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Long-term Trends in Population, Farm Income, and Crop Production in the Great Plains

WILLIAM J. PARTON, MYRON P. GUTMANN, AND DENNIS OJIMA

Despite concern about the social, economic, and ecological viability of the agricultural Great Plains, a century-long examination reveals that threats to society, economy, and environment are counterbalanced by surprising stability and the potential for short- and medium-term sustainability. Populations in metropolitan counties have grown, whereas rural populations may now be stable; both metropolitan and rural populations are aging. Technological advances in the past five decades enhanced production in the Great Plains despite periodic adverse economic and environmental conditions, and increases in crop yields, animal feeding, and government payments have sustained agriculture and income. Nonmetropolitan counties with irrigated farming have been more successful than those without irrigation. However, overuse of groundwater and rising energy costs for irrigation affect economic margins and the ability to sustain environmental integrity. Long-term projections of agricultural productivity must balance recent stability with the risks posed by reduced irrigation, higher energy prices, disruptive demographic changes, and further loss of environmental integrity.

Keywords: biogeochemical modeling, land-use change, population, Great Plains, agricultural economy

The long-standing debate over the trajectory of extensive agricultural production in the US Great Plains deserves a new look. At issue is whether it is possible in the long term to maintain an agriculturally oriented population in this region, as well as in other similar regions around the world. One group of analysts, whom we call "catastrophists," sees Great Plains farming, especially dryland production of small grains, as an ongoing ecological mistake that will lead to another disaster like the crop failures and soil erosion of the 1930s (Sears 1935, Lockeretz 1978, Worster 1979, Popper and Popper 1987). Another group, the "adaptationists," recognizes the negative environmental effects of extensive cropping in this semiarid region, yet acknowledges the benefits of technical and social innovations, including adaptations to climate variability ranging from no-till management to crop insurance, which adaptationalists believe have stabilized the agroecosystem on the plains (Webb 1931, Thornthwaite 1936, US Great Plains Committee 1936, Malin 1944, Hewes 1974, Hargreaves 1993, Cunfer 2005). The two schools interpret the Dust Bowl droughts differently. Catastrophists emphasize the influence of farming practices that were incompatible with the environment, whereas adaptationists regard climatically extreme conditions as the main cause of soil erosion, economic loss, and out-migration. Given recent advances in agricultural practices, the question for the Great Plains is whether these technologies and adaptations can keep pace with environmental degradation resulting from declining water resources, impacts on soil and water quality, greater climate stress due to climate warming, and changing sociopolitical perspectives on agricultural land use in the Great Plains.

Most of the available historical data on the status of Great Plains agriculture support the adaptationists. Except for two important points of punctuation (in the 1930s and 1970s), the region's experience in the areas we describe has followed

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a set of fairly smooth trajectories. These paths do not always go in the same direction. What is striking to us, however, is that despite the risks, there have been few abrupt changes of direction, and the two points of punctuation that are best known (the drought and depression of the 1930s and the increase in prices in the 1970s) had consequences that, although lasting, were eventually incorporated into a relatively smooth line of change. The persistence of extensive cropping, and the 100% to 300% increase in crop production since 1940 for the major crops, falsifies the direst predictions of the catastrophists.

Our analysis focuses on long-term patterns in population, agricultural production, and economic activity. In the US Great Plains, human population data show continued regional growth, but detailed data show finer-grained patterns, such as out-migration from the most agricultural counties and in-migration to metropolitan (metro) counties (those with a population of 50,000 or more) and near-metro counties. These population movements reflect both national demographic trends and the changing nature of agriculture, whereby technological change leads to reduced labor demand. The decrease in total population and the increase in population aging since 1930 in nonmetropolitan (nonmetro) counties where dryland agriculture predominates reflect a weak environmental signal in the population data (Gutmann et al. 2005). The economic status of Great Plains agriculture has been steadier than many would have expected, with total inflation-adjusted gross income slightly higher and net income somewhat lower over the long term because of increased animal production, growing government payments, and higher crop yields.

Researchers on both sides of this argument would agree that regional natural ecosystems have been disrupted and degraded by extensive crop and livestock production on the plains, yet they would probably disagree about whether this threatens the long-term trajectory of agriculture. It is useful to note that during much of the period when extensive agricultural expansion took place in the Great Plains, climate conditions were highly conducive to cropping systems. Given historic cyclical patterns of drought in the region, current agricultural practices may not be appropriate if these drought conditions resume and persist, as has occurred in the past (Miner 2006).

During the past five decades, the Great Plains region has displayed long-term differential patterns for three types of counties: metro counties, dryland nonmetro counties with minimal irrigation, and nonmetro counties with substantial irrigation. We separated the counties into these categories using 1990 population census data and 1997 agricultural census data (figure 1 shows the location of these counties within the Great Plains). Metro counties include those that were within a US Census–defined metropolitan area in 1990. There was little change in the inclusion of counties in metropolitan areas from 1980 to 2000. The 1990 definitions effectively represent the attributes of metro counties at the end of the 20th century. Irrigated nonmetro counties are those with more than 50,000 acres (about 20,000 hectares [ha]) of irrigated, harvested cropland, and with a total harvest of irrigated crops equal to more than 25% of the county's total cropped area, as reported in the 1997 agricultural census. There is some year-to-year variation in the amount of land irrigated, but the selection of counties using 1997 criteria produces results that are not significantly different from those using other years, especially 1992 and 2002. Irrigated cropland in these counties constitutes nearly 74% of all irrigated cropland in the region, substantiating our categorization. We describe the remaining counties as dryland nonmetro.

