

# Measuring Agricultural Changes Related to Marcellus Shale Development

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*The Marcellus Shale Impacts Study Wave 2: Chronicling Social and Economic Change in Northern and Southwestern Pennsylvania*

March 2017

## Executive Summary

Agricultural production accounts for a substantial portion of Pennsylvania's economy. The primary objective of this research was to investigate the direct and indirect effects of Marcellus Shale natural gas development on the economic, social, and environmental dimensions of Pennsylvania agriculture. Direct effects may include lease and royalty income paid to farmers; changes in farmland use, groundwater, and other resources; and changes in demand for agricultural production. Indirect effects on farmers may include farmers' responses to the changes brought on by gas development, such as changing production practices or products, as well as those from the larger agricultural system, such as availability of farm labor, effects on water and soil quality, and road accessibility. Agribusinesses may also be affected in the form of higher revenues from increased sales to the gas industry and to some farmers with newly found lease and royalty income, shifts to providing services and products that they did not previously provide, and competition with gas companies for workers.

To identify changes in agriculture, the research used secondary data from the U.S. Census of Agriculture, comparing county statistics prior to development (2002), early in development (2007), and about 4 years into development (2012). Key findings are listed below.

### Secondary Data Findings:

- **Changes in Number of Farming Operations (2002-2012):** The number of farms in Bradford County increased substantially between 2002 and 2012 while the number of farms in the other study counties, and Pennsylvania in general, declined.
- **Changes in Average Acreage per Operation (2002-2012):** Average acreage in the four study counties increased, with the exception of Lycoming County. However, those increases were smaller than in adjacent counties and Pennsylvania generally.
- **Changes in Number of Milk Cows (2001-2013):** The milk cow inventory declined modestly statewide and substantially in the four study counties. Most dramatic is the drop in milk cow inventory in Lycoming and Bradford counties, because their drop is so dramatic when compared to their neighboring counties and statewide. Moreover, the decline in milk cows increases steadily from no drilling to high drilling counties. This suggests a possible link between Marcellus Shale gas drilling activities and a decline in dairy cows, which would further suggest a decline in dairy activity.

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The Center for Rural Pennsylvania is a bipartisan, bicameral legislative agency that serves as a resource for rural policy within the Pennsylvania General Assembly. It was created in 1987 under Act 16, the Rural Revitalization Act, to promote and sustain the vitality of Pennsylvania’s rural and small communities.

Information contained in this report does not necessarily reflect the views of individual board members or the Center for Rural Pennsylvania. For more information, contact the Center for Rural Pennsylvania, 625 Forster St., Room 902, Harrisburg, PA 17120, telephone (717) 787-9555, email: [info@rural.palegislature.us](mailto:info@rural.palegislature.us), [www.rural.palegislature.us](http://www.rural.palegislature.us).

## About this Project

The Marcellus Shale Impacts Project chronicles the effects of shale-based energy development in Pennsylvania by focusing on the experiences of four counties with significant extraction and production activity – Bradford, Lycoming, Greene, and Washington counties. Wave 1 of the project was completed in 2013 and Wave 2 began in early 2014. Wave 1 focused predominantly on data collection and the use of descriptive statistics to present changes in various outcomes over time. Wave 2 focused on developing statistical models to describe relationships between Marcellus Shale development and a set of social and economic indicators, identifying change in social and economic outcomes that are associated with Marcellus Shale development, and identifying the characteristics of people and places associated with the magnitude and types of impact experienced. A particular focus of Wave 2 was to explore the heterogeneity in Marcellus Shale development impact on different population groups. The purpose of this research was to investigate the direct and indirect effects of Marcellus Shale development on the economic, social and environmental aspects of Pennsylvania agriculture.

## Study Counties

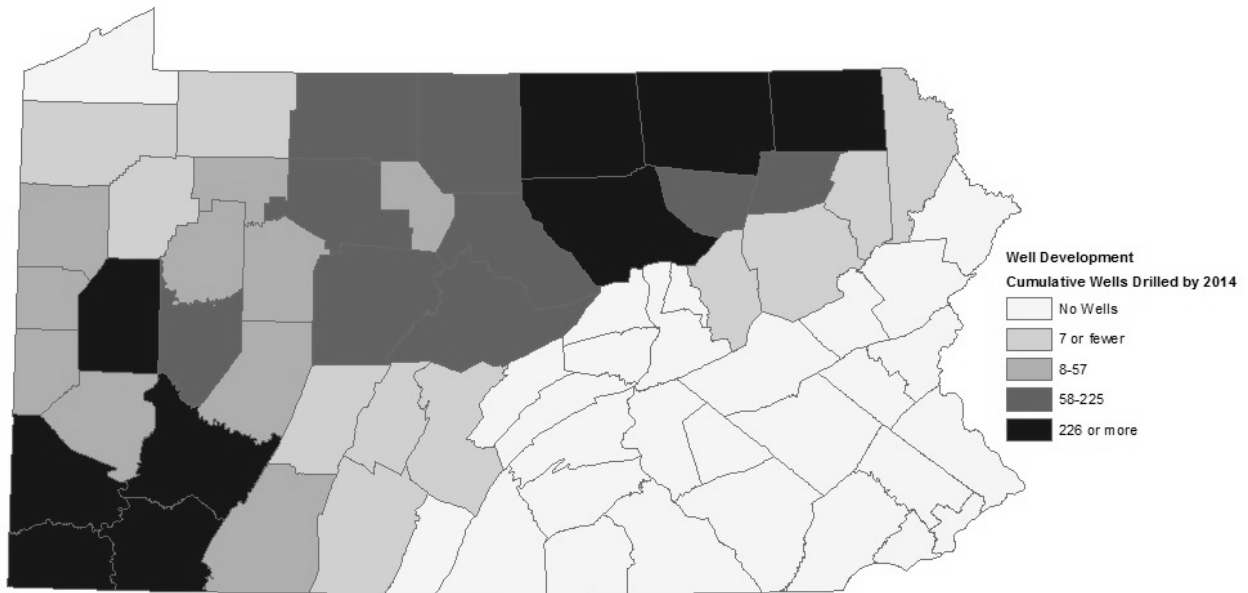
This study focused on the same four counties examined in Wave 1 of the Marcellus Shale Impacts Study: Bradford, Lycoming, Greene, and Washington. These counties experienced among the highest levels of Marcellus Shale development in Pennsylvania over the past 8 years, and have diverse populations, histories, economic bases, and geographic locations. These differences allow comparisons that facilitate understanding of the potential associations between Marcellus Shale development and various social, economic, and health outcomes. Regional comparisons are also made based on adjacency to the study counties. The northern tier counties include Bradford, Lycoming, Clinton, Columbia, Montour, Northumberland, Potter, Sullivan, Susquehanna, Tioga, Union, and Wyoming. The southwestern counties include Greene, Washington, Allegheny, Beaver, Fayette, and Westmoreland.

All four study counties are classified as rural by the Center for Rural Pennsylvania with population densities of less than 284 people per square mile. However, the U.S. Department of Agriculture's (USDA) Economic Research Service (ERS) and the U.S. Census Bureau classify Lycoming and Washington counties as metropolitan counties. Lycoming County is in the Williamsport metropolitan area, and Washington County is part of the Pittsburgh metropolitan area. Bradford and Greene counties are classified by the USDA ERS as nonmetropolitan counties with small urban populations of less than 20,000 people. Both are adjacent to metropolitan areas.

## Marcellus Shale Activity

Figure 1 presents the distribution of the cumulative number of wells drilled in each county in Pennsylvania through August of 2014. The cut points represent quintiles (intervals of 20 percent). Well development is concentrated in the northeast, north central, and southwestern portions of the state. In the northern tier, Bradford, Lycoming, Tioga, and Susquehanna have all experienced similar high levels of development. This suggests that comparisons of outcomes among these counties will be particularly useful. Similarly, the most useful comparisons will be between the neighboring southwest counties with the most natural gas well development. These include Greene, Washington, Fayette, and Westmoreland, although Greene and Washington counties have had substantially more wells drilled than Fayette and Westmoreland counties.

