted and implemented, particularly to increase yields for the war effort, as can be seen in farm bulletins from the war years (Farmers’ bulletin 1942). As agronomy became more of a problem based discipline focusing on technological innovations with the development of chemical inputs, ecology diverged from agronomy (Gliessman 2007:18).

During the 1960s, the environmental impacts of heavy agricultural chemical inputs on ecosystems were exposed through works such as Rachel Carson's *Silent Spring* (Dalgaard et al. 2003). This led to a revitalization of the idea of agroecology, and in the 1970s the environmental movement fueled research efforts for chemical free food production. During this time organic farming increased in popularity and ecologists and agronomists began to recognize the importance of viewing ecology and agronomy in a united manner. Thus agroecology re-emerged, albeit slowly (Dalgaard et al. 2003) in the scientific community, bolstered by the development of system-level approaches to ecology and the birth of the sustainable agriculture concept (Gliessman 2007:19).

4.3 Functional and participatory aspects

Agroecology places agriculture within nature and places humans within natural systems, rather than separating humans from nature to control it with artificial inputs and technology (Ikard in Bohlen & House eds., 2009). Specifically, cultivators should work with nature and even imitate ecosystem functions instead of working against nature and attempting to control it. Some concrete examples of agroecological techniques and practices include intercropping, crop rotation, integrated pest management (IPM), increasing landscape diversity (hedgerows, ponds, woodlands), increasing biodiversity, high functioning homegardens, etc. (Altieri 1999).

Dependent on cultivation for survival, societies have long manipulated natural systems for food and fiber production (Jackson 2002). Acknowledging this dependency, agroecology promotes the engagement of natural systems in such a way that ecosystem health and function is enhanced rather than degraded (Edwards et al. 1993). To this end, "human" tools of knowledge, skills, management and labor are emphasized rather than the use of artificial inputs that characterize industrial agriculture (Uphoff 2002:10). Additionally, agroecology proponents recognize that ecologically sustainable growing practices must also be economically viable for farmers and socially sustainable for rural communities (Bohlen & House 2009:3).

Essentially, agroecology promotes and transfers a knowedge base and skill set, including observation and experimentation (Uphoff 2002:10). This takes time and effort, and generally does not achieve as immediate results as a conventional "instant fix" package. The success of an agroecosystem comes from multiple years of experimentation, observation, studying and learning, and there is risk involved (Edwards et al. 1993). Community networks and knowledge sharing among farmers and researchers have proven effective in assisting individuals to implement agroecological practices, both in developing and developed contexts (Warner 2008).

4.4 Disciplinary aspects

It has been acknowledged that in conventional agriculture, the dominant discourse has been to isolate components of agricultural systems in order to develop input technologies and improve yields (Dalgaard et al. 2003; Magdoff 2007; Warner 2008). However, proponents and practioners of agroecology view the components as interconnected parts embedded in a complex ecosystem (Thompson & Scoones 2009). This system based approach leads to addressing long term issues of ecosystem health, and development of techniques which promote long term solutions to maintaining cultivation (Gliessman 2007:31).

Agroecology is fundamentally an interdisciplinary field (Francis et al. 2003). Dalgaard et al. (2003) propose the concepts of “hard” and “soft” agroecology which compliment one another. Hard agroecology refers to the natural and economic sciences, in which the researcher observes “measureable” data from outside the ecosystem in an empirical manner, whereas soft agroecology includes cultural, social and knowledge based dynamics of human systems as they interact with the ecosystem. In soft agroecology, the researcher is not separate from the data observed while studying agricultural systems, but he or she is also interacting with and becoming part of the systems under observation (Dalgaard et al. 2003).

Thus, in order to be studied agroecology requires a holistic framework that includes both hard and soft disciplines (Robertson et al. 2004). Indeed, “…ecological and social scientists have long recognized…that agroecosystems cannot be understood or managed ecologically without including perspectives from both the ecological and social sciences” (Rickerl and Francis 2004b, in Bohlen & House eds., 2009:4).

This leads us to identifying agroecology as embedded in the ecological paradigm, and to a discussion of ecology and holism at a theoretical level.

5. Theoretical considerations: holism and ecology

Stemming from ecology and agronomy (Dalgaard et al. 2003) agroecology as the study and application of ecological science to sustainable agroecosystems (Vanloqueren & Baret, 2009) incorporates a holistic world view. To understand holism, it is useful to first identify reductionism, its oppositional paradigm (Bergandi & Blandin 1998), particularly since reductionism reflects the scientific world view that has influenced the development of modern agriculture.

5.1 Epistemological debate: holism vs reductionism

Reductionism is an ontology and epistemology that has dominated the western scientific knowledge base since the time of the Scientific Enlightenment (Dalgaard et al. 2003). Reductionism has alternatively been referred to as mechanistic, atomistic, or “hard” science, particularly with regard to the method of isolating and focusing on one component of a system at a time (Francis 2009). Indeed, as Cochrane et al. highlight:

> “The conventional Newtonian approach to science is powerful in terms of its ability to break the whole into its parts and to interpret the operations of the parts. The underlying assumption is that an understanding of the parts makes it a simple matter to build a picture of the whole.” (2007:352-353).

The reductionist paradigm applies to traditional agricultural sciences. An example of the difficulties facing scientists can be seen in the pesticide-super pest cycle. By viewing the issue as a simple pest and crop relationship, constant technological innovations are needed to stay ahead of pests that quickly adapt to pesticides. In comparison, a holistic way to address the issue would take into account systemic factors such as the loss of biodiversity and natural predators as the underlying cause.

A shift has occurred over the past thirty years as concepts of more complex systems have developed into a new "complexity science" paradigm (Naveh 2000:8). As opposed to reductionism, holism is based on the concept that the system is only as functional as the sum of its parts. Holism has been applied mainly to ecology, dating back to Odum's definition of an ecosystem as the basic unit of ecology in the 1950s (Odum 1997).

More recently it has also been extended to agroecological applications through the concept that agricultural systems must be approached in a holistic manner with the goal of maintaining or improving the entire structure, rather than simply addressing isolated elements (Vanloqueren & Baret, 2009). In other words, the adoption of a holistic paradigm within agricultural research is to examine "higher levels of organization" (Weiner 2003:373), that is, the agroecosystem as a whole, as well as its individual components.

The scale of holism does not stop at the agroecosystem level, however, as it has been applied to socioeconomic systems as well, in this case pertaining to the concept of the greater agrifood system (Francis et al. 2003). Framing the issues related to agricultural production, distribution and consumption discussed in section 3 in a reductionist manner points to fragmented approaches to solving the issues, as illustrated by the technology treadmill, subsidization policies and the rationalization of food supply chains. Viewing these issues as interconnected links in a greater system reveals the need for complex and multilevel solutions. Therefore, holism is advantageous in comprehending the sustainability challenges of the U.S. agrifood sectors.

The emergence of the holistic paradigm has not been uniformly accepted among the scientific community, particularly among disciplinary scientists who feel it calls into question the basic principles by which they view scientific methods and reality (Phelan in Bohlen & House eds. 2009:123). As discussed in section 1.1, the basic goals of reductionist agricultural science, to maximize yields, and holistic agroecology, to maximize ecosystem funcionality, are understood differently on a deeper level (Altieri 1987). Tensions between agricultural scientists and agroecologists are visible in the questions that are asked as well as how to understand and interpret issues related to production.

Giampietro conceptualizes this dichotomy in a proposal for a new perception of the role of scientists in examining and solving agroecosystem sustainability issues. He postulates that reductionist analytical methods and tools, including the overall goal of disciplinary agricultural science to find optimal production solutions, must be reconsidered to fit into an interdisciplinary goal that takes multiple stakeholders and ecological wellbeing as well as yields into consideration (2004:18).