Although this division of counties emphasizes conditions at the end of the 20th century, we believe it is the most effective way to capture changes in the region and to balance past conditions with future prospects. This categorization is in contrast to other ways in which US counties have been divided, and it yields a different picture of the agricultural and demographic characteristics of the region's counties. Our approach recognizes that there is great diversity within a region as large as the Great Plains, but that a simple classification has the potential to produce important insights. Although the raw materials for these data are well known, they must be assembled and analyzed to help understand the past, present, and future of this environmentally sensitive region.

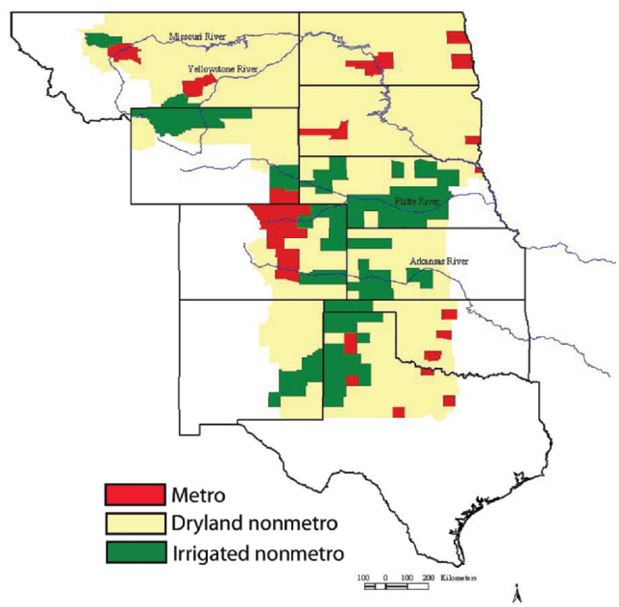

Figure 1. Counties within the Great Plains region. We classify the counties into three categories: Metro counties are those with populations of 50,000 or more in 1990. Irrigated nonmetro counties have 50,000 acres (about 20,000 hectares) or more of irrigated harvest cropland, with more than 25% of the total harvested cropland irrigated. Dryland nonmetro counties are what remain, with neither metro nor irrigated nonmetro characteristics. The largest metro area is along the Front Range of the Rocky Mountains in Colorado. Most irrigated nonmetro counties have access to water from rivers or the deep aquifers of the region, primarily the Ogallala.

Can long-term trends in population, production, and income reveal the region's potential for rapid change? What has the trajectory of change been in the past? If it has largely been one of smooth changes, what is the potential for abrupt transformations? The answers to these questions will provide a much better understanding of what has happened in the past, and some insight into what might happen in the future (although we recognize that predicting the future is extremely difficult).

To perform this analysis, we assembled a comprehensive Great Plains database that includes information about population, land use, and farm income for the region's counties (Gutmann et al. 1998, Gutmann 2005a, 2005b, USDA n.d.). The data came from federal censuses of population and agricultural production (Gutmann et al. 1998, Gutmann 2005a, 2005b). State-level agricultural income data from 1949 to the present are available from the US Department of Agriculture (USDA n.d.). To analyze net income and the components of income, we combined data from this source beginning in 1950 and ending in 2000 for the 10 Great Plains states. All income and price data in this article are inflation adjusted using the US Consumer Price Index (USDOL 2005).

Historical land-use patterns

Nearly 150 years ago, settlers of European origin arriving in the Great Plains from other parts of the United States and directly from Europe began the process of converting what had been a sparsely populated open prairie into a checkerboard of fields, pastures, and towns. Their arrival transformed the land and the lives of its inhabitants (West 1998) but also showed limits beyond which it would be difficult to venture, at least in terms of converting land to agricultural uses (Cunfer 2005, Gutmann et al. 2005). In the Great Plains—unlike regions farther east, where woodlands yielded to the axe and underwent a near-complete conversion to plowed fields—low precipitation and regional soil characteristics prevented farmers from cropping more than 70% of land in the east and 25% in the west, an average of 50% overall. Humans have nonetheless managed to transform the landscape of the Great Plains in many ways, a process that has continued into the 20th and 21st centuries with the advent of inorganic fertilizers and deep-well irrigation.

The 100-year historical patterns for land use in metro and nonmetro counties (figure 2) show that total farmland area increased rapidly from 1900 to 1945 and peaked in 1959. In 1900, metro counties were already more developed as farmland than nonmetro counties. Metro counties lost 25% of their total farmland from 1959 to 1997, with more than 90% of this farmland loss coming from rangeland. Nonmetro counties started losing farmland in 1959, with no loss of cropland, while rangeland declined less than 5% since 1959. Both metro and nonmetro counties lost total harvested cropland from 1950 to 1964, and then had stable levels of harvested crop area after 1964. Most of the loss of harvested cropland from 1950 to 1964 came from reductions in harvested wheatland. Nonmetro irrigated and nonmetro dryland counties had similar patterns of decline in harvested cropland since 1950, but the irrigated counties lost less harvested cropland.

The different scales for the two components of figure 2 reveal just how little farmland and cropland have ever been located in the metro counties, and therefore how little risk there is that urbanization, and even suburbanization, will swallow up large amounts of agricultural land in the Great Plains. Although this is not the case in Front Range Colorado counties (Parton et al. 2003), it is important to note for the region as a whole. The number of metro counties in the region has increased steadily since 1960, when there were 20 (the same number as in 1970), to 33 in 1980, 29 in 1990, and 32 in 2000 (Ruggles et al. 2004). The increase of metro counties shows that residences and businesses have expanded into formerly agricultural areas, but the small number of metro counties, and the small amount of farmland in them, confirms our point.