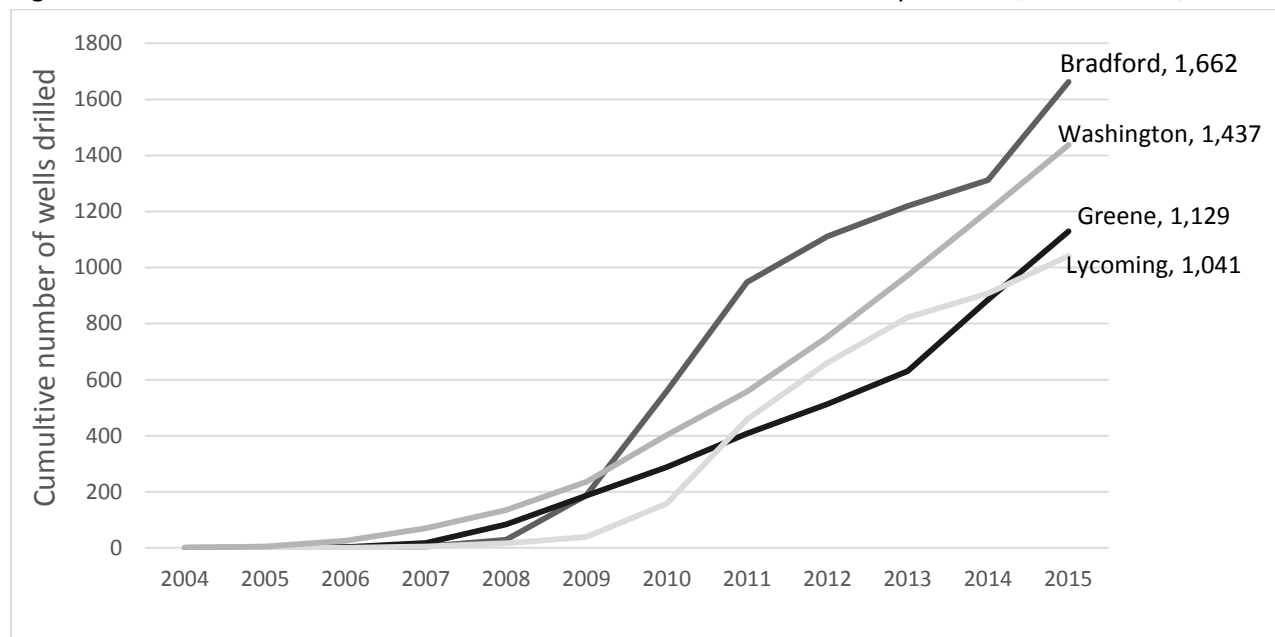
Figure 1. Cumulative Number of Unconventional Gas Wells Drilled, 2005-2014



Source: Pennsylvania Department of Environmental Protection, Office of Oil and Gas Management

Figure 2 shows the cumulative number of unconventional wells drilled in the Marcellus Shale in the four study counties since 2005. Although some wells that were drilled early in the period may no longer be in production, and some new wells have not yet been put into production, the lines reveal overall trends in the study counties. The increase in wells drilled since 2009 has been substantial in all four counties, with Bradford and Washington counties experiencing the most pronounced increases. The increase in Bradford County was particularly robust between 2009 and 2011 and then leveled off to a slower growth rate after 2011. Lycoming experienced its steepest increase between 2010 and 2011, with steady but slightly lower growth rates after 2011. Development began earlier in the southwest counties than in the northern tier counties, but growth in Washington and Greene counties has been relatively constant throughout the period, with no dramatic spikes like those seen in the northern tier counties. Finally, although the pace of drilling appears to be leveling off in Lycoming County, Bradford, Washington, and Greene counties continue to experience an upward trend in development.

Figure 2. Cumulative Number of Unconventional Wells Drilled in Four Study Counties, 2005-June 1, 2015



Source: Pennsylvania Department of Environmental Protection, Office of Oil and Gas Management

## Changes in Agriculture

Farming in the United States has changed substantially over the past 100 years. At the beginning of the 20th century, 41 percent of the employed labor force worked in agriculture, but the proportion has now decreased to 2 percent (Dimitri, Effland, and Conklin, 2005). In 1935, a sharp decline of farm numbers occurred simultaneously with an increase in average farm acreage (Hoppe and Korb, 2006). That period coincided with the Great Depression and the collapse of dairy prices. Dimitri et al. (2005) argue that technological development is one of the three most influential long-run forces that drove the consolidation of farms in the United States. They explain that, for many farmers, increased mechanization (e.g., tractors, plant and animal breeding) and the accessibility of chemicals led them to make larger income investments to pay for technologies, especially those that decreased the need for labor. The result was fewer farmers and farmworkers, and larger farms.

Although hydraulic fracturing and horizontal drilling do not affect farming in the same way that the introduction of tractors and chemicals have, these new technologies are having social and economic impacts on agriculture, particularly for farmers who have entered into gas leases. These impacts could influence the number and size of farms in counties where there is Marcellus Shale development. Landowners (often farmers in rural areas) who own the mineral and natural gas rights of their properties are approached by landmen from gas companies or independent contractors to sign leases. Landowners can choose to "...lease the right to explore for gas to a company that has the equipment and expertise to recover or receive the gas for a period of time, and accept payment for the lease and royalties for the value of the gas" (Weidner, 2008). There are many factors that influence the price per acre that a company will pay (e.g., anticipated quality of gas, expectations and acuity of landowners, demand for

gas) to drill for gas and can range from hundreds to thousands of dollars. In addition to lease payments, landowners are also paid royalties for gas that is extracted. Pennsylvania requires that landowners receive royalties of at least 12.5 percent of the value of the natural gas extracted from their property (Weidner, 2008).

Farmers who have entered into or are considering gas leases must make new decisions about their farms, such as how much land should be leased and how the income from the royalty and lease payments should be used. Some examples of how gas leasing could affect agriculture include taking farmland out of production to lease it, as well as investing in existing enterprises, downsizing existing enterprises, or switching to different types of farming (e.g., dairy to beef cattle).

## Statewide Agricultural Profile

To understand how Marcellus Shale development is affecting agriculture, it is important to grasp the features and trends of agriculture in the state. Therefore, it is appropriate to begin with a brief overview that characterizes the sector at region, state, and county levels.

Measured by value of sales by commodity group, Pennsylvania nationally ranks fifth in milk and other dairy products from cows, fourth in nursery, greenhouse, floriculture, and sod, fourth in cut Christmas trees and short rotation woody crops; eighth in horses, ponies, mules, burros, and donkeys, and sixth in tobacco. The total value of agricultural products sold in 2012 in Pennsylvania was about \$7.4 billion, first in the Northeast and mid-Atlantic region, and 22<sup>nd</sup> in the nation. There were 59,309 farms in the state in 2012, which represents a 6.1 percent decrease between 2007 and 2012.

Between 2007 and 2012, the average farm size increased from 124 acres to 130 acres in Pennsylvania. Of the 59,309 farms, only 11,814 have total sales over \$100,000, and 15,058 have a value of sales under \$1,000. Milk from cows accounts for the greatest proportion of the state's value of sales, followed by poultry and eggs. The average age of a principal operator in the state is 56.1, and about 85.8 percent of them are male and 14.2 percent are female.

It is difficult to measure the influence that Marcellus Shale drilling activities has had on agriculture, in general, and changes in farm composition in particular. Studies have documented some agricultural impacts from Marcellus Shale activities.

Using USDA's National Agricultural Statistics Service (NASS) data on the number of dairy cows, Adams and Kelsey (2012) found that intensity of gas drilling and decline in dairy cow numbers seem to be associated. However, they caution that the data do not allow them to do more than speculate on the nature or direction of that association. Finkel et al. (2013: 189) conducted a similar study and found that, "Milk production and milk cows decreased in most counties since 1996, with larger decreases occurring from 2007 through 2011 (when unconventional drilling increased substantially) in five counties with the most wells drilled compared to six adjacent counties with fewer than 100 wells drilled." Like Adams and Kelsey (2012), the authors caution that these are findings from a descriptive study that has not established causation.

The Center for Dairy Excellence conducted a survey of dairy farmers in the northern tier (Bradford, Lycoming, Potter, Sullivan, Susquehanna, Tioga and Wayne counties) and southwest (Armstrong,

Cambria, Clearfield, Fayette, Indiana, Jefferson, Somerset, Washington, and Westmoreland counties) regions in the summer of 2011. The results indicated that, in the northern tier, 60.0 percent of dairy farmers intended to leave their herd sizes unchanged, 6.5 percent planned to reduce their herd size, 14.8 percent planned to increase their herd size, and 18.7 percent were uncertain. In the southwest, 65.7 percent intended to leave their herd sizes unchanged, 4.6 percent planned to reduce their herd sizes, 24.1 percent planned to increase their herd sizes, and 5.6 percent remained uncertain (Frey, 2012). Unlike the Adams and Kelsey (2012) and the Finkel et al. (2013) studies, The Center for Dairy Excellence data were not analyzed to control for intensity of drilling activity in counties where farmers are located. However, the authors did include a variable measuring whether farmers received natural gas lease or royalty fees. In the northern tier, 62.9 percent of farmers receiving gas revenue would be more likely to modernize their dairy operation, 36.8 percent would be less likely to invest in the dairy operation, and 48.1 percent would consider investing in alternative forms of agriculture. In the southwest, 50.6 percent of farmers receiving gas revenue would be more likely to modernize their dairy operation, 31.0 percent would be less likely to invest in the dairy operation, and 58.8 percent would consider investing in alternative forms of agriculture (Frey, 2012). These findings suggest that dairy farming could move in different directions as a result of the influx of gas drilling revenues.