However, it is crucial to point out that the question is not one of completely rejecting reductionist science and techniques for holistic ones, but rather to incorporate both epistomologies in addressing agroecosystem and agrifood system complexities (Watson et al. 2008). Both reductionism and holism can be seen as being useful and necessary. For instance, studying components of an agroecosystem such as soil organic matter or the relationship between two insect species may be just as important as conceptualizing the entire agroecosystem in terms of energy, nutrient and material flow, or the interaction of an agroecosystem with the regional socioeconomic system.

6. Analysis and results

The results and analysis sections are split into three sections which correspond to the three sub research questions. They are split into

- **policy**, which examines the overall importance afforded agroecology (in the form of organic and sustainable agriculture) within the legal context of the federal government;
- **research and development**, which addresses both field level technological advancements and the spread of knowledge and innovations through the extension system; and
- **food flow dynamics**, including local food networks and ecological citizenship, which are investigated as alternative channels through which agroecology is gaining a foothold.

The first two sections, policy and research and development, represent the established institutional framework under which agroeocology has some potential but also barriers for expansion. The third section, food systems, represents a more flexible framework through which agroecology has the most potential for adoption at a wider scale.

6.1 Policy

Agriculture is one of the most regulated and subsidized sectors in the U.S. economy (Gardner 1995:4). Agricultural production does not respond to pressures of supply and demand as in other industrial sectors (Ray et al. 2003), which has resulted in production control measures and surplus disposal tactics imposed by the federal government. Given the high level of influence of policy in the agricultural sector, it is useful to explore the intersection between policy and agroecology in order to determine the presence of institutional support for alternative projects.

Agroecology is not mentioned explicitly in USDA policies, but rather it is implied within two main concepts: sustainable agriculture and organic farming. Organic farming has a concrete definition, and a legal set of standards under the USDA that must be complied with in order to be labeled for commercial use. Sustainable agriculture, however, appears in a more vague form with several definitions offered but seemingly open to interpretation. This section will investigate the latest Farm Bill, the policy alloting the public funding for the majority of agricultural related programs, and the National Organic Program (NOP) and the Sustainable Agriculture Research and Education Program (SARE), which are the two main programs dealing with agroecological concepts within the governmental framework.

Organic farming

The basic concept of organic cultivation falls within the greater agroecological concept, as it shares basic principles of employing ecological principles in a holistic way within agroecosystems and rejects the use of pesticide, herbicide and synthetic fertilizers (Holt-Gimenez & Patel 2009:102). With this in mind, the USDA defines organic production as “a system that is managed…to respond to site-specific conditions by integrating cultural, biological, and mechanical practices that foster cycling of resources, promote ecological balance, and conserve biodiversity....” (USDA Agricultural Marketing Service 2010). This definition is provided by the National Organic Program (NOP) which develops and implements the organic standards for production, handling and labeling (ibid).

Although the organic movement began as a grassroots action in the 1960s and 70s (Boström & Klintman 2006), national organic standards were not set until 2002 (Duram 2005:31). Part of the delay in creating a set of national organic standards lay in the challenge the organic movement presented to the hegemony of conventional agriculture. The very existence of organic production methods criticizes the scientific and governmental institutions that claim conventional methods are safe for human health and the environment (Allen & Kovach 2000).

A close examination reveals that the USDA attempts to please conventional stakeholders in the agriculture sector by granting the organic movement official status but simultaneously refraining from lending it any political support. It is stated on the USDA website that "USDA makes no claims that organically produced food is safer or more nutritious than conventionally produced food. Organic food differs from conventionally produced food in the way it is grown, handled, and processed" (2010).

This shows the neutrality of the Department of Agriculture towards the organic-conventional debate: although organic is implied to be more environmentally friendly in its methods of production, it is not specifically stated. Furthermore, the health benefits of purchasing organic products are carefully sidelined (Duram 2007:31). Thus, the pressure placed upon the USDA by other, more powerful agricultural interest groups such as agribusiness and trade organizations is also reflected (Boström & Klintman 2006).

Another indication of the USDA's perspective on organic farming as strictly a "market label based on consumer preference" (Constance 2008:153) rather than an ecologically beneficial process that might have merits as an alternative agricultural model, are in the wording of the standards themselves. The NOP standards for certification of crops require that:

- Land must have no prohibited substances applied to it for at least 3 years before the harvest of an organic crop.
- Soil fertility and crop nutrients will be managed through tillage and cultivation practices, crop rotations, and cover crops, supplemented with animal and crop waste materials and *allowed synthetic materials.*
- Crop pests, weeds, and diseases will be controlled primarily through management practices including physical, mechanical, and biological controls. *When these practices are not sufficient, a biological, botanical, or synthetic substance approved for use on the National List may be used.*
- Preference will be given to the use of organic seeds and other planting stock, *but a farmer may use non-organic seeds and planting stock under specified conditions*.
- The use of genetic engineering (included in excluded methods), ionizing radiation and sewage sludge is prohibited.

(National Organic Standards 2008, emphasis added)

Here is is clear that the National Organic Program leaves room for interpretation of the standards. By allowing certain synthetic materials, non-organic seeds "under specified conditions" and biological herbicides and pesticides when organic management practices are "not sufficient", the standards board is opening the door to producers who may be less than 100% dedicated to the organic principles, or willing to take an easier or quicker route to gaining access to the organic premium.

Indeed, there is much debate among organic farmers, activists and consumers whether or not the USDA's NOP has stringent enough standards (Duram 2007:30, Boström & Klintman

2006, Allen & Kovach 2000). For instance, during the first drafts of the standards there was a struggle among the established organic community to exclude the "big three", namely, GMOs, sludge and irradation (Constance 2008:153). Moreover, there is concern among small, diversified and ethically commited producers that the centralized federal standards allow for the "conventionalization" of organic practices, that is, large scale operations converting portions of their fields and meeting the minimum certification requirements for the organic price premium (Guthman 2004, Buck et al 1997, Best 2007, Guptill 2009). The conventionalization debate will be discussed further in section 6.3.

Sustainable agriculture and SARE

Shifting the discussion from clearly framed, standardized organic production system to the more openly defined, "soft" concept of sustainable agriculture, we find that the USDA offers the following definition for sustainable agriculture:

> "… an integrated system of plant and animal production practices having a **site-specific application** that will, over the long-term—(A) satisfy human food and fiber needs; (B) enhance environmental quality…; (C) make the most efficient use of nonrenewable resources…; (D) sustain the economic viability of farm operations; and (E) enhance the quality of life for farmers and society as a whole" (Sustainable Agriculture, USDA 2010).

The phrase "site specific application" is key to this definition. It is evident by the lack of easily transferable technology available for sustainable agricultural practices that the USDA acknowledges the challenge of achieving a sustainable farming system within the current monocultural structure. Growers that are dependent upon reductionist based technology transfer and "silver bullet" solutions are losing their ability to experiment and exercise their own problem solving skills (Weis 2007:30). In many cases, they must relearn how to make informed decisions and manage their own systems; practices that are all central to maintaining agroecological based systems (Uphoff 2002:244, Altieri & Rosset 1996).

The SARE program provides support through awarding competitive grants to farmers who are interested in alternatives to the mainstream. It specifically avoids stating a definition of the "fuzzy" concept (Duram 2007:35) of sustainable agriculture on its website. Instead, it provides examples of sustainable farming systems from personal stories and case studies.