Population

A number of authors have suggested that the decline and aging of the population in nonmetro Great Plains counties pose the potential for significant problems for the long-term sustainability of the region (Rathge and Highman 1998, Rowley 1998, Johnson and Rathge 2006, Leonard and Gutmann 2005). Population in metro, dryland nonmetro, and irrigated nonmetro counties increased from 1900 to

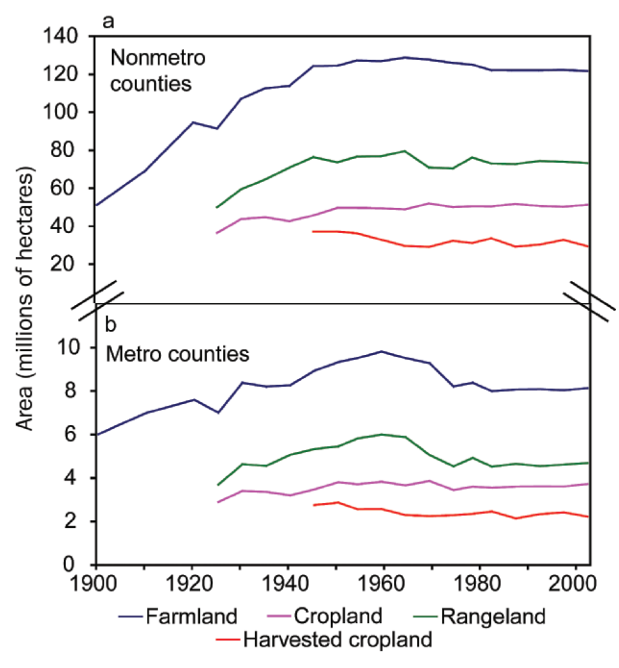

Figure 2. Historical land-use patterns for (a) nonmetro and (b) metro counties in the Great Plains. Irrigated nonmetro and dryland nonmetro counties are combined because they have similar characteristics over time. Most agricultural land is in nonmetro counties. The differences in scale between metro and nonmetro counties show that there is little risk of metro sprawl overwhelming agricultural land in the Great Plains.

1930 (figure 3a). Population in dryland nonmetro counties decreased after 1930, with a 19% reduction from 1930 to 2000. Irrigated nonmetro counties lost population from 1930 to 1940, but gained population after 1940 as irrigated harvested land increased from 0.8 million ha in 1940 to 6.5 million ha in 1980. In the metro counties, population increased throughout the 100-year period, adding more than 300% since 1950. Before 1940, there were more males (53%) than females (47%) in the population of the whole region (irrigated and dryland nonmetro and metro), but after 1940, the trend reversed, and 51% of the population were female in 2000. The decline in the male population since 1930 caused most of the decrease in total population of the dryland nonmetro counties, while female population has remained stable since 1940.

Despite alarms about population loss, our research shows that the population of irrigated and dryland nonmetro counties has stabilized and perhaps increased slightly since 1960. However, the interpretation of this finding depends on one's point of view. The population of the United States has grown rapidly since 1945, and has become mostly urban and suburban. If one's standard for the Great Plains is that it should have kept up with population growth in expanding metro regions, then our conclusion that the region is undergoing adequate, though modest, population growth is wrong. If one's point of view is that population stability and some growth is a reasonable target for a rural region that is relatively far from the coasts, then stability or slight growth is a reasonable—and not unfavorable—conclusion.

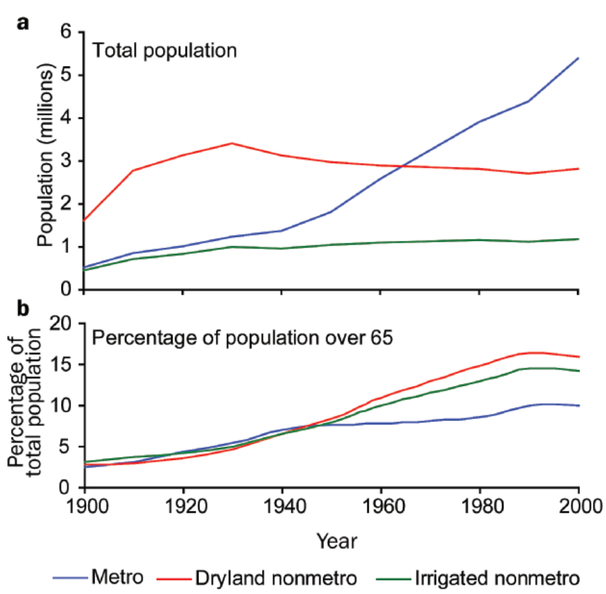

Figure 3. (a) Total population and (b) percentage of population over 65 in metro, dryland nonmetro, and irrigated nonmetro counties in the Great Plains. The dramatic rise in the population of metro counties shows the influence of Denver and nearby cities. The population of the irrigated nonmetro counties has risen slowly through time, while that of the dryland nonmetro counties has declined slowly since 1930, stabilizing in 1990. Source: Gutmann 2005a, 2005b.

Aging is another important concern. The proportion of the population over age 65 (figure 3b) increased during the 100-year period, but after 1940, the nonmetro counties experienced a more rapid increase than the metro counties (16% for dryland nonmetro, 14% for irrigated nonmetro, and 10% for metro counties in 2000). We observed similar trends in the proportion of the population over 55 for metro and nonmetro counties (not shown). The aging of the nonmetro population is largely a consequence of the out-migration of the working-age population from agricultural communities (Johnson and Rathge 2006). This out-migration of younger cohorts has recently had the severe secondary consequence of reducing fertility and therefore intensifying the reduction in many aspects of community life, especially in schools and activities focused on children, which may lead to acceleration of further out-migration. It remains to be seen whether the relatively steady (and relatively young) populations of counties with irrigated agriculture will avoid the loss of their younger population or whether the demographic changes in these counties are only slightly slower because of improved economic conditions and, in the long term, these counties will begin to age as others have done.

