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Interactions in integrated US agricultural systems: The past, present and future

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Abstract

During the 20th century, American agriculture underwent dramatic changes. At the beginning, farms were more diverse, dependent on animal traction, on-farm inputs and income and, after initial land grants, nearly independent of government policy. However, external issues, such as government policies, mechanization, fossil fuel costs, increased consolidation and vertical integration of markets and increased societal awareness of the environment and concern with farming practices, have substantially altered the structure of agriculture. These external issues are significant drivers of agriculture and we grouped them into social/political, economic, environmental and technological drivers. Previous papers have examined specific effects of these drivers. Our objective is to examine how these drivers interact and influence today's agricultural systems. We developed four categories: (1) Commodity Crop Production, (2) Supply Chain Livestock Production, (3) Organic Production and (4) Extensive Livestock Production, to describe major current agricultural systems. These categories were developed as major and contrasting systems but do not represent all of American agriculture. Although it is not possible to predict the future, interactions among the various drivers will affect these systems differently. By examining multiple scenarios, we conclude the highly specialized systems (Nos. 1 and 2) are highly vulnerable to future changes, and that developing adaptive capacity is critical for dealing with new uncertainty. Sustainable agricultural systems will need balance among various domains to be able to adapt and survive. We suggest that the concept of dynamic-integrated agricultural systems may be the best way to meet this goal because of its ability to consider multiple goals and flexible producer decision-making.

Key words: dynamic-integrated production systems, economic drivers, social/political drivers, environmental drivers, technological drivers, system adaptability

Introduction

Present-day American agriculture is vastly different from American agriculture at the beginning of the 20th century. Major changes have occurred in the number of farmers, the primary source of their income, the role of government, the technology used and the expectations of consumers and society[1]. These changes have come about from the interaction of multiple factors, which are often largely external to the agricultural system itself.

American agriculture will continue to change in the future. The rate of change will occur more rapidly as farmers, not only in the US but also globally, have increased access to information via improved communication technology such as the Internet. The challenges facing agriculture in the future will be more difficult than in the past. An increase in the world's population to 9 billion people[2], increasing urbanization and expansion of cities[3], rapid human-induced introductions of invasive species[4] and increased emphasis on environmental sustainability will place unprecedented demands on agricultural systems.

Holling[5] described a key component of sustainability as the 'capacity to create, test, and maintain adaptive capacity'. Integrating multiple enterprises into an agricultural operation can enhance the adaptive capacity needed to respond to future challenges. Integrated agriculture may