The informational brochure stresses that there is no one set of methods or practices that can be applied in every situation, but rather, that "there are thousands of ways to farm more sustainably" (SARE brochure 2010). This climate of transparency and sharing of success stories reflects a participatory process rather than farmers simply acting as passive recipients of the newest technologies. Building a network of site specific innovations is important for the transfer of knowledge and highlights the system thinking and observation that are integral to agroecology.

While the lack of a concrete definition or set of methods may prove the transfer of sustainable agriculture knowledge and skills difficult in a system that traditionally transfers problem based input solutions, it is also crucial that the definition remain vague so as not to become associated with a "silver bullet" approach. In other words, the "site-specific application" of long term, knowledge based integrated system practices presented in the USDA definition of sustainable agriculture might be challenging to the average farmer but it will prove necessary if any large scale transition to agroecological practices is to ensue (Altieri & Rosset 1996).

Moreover, the SARE program and institutions such as the Alternative Farming Systems Information Center (AFSIC), which provides library services focusing on "topics related to sustainable and alternative agricultural systems, crops and livestock" (About AFISC 2010). demonstrate that there are resources and educational support available to growers to help them to navigate the system based approach of sustainable agriculture.

These programs and institutions, along with the national organic standards, clearly illustrate the presence of alternative agriculture within the national government and policies, although how much influence they possess in comparison to conventional support programs is subject to debate, which will be addressed in the next section.

The 2008 Farm Bill

The USDA Farm Bills are comprehensive policies containing various laws pertaining to different aspects of agriculture. They serve as a guide to federal agricultural and food policies during their legal period and include trade, marketing, food assistance programs and development policies, as well as the budget for funding programs and offices. They are grouped together to enable easier passage of legislation, especially since some of the laws included may serve conflicting interests (CRS Report for Congress 2008). Farm bills are modified and renewed about every five years, the most recent having been adopted in June 2008.

Traditionally, the farm bill has served the interests of commodity lobbyists such as the National Corn Growers Association and the American Soybean Association and protected conventional food production (Lehrer 2009). This is evident in the distribution of estimated spending among the main areas of the agricultural sector[3] (Figs. 4 and 5). The portion of the 2002 Farm Bill budget allocated towards commodity subsidies was 38.4%, with 33.4% going to crop insurance and 26.6% for conservation programs (ERS 2010), seen in Fig. 4.

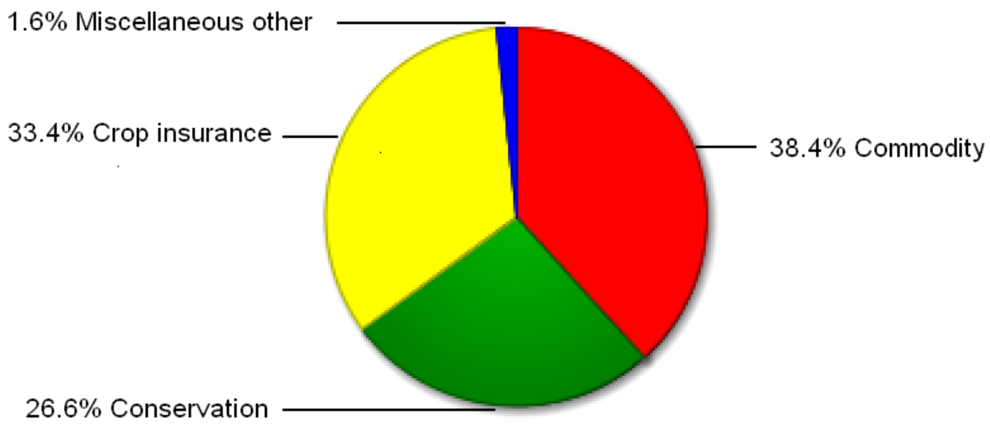

Figure 4. Estimated budget expenditure, 2002 Farm Bill. (Source: ERS 2010)

[3] More than half the total Farm Bill budget is alloted for nutrition programs such as school lunches

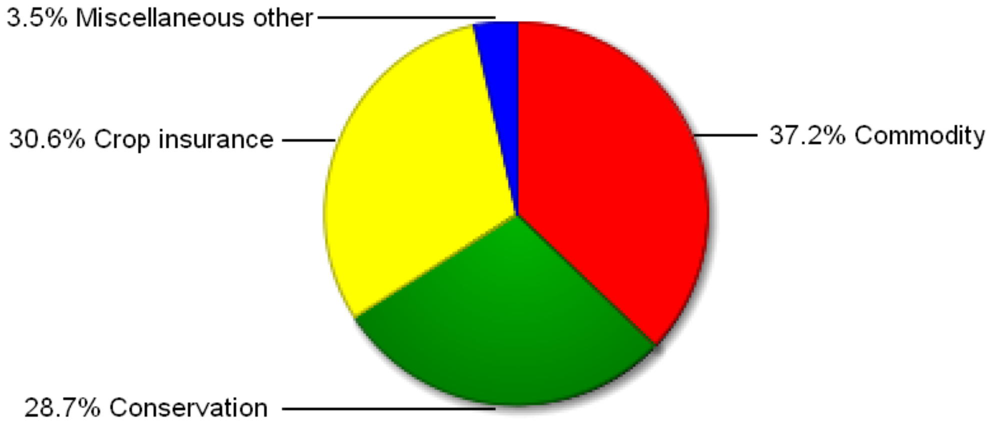

Figure 5. Estimated budget expenditure, 2008 Farm Bill. (Source: ERS 2010)

When compared the 2008 Farm Bill (Fig. 5), some slight changes from 2002 to 2008 are apparent: commodity programs are reduced from 38.4% to 37.2%; crop insurance is reduced from 33.4% to 30.6%; and conservation program budget share is increased from 26.6% to 28.7%. Organic agriculture is lumped together with agricultural trade programs, new horticulture spending and supplemental disaster assistance in "miscellaneous other" at 3.5% of the total spending share, increased from 1.6% in 2002 (Briefing Room, ERS/USDA 2010).

The relatively minute share of USDA spending for organic farming attests to the majority of funding given to conventional farmers. However, the very slight increase between 2002 and 2008 in the overall share of budget going towards the miscellaneous section containing organic funding indicates a step in the right direction.

The actual organic funding programs covered by the Farm Bill include research and analysis of organic market trends, increased spending for the USDA's national organic certification program and a small cost share program to assist farmers in achieving organic certification (USDA Farm Bill 2008). Additionally, the conservation share of funding contributes to indirectly to sustainable agriculture practices through soil, water and other land conservation programs that improve ecosystem health (ibid).

In terms of actual numbers, funding for research in organic agriculture has been increased from $15 million USD in the 2002 Farm Bill to $78 million in 2008 (Fig. 6). The areas specified for research include developing improved seed varieties and desirable traits through "classical and marker-assisted" breeding (presumably as opposed to biotechnology or gene technology breeding) and through field trials; identification of marketing and policy constraints on expansion of organic agriculture, segregation of organic sector data in agricultural production and marketing; production and socioeconomic conditions on organic farms; environmental and conservation outcomes of organic practices; and facilitating access to research conducted outside the U.S.