## Data Sources and Methods

Data from NASS's Census of Agriculture were used to examine changes in the number of farm operations, the average size of these operations, and the agricultural profile of the four study counties, as well as comparisons to neighboring counties. These USDA data are collected every 5 years. They are complemented with data from the USDA NASS Annual Program for Crop and Livestock Production. Variables analyzed in this research include changes over time and among counties in forage, corn for grain, corn for silage, composition of land in farms, percentage of farms by value of sales, change in number of farms, change in average acreage per operation, and milk cow inventory.

### **What is the U.S. Census of Agriculture?**

The first Census of Agriculture was conducted in 1840 by the U.S. Census Bureau, Department of Commerce and in 1997 the responsibility was given to NASS. According to USDA, "The [Census of Agriculture](#) is conducted every five years and, by definition, is a complete accounting of the crops and livestock produced on all farms and ranches for the Census year and the inventories of livestock on all farms. The Census also collects information concerning operator characteristics, demographics, and income and expenses....The Census information includes data for most commodities produced on U.S. farms and is published by state and county. The data are also summarized by operator/farm characteristics (operator age, etc., and acres in farm, etc.), to the county level" (USDA).

### **NASS Survey**

In addition to conducting the Census of Agriculture each year, NASS conducts annual surveys on specific topics and issues. These surveys are informative, but depending on the topic, are not consistent from year to year and do not cover every county in the nation like the Census of Agriculture. NASS survey data were used for this research to document trends in the number of milk cows.

## County Agricultural Profiles

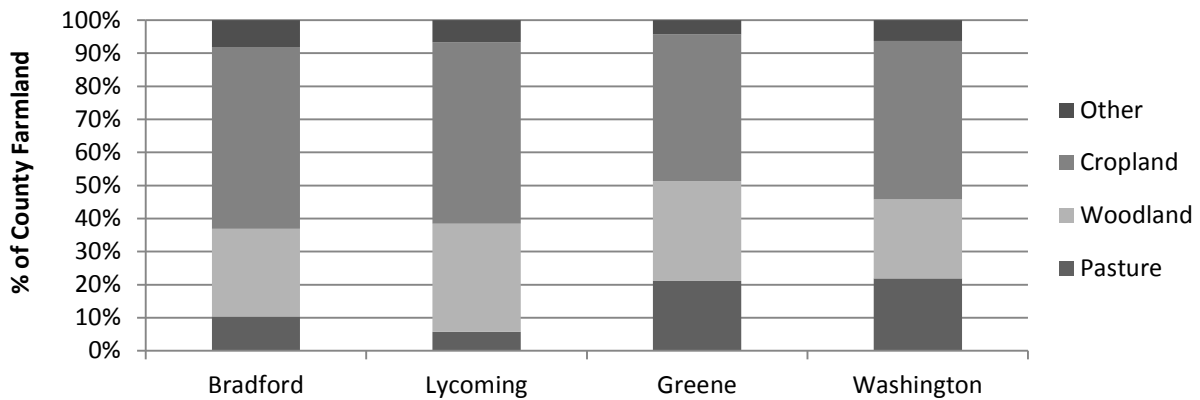
There were substantial differences in changes in the four study counties between 2007 and 2012. Table 1 shows that Bradford County was the only county that had an overall increase in the number of farms. Lycoming County held steady, while Washington County declined slightly, and Greene County declined dramatically. Average farm size did not change dramatically. However, market value of products sold increased substantially in Lycoming (35 percent) and Washington (24 percent) counties, and especially in Greene County (56 percent).

County	2012	2007	% Change in Farm Numbers	Average Farm Size	% Change in Market Value
Bradford	1629	1457	12	3	6
Lycoming	1207	1211	0	-1	35
Greene	876	1245	-30	6	56
Washington	1915	2023	-5	3	24

The contribution to the value of the state’s agricultural products sold varies among the four study counties. Bradford ranks 14<sup>th</sup>, Lycoming ranks 29<sup>th</sup>, Washington ranks 43<sup>rd</sup>, and Greene ranks 54<sup>th</sup> out of Pennsylvania’s 67 counties. Figures 3a and 3b indicate that the four counties have a similar composition of agricultural land use with high proportions of cropland and woodland. Pasture land is more common in the study counties located in the southwest than in the northern tier. In the southwestern counties, pasture accounts for about one fifth of farmland, while in Bradford and Lycoming counties it makes up only 6.5 and 10.7 percent of farmland, respectively. Dairy is the most prevalent commodity in three of the study counties: Bradford, Lycoming, and Washington. Bradford has by far the highest annual sales from dairy at \$56.2 million. The next highest county is Lycoming with \$16.4 million, while the other two counties have less than \$10 million in annual sales from dairy. Greene County’s primary commodity, in terms of values of sales by commodity group, is cattle and calves, but it still has fewer cattle and calves than the other study counties. Forage is the top crop item in all four counties (Figures 4a, b). Lycoming County has the least forage acreage, but it is the leading county for acreage in corn for grain.



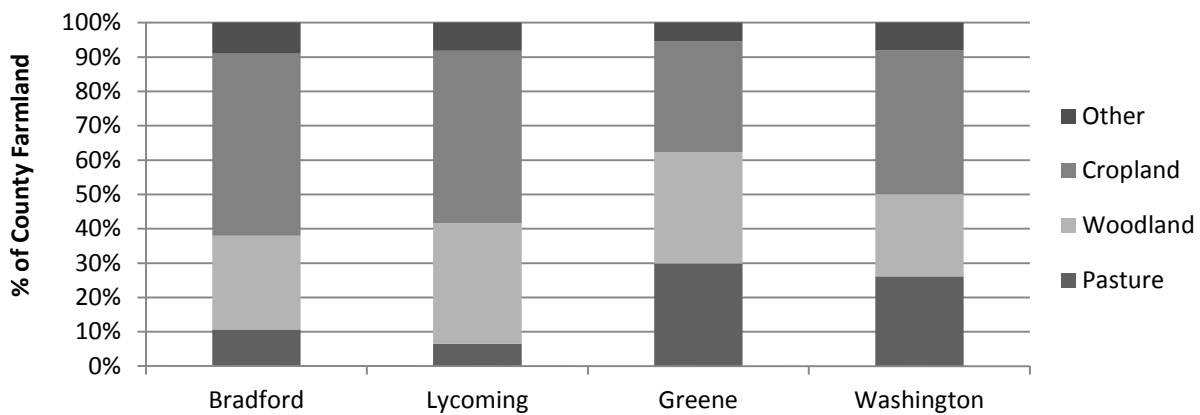
**Figure 3a. Composition of Land in Farms<sup>1</sup> by Type, 2007**



Source: USDA Census of Agriculture 2007

<sup>1</sup> “Land in farms consists of agricultural land used for crops, pasture, or grazing. Also included is woodland and wasteland not actually under cultivation or used for pasture or grazing, provided it was part of the farm operator’s total operation. Land in farms includes acres in the Conservation Reserve, Wetlands Reserve Programs, or other government programs” (USDA NASS 2013).