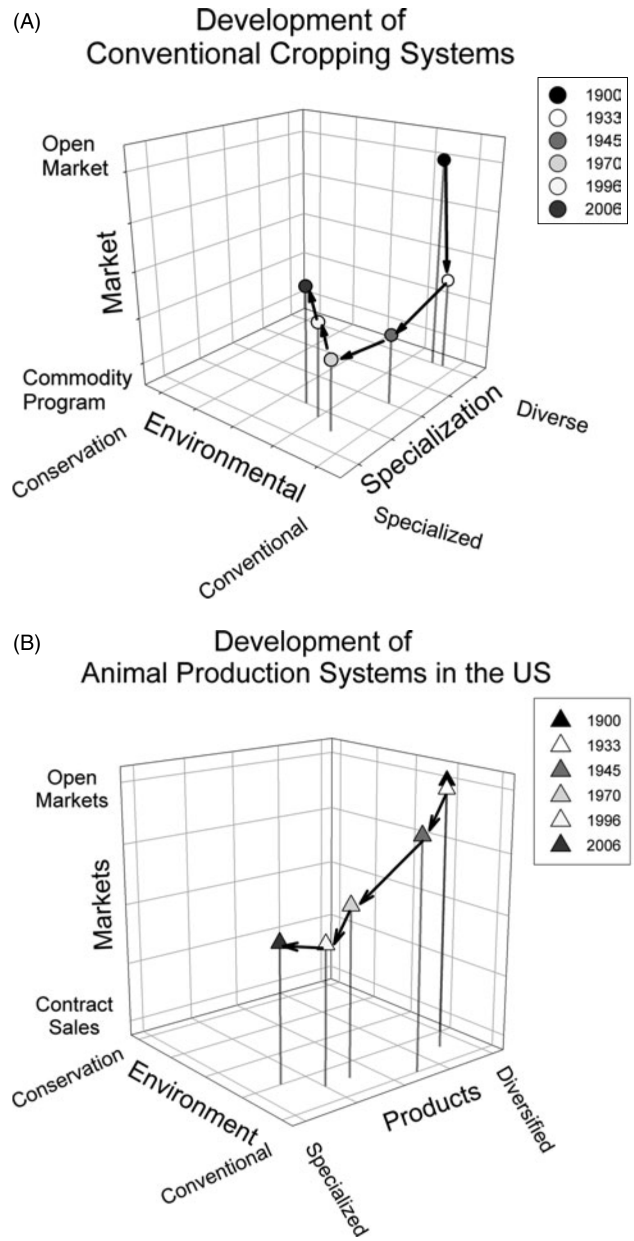

Figure 1. Transitions in conventional production systems in response to economic, social, political, environmental and technological influences. (A) Conventional crop production. (B) Animal production. Except for 1933 and 1996 when specific changes in agricultural policy occurred, year refers to a more general time frame.

well provide the model to develop sustainable agricultural systems in the future. However, to develop these systems, interactions between factors, external and internal to the system, must be understood.

Previous papers in this issue have established a background for a discussion of agricultural production systems[6], and explored the four main drivers shaping agricultural production systems: social/political[7], economics[8], technology[9] and environment[10]. Our objective is to examine how interactions among these drivers have influenced the structure of US agriculture in the past, and how they may shape it in the future.

Development of Current Production Systems

Over the past century, many changes have occurred in agriculture. Potentially the most dramatic of these changes has been to the farm unit itself. The structural evolution of US agriculture can be seen by examining the characteristics of two common production systems, a conventional cropping system and an animal production system, over time (Fig. 1). Farms have tended to become larger, fewer in number and more specialized[1,11]. At the turn of the 20th century, farms were highly diversified, typically including both animal and row-crop production. Increasing specialization since then has reduced the average number of commodities produced per farm from around five in 1900 to just over one in 2002[1]. These structural changes in agriculture have been driven by the interaction of social/political, economic, environmental and technological factors.

Specialization

One fundamental change in the structure of US farms has been increased specialization. A key driver encouraging the shift towards specialization came from US agricultural policy. During the Great Depression, agriculture and rural America was in the most devastating period in recent American history[12]. The economic crisis of the 1930s precipitated the development of modern US agricultural policy in the Agricultural Adjustment Act of 1933[12], designed to address the needs of rural poverty and depressed farm income[8]. The US farm programs increased specialization by supporting only a limited number of commodities[13] (Fig. 1A, 1933). Changes in trade and monetary policy in the 1970s promoted the production of exportable crops and further increased specialization (Fig. 1A, 1970). Changes in the support programs with the Freedom to Farm bill of 1996 increased the planting options available to farmers (Fig. 1A, 1996), although most support still focused on a select few commodity crops.

Specialization on US farms has also been increased by reliance on petroleum-based inputs. An FAO report[14] indicated that cheap resources lead to specialization but restricted resources lead to mixing enterprises. US farmers have relied on relatively cheap fossil fuels for mechanization, pesticides and fertilizers. This reliance has also impacted livestock, such as the beef cattle industry, which relies heavily on fossil-based fuel[15].

Petroleum-based inputs have resulted in dramatically higher yields[16] but have also increased the specialization of agriculture. For example, prior to the adoption of the tractor, at least a portion of the farm's acreage needed to be in forage for feeding draft power[17]. While energy intensity (total farm output per unit of energy use) has declined,

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energy costs as a share of total production costs are still high for many crops such as corn and wheat[18]. However, because of increases in fossil-fuel prices, costs of petroleum-based inputs have increased. For example, according to Economic Research Service data[19], N fertilizers have increased in price over 80% since 2000. While increases in petroleum-based input costs may decrease specialization as producers search for crops and livestock requiring fewer inputs, increased demand for biofuels, such as ethanol from corn, may lead to increased specialization as more acres are planted to meet demand.

Advances in technology also helped to increase farm-level specialization. Technology was driven by a fundamental desire to improve yields, reduce costs and reduce the amount of labor needed[8,9]. Refinements in tractor design during the 1920s and 1930s increased the tractor utility, and an acceleration of tractor adoption followed World War II, which increased farm size[11,17] and corresponded with a decline in average number of commodities produced per farm from almost 4.5 in 1945 to under 3 in 1970[1] (Fig. 1A, 1945). Technological enhancements were often focused on program crops, increasing specialization. Economic expenses associated with adoption of technologies often further limited diversification of production operations[20].