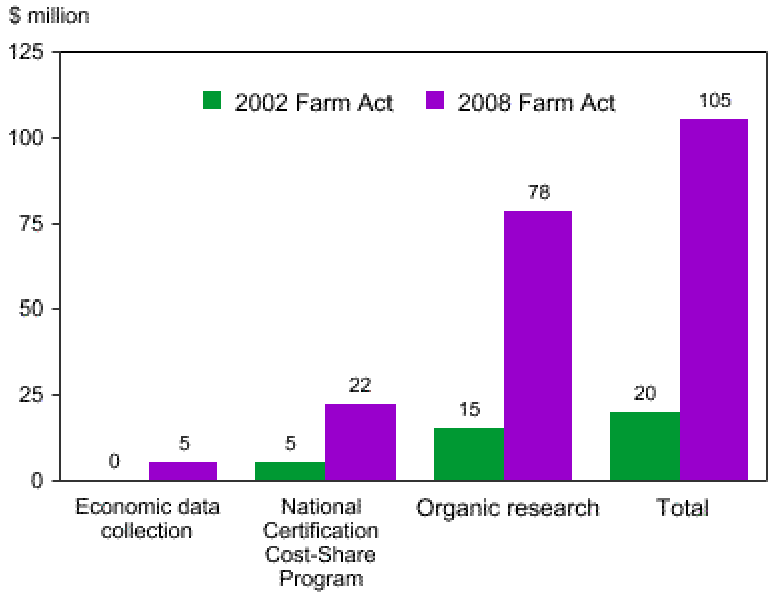

Figure 6. Changes in organic spending in the Farm Bill from 2002 to 2006. (Source: ERS 2010).

Analysis demonstrates the presence of some federal policy and program support for organic, conservation and small farms in the 2008 Farm Bill. In some research objectives of USDA projects (particularly in SARE), "sustainable" agriculture and systems thinking are encouraged. Four main themes emerge from the funded research areas for organic agriculture: improving seed and crop varieties, close scrutinization of economic trends including desegregation of organic market data from conventional market data, socioeconomic conditions of organic agriculture and environmental outcomes of organic practices.

These increased research funding areas imply the following for agroecology. They suggest that organic agriculture is growing in economic importance enough to warrant a dramatic increase in research funding from 2002 to 2008. Moreover, the fact that the research funding objectives include environmental and socioeconomic aspects of organic practices illustrates that the policymakers acknowledge the ecological and social value of alternative agriculture, as well as simply taking the economic value as a starting point for research.

The EPA-USDA dynamic

The collaboration between the USDA and the EPA dates back to the 1985 Farm Bill, in which a program was introduced with the goal of addressing issues related to non point source water pollution by encouraging ecologically sound agriculture practices (Constance 2008:152).

This collaboration is still apparent in the common goals of environmental and agricultural health shared by the two government bodies. For instance, the conservation funding in the 2008 Farm Bill provides for practices such as wetlands creation or wildlife habitat maintenance. Additionally, the EPA outlines a national agricultural strategy for achieving the agency's goals of protecting the food, air, water and land of the U.S. This strategy seeks to work together with other government branches to address non point source pollution and other environmental concerns (EPA Agricultural Strategy 2006).

However, the concerns of the EPA stated in the agricultural strategy are limited to water and air quality and to prevent or reduce the use of toxic pesticides (ibid). There is no provision for the EPA's goals relating to ecosystem health, habitat restoration or soil erosion reduction within its agricultural strategy.

This demonstrates that the EPA does not consider the connection of ecosystem health to agricultural practices as a starting point for finding solutions. Therefore, the failure of government bodies to conceptualize environmental, agricultural and socioeconomic realities as integrated systems constitutes a barrier to pursuing the holistic vision of agroecology at an institutional level.

6.2 Research and development

This section will investigate the potential for agroecology in the research and development of cultivation technologies and practices, as well as the priority given to agroecology in disciplinary science. It will also address how newly developed technology and knowledge is transferred to farming communities for adoption.

Research and technology transfer within the agricultural sector, whether conducted for public knowledge or for the commercial market, plays an integral role in the constantly evolving cultivation practices of modern food production (Vanloqueren & Baret 2009). The enormous increase in agricultural productivity during the past sixty years discussed in section 3.1 is due in large part to focused efforts to develop high yielding varieties and the technological inputs to support them (Thompson & Scoones 2009).

The drivers of agricultural research and development are more than just increasing agricultural efficiency or knowledge for its own sake. As the population increases, more inputs are needed to maintain yield levels (Rosset & Altieri 1997:285), pollution spreads and new plant and animal diseases occur, the U.S. invests more than four billion dollars a year in research and development to maintain average food consumption levels over time (Cochrane 1993:248). Agricultural research scientists are under constant pressure to respond to socioeconomic and ecological issues by producing technological solutions, reinforcing the "technological treadmill" (Weis 2007:56, Duram 2005:13).

If agroecology is to be considered an option for adoption on a larger scale, it must be given some priority within research and development in order to keep pace with, and even compete with, conventional innovation trajectories (Gliessman 2007). Moreover, technology and knowledge transfer systems must also promote agroecology so that farmers are made aware of agroecological practices and given access to alternative knowledge and technologies. Therefore, it is fruitful to examine current research and development funding mechanisms and technology transfer systems that operate within the conventional model in order to determine whether there is potential for agroecology to be carried via existing pathways to a wider grower audience, and if not, what alternatives may be utilized.

Technology transfer: the land grant university and extension model

To fully understand the public and private funding mechanisms for agricultural research and development, it is important to examine the land grant university and extension system.

The land grant system was established during the 19^{th} century with the mission of providing resources and education for agricultural communities (Franz & Townson 2008). Agricultural colleges, identified as land grant universities (LGU), were established within universities that received federal funding for developing technologies and practical knowledge to increase agricultural productivity.

Agricultural knowledge developed in land grant universities would then be disseminated to rural communities through the cooperative extension system (Trauger et al. 2010). The idea behind the establishment of the extension system was to place a university educator in each agricultural community to engage members directly and serve as a line of communication between the research being done and the intended recipients of new technologies and information (Franz & Townson 2008).

Today the extension system is a "nationwide, non-credit educational network" where each state has a central office at its land-grant university supplemented with regional and local offices staffed by experts (NIFA 2010). Along with the extension departments of the agricultural colleges are experimental stations and demonstration farms on which to carry out research projects (Cochrane 1993:243).

Knowledge dissemination

The basic technology transfer structure seen today can be simplified as follows: farmers experience these problems (ie. pests, diseases) which they communicate to extension staff. The staff then communicate problems to university researchers and scientists in the land grant institutions who are specifically assigned to extension work. The land grant researchers carry out the required research to "solve" the problems through technological innovations. The solutions are then communicated and/or transferred back through the extension agents to the farmers where they are incorporated into field practices (Warner 2008, see Fig. 7). This is how it works in theory, but in reality there are several dimensions of complexity.