Crop production and technology

The major harvested crops in the Great Plains are wheat, hay, corn, and cotton. Wheat is the dominant harvested crop (50% of the harvested land), followed by hay (20%), corn (15%), and cotton (4%). Cotton is grown primarily in the southern Great Plains (Texas, Oklahoma, and New Mexico). Other important harvested crops include barley (3%), sorghum (2%), and sugar beets (1%). Historical data (figure 4a) for the production of corn, wheat, hay, and cotton show that before 1945, total production of these crops was stable except for low production during the 1930s. After 1945, there was a dramatic increase in production for all of the major crops. Cotton production doubled from 1945 to the 1950s, and corn, wheat, and hay production rose sharply from the 1950s to the early 1980s. The major cause of increased production was improved crop yield per ha, despite the reduction in total harvested area from 1950 to the 1960s. The applications of crop technology that contributed to additional crop yields include greater irrigation using fossil water supplies (resulting in two to four times greater yields for irrigated than for dryland crops in the Great Plains; Parton et al. 2003), supported by relatively inexpensive energy supplies for farm operations, increased application of inorganic fertilizer (figure 4c), improvements in tillage practices (Smika and Wicks 1968) and crop varieties, greater herbicide and insecticide use, and increased use of summer fallow for the wheat system (ARS/USDA 1974).

Cotton production data (figure 4a) show a 400% increase in cotton production since 1940. Production rose as a result of continuous increases in yields per ha, from 0.7 bales per ha in 1940 to 2.5 bales per ha in 1997. The primary causes for the

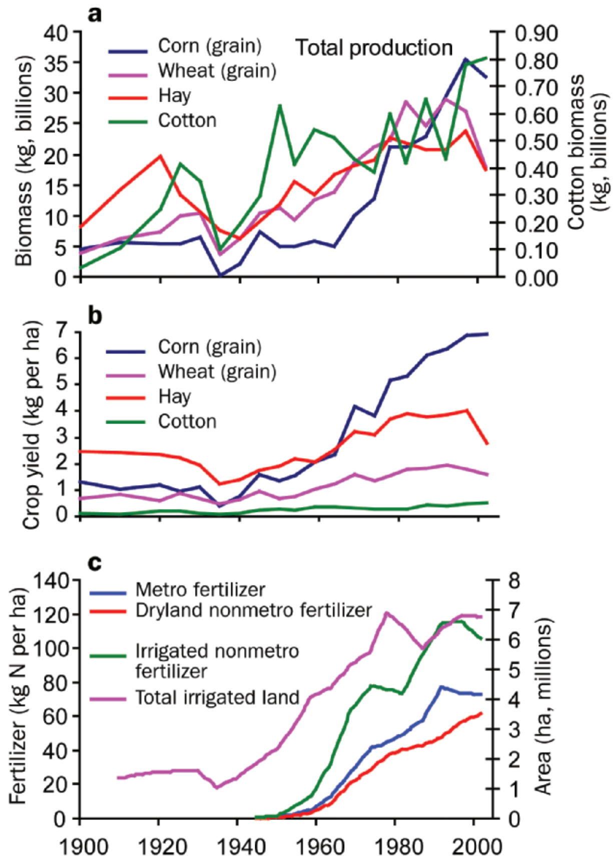

Figure 4. (a) Total Great Plains plant production for corn, wheat, hay, and cotton, and (b) average Great Plains crop yields for the same crops. (c) Total area of Great Plains irrigated nonmetro land and average nitrogen inputs from fertilizer for metro, dryland nonmetro, and irrigated nonmetro land. Total production and yields have risen steadily since the 1930s, with the greatest increases in corn and hay, the crops that benefit most from irrigation. Cotton production and yields have grown the least. The bottom panel shows the growth of inputs: the rise of fertilizer application from very low levels to more than 100 kilograms per hectare for corn in 1992, and the large increases in irrigated land that took place from 1950 to 1974. Source: Gutmann 2005a.

higher yields were the introduction of improved crop varieties and the increased use of irrigation, inorganic fertilizer, and insecticides. The major increase in cotton fertilizer application occurred between 1940 and 1960.

The wheat data show that production was low until 1940, increased 100% from 1940 to 1964, and went up another 100% from 1964 to 1982. These increases were caused by wheat yields that improved from 750 kilograms (kg) per ha in 1940 to 1300 kg per ha in 1964 and 1900 kg per ha in 1982. The yield increases from 1940 to 1964 were correlated with an increase in summer fallow (ARS/USDA 1974), improved water storage in summer fallow through stubble mulching techniques (40% increase; Smika and Wicks 1968), increased application of nitrogen fertilizer (figure 4c), and improved wheat varieties (Quisenberry and Reitz 1974, Olmstead and Rhode 2002). The additional yield per ha from 1964 to 1982 is correlated with increases in nitrogen fertilizer application (figure 4c), typically from 10 to 30 kg nitrogen per ha in 1964 to 40 to 90 kg per ha in 1982. Wheat yields per hectare have remained stable, and rates of nitrogen fertilizer application have increased slowly (< 10 kg nitrogen per ha) since 1982.

Corn production was stable until 1964 and then increased by more than 400% from 1964 to 1997 as a result of planting more land in corn (a 100% increase since 1964), which brought about a growth in yields from 3000 kg per ha in 1964 to 7000 kg per ha in 1997. Corn yields grew because of increased irrigation (figure 4c), improved crop varieties, and application of nitrogen fertilizer (figure 4c), which went from 60 kg nitrogen per ha in 1964 to more than 160 kg per ha in 1980. Levels of nitrogen fertilizer application have remained fairly steady since 1980 (Metherell et al. 1995). More than 65% of the corn production in the Great Plains is produced in the irrigated nonmetro counties.