Although livestock production was minimally affected by commodity programs, other factors contributed to increasing specialization in these systems. Barkema et al.[21] suggest that food demand and technology have been the driving forces shaping consolidation in the meat industry. Technological advances in engineering systems led to the development of confinement buildings, while improvements in biological technologies led to genetic improvements in livestock, animal feeding and improved disease control, allowing large-scale animal production in small areas[22] (Fig. 1B, 1970). Vertical integration and contracting began in the broiler industry[23] and increased specialization and scale of agricultural production of livestock[1]. Changes in marketing combined with technological innovations have resulted in nearly 100% of broilers and almost 80% of pork being produced in supply chain agricultural systems in 2000[24]. This shift to supply chain livestock production has greatly reduced the diversity of animal production systems (Fig. 1B, 2006).

Markets

A second fundamental change in the farm structure can be seen in the marketing of products. Changes in agricultural policy, marketing concentration and social pressures have interacted to influence today's farm structure. Beginning with the Agricultural Adjustment Act of 1933, the US government sought to protect farm income and control surplus production through price supports and acreage reduction programs[12]. These policies shifted crop sales away from open markets and increased reliance on contract sales through commodity supports (Fig. 1A, 1933). Beginning in the mid-1980s, there was a trend to decouple farm payments from production and move to greater market orientation, which culminated in the 1996 Federal Agricultural Improvement and Reform (FAIR) act[25]. The FAIR act focused on decoupling agricultural payments from production decisions[25] which may eventually open markets for a greater diversity of products (Fig. 1A, 1996).

Consolidation among agricultural input industries and processors developed rapidly during the 1990s. For example, from 1995 to 1998, 68 seed companies were acquired by six life science firms[26]. Many of these acquisitions were driven by the desire of chemical companies to acquire new genetically engineered plant traits[26]. In agricultural processing firms, a similar consolidation has taken place. The CR4 ratio (the amount of a market controlled by the four largest firms) is greater than 70% for corn milling and soybean processing and has increased by 50% in the meat packing industry[27].

As industries consolidate, often in response to cost and technological factors[21,27], production to consumption may be tightly linked through the use of supply chains[24]. Development of meat supply chains has also been enhanced by social pressures from consumers demanding foods that are safe, nutritious, consistent and easy to prepare[23]. In supply chain production, livestock is grown and sold under contract. While this guarantees a market for the product in much the same manner as commodity crop programs, the independent production decisions are removed from the control of the producers, and are instead the purview of major food companies[7]. This has resulted in a shift in many livestock market segments from open markets to contract sales (Fig. 1B, 1970). While the poultry industry has been vertically integrated for some time, other agricultural products are also moving in this direction. The number of hogs sold under some type of contractual arrangement has increased to over 80% in 2001[21]. The emergence of biotechnology may lead to new supply chains in other types of agricultural production[24].

Environmental awareness

Growing awareness of the negative environmental impacts of traditional farming practices and concern for public health and safety have led to the use of more environmentally friendly production practices in both animal and row-crop systems (Fig. 1A, B). For example, soil erosion in the US has declined 40% since 1938, mainly after implementation of government programs aimed at mitigating losses in 1985[28]. Research and development leading to improved knowledge of the impact of agricultural practices on natural resources and implementation of more environmentally friendly production systems have greatly reduced their environmental impact. Over the past 30 years, reduced tillage equipment has replaced more intensive tillage operations on many farms (Fig. 1A, 1970)[29]. Although the primary reasons given by farmers for using reduced tillage has been efficiency, equipment width and speed,

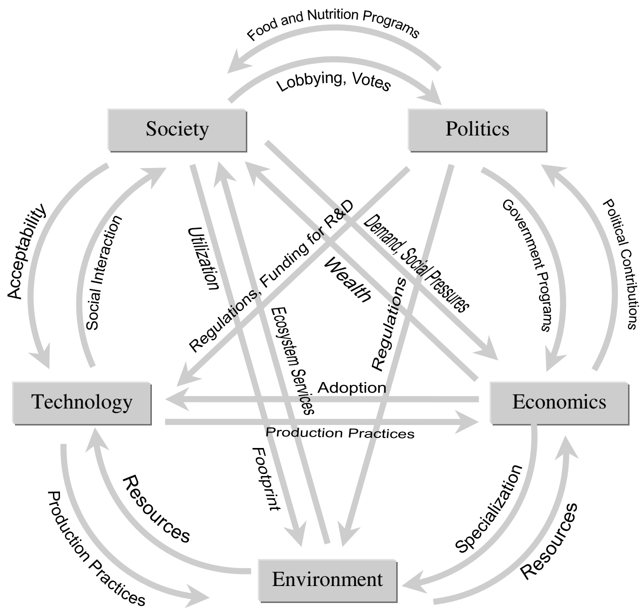

Figure 2. Interactions between social, political, environmental, economical and technical drivers of agricultural production systems.