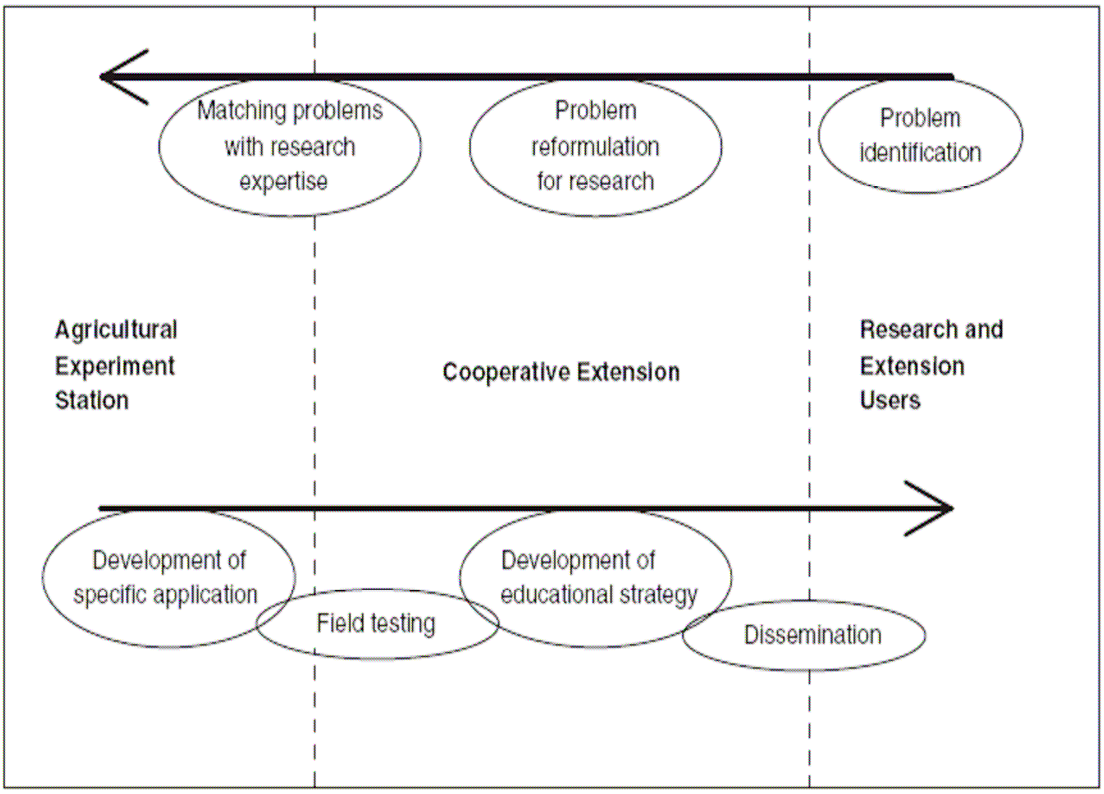

Figure 7. Typical cooperative extension roles in the research-technology transfer process. (Adapted from Warner 2008:756)

Warner addresses the issue of knowledge dissemination, which is one of the current debates of the extension system as it relates to developing sustainable agricultural alternatives. Since agroecological growers must trust their ability to solve complex problems, participate in knowledge formation and not just passively recieve information, the conventional pathways of knowledge transfer are contradictory to ecosystem based farming (Warner 2008, Weis 2007:30).

Additionally, there are multiple pathways of technology and knowledge transfer that often depend on contextual situations. In reality farmers have a more active role and are more involved in the innovation cycle (Interview, 30 March 2010). This illustrates the difficulty in generalizing the process of technology transfer as being carried out in one direction.

For many years the land grant extension model was an effective system in which to improve yields and it increased overall agricultural production efficiency during the 20th century (Trauger et al. 2010). However, in recent decades the extension model has come under increasing criticism for a failure to keep up with farmers' needs, focusing too much on non-agricultural services such as urban and health extension programs, budget constraints and competition from private research companies (Foltz & Barham 2009). In addition, the success of public domain research and extension in increasing production, particularly during the "Golden Age" in the 1960s-1970s which culminated with Norman Borlaug's development of high yielding varieties that led to the Green Revolution, is attributed to benefitting large scale monocultural operations and agroindustry more than diverse, small scale operations (Buttel 2005) that better fit the agroecological model.

Funding for R&D: public vs private

The division of public (government) and private (industry and corporate) research can be roughly described as follows. Public research is destined to enter the public domain as open knowledge, whereas private research results in technology targeted at an existing market, through patents and intellectual property rights, and most importantly, is carried out with the intention of making a profit for the private investor (Cochrane 1993:246).

Federal funding for agricultural research has been built into policy through the land grant universities and the extension system. However, the public research budget for the food sector is shrinking: in 1940 nearly 40% of the federal research and development budget went to agriculture, but only 1.4% in 2007 (Rausser et al. 2008:1).

Moreover, private interests have increasingly grown in influence (see Fig. 8) over the direction of research and development of technological trajectories as public-private partnerships grow more common and as corporate lobbying groups grow in strength (Vanloqueren & Berat 2009). As a result, the division between public and private research is becoming increasingly blurred and the funding for research and development is largely industry financed or influenced through industry lobbying for policies favorable to private investment (Vanloqueren & Baret 2009). Indeed, as stated by Ostrom & Jackson-Smith "the research and extension priorities on many LGU campuses are more often driven by regional or national political pressures emanating from influential agricultural interest groups…[as opposed to being driven by the farmer's interests]" (Ostrom & Jackson-Smith 2005:59).

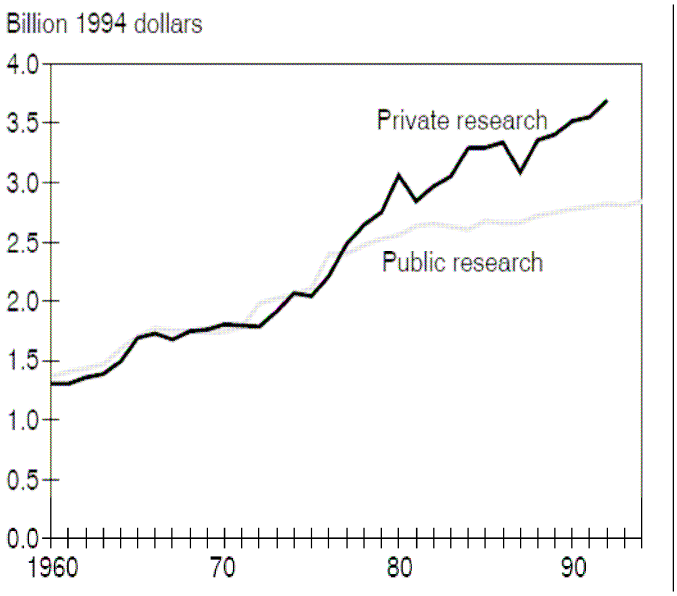

Figure 8. Public vs Private research funding 1960-1994. (Adapted from Fuglie et al. 1996:3)

This is confirmed in a study by Woodward mapping the linkages between governing boards of land grant universities and Fortune 1000 companies, which finds that the majority of board members have business backgrounds (2009). This points to the possibility of economic interests being served through decisions and policies made by land grant trustees affecting the overall research mission and goals of their respective universities.

Intellectual property rights

A crucial factor in the relationship between industry funding and research is the presence of intellectual property rights. In 1970 the Plant Variety Protection Act was passed, which gave seed developers patent rights, and in 1980 the Supreme Court decision Diamond vs. Chakrabarty established the right to patent microorganisms; both of these legal landmarks resulted in expanded property rights on agricultural technological innovations (Feller et al. 1987). This encouraged a commercialization trend in research and development (Fig. 9), particularly for chemical and increasingly, biological inputs including genetically modified seeds and other biotechnological innovations (Mascarenhas & Busch 2006). Indeed, Buttel refers to the era since 1980 as the "molecularization of agricultural research", which reveals the emphasis placed upon gene technology within the dominant discourse (2005).