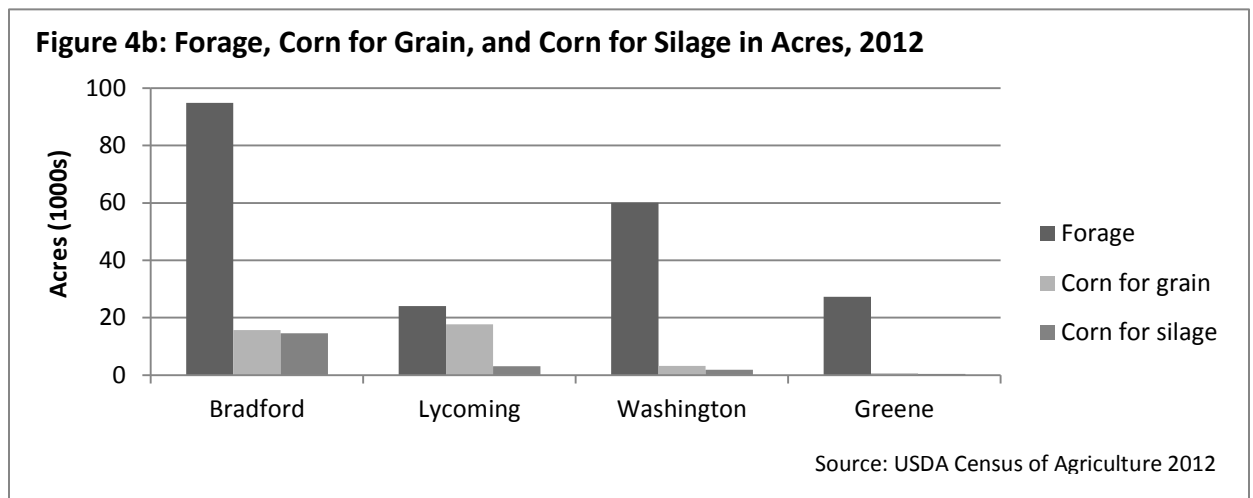
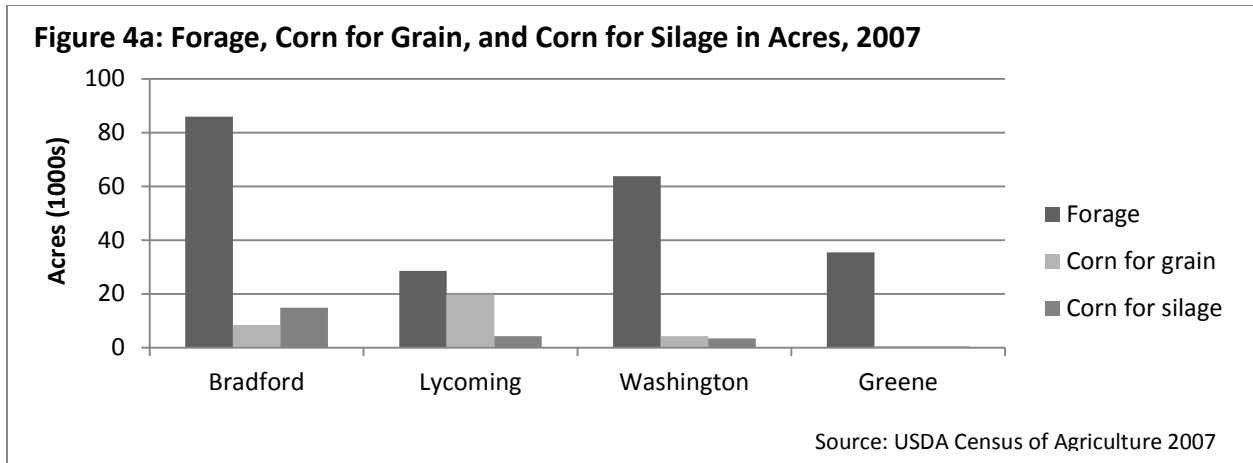
**Figure 3b. Composition of Land in Farms<sup>1</sup> by Type, 2012**



Source: USDA Census of Agriculture 2012

<sup>1</sup> “Land in farms consists of agricultural land used for crops, pasture, or grazing. Also included is woodland and wasteland not actually under cultivation or used for pasture or grazing, provided it was part of the farm operator’s total operation. Land in farms includes acres in the Conservation Reserve, Wetlands Reserve Programs, or other government programs” (USDA NASS 2013).

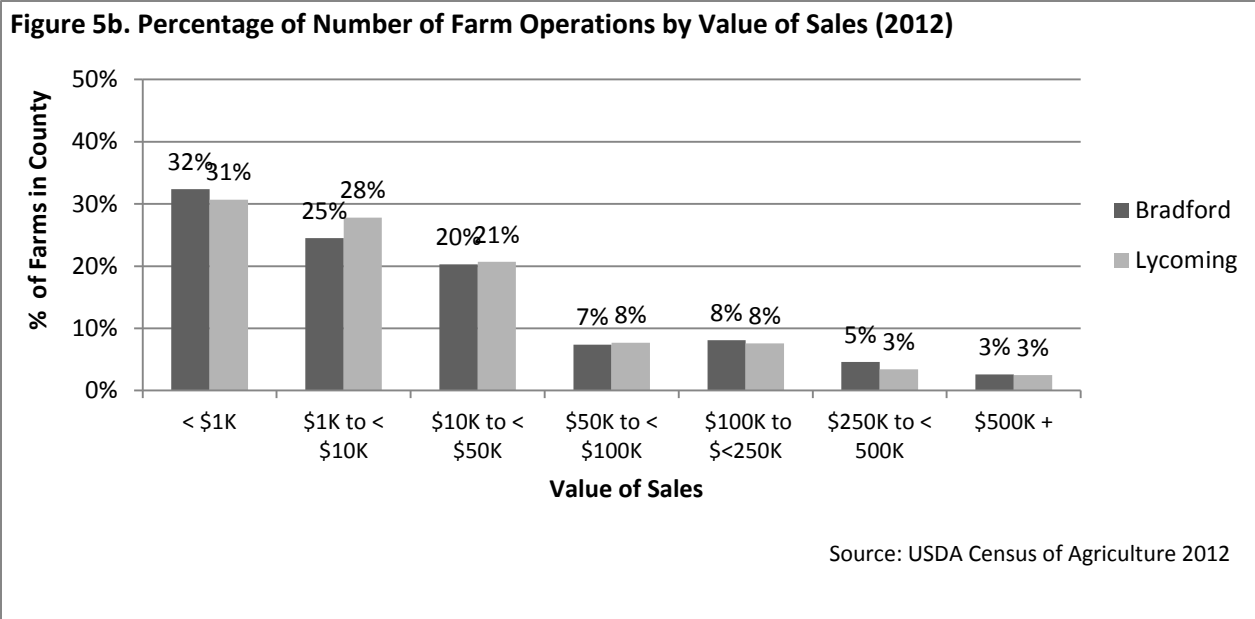
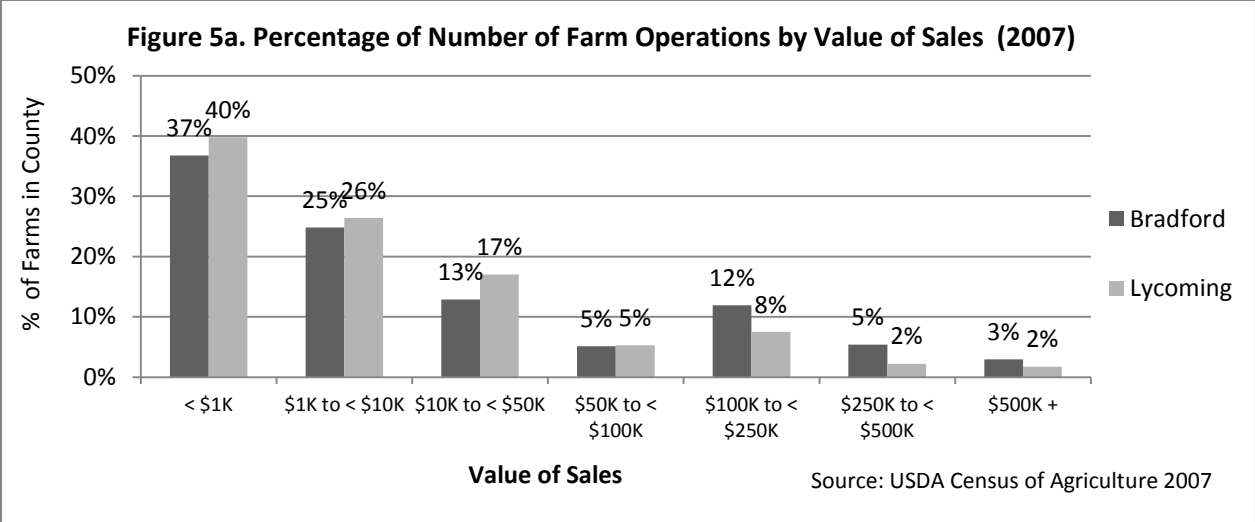
Figures 3a and 3b indicate modest changes in land composition in three of the study counties. Lycoming had a slight decrease in cropland and slight expansion of woodland. Greene had a decline in cropland and an expansion in woodland and pasture. Washington had a decline in cropland and an expansion in pasture. Bradford had no discernable change.



A comparison of Figures 4a and 4b indicates a modest increase in forage acreage in Bradford County, but a decline in forage acreage in the other three study counties. There was a slight uptick in corn for grain produced in Bradford County and a slight decline in Lycoming County. There was no discernable change in Washington and Greene counties. Corn for silage acreage seems to have held stable in all four counties.

## Northern Tier

Agriculture is a significant contributor to Bradford County’s economy. Bradford County has 1,629 farms, with slightly more than half (883 farms) of those farms providing the primary household income source. Although the average market value of products sold per farm is \$79,063, 56.9 percent of farms have less than \$10,000 in total value of sales. The average size of a farm is 189 acres. Out of the state’s 67 counties, Bradford County ranks 14<sup>th</sup> for the total value of agricultural products sold. Its relatively high rank can be attributed to the sale of cattle and dairy products from cows—77.4 percent of the market value of products sold in Bradford is generated from livestock sales. In addition, Bradford is also ranked number one for land used for forage (hay, haylage, grass silage, and green chop). The average age of farmers in Bradford County is 58.5 years, and the majority of farmers are white males (female=187; male=1,442; only 19 of 2,169 operators did not choose the white category).