changes in the farm bill to encourage conservation farming have also promoted the development and adoption of reduced tillage technology[29]. Concerns about the unintended negative environmental consequences of previous farm programs resulted in the introduction of plans in the 1985 Farm Bill to mitigate environmental damage on environmentally sensitive land[30].

Recognition of the potential negative environmental impacts from animal waste has led to regulations aimed at reducing water and air quality impacts and programs to assist producers in implementing waste management practices, increased adoption of waste management practices[31] and research on methods to utilize animal waste products and minimize environmental contamination. Adoption of other conservation practices such as rotational grazing systems, fencing to exclude livestock from sensitive areas and water developments to protect riparian areas have also increased, in part due to an increase in availability of program funding to assist producers by implementing these practices. These practices help reduce soil erosion, improve water quality and improve wildlife habitat on grazing lands[31].

Interactions among Drivers

Current agricultural production systems have been shaped by complex interactions among social, political, economic, environmental and technological drivers (Fig. 2). Societal concerns and demands do not directly affect farmers' choices of production practices, but do exert substantial influence through political and economic pressures. Social drivers impact the farm economy through consumer demand, and impact policy through votes. More direct social pressure is felt on the development and adoption of technology through its acceptance, such as with conservation technologies, or rejection, such as with genetically modified organisms (GMO). The utilization footprint, or amount of resources used by society, directly affects the environment.

Politics impact the development of technology through the availability of funds for research and development, expansion of intellectual property rights, alternative institutional arrangements to promote private–public research cooperation[32] and the adoption of technology through regulations. These political regulations also impact the environment. The political environment has a direct effect on farm economics through federal farm programs. Politics can also affect society through government food and nutritional programs. Producers have used political power by forming private organizations to support specific commodity groups. These private organizations have substantial political clout through lobbying efforts.

Technology interacts with society in two ways: (1) through impacts on the scale of farm production reducing rural populations and (2) increasing communication and awareness of issues at the national and global level. New technology, such as production practices or GMO, can positively or negatively impact the environment. The adoption of technology has a bi-directional interaction with the farm economy. While economic factors often determine adoption of new technology, implementing technology through production practices affects economic risks and returns.

Economics impact and are impacted by other drivers. Halloran and Archer[8] indicated that many future economic trends in the US point toward increasing specialization. For example, cattle slaughter facilities have gotten larger and are located near large feedlots[33]. These plants buy most of their cattle within a 150-mile radius but because of low transportation costs, some cattle come from 650 miles away[21]. With the increase in transportation costs, feedlots may need to be located nearer slaughter facilities. Drabenstott[24] suggested that increased use of supply chains will benefit fewer rural communities and concentrate specific agricultural production into certain geographical regions, similar to what has occurred in the poultry industry. Increased specialization may have a negative effect on both environmental awareness and social factors, such as farmer satisfaction and rural communities. Economics can impact society by creating wealth. Wealth creation can impact society via food cost influences on human health and nutrition, and availability of income for other uses. Halloran and Archer[8] also pointed out the increased demand for ethnic and other food choices in the US as well as social pressures which have altered buying decisions for the three biggest US fast food chains.

The environment also has complex interactions with the other drivers. The environment provides resources which directly affect both economics and technology. Also, increased environmental awareness has impacts on society

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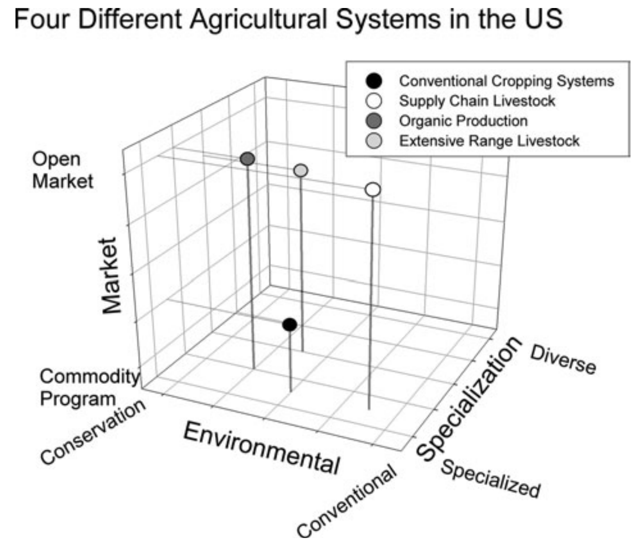