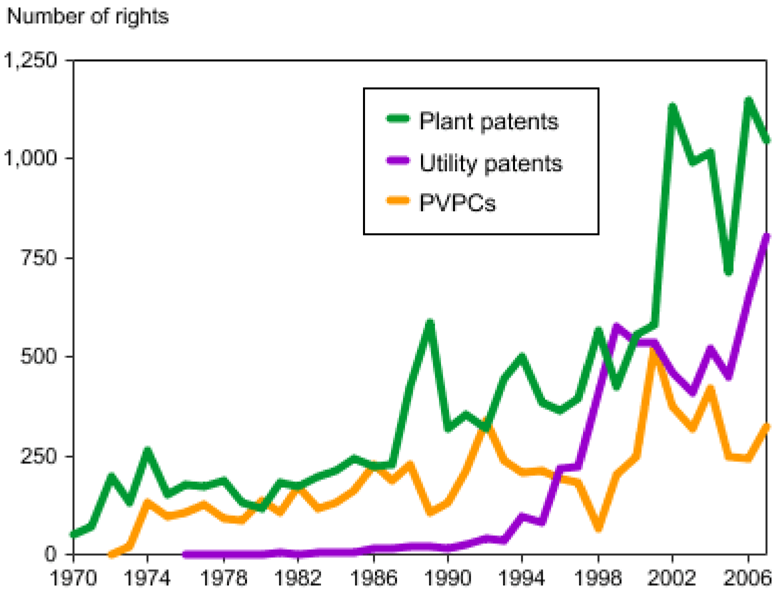

Figure 9. Intellectual property rights in private research. (Source: ERS 2010)

The Bayh-Dole Act of 1980 allowed universities access to intellectual property rights for molecular technologies developed with public funding (Rausser et al. 2008, Buttel 2005). Thus, universities as well as private companies are able to capitalize on patents, as can be seen in the University of California's patent for the Camarosa strawberry which earns approximately $2 million annually in revenues (Parker et al. 2001:738).

In turn, the structure of the land grant university and extension system is shifting from an emphasis on responding to farmer's needs directly to creating innovations to sell commercially (Rausser et al. 2008) that will reach growers indirectly via market channels. This presents a conflict of interest for the land grant and extension system and its fundamental mission of assisting farmers and rural communities through education and provision of innovation technologies (Warner 2008). Moreover, land grant universities are gradually phasing out "traditional" applied agricultural researchers such as plant breeders and replacing them with molecular and genetic researchers, to increase patent developing capability (Buttel 2005). Indeed, as land grant researchers receive more funding from private companies, they have more incentives to pursue innovations that will bring a profit or secure patent rights.

Some authors caution against the arrangement of public-private research investment partnerships (Vanloqueren & Baret 2009), specifically with regard to biotechnology firms and gene modification patents (Ervin et al. 2003, Macarenhas & Busch 2006). Without going into the genetic engineering debate, it is suffice to say that considering agroecology's zero tolerance stance on genetically modifed organisms, the growth in political influence and market share of multinational agritech corporations such as Monsanto, DuPont and Novartis (Mascarenhas & Busch 2006) point to the challenges facing growers considering alternative production methods.

Furthermore, leaving agricultural innovation to the market through intellectual property rights policies fails to focus research on "non profitable" areas such as environmental well being or improving farm worker conditions (Feller et al. 1987). Indeed, the areas of agroecological potential will not receive much attention from private research funding as long as it cannot be easily marketed. An exception that confirms the rule is that biological pesticide innovations targeting organic growers are booming (Rosset & Altieri 1997).

Instead, research in agroecology must preferably be supported from non-profit and public investment, and therein lies the issue of disciplinary conflict.

Disciplinary barriers

An important factor in the private-public research dynamic is the tradition of disciplinary science. The question of how science is framed, which issues are studied and what questions are asked tends to be formulated within the reductionist discourse (Francis 2009) discussed in section 5.

A reluctance among "traditional" disciplinary scientists to take part in interdisciplinary collaborations poses a challenge to carrying out research on agroecology and sustainable agriculture topics. Francis et al. agree that agricultural scientists are "more comfortable dealing with components of systems, simple cause-effect relationships, and questions that can be answered by standard experimental designs… [interdisciplinary approaches] threaten the autonomy and budgets of our disciplinary departments" (2003:110).

Another challenge is that the standard experimental design of studying components of systems in isolation from one another is not entirely compatible with agroecological research, as demonstrated by Eksvärd et al.:

> "One limitation…[of] disciplinary natural science research is the quest to isolate one or a few discrete factors to study while holding the rest of the system constant…the results apply in a strict sense only to the conditions and the year when the experiment was conducted." (in Bohlen & House eds. 2004:274)

The implications of this type of experiment are that the results cannot be easily applied to diverse agroecosystems under different conditions or at different time scales. Therefore, longer term experiments under evolving conditions or experiments that take a system wide approach are also appropriate for agroecological research.

Furthermore, within agricultural science there is a diverse set of perspectives on agricultural sustainability, as seen in a survey conducted by Lyson. The author found that only half of the 1011 agricultural scientists were concerned with agricultural sustainability, and among those that viewed agricultural sustainability as a concern were many different ideas of what the term actually meant (1998). This points to the importance of the perspectives of individual scientists and researchers, that is, personal opinions on what is more pressing or relevant for the research agenda. Thus, disciplinary plurality is also a factor affecting the selection of topics researched and projects proposed and accepted (Lyson 1998).

6.3 Food flow dynamics

So far the discussion of agroecological processes as they fit into conventional agricultural systems has revolved around political, institutional, research and developmental themes. The final theme for discussion is the way food flows from producers to consumers, both literally over geographical and temporal spaces and conceptually through consumer awareness, community networks and other channels. Here it is useful to recall the principles of agroecology relating to creating socioeconomically sustainable food systems, including social justice for both producers in the form of safety at the field level and for consumers in food supply chain transparency and access to healthy, nutritious food (Gliessman 2007, Francis et al. 2003).

This section will examine two trends that have actually made progress in implementing agroecological principles within the conventional model. First, the idea of ecological citizenship in building local food networks among multiple actors will be looked into as containing a great deal of potential for agroecology. Then, the organic conventionalization debate will be discussed as an example of the difficulty in retaining agroecological ethics and principles when integrating into the conventional model.

The Hourglass model revisited

As discussed previously, conventional food supply chains in the U.S. are characterized by oligopsony, the market phenomenon in which a small number of buyers exerts power over large number of sellers (Thompson et al. 2007:9). The oligopsony model is shaped like an hourglass, with many producers at one end and many consumers at the other, and the middle squeezed by a powerful handful that control all the steps in between (Weis 2007:13).

Alternative market channels

As Hendricksen and Heffernan postulate, a major roadblock for corporations in the hourglass shaped food supply chain that has evolved to mass produce and distribute industrially streamlined, uniform food across the global food system is being able to source local products (2002:360). These “differentiated markets”, including for example consumers eager to learn where their food comes from or to support the farmers who raise their meat practicing humane animal husbandry, are inaccessible for the oligopsony firms (ibid). Herein lies the opportunity for agroecological producers to directly market their products and achieve economic returns.

Local marketing channels provide a way to bypass the conventional supply chain for both producers and consumers. By choosing local channels through which to market their wares, farmers are able to cut out many of the middle men that dominate conventional supply chains, and in many cases they use direct marketing, selling directly to consumers at farmers' markets, through CSAs[4] and through farm visit or rural tourism programs (Morgan et al.

[4] “Community Supported Agriculture (CSA) consists of a community of individuals who pledge support to a farm operation…with the growers and consumers providing mutual support and sharing the risks and benefits of food production.” (DeMuth, 1993).

2006). Alternative food supply chains still follow the basic economic exchange of goods for money, but the connection between "farm gate" and table is nearer as local food networks grow in number (Follet 2009). For instance, the number of farmers markets across the U.S. have increased from1,755 in 1994 to 5,274 known facilities in 2009 (USDA 2010).

Ecological citizenship: Consumers "vote" with their choices

By definition, alternative market channels and networks provide consumers with a different option than conventional food channels. Thus, they give consumers the power to exercise their economic voting power. This can be interpreted as a form of civic engagement, in which social bonds are forged within communities of "embedded market fields", between all actors involved (Dupuis & Gillon 2009:45). This concept of embedded market includes more than just buyers and sellers but all actors affecting the entire chain; NGOs, government, lobbying groups, consumer organizations, etc. (DuPuis & Gillon 2009). Moreover, the "food citizen" takes responsibility in forming and maintaining alternative market networks and plays an active role in creating more sustainable food options (Lockie 2009:194).