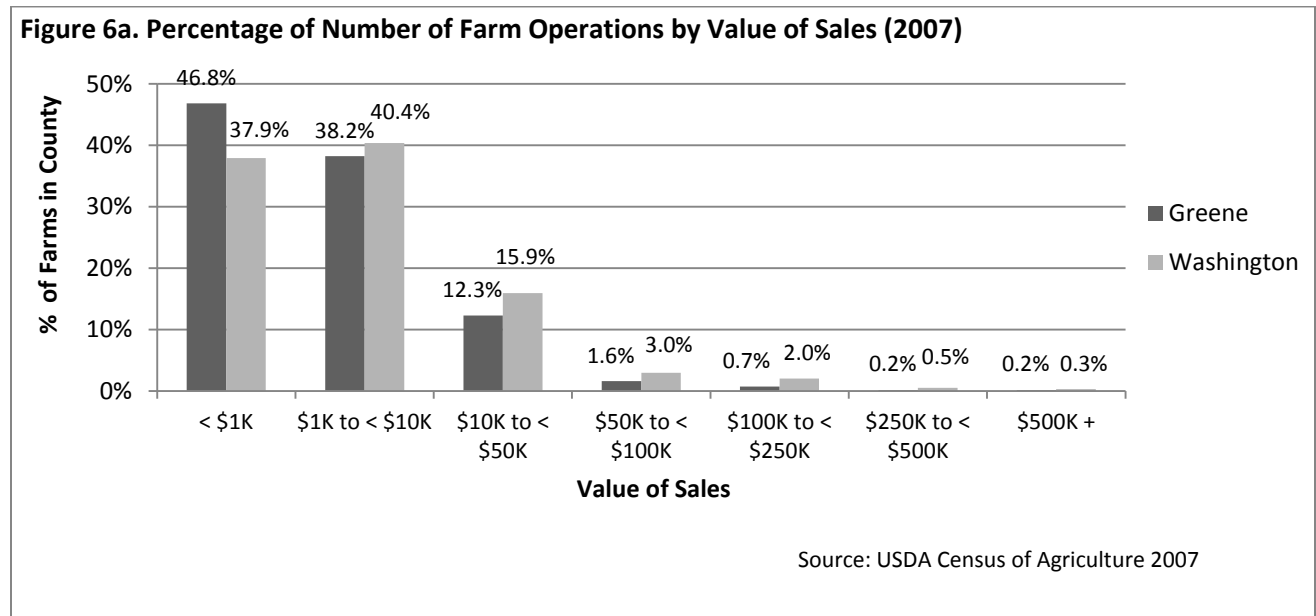


There are fewer farms in Lycoming County (1,207) than in Bradford County. Lycoming County’s farms also tend to be smaller and have a lower average market value of products sold per farm than Bradford County’s farms. The average size of Lycoming County farms is 131 acres. Of the 1,207 operators, 531 of them indicated farming as a primary occupation, while the remaining farmers rely on other sources for their primary income. The market value of products sold by Lycoming County farmers (\$72.2 million) is substantially less than Bradford County farmers’ market value (\$128.8 million). Lycoming County ranks 11<sup>th</sup> in the state for value of sales of cut Christmas trees and short-rotation woody crops and seventh for values of sales of tobacco. The average age for farmers in Lycoming County is 59, and almost all farmers are white males (11 of 1,207 operators did not choose the white category; female=158; male=1,049).

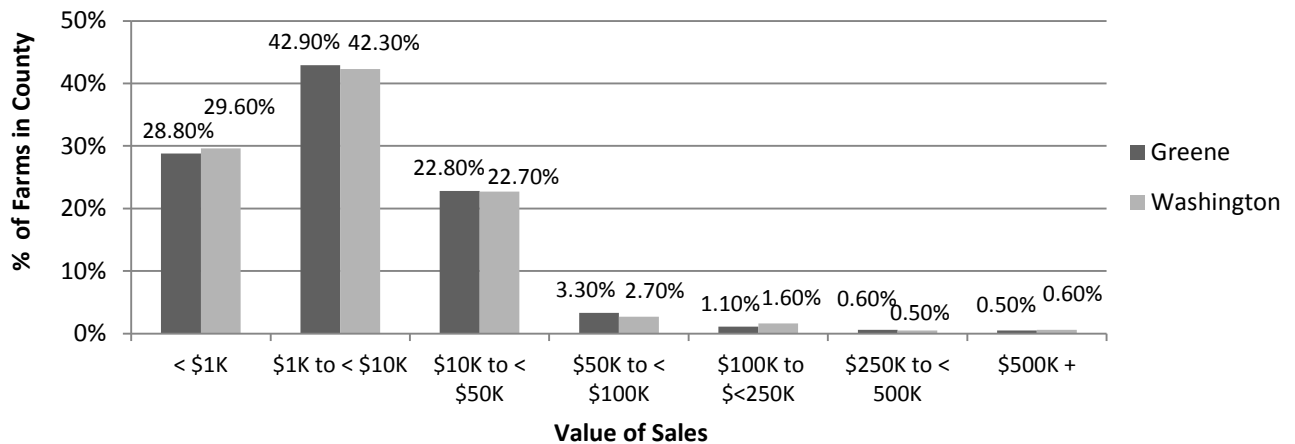
Data on farm operations by value of sales for 2007 and 2012 are included in Figure 5a and Figure 5b. The figures show that the percentage of farms with sales less than \$1,000 declined in both Bradford (37 percent to 31 percent) and Lycoming (40 percent to 31 percent) counties between 2007 and 2012. The percentage of farmers in the \$10,000 to \$50,000 range increased during that same time in both counties (13 percent to 20 percent in Bradford and 17 percent to 21 percent in Lycoming). Bradford County had a slight decline in the number of farms (12 percent to 8 percent) with sales in the \$100,000 to \$250,000 range.

## Southwest

Greene County is ranked 54<sup>th</sup> (out of 67) for value of agricultural sales. It is ranked 14<sup>th</sup> in number of sheep and lambs. Dairy farming is not common in the county, ranking 59<sup>th</sup> among all counties in the state for value of sales of milk and other dairy products from cows. Of the 876 principal operators in the county, only 354 farm as a primary occupation. Only 5.5 percent of Greene County farms have value of sales over \$50,000. The average age of farm operators is 55.9 years and operators are typically white males (4 of 876 operators did not choose the white category; female=113; male=763).



**Figure 6b. Percentage of Number of Farm Operations by Value of Sales (2012)**



Source: USDA Census of Agriculture 2012

Washington County has the fourth highest number of farms in the state. Of the 1,915 principal operators in the county, 1,061 reported a different primary occupation. The county has the highest number of sheep and lambs in the state and ranks fifth in value of sales of sheep, goats, and their products. It ranks third in number of horses and ponies. For value of sales by commodity group, Washington ranks eighth in “other crops” and hay and ninth in horses, ponies, mules, burros, and donkeys. It has the fifth highest acreage of forage. It is important to note that Washington County’s proximity to Pittsburgh affords it more non-farm opportunities than other study counties.

Data on farm operations by value of sales for 2007 and 2012 are included in Figure 6a and Figure 6b. Similar to farms in Bradford and Lycoming Counties, farms in Greene and Washington counties became modestly more profitable between 2007 and 2012. The percentage of farms in the less-than-\$1,000 sales category declined (46.8 percent to 28.8 percent in Greene and 37.9 percent to 29.6 percent in Washington). Farms in the next three categories tended to increase slightly. Farm operations making between \$1000 and \$10,000 rose from 38.2 percent to 42.9 percent in Greene and 40.4 percent to 42.3 percent in Washington. Operations making between \$10,000 and \$50,000 rose from 12.3 percent to 22.8 percent in Greene and 15.9 percent to 22.7 percent in Washington. Operations in the \$50,000 to \$100,000 category rose from 1.6 percent to 3.3 percent in Greene, but declined from 3.0 percent to 2.7 percent in Washington. There were no discernable changes in the other categories.

## Changes in Number of Farms<sup>1</sup> and Acreage per Operation

Gas leasing may be having impacts on how farmers are using their land and making decisions about their farms. The decision to invest in upgrading a farm enterprise, to stop farming altogether, or to farm less land in response to gas leases could be reflected in changes in the number of farms and average acreage per operation. In this section, county- and state-level data from the US Census of Agriculture were used to measure changes in these indicators for the years 2002, 2007, and 2012 and for average acreage per operation for the years 2002, 2007 and 2012. With the exception of Washington County, which had a sudden initial increase in 2007, the information below is helpful for understanding trends in agriculture before drilling took off in the study counties.