Figure 3. Four major and contrasting agricultural systems in the US. The four systems are conventional cropping systems, supply chain livestock systems, organic production systems and extensive range livestock systems. Descriptions of the systems are provided in the text.

as a whole. Additional social and political pressure has begun to come from the private sector in the establishment of focus groups, such as Ducks Unlimited or the Nature Conservancy, which place a high public emphasis on ecosystem services.

Predominant Production Systems in the US Today

The complex interactions among drivers have resulted in the development of at least four distinct major agricultural production systems in the US (Fig. 3). While these systems do not represent all of US agriculture, they are major and contrasting systems. The focus of US farm policy on relatively few commodities[13] and low margins[7] has produced a highly productive 'Commodity Crop Production' system that relies on high inputs and is heavily influenced by government policy (Fig. 3). This system is highly specialized, often focusing on one or two crops such as corn and soybeans, relies on farm policy for income and risk protection, and is impacted by government policies regarding conservation, such as the Conservation Reserve Program.

Decoupling of livestock and crop production[34] together with increased vertical integration, especially in the meat industry, have led to the development of another production system: 'Supply Chain Livestock Production.' As with crop production, this system is highly specialized, requires high inputs to maintain high productivity levels, and uses contract sales to reduce risk (Fig. 3). Consumer marketing needs and the desire to deliver a consistent product at a minimal cost have been key factors influencing the development of this production system. Markets can have an important influence on the success of this production system as similar products produced at a lower cost get a higher market share.

The growing social awareness of environmental impacts of conventional farming practices and concerns for food safety and consumer health have led to the development of niche markets in specialty crops such as organic production. Social drivers are key factors promoting the increased preference for organic foods[35]. Organic sales have been increasing 20% annually since 1990 and US organic cropland doubled between 1992 and 1997[36]. Changes in policy reflect these social concerns, and further encourage organic production. Moreover, the market 'pull', again responding to social pressures, is further enhancing the demand and markets for organic products[37]. Currently, the largest category of organic production is fresh produce, although organic dairy was the most rapidly growing segment in the 1990s[36]. While organic farming may be a lifestyle choice, economic benefits exist from the premiums often received for organic produce[36]. The rapidly expanding 'Organic Production' system relies on a diverse crop rotation to achieve environmental benefits for the entire system, resulting in greater diversification in organic systems than that seen in other systems (Fig. 3). Organic systems have had a history of marketing directly to the consumer but with the rapid growth of this segment[26] there is increasing concern among traditional growers about the potential industrialization of organic agriculture. As organic foods are more available in traditional supermarkets[36], expanding market opportunities may outweigh these concerns. The result is an emerging division between the philosophically committed small-scale growers and larger-scale operators[38].

'Extensive Range Livestock Grazing' systems are common in the western US. These systems are based on livestock grazing forage produced by rangelands. Although these systems rely on a diverse forage base, the animal component is highly specialized (Fig. 3). The lack of direct government payments in livestock production indicate the importance of markets in determining prices received for products. 'Extensive Range Livestock Grazing' systems are sometimes impacted by government policy in establishing grazing fees on public rangelands[39] as well as the impact of environmental concerns with livestock grazing on western rangelands. Lifestyle is a major concern of producers in 'Extensive Range Livestock Grazing' systems and a study of Colorado ranchers indicated that way of life was a primary motivator for ranchers to continue ranching[40].

The Role of Drivers in Defining Future Production Systems

Agriculturalists are the primary managers of over half of the globally available useable lands[41]. In the US, agriculture (cropland, range and pasture) accounts for 55% of the total land use in the contiguous 48 states[42]. The extent of land in agriculture means that agriculture can have a large impact on ecosystem services that provide benefits to the larger population[43]. However, the environmental impact of agricultural practices is often unquantified[41] and therefore costs and benefits are not measured. As agriculture intensifies, it can cause changes in ecosystem function[16]. Therefore both agricultural workers and society as a whole have vested interests in maintaining agricultural sustainability.