In addition to exercising their economic power, consumers can express their social, political and environmental beliefs and values (Moore 2006, Lockie 2009). The political side of alternative channels can also be witnessed in the various coalitions and organizations that have formed in response to a perceived threat to both ecological and human health, as well as grower autonomy: GMOs. Products containing genetically modified organisms are not required by law to be labeled in the U.S. (Roe & Teisl 2007). The Center for Food Safety is a grassroots network of concerned citizens that

> "works to protect human health and the environment by curbing the proliferation of harmful food production technologies and by promoting organic and other forms of sustainable agriculture…where concerned citizens can voice their opinions about critical food safety issues, and advocate for a socially just, democratic, and sustainable food system" (Center for Food Safety/About 2010)

Boasting a membership of more than 100,000 people, this organization illustrates the desire among consumors to exercise their rights as citizens as well as shoppers in bringing about change in the agrifood system. The Organic Consumers Association, with a membership of 850,000, has a similar agenda but also overlaps with other political issues. It campaigns for "health, justice and sustainability" by targeting industrial agricultural practices, GMOs, unfair trade policy and calling for universal health care, renewable energy and a conversion of 30% of agriculture to organic by 2015 (OCA/About 2010).

These civic organizations demonstrate the existence of a participatory and action oriented consumer that prioritizes ecological and social wellbeing as well as the right to a choice of food sources. Thus, it can be interpreted that ecological citizenship serves to link consumption practices with ecological production methods. Moreover, the synchronization of health and environmental concerns with agroecological principles facilitates the spread of awareness of agroecology as a viable alternative to the greater public.

Conventionalization of organic production debate

Producers of organic goods have the advantage of being able to charge premiums for their products, if they are certified, and thus reap the benefits of "value-added" farming. This is reflected in the average annual sales of organic farms ($217,675), compared with the average annual sales for U.S. farms overall ($134,807) in 2007 (USDA Census 2010). At the same time, consumer demand for organic products is growing steadily. Table 2 illustrates the organic "boom", in which sales have steadily increased over the past decade.

Table 2. Organic sales, 1997 to 2008. Modified from Organic Trade Association 2009

	Organic Food Sales ($ Million)	Change from Prior Year	Total Food Sales ($ Mil)	Organic Penetration*
1997	3,594	Na	443,790	0.81%
1998	4,286	19.2%	454,140	0.94%
1999	5,039	17.6%	474,790	1.06%
2000	6,100	21.0%	498.380	1.22%
2001	7,360	20.7%	521,830	1.41%
2002	8,635	17.3%	530,612	1.63%
2003	10,381	20.2%	535,406	1.94%
2004	11,902	14.6%	544,141	2.19%
2005	13,831	16.2%	566,791	2.48%
2006	16,718	20.9%	598,136	2.80%
2007	19,807	18.5%	628,219	3.15%
2008	22,929	15.8%	659,012	3.47%

* Organic food as a percent of total U.S. food sales. Source: *OTA's Manufacturer/Organic Industry Surveys, 2006-2009*

The organic movement began with committed small scale producers following ecological ideals, but more recently there has been a shift to economic incentivization as conventional producers convert small portions of their production land to organic to take advantage of the price premium (Smukler et al. 2008). Moreover, corporations producing organic products are accused of not doing so for ethical reasons, but rather to capture the profits associated with the niche (Follett 2009). The concern with the conventionalization, in addition to corporations competing against small producers with unfair advantages of production of scale, is that it will erode the philosophy and principles under which the organic movement was founded (Lockie 2009).

Organic food caters to a still relatively small percentage of the market but with a strong growth rate. It has been proposed that the organic market share could hypothetically grow enough to overtake conventional food products and become the norm (Blank & Thompson 2004), in which case the question of retaining the principles of the organic movement would surely be called into question by economies of scale.

Indeed, while some researchers argue that the "conventionalization" of organic production (Guthman 2004) is detrimental to the organic movement, others are confident that the niche market for local, community oriented and ecologically committed production and independent distribution through farmers' markets, CSAs and other direct sales remains strong (King, 2008). Moreover, as organic certification has been institutionalized by the USDA and in some instances the original standards have been weakened by large scale appropriation, the alternative network continues evolving in response. The emergence of the "post organic" concept witnessed in local networks, which prioritizes products sourced locally over organically certified products coming from afar, attests to this claim (Follett 2009, Moore 2006).

In summary, although there is promise for both organic producers and local food networks as alternatives through which agroecological practices can be spread, it remains to be seen in which direction the alternatives will develop. If they are incorporated into the productivist discourse through conventionalization, they will likely not maintain a sustainable trajectory. However, if civil engagement continues and consumers “vote” with their choices, the conventional agri-food supply chain may be challenged and a local system based on agroecological principles of transparency and social justice, both for producers and consumers, may flourish.

7. Discussion

This section will tie together the findings from the results section to create an overview of the atmosphere surrounding alternative agriculture in the U.S. It is now possible to revisit the main research question, that is, to determine to what extent agroecological practices can be implemented within the existing infrastructure of the conventional agrifood system, with new insight on the opportunities and also the barriers to achieving such a goal.

7.1 Results revisited

The analysis of U.S. agricultural policy, trends in research and development, and market channels have yielded a complex picture of the current dynamic of agroecology within the greater conventional framework. There are tangible opportunities for agroecological principles and practices within production, distribution and consumption systems, but there are also some barriers to contend with.

Policy

Regarding policy, the increase in government spending on organic research and available funds for direct assistance to individual growers transitioning to organic and sustainable farming methods illustrates the growing influence of lobbying groups such as the National Sustainable Agriculture Coalition (NSAC 2010). The relatively small percentage of the 2008 Farm Bill funding alloted for alternative agriculture in comparison with the funds earmarked for staple crop subsidies, however, indicates that the conventional model is far from being challenged within agricultural policy. As Buttel states, “…a national public policy environment that favors capital-intensive, monocultural, chemical intensive agriculture makes it enormously difficult to develop mere technological alternatives that help small farmers…” (2005:278).

Additionally, the lack of a shared holistic vision of environmental and agricultural systems in the collaboration between the EPA and the USDA presents an institutional barrier to implementing agroecology at the landscape and regional level.

However, it is useful to remember that Rome was not built in a day, as the saying goes, and considering how entrenched the USDA is in supporting industry lobbyists and in subsidizing commodity crops, the five fold increase in spending for organic farming from 2002 to 2008 should be considered a small victory for agroecology within national agricultural policy. Moreover, the continuation of government funded programs supporting agroecological practices and experimentation such as SARE illustrates the USDA's acknowledgment of successful alternative models of production.

Research & Development

The mechanisms of technology transfer and knowledge dissemination pose a considerable challenge to agroecological research and development. This is partly due to the gradual replacement of public research funding by private investment in a "privatization" of public research universities. Additionally, the legal framework supporting intellectual property rights provides incentives for land grant institutions to pursue research for commercial patents, rather than for the public good. When public and private investment, technology transfer systems and disciplinary academics are factored into the situation, it becomes clear that research and development in the agricultural sector is entrenched in the conventional paradigm of industrialized production. Indeed, "[p]aradoxically, much of the research and research process that has made conventional agriculture so productive has been a barrier to implementing sustainable agriculture." (MacRae et al. 1989:174 in Parr et al. 2007).