The average annual rate of change helps to reveal proportional changes that may be less visible when examining counts. The average annual rate of change was calculated by subtracting the value of the later year by that of the earlier year and dividing by the value of the earlier year. For example, in 2002 there were 1,495 farms in Bradford County and in 2007 there were 1,457. The percentage change was calculated as showed below:

$$(1457-1495)/1495 = 0.025 * 100 = -2.5\%$$

### Northern Tier Pennsylvania Counties

The number of farms across the commonwealth increased 2.0 percent between 2002 and 2012 and increased 1.4 percent in the northern tier (see Table 3). The notable increase in number of farms in several northern tier counties and across the commonwealth between 2002 and 2007 can be attributed, at least partially, to NASS's effort to enumerate more small farms.

Although reported farm numbers increased in the state and region, they declined in both Bradford and Lycoming counties from 2002 to 2007 (Table 3). Bradford continued to decline at about the same rate as it had from 1997-2002. However, Lycoming experienced a sudden decline in farms, at 8.5 percent, compared to a substantial increase 5 years prior. It is important to note that although there were only two wells in Bradford County and five wells in Lycoming County in 2007, landowners tend to receive both leasing and royalty payments when they enter a lease. Therefore, despite the low well counts, farmers still could have been leasing their land to gas companies during this time, which could have potentially affected their farming operations. The rate of change in farm numbers increased dramatically in Bradford County between 2007 and 2012. With 11.8 percent more farms in 2012 than 2007, Bradford's growth was substantially higher than the northern tier average of -1.1 percent. Lycoming County had a modest decline of -0.3 percent, but this too is less substantial than the northern tier average of -1.1 percent and the Pennsylvania county average of -6.6 percent.

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<sup>1</sup> According to the USDA NASS, "A farm is 'any place from which \$1,000 or more of agricultural products were produced and sold, or normally would have been sold, during the year.' Government payments are included in sales. Ranches, institutional farms, experimental and research farms, and Indian Reservations are included as farms. Places with the entire acreage enrolled in the Conservation Reserve Program (CRP), Wetlands Reserve Program (WRP), or other government programs are counted as farms. The definition of a farm was first established in 1850 and has changed nine times since. The current definition was first used for the 1974 Census" (USDA NASS 2013).

**Table 3. Change in Number of Farms in Northern Tier, 2002 – 2012**

	2002	% change (2002-2007)	2007	% change (2007-2012)	2012
<b>Northern Tier (county average)</b>	<b>719</b>	<b>20.1%</b>	<b>789</b>	<b>-1.1%</b>	<b>777</b>
Bradford <sup>a</sup>	1,495	-2.5%	1,457	11.8%	1,629
Lycoming <sup>a</sup>	1,323	-8.5%	1,211	-0.3%	1,207
<b>Adjacent counties only (average)</b>	<b>580</b>	<b>25.2%</b>	<b>680</b>	<b>-2.4%</b>	<b>649</b>
Susquehanna <sup>a</sup>	1,116	-9.7%	1,008	-0.3%	1,005
Tioga <sup>a</sup>	973	3.9%	1,011	11.3%	1,025
Clinton <sup>b</sup>	420	27.9%	537	-12.6%	469
Potter <sup>b</sup>	343	10.2%	378	16.9%	442
Sullivan <sup>b</sup>	170	-2.9%	165	8.5%	179
Wyoming <sup>b</sup>	358	81.3%	649	-21.7%	508
Columbia <sup>c</sup>	884	8.8%	962	-1.9%	944
Montour <sup>c</sup>	304	91.8%	583	-21.3%	459
Northumberland <sup>d</sup>	719	30.2%	936	-9.5%	847
Union <sup>d</sup>	521	10.4%	575	6.6%	613
<b>Northern Tier (regional total)</b>	<b>8,626</b>	<b>9.8%</b>	<b>9,472</b>	<b>-1.5%</b>	<b>9,327</b>
<b>Pennsylvania (county average)</b>	<b>867</b>	<b>15.5%</b>	<b>943</b>	<b>-6.6%</b>	<b>885</b>
<b>Pennsylvania (statewide total)</b>	<b>58,105</b>	<b>8.7%</b>	<b>63,163</b>	<b>-6.1%</b>	<b>59,309</b>

Source: USDA Census of Agriculture (2002, 2007, 2012). <sup>a</sup> Core, high-drilling activity county. <sup>b</sup> Core, low-drilling activity county.

Between 2002 and 2007, the average size of farms decreased throughout the state, study counties, and region, which may be partially explained by the increased representation of small farms in the 2007 Census (Table 4). Compared to the state, the change in size of farms in the northern tier was drastic—over 5 years the average acreage in the northern tier had dropped 13.5 percent compared to 4.3 percent statewide. Lycoming County was not consistent with the regional change in acreage with just a slight drop at 1.5 percent. Bradford, on the other hand, did not drop as much as other counties in the region, but still had a 9.4 percent decline. The changes in size of farms between 2002 and 2007 are most notable in Montour and Wyoming counties where acreage dropped by about one third. The declines in the northern tier are likely connected to the volatility in milk prices and general trends in consolidation. That trend was slowed and, in some counties, reversed between 2007 and 2012. Bradford County had a modest increase in the rate of change at 3.3 percent. Lycoming County’s rate of change continued to be negative, but not as much as it had been in the previous 5-year period. However, both counties saw less growth than the northern tier average and the state average. Sullivan, Wyoming, Montour, and Union counties had dramatic acreage increases.

**Table 4. Change in Average Acreage per Operation in Northern Tier, 2002 – 2012**

	2002	% change (2002-2007)	2007	% change (2007-2012)	2012
<b>Northern Tier (county average)</b>	<b>170</b>	<b>-12.9%</b>	<b>147</b>	<b>6.6%</b>	<b>156</b>
Bradford <sup>a</sup>	202	-9.4%	183	3.3%	189
Lycoming <sup>a</sup>	134	-1.5%	132	-0.8%	131
<b>Adjacent counties only (average)</b>	<b>170</b>	<b>-15.5%</b>	<b>145</b>	<b>7.7%</b>	<b>155</b>
Susquehanna <sup>a</sup>	170	-7.6%	157	5.7%	166
Tioga <sup>a</sup>	206	-11.7%	182	0.0%	182
Clinton <sup>b</sup>	127	-17.3%	105	6.6%	112
Potter <sup>b</sup>	275	-14.9%	234	-6.4%	219
Sullivan <sup>b</sup>	183	-7.7%	169	19.1%	209
Wyoming <sup>b</sup>	173	-30.6%	120	12.5%	135
Columbia <sup>c</sup>	140	-9.3%	127	2.4%	130
Montour <sup>c</sup>	131	-34.4%	86	10.5%	95
Northumberland <sup>d</sup>	166	-4.8%	158	-3.2%	153
Union <sup>d</sup>	133	-16.5%	111	30.0%	152
<b>Northern Tier (regional total)</b>	<b>2,040</b>	<b>-13.5%</b>	<b>1,764</b>	<b>6.2%</b>	<b>1,873</b>
<b>Pennsylvania (county average)</b>	<b>141</b>	<b>-5.3%</b>	<b>131</b>	<b>5.7%</b>	<b>138</b>
<b>Pennsylvania (statewide total)</b>	<b>9,148</b>	<b>-4.3%</b>	<b>8,575</b>	<b>5.8%</b>	<b>9,265</b>

Source: USDA Census of Agriculture (2002, 2007, 2012). <sup>a</sup> Core, high-drilling activity county. <sup>b</sup> Core, low-drilling activity county. <sup>c</sup> 2nd tier Marcellus Shale. <sup>d</sup> No Marcellus Shale wells.

+ 65 counties used to calculate 2002 average and rate of change (Delaware and Philadelphia excluded).

### Southwestern Pennsylvania Counties

Data for the southwest Counties show substantial increases and decreases in farm numbers between 2002, 2007, and 2012 (Table 5). The 2002-2007 period shows a sudden drop in Washington County's farm count of almost one fifth of its farms. Farm numbers continued to decline in Washington between 2007 and 2012 but, at -5.3 percent, that rate of change was less dramatic than the previous five-year period. It was substantially lower than the southwest county average of -18.2 percent and slightly lower than the Pennsylvania county average of -6.6 percent. Although not proportional, changes in Greene County were more consistent with the state and region during the 2002-2007 period than Washington. While the state and region increased by 6.4 and 8.7 percent, respectively, Greene County increased by 41.3 percent. Part of this increase may be explained by the effort of NASS to include small farms measured by value of sales in the 2007 Census; however Washington appears to be unaffected. The decline in farm numbers in Washington County may also be partly a consequence of suburban sprawl from Pittsburgh. During the 2007-2012 period, Greene County saw a dramatic drop in the number of farms, a change of -29.6 percent. This decline is much steeper than the southwest average of -18.2 percent and the Pennsylvania county average of -6.6 percent.