Hay production has also increased, primarily because of increased yields per ha, with a 200% increase from 1950 to 1980. Improved plant varieties and increased irrigation of hay (a 100% increase from 1950 to 1980) are the primary factors contributing to larger hay yields. Hay yields from irrigated land, which were approximately 100% higher than dryland yields in 1950, were 300% to 400% higher than dryland yields after 1980 (Smika and Wicks 1968).

To summarize, the most important technological factors that have contributed to all crop yield increases are increased irrigation, pest management and fertilizer applications, improved tillage practices, and improved plant varieties. It is difficult to separate out the impact of each factor, because greater fertilizer use and more irrigation occur in conjunction with stepped-up use of herbicides and insecticides and with continued improvement in plant varieties.

Some of the improvements in agricultural technology have had negative environmental impacts. The expansion of the summer fallow system for winter wheat has produced greater losses of soil carbon (Metherell et al. 1995), increased nitrous oxide (N_2O) fluxes from the soil (Mosier et al. 1997), and more sodic land problems. More intensive use of irrigation, nitrogen fertilizer, herbicides, and insecticides has resulted in leaching of nitrate (NO_3), pesticide, and herbicide into groundwater (Matson et al. 1997, Rabalais 2002), reduction of deep aquifers and fossil water supplies, increased N_2O emissions (Mosier et al. 1997), and increased runoff of agricultural chemicals into lakes and ponds (Matson et al. 1997, Rabalais 2002). Future research about the long-term prospects of Great Plains agriculture must consider the trade-off between successful crop production and the long-term environmental impacts of agricultural systems that produce gains in crop yields (Cassman et al. 2002, Fixen and West 2002).

The impact of historical and current land-use practices in the Great Plains on county-level carbon budgets and fluxes of NO_3 and N_2O has been evaluated in two recent papers.

Parton and colleagues (2005) simulated the impact of observed changes in land use for the last 150 years derived from county-level agricultural census data (Gutmann 2005b) on soil carbon levels using a set of Century model runs that represent the major land uses for each county. The major land-use patterns represented by the model include irrigated agriculture, dryland agriculture, grazed grasslands, and the Conservation Reserve Program.

There is a general pattern of soil carbon loss following initiation of cultivation for 30 to 50 years, with up to 50% loss of soil carbon (figure 5). The initiation of irrigation (figure 5a, 5b) after 1950 in the Great Plains resulted in an increase in soil carbon for farms using corn–alfalfa rotations in the central and northern Great Plains counties, whereas irrigated cotton rotations in the southern Great Plains resulted in substantial decreases in soil carbon. Parton and colleagues (2005) suggest that irrigated corn–alfalfa rotations in the central and northern Great Plains have resulted in a net carbon storage of 21.3 teragrams since 1950. Increased carbon storage for the corn–alfalfa system results from large increases in soil carbon inputs from alfalfa roots and corn stover, while decreases in soil carbon for the cotton rotations occur because of low inputs of plant residues and elevated soil decomposition rates associated with reduced water stress, the latter caused by irrigation of soils with high background soil temperatures in the southern Great Plains. The dryland nonmetro counties (figure 5c) show a pattern of slight increases in system carbon since the 1960s, which result from the transfer of cropped agricultural land to grasslands, land converted to the Conservation Reserve Program, and improved crop yields resulting from advanced cultivation practices and increased fertilizer inputs.

Del Grosso and colleagues (2006) used the DAYCENT model to simulate county-level total N_2O gas fluxes and NO_3 leaching below the rooting profile for the United States. The model simulates all of the major agricultural land uses for each US county, using computer runs for each of the major land-use practices, and then calculates county-level NO_3 leaching and N_2O trace gas fluxes by weighting the results of each model run depending on the observed area represented by each land-use practice. The observed fertilizer inputs for each of the crops are included in the model runs. The regional N_2O gas fluxes and NO_3 leaching follow similar patterns (figure 6), with both being low in the western Great Plains and increasing rapidly eastward across North and South Dakota, Kansas, and Nebraska. The eastward increase in NO_3 leaching and N_2O gas fluxes results from a general pattern of increased cultivation: less than 30% of the land in the far western Great Plains region is cultivated, compared with more than 70% of the land in the far eastern part of the Great Plains (Gutmann et al. 2004, 2005, Cunfer 2005). This regional land-use pattern is also associated with an increase in nitrogen fertilizer use going eastward across the Great Plains. Nitrate leaching and N_2O gas fluxes follow the same pattern because both increase with greater cropping intensity and nitrogen fertilizer application.

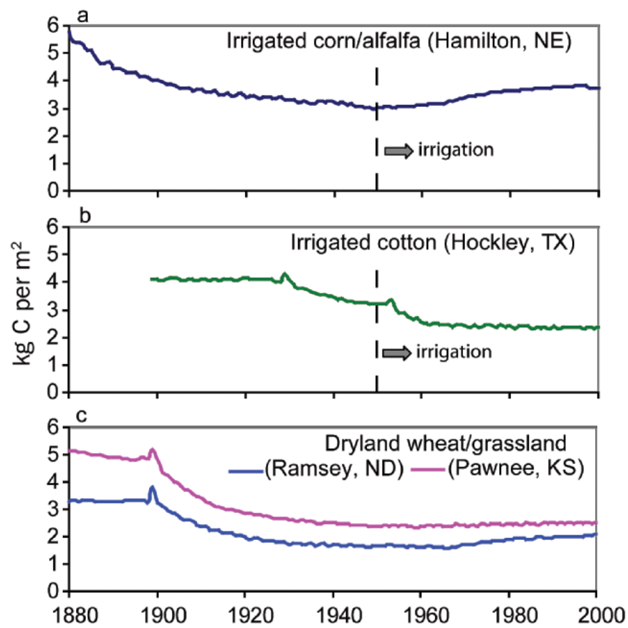

Figure 5. Century model–simulated (Parton et al. 2005) county average soil carbon levels for (a) Hamilton, Nebraska, (b) Hockley, Texas, and (c) Ramsey, North Dakota, and Pawnee, Kansas. Irrigated corn–alfalfa rotations are dominant in Hamilton; irrigated cotton is dominant in Hockley; and dryland wheat–grassland systems are dominant in Ramsey and Pawnee. Soil carbon levels decrease following the initiation of cultivation for all regions. Irrigation of cotton tends to decrease soil carbon, whereas irrigated corn–alfalfa rotation increases soil carbon levels.