One challenge to researchers is that agroecology is a very case specific field. While the main goals of ecosystem health, crop production and socioeconomic wellbeing are common to agroecological research, the technology and methods differ greatly from one climate and ecosystem to the next (Edwards et al. 1993). There is no simple solution, no "silver bullet" technology such as those promoted during the Green Revolution but rather a a myriad of techniques that can be employed depending upon specific situations (Pearse, 1980 in Altieri, 2002). Importantly, long term system health and sustaining yields may take years to achieve since the agroecosystem must be studied as a whole and experimented with to find the right combination of methods and species that compliment each other in that specific setting. Economic incentives or insurance against crop failures may be helpful to encourage farmers participation in adopting and experimenting with agroecological methods.

Disciplinary challenges

In a climate of dwindling public support for non-profit research and development, along with a reluctance among disciplinary "hard" and "soft" scientists to collaborate with one another to pursue long term interdisciplinary experiments characteristic of agroecology, it may appear difficult to follow holistic technological trajectories. Furthermore, if such interdisciplinary projects were to be carried out on a regular basis, there would have to be a major shift in the extension model so that farmers' participation and input would be integrated into the research design and process, rather than the current (primarily) one-way knowledge transfer.

However, more holistic or system based frameworks are beginning to emerge among research programs and organizations such as University of California's Sustainable Agriculture Research and Education Program, undergraduate and graduate agroecology programs at the University of Maine, Iowa State University, and the University of Nebraska, the Center for Agroecology and Sustainable Food Systems at U.C. Santa Cruz and other public and private institutions (Francis et al. 2003). These hold promise for future expansion and adoption of agroecological based research.

Furthermore, Weiner postulates that in the future, agricultural science will shift from traditional "reductionist" disciplines such as soil science and agronomy to applied ecology or "ecological engineering" (also found in Vanloqueren & Baret 2009 as agroecological engineering). This will reflect a paradigm change from viewing the farm as a production system to viewing the farm as an agroecosystem with natural processes to maintain, as well as manipulating for human use (2003:373).

Food flows

There is considerable opportunity for agroecological principles and practices via local food networks, some of which are already spreading at a grassroots level across the nation. This movement among consumers to address health and transparency related concerns raised by the hourglass model employed within the conventional agrifood system, is visible in farmers' markets, community supported agriculture ventures and direct marketing. In local food networks producers can make a decent living and also build relationships with their customers based on trust and accountability, and the participation of the "food citizen" strengthens community networks (Lockie 2009).

Consumers making both ideological and political statements through their purchasing power are a manifestation of a "new moral economy of food" which "embodies norms and sentiments regarding the responsibilities and rights of individuals and institutions with respect to others" (Sayer, 2000 in Morgan et al. 2006:167). This is particularly apparent in organizations such as the Center for Food Safety and the Organic Consumers Association that reveal the compatabilities between concerns for consumer health and safety and agroecological principles of environmental and socioeconomic wellbeing. Ecological citizenship, then, functions to raise awareness among the public, not only of the negative externalities related to the conventional production and distribution model, but also of the alternatives available to them in the form of agroecological cultivation and direct marketing methods. Thus, local market channels and ecological citizenship are making inroads into the conventional agrifood system and proving that there is a growing support base for agroecological alternatives among civil society.

Organic conventionalization

However, alternative models must also function within the existing conventional agrifood system, and to envision organic farming and local food networks as operating free of profit motives is to oversimplify them. Morgan et al. hypothesize that the agrifood system is not strictly split into a dichotomy between conventional and alternative models, but that there are many grey areas within complex and overlapping food "worlds" where actors from both "conventional" and "alternative" spaces can and do travel between them (2006:2).

The conventionalization debate of organic production represents one of these grey areas. It demonstrates what can happen to well intentioned agroecological producers attempting to scale up their operation to "fit into" the conventional model. Incorporation of organic certification into the standardized national framework may have compromised the original principles of the organic movement, as the less stringent regulations provide an inroad for conventional operations to capture part of the niche market.

On one hand, it can be argued that the establishment of the national organic standards is a major accomplishment, since it acknowledges a divergence between conventional and alternative models, and it was created under pressure from organic lobbyist groups concerned with environmental and socioeconomic issues arising from the conventional food system. On the other hand, in catering to agribusiness through watered down standards, the national organic program may simply be promoting the status quo. Thus, it is both a triumph and a cautionary tale for the agroecological movement.

While proponents of agroecology would extoll its inability to be “corrupted”, it also must develop within the dominant system, and perhaps in so doing it will evolve so that it more closely resembles the conventional model in various aspects, as in the conventionalization hypothesis. We cannot predict how the narrative of agroecology will unfold, but we can hope that the ecological and socioeconomic integrity will be retained, considering that they were foundational in the movement from the start.

8. Concluding remarks

The diverse array of ecological, socioeconomic and political issues behind the current conventional agricultural model confirm that it is an excellent example of a complex problem lacking a simple solution. However, complex problems require multiple and complex solutions; agroecology as a scientific field and as an active movement containing local food networks and organic farming, it is one of various alternatives emerging as a response to the conventional model in an evolving agrifood system.

This thesis has attempted to gain an understanding of the barriers and opportunities to agroecological practices and principles being adopted on a larger scale, to determine the extent to which agroecology can grow within the conventional system. In so doing it has demonstrated the emergence of areas within policy, research, education and civil society that can support the integration of agroecology in the agrifood system. An example of this is the effort toward interdisciplinary collaboration within universities and research institutions. The establishment of new agroecology and sustainable agriculture programs of study is a step toward achieving an agricultural research agenda that includes holistic as well as reductionist approaches.

At a optimized theoretical level, the fundamental differences between the conventional and agroecological models would be reconciled through a paradigm shift in the agrifood system from productivism to holism. However, due to entrenchment of the conventional model in institutional and economic systems favoring reductionism and productivism, at a practical level such a complete transition to an agroecological reality is doubtful. Therefore, the **main finding** of this thesis demonstrates that **the integration of agroecology into the conventional model is likely to continue along its current trajectory** of somewhat limited development. This trajectory holds policy, research and development challenges but is aided by opportunities within local producer-consumer networks and supported by ecological citizenship.

However, an agrifood system based on coexisting and partially overlapping conventional and alternative systems is conceiveable. Where the two models overlap, some compromise of both agroecological principles and conventional practices is inevitable. One instance of an overlapping area can be identified in the conventionalization of organic farming, where large scale firms meet the minimum organic certification standards to access the organic market. However, the establishment of the national organic program can still be seen as a step in the right direction in terms of promoting the adoption of ecological production practices on a wider scale.

Further investigation of how an overlapping coexistence of conventional and agroecological realities might be conceptualized is relevant. For instance, more effectively facilitating interdisciplinary research efforts such as introducing agroecological practices into monocropping, investigating how farmers can participate in experiments and build knowledge sharing networks, determining how civic participation in local food channels can be better administered, etc. Studies over multiple scales from the field level to the regional or national level, addressing both theoretical and practical topics, would be useful to better understand agricultural and agrifood system dynamics and to pave the way for agroecological integration.

Field level practices identified within the current literature and debate as agroecological are not new to U.S. agriculture, as can be seen in archived farming literature (Farmers' bulletin 1942); they have only been abandoned in favor of "silver bullet" technologies tailored to large scale operations. Perhaps some of these ecologically based production techniques can be revitalized and incorporated into the research agenda for current use.

In short, further research to better facilitate the integration of agroecology into the conventional agrifood system is recommended. The implications of continuing to approach food production, distribution and consumption processes from a productivist perspective and continuing to employ solely reductionist viewpoints to solving agricultural issues, would be further detrimental to ecological and socioeconomic wellbeing. However, the enthusiasm and dedication of farmers, researchers, organizations and community members exploring agroecological alternatives suggests another agicultural model is possible, one which allows for diverse visions and practices that take natural and social components of complex agrifood systems into account in providing food and fiber for human use.

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