**Table 5. Change in Number of Farms in the Southwest, 2002- 2012**

	2002	% change (2002-2007)	2007	% change (2007-2012)	2012
<b>Southwest (county average)</b>	<b>1,138</b>	15.7%	<b>1,210</b>	-18.2%	<b>1,013</b>
Greene <sup>a</sup>	881	41.3%	1,245	-29.6%	876
Washington <sup>a</sup>	2,506	-19.3%	2,023	-5.3%	1,915
<b>Adjacent counties only (average)</b>	<b>860</b>	18.0%	<b>998</b>	-18.6%	<b>822</b>
Fayette <sup>a</sup>	978	24.7%	1,220	-22.9%	941
Allegheny <sup>b</sup>	464	15.1%	534	-19.9%	428
Beaver <sup>b</sup>	645	27.8%	824	-21.6%	646
Westmoreland <sup>b</sup>	1,353	4.6%	1,415	-9.96%	1,274
<b>Southwest (regional total)</b>	<b>6,827</b>	<b>6.4%</b>	<b>7,261</b>	<b>-16.3%</b>	<b>6,080</b>
<b>Pennsylvania (county average)</b>	<b>867</b>	<b>15.5%</b>	<b>943</b>	<b>-6.6%</b>	<b>885</b>
<b>Pennsylvania (statewide total)</b>	<b>58,105</b>	<b>8.7%</b>	<b>63,163</b>	<b>-6.1%</b>	<b>59,309</b>

Source: USDA Census of Agriculture (2002, 2007, 2012). <sup>a</sup> Core, high-drilling activity county. <sup>b</sup> Urban Marcellus.

Changes in farm size in the southwest showed a trend toward smaller farms between 2002 and 2007 (Table 6). The southwest region declined at a proportion greater than that of the state. Greene County had the greatest change in average acreage per operation between 2002 and 2007, a drop of -24.8 percent. Farm acreage held steady for Washington County between 2002 and 2007. Both Greene and Washington counties saw an increase in farm size between 2007 and 2012. However, neither county increased at the same rate as the southwest county average of 9.8 percent. Greene County was in line with the Pennsylvania county average of 5.7 percent. Washington County was more modest.

**Table 6. Change in Average Acreage per Operation in the Southwest, 2002-2012**

	2002	% change (2002-2007)	2007	% change (2007-2012)	2012
<b>Southwest (county average)</b>	<b>113</b>	<b>-8.1%</b>	<b>102</b>	<b>9.8%</b>	<b>106</b>
Greene <sup>a</sup>	161	-24.8%	121	5.8%	128
Washington <sup>a</sup>	104	0.0%	104	2.9%	107
<b>Adjacent counties only (average)</b>	<b>103</b>	<b>-6.0%</b>	<b>96</b>	<b>12.5%</b>	<b>100</b>
Fayette <sup>a</sup>	128	-10.2%	115	4.3%	120
Allegheny <sup>b</sup>	73	-2.7%	71	14.1%	81
Beaver <sup>b</sup>	97	-16.5%	81	6.2%	86
Westmoreland <sup>b</sup>	112	5.4%	118	-5.1%	112
<b>Southwest (regional total)</b>	<b>675</b>	<b>-9.6%</b>	<b>610</b>	<b>3.9%</b>	<b>634</b>
<b>Pennsylvania (county average)</b>	<b>141</b>	<b>-5.3%</b>	<b>131</b>	<b>5.7%</b>	<b>138</b>
<b>Pennsylvania (statewide total)</b>	<b>9,148</b>	<b>-4.3%</b>	<b>8,757</b>	<b>5.8%</b>	<b>9,265</b>

Source: USDA Census of Agriculture (2002, 2007, 2012). <sup>a</sup> Core, high-drilling activity county. <sup>b</sup> Urban Marcellus. + 65 counties used to calculate 2002 average and rate of change (Delaware and Philadelphia excluded).

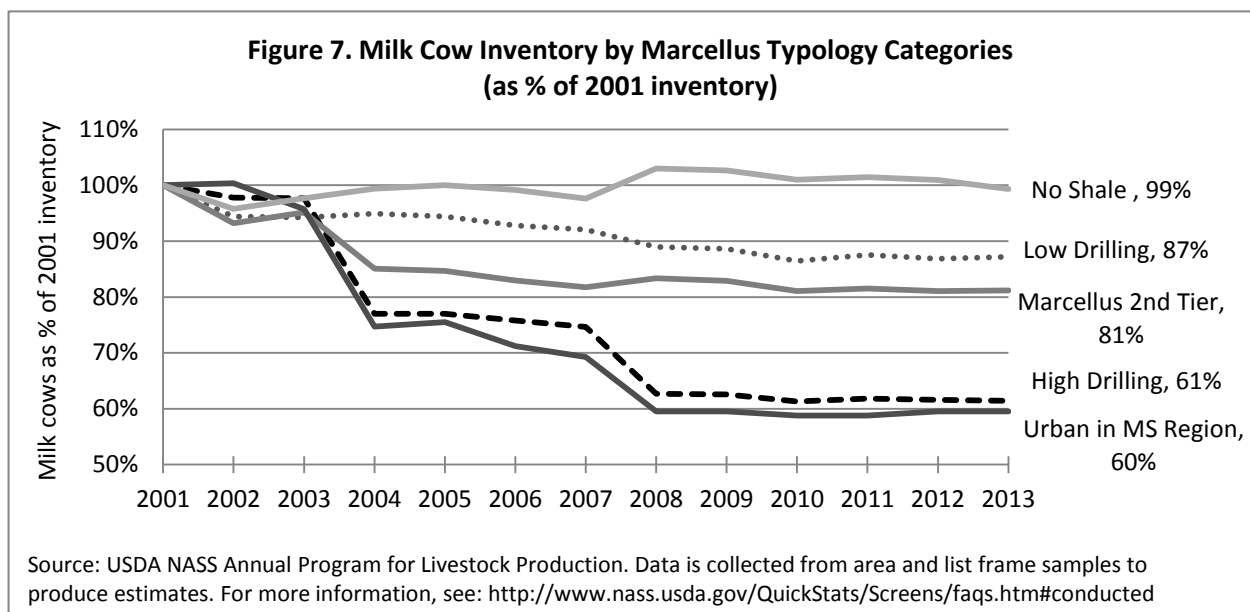
## Statewide and Regional Changes in Dairy

Dairy is the top agricultural commodity in Pennsylvania (in terms of value of sales) and in three of the four study counties. Dairy farming is often perceived as a particularly intensive activity, given that cows are milked two or more times each day. In the Wave 1 report, focus group participants in the northern tier noted that the signing of a profitable gas lease has led some farmers to exit the dairy industry and enter into “less intensive agriculture.” To explore the potential impacts of Marcellus Shale development on the industry, changes in milk cow inventory are explored across levels of drilling activity, by region, and across the four study counties.

Note that the Marcellus Shale county drilling activity levels were created by combining definitions based on estimated shale value and actual development activity, including publicly available maps of the thickness, depth, and thermal maturity of the shale (McLaughlin, et al., 2012). Those counties with the highest geological potential for production of natural gas are classified as “core” counties and those within the Marcellus Shale “footprint” but with lower potential for development are classified as “2<sup>nd</sup> Tier.” The core area was further divided into two categories based on levels of well development activity during the main study period. There are seven counties (including the study counties) that account for 90 percent of the total number of wells drilled through June 30, 2013. These seven counties are classified as “core” counties with high drilling activity. The remaining counties in the “core” are classified as “core” with low drilling activity. The typology also separates urban counties in both the “core” and “2<sup>nd</sup> Tier” classification because urban counties (as defined by the Center for Rural Pennsylvania) historically have differing population and economic dynamics. The final category includes all other counties not in the Marcellus Shale “footprint.”