The other striking pattern evident in these results is a high value for NO_3 leaching and N_2O gas fluxes associated with the irrigated regions in the Great Plains (cf. figure 1, figure 6). The results show high levels of NO_3 leaching and N_2O gas fluxes for irrigated regions associated with the Platte River in Nebraska, the Arkansas River in Kansas, and the Ogallala Aquifer in western Texas. High levels of NO_3 leaching and N_2O gas fluxes result from the large amounts of nitrogen fertilizer applied to irrigated agricultural systems (see figure 4c) and the use of intense soil cultivation practices.

Market value of agricultural products

US agricultural census data for the market value of agricultural products, available since 1950 (figure 7), show that the inflation-adjusted gross income for all agricultural products follows a similar overall pattern for the metro, irrigated nonmetro, and dryland nonmetro counties. Income was fairly stable prior to 1964 and then increased rapidly in all counties from 1964 to 1978; more than 90% of this change came from an increase in animal products. After 1978, there was a steep decrease (> 90%) in total agricultural income, including a substantial decrease (> 55%) in income from animal products (livestock) for the metro counties. The nonmetro

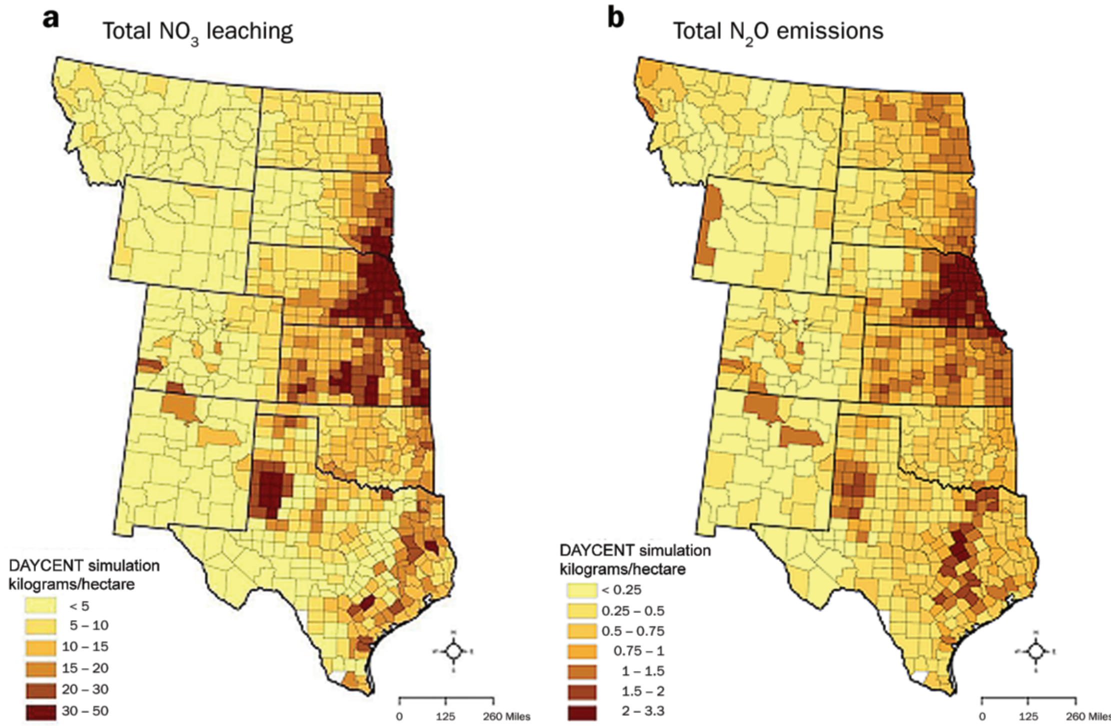

Figure 6. Average DAYCENT model–simulated (a) nitrate (NO_3) leaching below the rooting depth and (b) nitrous oxide (N_2O) gas fluxes for counties within the Great Plains (Del Grosso et al. 2006). The county average flux values were derived by weighting the simulated fluxes for each of the model runs that represent the major land uses by the observed area for the specific land use. High levels of NO_3 leaching and N_2O fluxes occur in the eastern Great Plains and irrigated nonmetro counties.

dryland and irrigated counties showed more moderate decreases in total agricultural and animal product income during the same period. In recent years (1987–1997), there has been a slow increase in agricultural income from all sources for the irrigated nonmetro counties. The data for the entire Great Plains region show that the percentage of total agricultural income that derived from animal products increased from 20% in 1950 to more than 52% in 1997. The fraction of the total agricultural income for the Great Plains that comes from the irrigated nonmetro counties (which make up approximately 20% of the total land area of the Great Plains) increased from less than 20% in 1950 to more than 50% in 1997. The large increases in the value of animal products and in total agricultural income for the irrigated nonmetro counties occurred from 1964 to 1978, in conjunction with a dramatic increase in irrigated land planted with corn and in corn yields (figure 4). These counties provide 65% of total Great Plains corn production.