For US farmers to prosper, agricultural systems must be developed to meet future challenges[11]. However, the future influence and direction of the political/social, economic, environmental and technological drivers are unknown and create difficulties in tailoring agricultural systems to specific, as yet unidentified, challenges. Drivers can positively or negatively influence the ability of current agricultural systems to meet future challenges.

Social drivers

Social concerns are made apparent by changing market demands, as consumers continue to vote with their pocket-books. In 2000, a majority of families had two incomes[44], and little time for traditional food preparation. This has resulted in increasing amounts of the food budget being spent on convenience foods[1] and dining away from home[45]. This trend will likely remain constant or increase in the future, and amplify the desire for low-cost and consistent products, currently being met by the supply-chain livestock industry.

Environmental concerns have been identified as a leading social factor[7]. Increasing environmental, health and ethical concerns with agricultural production have resulted in rapid growth in organic agricultural systems. In response to social pressure, the three largest US fast food chains require that animals used in their products be produced under humane conditions[8]. These concerns, together with a desire for convenience foods, will probably act in concert to shape agricultural systems in the future. This social pressure will be manifested in either increased pressures in marketing or an increased emphasis in farm legislation, such as regulation of confined animal feeding operations.

Additional social concerns will become apparent with the potential emerging markets in bio-fuels and use of agriculture to produce pharmaceuticals. The Energy Act of 2005 set a requirement of an annual use of 7.5 billion gallons of renewable fuels by 2012[46] and the ethanol industry has expanded its annual capacity by over 2 billion gallons[47].

Global social pressures, seen in the cultural values in trading partners, will also influence markets and agricultural production in the US. Such issues as European trepidation over GMO corn and soybean, demands for better cotton quality, or the Japanese fear of bovine spongiform encephalopathy (BSE) will impact agricultural production. Because of these concerns, better tracking of agricultural products will become a necessity.

Political drivers

Policy impacts technology through funding for research and development, as the areas in which society puts its research dollars make the most progress[48]. The results of social pressures are often translated into political policies, on both a national and global scale. Within the US, USDA expenditures on conservation programs have expanded dramatically since 1983[49] and public support for the protection of agricultural lands from development is growing[50]. In addition, there has been increased interest in the role of agricultural lands in greenhouse gas emissions[51]. This has resulted in the development of mechanisms for agricultural producers to market carbon credits, such as through the Chicago Climate Exchange (http://www.chicagoclimatex.com/) based on conservation agricultural practices.

External social policies also affect US agricultural systems. Agricultural trade issues and domestic agricultural aid were blamed for the collapse of the World Trade Organization talks in July 2006[52]. Most of the direct payments from the US government target few crops, such as corn, soybeans, wheat, rice and cotton[13]. These crops account for 70% of the harvested acreage in the 48 contiguous states in 2002[42]. In 2004, government payments represented 21.9% of the net cash income of farms receiving payments[53]. Loss of these payments would represent a major income loss for farms that receive government payments. External political factors can also affect the sales of non-subsidized products. Japan's concerns over incidents of BSE in the US cattle herd resulted in a 1 billion dollar loss in exports to Japan, although it had little overall impact on beef prices[54]. Still, strong political pressures in major agricultural trading partners could impact the ability of US producers to export their products.

Economic drivers

Future economic trends for US agriculture will be affected by national and global pressures. Halloran and Archer[8] point out that most of the market trends appear to favor larger and more specialized production systems. However, they also indicate that the price premium for organic products is increasing, suggesting that demand is increasing faster than supply. Markets for organic and also sustainable, locally produced, grass-fed and free-range labeled products have also increased[8], suggesting that social concerns of US consumers are being felt in the market place. Increasing demand for bio-fuels could also impact corn and soybean prices, although it is not clear to what extent[46,47].

Internal and external political impacts on US agricultural policy may result in changes to the system of agricultural payments. While the 1996 Farm Bill attempted to decouple agricultural supports from production decisions, it is unclear how farmers are reacting to these changes[8]. Archer et al.[7] point out that the US consumer's demand for environmental quality may grow faster than food demand which could result in future payments to farmers to manage landscapes rather than produce food, similar to that seen in other countries.

Agriculture is operating in a global environment, which increases the competitive pressures faced by agricultural producers and can negatively impact production. Brazil and Argentina have expanded their share of the global market of corn and soybeans due to a suitable climate, abundant land resources and favorable cost of soybean[55]. Similarly, the loss of much of the US textile industry and increasing demands from off-shore cotton textile plants have increased pressure on American farmers to improve the quality of cotton fiber while reducing the costs of production. Increasing demand for fresh fruits and vegetables year round[56] has led agricultural imports into the US to increase[57].