Inflation-adjusted values for crop income for the metro and nonmetro counties were steady from 1950 to 1997 (figure 7), but there was an increasing trend in crop income for irrigated nonmetro counties. All three groups of counties had their highest income from crops in 1978, a result of high crop prices at that time. The relatively steady value for crop income from 1950 to 1997 is largely a result of large increases in crop yields (figure 4b). The total area of harvested cropland decreased slightly during this period, and the inflation-adjusted value of a bushel of corn or wheat decreased by more than half since 1950 (Olmstead and Rhode 2006a, 2006b).

These agricultural census data only represent gross income from agricultural activities. They do not reflect expenses incurred in producing the crop, nor income from other activities. Nevertheless, they are the only county-level data that are readily available. State-level inflation-adjusted net farm income data for the Great Plains (USDA n.d.) generally follow the same trend (figure 8), with two significant exceptions. Since the 1950s, both government payments to farmers and the proportion of farm income spent on agricultural inputs for crop and animal production have increased. The increased expenses resulted from large increases in agricultural inputs (fertilizer, herbicides, insecticides, and energy use), which accounted for 30% of gross farm income in 1949, compared with more than 60% of gross farm income during the 1990s. The increased cost of agricultural inputs has caused the ratio of net income to gross income to decrease from 40% in 1949 to 25% in the 1990s. This rise in the cost of farming has diminished the potential for profit, even though the increase in irrigation has tended to reduce variation in yields and production and thereby increased the predictability of farming. The other factor that has maintained levels of net farm

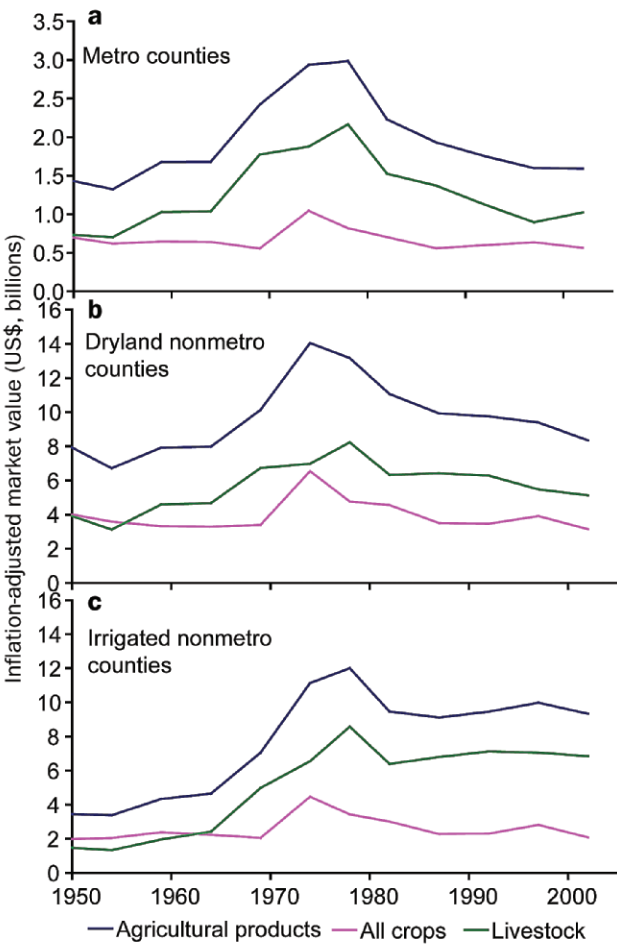

Figure 7. Inflation-adjusted market value of all agricultural products (crops and livestock) sold by farms based in (a) metro counties, (b) dryland nonmetro counties, and (c) irrigated nonmetro counties. The inflation-adjusted value of agricultural production reported in the US agricultural census rose sharply in the 1970s and stabilized at a relatively high level beginning in the 1980s. The value of products sold in irrigated nonmetro counties has become a larger proportion of the regional total in recent years because of increasing livestock production in irrigated nonmetro counties. Source: Gutmann 2005a.

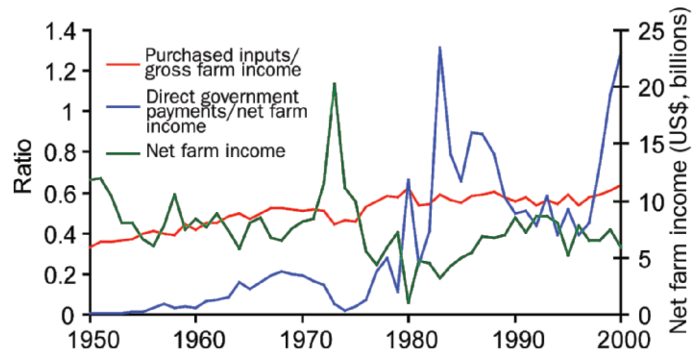

Figure 8. Net farm income (billions of inflation-adjusted dollars), ratio of purchased inputs to gross farm income, and ratio of direct government payments to net farm income for the 10 Great Plains states. Net income has slowly declined in the Great Plains states, purchased inputs have gradually become a larger share of gross income, and government program income has become a significantly larger share of net income. Source: USDA n.d.

income is the increase in government payment to farmers, which was minimal in the 1950s and has increased to more than 60% since the 1980s. Like irrigation, government payments diminish the risks associated with farming, although increased costs have raised those risks.

Past, present, future

It is difficult to make accurate predictions of future trends for land use, population, and agricultural economic return, but analysis of the historical data suggests trends that are likely to continue into the future. The data used in this article encourage separate analyses of population, agricultural productivity, agricultural income, and environmental outcomes, yet these topics are thoroughly, if imperfectly, intertwined. Historically, population growth has spurred agricultural development, production, and income, and it still does so at national and global levels. However, in the 21st century at the local level, population growth rarely leads to increases in agricultural input or output, and population decline also has little impact on agriculture. Conversely, agriculture has become so mechanized and efficient, and salaries for agricultural work so low, that growth or stability in agricultural productivity and income can preserve population stability but does not lead to growth. Metro and suburban dwellers also object to livestock-oriented agricultural activities—often the most profitable of agricultural enterprises—near their homes. On the other hand, changes in the nonmetro population appear to be driven partly by changes in agriculture, which is why populations in the irrigated nonmetro counties have remained larger than those in the dryland nonmetro counties. There is more farm and nonfarm work where irrigation prevails, and that has helped sustain populations.

The connections go beyond the straightforward and economically driven ways that population and agriculture influence each other. Land-use practices, many of them directly tied to farming, contribute to environmental change. The growth of population in the metro counties has been largely exogenous to the agricultural economy in recent years, but it does have an impact on agriculture. Metro and suburban development takes land from agriculture and water from irrigation. On the other hand, if forecasts of world population growth are correct (Tilman et al. 2001, Howarth et al. 2002), the Great Plains could experience increases in cropland, production on existing cropland, and animal production.

Notwithstanding these links between population and agriculture, most of the changes in farming are not caused by changes in population. Largely external forces have changed farming, including dramatic shifts in weather (in the 1930s) and prices (in the 1970s) and, more generally, changes in technology and in the external market forces that affect prices for the inputs farmers use and the products they sell. There is no simple synthesis that links population, agriculture, and environment in the US Great Plains, but the story told here shows the many ways in which these factors have come together and shaped one another since the 19th century. Even if we initially separate out each factor, any conclusions we draw about prospective outcomes make sense only when they are combined.

Population trends are in some ways the most independent factor in regional change, because the population has been growing rapidly for a long time throughout the United States, mostly in metro regions. The Great Plains region is no exception. Metro population growth in the Great Plains could continue and may accelerate in the future. On the other hand, the population of the dryland nonmetro counties has stabilized during the last 30 years, while that of the irrigated nonmetro counties has increased slightly, and the proportion of the population over ages 55 and 65 in both dryland and irrigated nonmetro counties has grown rapidly. While this stability is reassuring, virtually all other US populations are growing. These demographic patterns will bring substantial social change to the plains. A static, aging population will be even more different from the dominant metro United States in the future than it is now. All of these trends are likely to continue.

Data on agricultural income also show trends that have the potential to persist, and that pose significant challenges for the future. The dominant trend of the last 30 years has been an increase in income from animal production for the nonmetro counties. In the metro counties, on the other hand, income from animal production fell sharply and then stabilized in relation to crop production in the past 20 years. This trend is likely to continue, because growing metro populations have concerns about the air and water pollution produced by intensive animal production (Mosier et al. 1997, Howarth et al. 2002). Income in both metro and nonmetro counties is also at risk, as the ratio of net to gross income has fallen and government payments have increased. The recent increase in the cost of petroleum and natural gas will push the cost of inputs still higher, and the potential that government payments may be reduced will lower incomes.

Plans to develop biofuels from crop residue, and to use corn to produce ethanol and oil seed to produce biodiesel (Barrionuevo 2006), have the potential to contribute to a shift in crop selection in the future and will lead to a new period of uncertainty. The irrigated agricultural counties have the greatest short-term potential to respond to a higher demand for corn. The dryland nonmetro counties also have the potential to gain from the use of plant residues to produce ethanol. At the same time, demand for corn for biofuels will raise prices, which has the potential to affect livestock production. Higher prices for animal feed, and for fuel to transport the feed to livestock and the livestock to processing plants, can lead to lowered incomes in the livestock sector. Expanded biofuel production could also lead to adverse environmental impacts such as increased soil erosion and reduced soil carbon.

Potential water shortages are another major threat to the future of the Great Plains. Aquifers are declining (Kromm and White 1986, Lehe 1986, Wilhite 1988), metro growth is taking water from agriculture, and climate change poses a substantial risk, although its impacts may not all be negative (Reilly et al. 2001, Ojima et al. 2002). Responses to potential water shortages include improvement of dryland cropping systems (Peterson et al. 1998, Del Grosso et al. 2002) to reduce fallow frequency, and more efficient irrigation methods. Although these changes are likely to be widely implemented, it is unclear whether improved irrigation efficiency, better crop management practices, and reduction in plant transpiration levels associated with increased atmospheric carbon dioxide levels will allow crop yields to be maintained at current levels. It is likely that these and other improved agricultural techniques will reduce the negative impacts of agriculture on the environment. These techniques, coupled with programs like the Conservation Reserve Program (which encourages farmers to convert cropland to grassland), can increase carbon storage and reduce N_2O soil fluxes and NO_3 leaching.

This research draws on the assumption that there are meaningful observations to be drawn from the experience of the Great Plains over the past century, with special consideration of the past 30 or 40 years. There are fundamental differences in the viability of agriculture and agricultural society in the three areas we have defined, with metro and dryland nonmetro counties more likely than irrigated nonmetro counties to run into problems. Irrigated nonmetro areas may prove vulnerable because of the increased cost of pumping water from deeper reaches of the aquifer, the increased water demands due to greater evapotranspiration under a warmer climate, and the increased competition with human consumption in metro areas for water resources. At present, however, the conditions in terms of population and production are not as bad as they might be, and not as bad as some observers suggest. There is little recent evidence to suggest that the near future will be different from the recent past, but the prospect of high energy costs and reduced government payments to farms may disrupt what has been a quarter-century of stability. The expanded use of crops for biofuel production has the potential to increase rural incomes through higher crop prices (corn prices have increased by 175% during the last year) and industrial incomes through the construction and operation of ethanol biorefineries. We see few indications on the horizon that agricultural production will decline sharply, or that patterns of population change will depart radically from those in place since the 1970s and 1980s. The prospect of new trends in petroleum prices, the reduced availability of water for irrigation, and new departures from recent demographic patterns are all cause for continued monitoring.

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