Conversely, global pressures from increasing populations and improvements in the standard of living in developing countries will increase the demand for food, feed, fuel and fiber, and may allow farmers to capitalize on emerging markets. Internal US need for corn and soybeans may increase if demand for ethanol and bio-diesel grows. This may result in increases in corn and soybean prices either through greater demand[47] or shifts from soybean to corn[46]. Similarly, improvements in the standard of living in other countries may increase the demand for animal protein, raising both animal and feed prices. Such changes may encourage further specialization in animal and crop production systems.

Environmental drivers

One of the primary environmental concerns is the impact of climate change on agriculture and how agriculture can mitigate the impacts of greenhouse gases. Modest global warming has been suggested as being beneficial to agriculture in high-latitude countries such as the US[58] but Reilly et al.[59] pointed out that lower crop prices because of increased productivity could negatively affect producers. Overall, there is a great deal of uncertainty in forecasting impacts of climate change on net ecosystem productivity[60].

In 2001, invasive species in the US were reported to result in losses of $120 billion annually[61]. There are approximately 50,000 non-native species in the US and their number is increasing[62]. Entry of new pests such as Asian soybean rust (*Phakopsora pachyrhizi*) could result in losses of $240 million to $2 billion annually[63]. Other diseases such as bird flu or outbreaks of BSE could devastate the US livestock industry.

Increasing emphasis on ecosystem services may also affect agriculture in the future. Agriculture represents a large percent of the land use in the 48 contiguous states[42] and because of its extent can have a large impact on ecosystem services. Societal emphasis on these services may force agricultural producers to focus more on managing landscapes than on production[7]. However, many farmers are philosophically[64] and economically[20] attached to their current production systems. Changing attitudes toward managing for ecosystem services rather than production may be one of the greatest challenges in the future.

Technological drivers

Technological solutions have historically been developed to address the problems and concerns raised by other drivers and influences of the system. For example, problems with yield limitations led to genetic improvements, while concern for the environment has resulted in development of conservation systems. On the whole, we have faith in the ability of society to expand its knowledge base and invent solutions to the unknown problems of the future.

To address societal concerns and maintain a competitive advantage, farmers frequently feel pressured to incorporate technological advances into their production system[7]. Pressure to implement the latest technology the fastest is real, as the earliest innovators are poised to reap the (potentially) biggest gains[65]. However, they also take the biggest risk should the technology not prove useful.

Improvements in production technology may help address social concerns for the environment. For example, continuous cropping with no-tillage technology resulted in a consistent increase in soil organic carbon while continuous cropping under conventional tillage resulted in soil organic carbon losses[51]. Although, livestock manure from confined feeding operations is a potential source of air and water quality degradation[66], livestock waste has the potential to be used in bio-ethanol production[67] or as a fertilizer, which may reduce fossil-fuel use. Technological advancements will not solve all of the environmental problems related to agriculture. However, within the agricultural system, technology should be considered when developing solutions.

Potentially the greatest impact of future technologies will come from advances in information technologies. These tools allow increasingly rapid exchange of information, reducing lag time between senders and receivers. Information systems greatly expand the capacity for management, sharing of expertise, and the knowledge base available for decision-making. These systems also allow the transfer of scientific information to the end user more directly through decision support tools and expert systems. Unfortunately, increased knowledge gained through tracking of production may reduce personal privacy.

Adaptability

The overriding emphasis in the preceding discussion has been on the uncertainty of future trends. For every possible trend there exist several scenarios as to how that trend could play out. Holling[5] points out the need for adaptability to achieve sustainability. As has been discussed, many current US agricultural systems are highly specialized[1], and many current economic trends predict future specialization[8]. However, a high degree of specialization reduces the ability of a system to adapt. While US agriculture has been suggested to be resilient in responses to individual factors, such as an outbreak of Asian soybean rust[63], a simultaneous convergence of several trends could be devastating. In addition, managing risk is often managing uncertainty. Highly specialized systems commonly utilize economic methods (e.g. contracting or hedging) rather than biological methods (e.g. crop rotation) to manage risk.

US agricultural production is remarkably diversified, but this diversity is not evident on individual farms. This lack of farm level diversity can affect the sustainability of individual production units and potentially the entire system. A sustainable system will incorporate economic, environmental and social aspects[68], as well as being adaptable[5]. Sustainable agricultural systems at the farm level will need to encompass the three aspects of sustainability while maintaining adaptability. We suggest that to achieve this balance, successful future systems will need to incorporate both economic and biological methods as well as increased access to relevant information. An integrated agricultural system, as defined by Hendrickson et al.[6] may be the best method to achieve sustainability.

However, a large question remains unanswered. If integrated systems can achieve the desired balance and adaptability, why is US agriculture becoming increasingly specialized? We suggest that there are three major factors that have limited the adoption of integrated systems. The first factor is the economics of the farm program. Although the 1996 farm bill decoupled US agriculture to a large degree, the continued use of Loan Deficiency Payments (LDPs) and crop insurance have resulted in a continued lower financial risk in growing program crops. Halloran and Archer[8] pointed out that farmers have continued to grow program crops because of uncertainty in the upcoming farm programs, and Archer et al.[7] indicated that financial returns are low enough that farmers prefer to increase farm size to increase financial income versus the risky approach of trying to increase income on their existing acreage. The continued reliance on crops in the farm program is illustrated by the fact that program crops made up 70% of the harvested cropland in the contiguous 48 states[42].

The second factor is market entry. If a producer wishes to integrate livestock or alternative crops into his system, market entry can be difficult. In the meat industry in particular, vertical integration and the use of contracts can result in barriers to small-scale producers. Drabenstott[24] pointed out that there is also a growing regional specialization. For example, most poultry processing plants are located in the southeastern US[24]. Markets can also pose a barrier to crop producers who wish to grow alternative crops and may have to truck their crops long distances because of the lack of a local infrastructure to handle alternative crops.

The third factor is age demographics. The farm population is aging and the rural communities they depend on are shrinking. The current average age of US farmers is 56.3 years old[69]. As farmers approach retirement, they may not wish to take up the additional management and physical intensity needed in integrated systems. Also, more integrated agricultural systems may require additional labor. A shrinking rural labor pool and/or competition from other non-farm industries may limit producers' ability to get dependable labor for their operations. The increase in off-farm income on many farms[1] may also decrease the family labor pool. Aging farm population may also explain why leasing has increased from 35% in 1950 to 41% in 1997[70]. Because of land tenure insecurity, lesees may be less likely to adopt certain strategies, especially those that impact soil quality. For example, cash renters have been shown to be less likely to adopt conservation practices than are landowners or share renters[70]. The problem then is developing a system that can achieve the goals of sustainability and adaptability while overcoming these obstacles.

Integrated agricultural systems can enhance adaptability and sustainability. Currently, some agricultural producers have integrated through farmer controlled vertical integration. This is in contrast to the current industry vertical integration that is outside of farmers' control. An example can be seen in the catfish industry that requires catfish feed and catfish processing. Because these industries are capital intensive, individual farmers have developed cooperatives to pool economic resources into feed and processing plants. By retaining some control of these secondary industries as part owner, the farmers recoup some of the expense while still maintaining flexibility. Another example is farmer investment in ethanol plants. These plants provide an alternative market for corn as well as providing byproducts for animal feeds. These types of multiple enterprises that contribute to the overall production can be used by farmers to recapture some of the dollars spent on production. By forming cooperatives or partnerships, individual farmers can expand their enterprises, while sharing the risk. This would build an integrated and dynamic production system at a higher level than the individual farm.

In contrast to farmer-controlled vertical integration, Hendrickson et al.[6] suggested the use of dynamic-integrated agricultural systems as a horizontally integrated system which could potentially meet sustainability and adaptability goals. Dynamic-integrated agricultural production systems are agricultural production systems with multiple enterprises managed in a dynamic manner that interact in space and/or time and these interactions result in a synergistic resource transfer among enterprises[6]. This system uses annual and intra-annual decision-making to decide what to grow based on the producers' goals, management concerns and exogenous factors. The dynamic aspect of this concept is a management philosophy that requires management decisions not be predetermined but rather made at the most opportune time with the best available information[6]. Its use of multiple enterprises and tactical decision-making will maintain producer flexibility in a rapidly changing environment. Because of its emphasis on producers' goals and management concerns, producers can modify it to reflect their current labor and management abilities. A bi-directional flow of information from producers to researchers allows producers to use the best possible information in making management decisions. As technology, and in particular, information technologies, grow, these can be used by producers to ease the management burdens of dynamic systems. These technologies will allow producers faster and more complete and accurate access to information on marketing and management. The challenge is the strategic design of these systems to allow them to respond to changes in an external driver to gain benefits but still maintain sufficient stability[6,71].

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