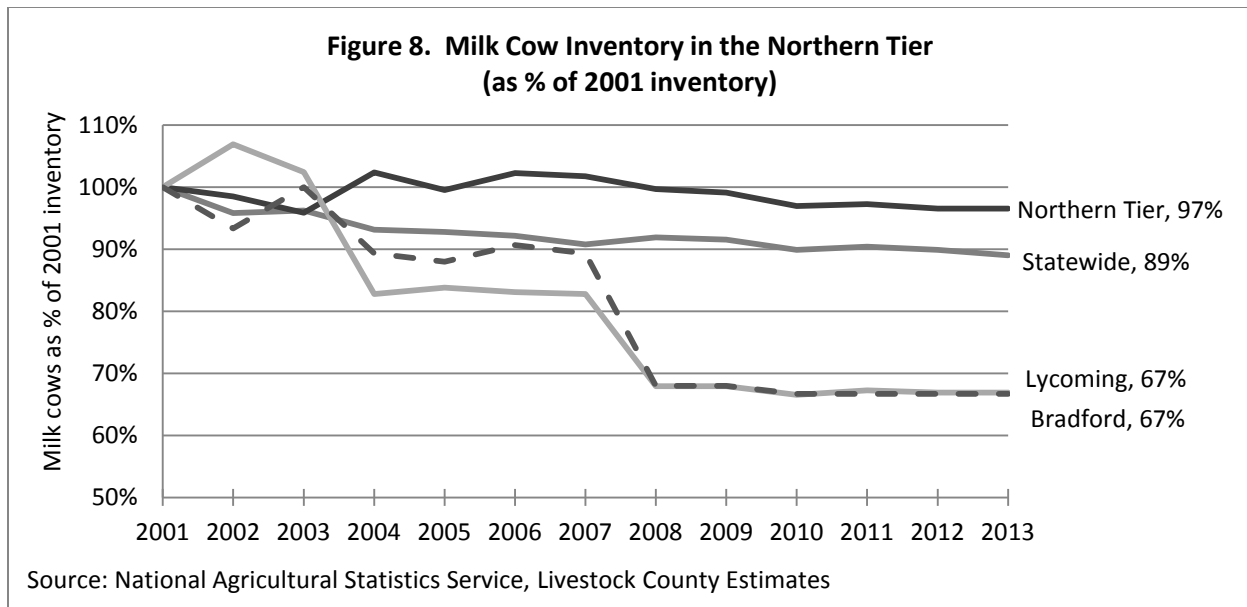
The number of milk cows varies across the state and by drilling activity. From 2001 to 2013, the average annual inventory was just over 60,000 cows in all high-drilling counties and just over 50,000 in low-drilling counties. This compares to a much lower total in urban Marcellus counties (just under 20,000) and much larger inventories in 2<sup>nd</sup> tier Marcellus counties (105,000) and across counties outside of the Marcellus Shale region (325,000) (NASS). About 20 percent of all milk cows could be found in counties with high- or low-drilling activity across this time period.

Figure 7 shows the milk cow inventory across these five areas as a percentage of the number of milk cows in 2001. The least amount of change was observed in the No Shale counties, whereas low-drilling and Marcellus 2<sup>nd</sup> Tier counties experienced steady but comparatively small declines in inventory, with 87 percent and 81 percent (respectively) of the number of milk cows as in 2001. In contrast, the number of milk cows in the high-drilling and in the urban Marcellus regions was less than two-thirds of the number in 2001. The largest drops were observed 2003-2004 and then again in 2007-2008, which coincides with the beginning of Marcellus Shale development. Although the number of dairy cows has not been restored since these declines, it has stabilized. Estimates for 2014 were not yet available at the time of the research.



### Northern Tier Pennsylvania Counties

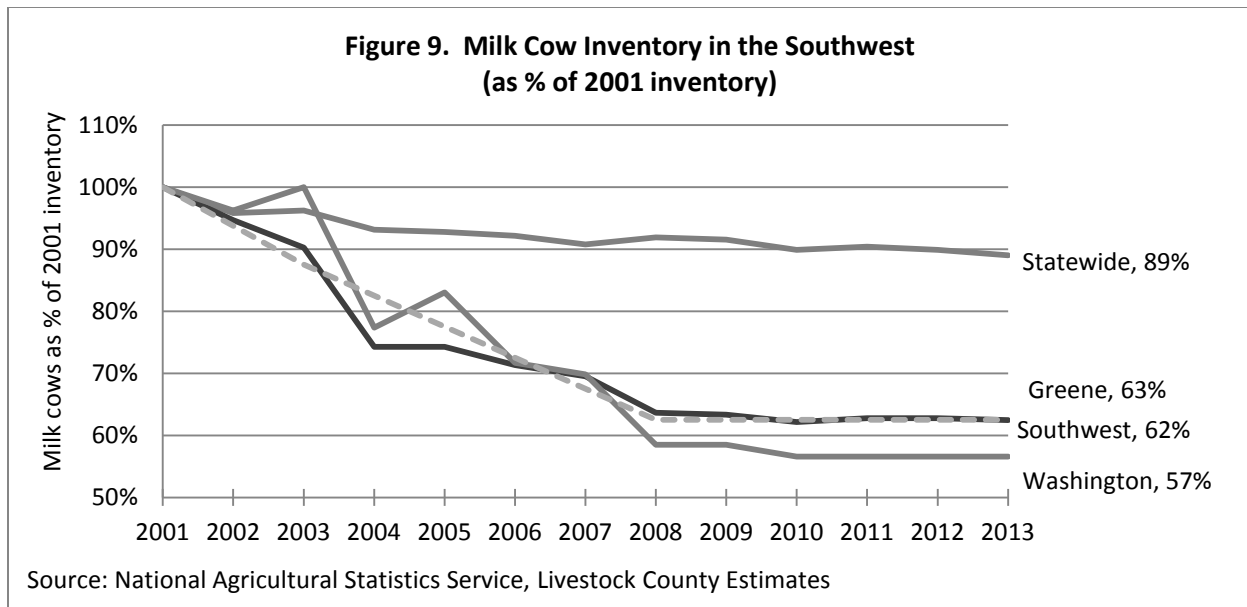
As drilling activity in the Marcellus Shale region rapidly increased in some counties, statewide there was a slight decline in the number of dairy cows (Adams and Kelsey, 2012). Between 2007 and 2010 the number of milk cows in Pennsylvania declined by about 1.7 percent. However, different counties experienced different levels of change, which Adams and Kelsey (2012) contend may be associated with the size of a county's dairy sector and level of Marcellus Shale drilling activity. Figure 8 shows the milk cow inventory by county as a percentage of 2001, from 2001 to 2013.



Whereas the number of milk cows remained relatively stable across the northern tier region, the milk cow inventory statewide declined to 89 percent of the 2001 level. Changes in Lycoming (dotted line) and Bradford were more striking, as they both experienced greater fluctuation between 2001 and 2008. These changes include notable declines in milk cow inventory from 2007 to 2008, the years that Marcellus Shale development began to pick up. During this time of decline, milk prices were very low and the number of wells drilled increased, especially in the following years. Causation, however, is difficult to establish given the many factors that may affect milk cow inventory and the earlier patterns of decline (i.e. 2003 to 2004).

### Southwestern Pennsylvania Counties

Figure 9 presents the milk cow inventory as a percentage of the 2001 inventory in the state, across southwest counties, and in Washington and Greene counties. The changes in dairy farming over the study period reflect dramatic fluctuations across the southwest despite relative stability in the milk cow population statewide. More than one-third of the milk cow population was lost in Greene and Washington counties and in the southwest region overall from 2001 to 2013, although most of the change occurred leading up to 2008. Adams and Kelsey (2012) conclude that intensity of gas drilling and decline in dairy cow numbers seem to be associated, but caution that the data do not allow one to do more than speculate on that association.



## Conclusions

The Wave 1 report described how focus group participants consistently identified both positive and negative impacts from Marcellus Shale development. Most participants appreciated the economic benefits, but many also expressed concerns about effects on the quality of life, and the long-term impacts on farming. Whether the overall impact of Marcellus Shale gas drilling on Pennsylvania agriculture will be beneficial or detrimental was unclear because the 2012 USDA Census data were not available before the Wave 1 report was completed. Now that the 2012 USDA Census data are available, it is clear that there have been some important changes in the four study counties. The number of farms in Bradford County increased substantially between 2002 and 2012, while the number of farmers in the other counties and Pennsylvania in general declined. Average acreage in the four study counties increased, with the exception of Lycoming County. However, those increases were smaller than their adjacent counties and Pennsylvania generally. However, there were no clear patterns across the four study counties and the data do not allow for an analysis that would link variations in changes to Marcellus Shale activities. Perhaps the most dramatic change that might be linked to Marcellus Shale development is evident in the milk cow inventory. The milk cow inventory declined modestly statewide and substantially in the four study counties. Most dramatic is the drop in milk cow inventory in Lycoming and Bradford counties, because the drop is so dramatic when compared to their neighboring counties and statewide. Moreover, the decline in milk cows increases steadily from no drilling to high drilling counties. This suggests a possible link between Marcellus Shale gas drilling activities and a decline in dairy cows, which would further suggest a decline in dairy activity.

By combining the results from the focus groups in Wave 1 and the Agricultural Census data from Wave 1 and Wave 2, one may speculate that Marcellus Shale activity is one of many factors influencing farm practices and changes. However, one would need to explore individual-level farm and farmer characteristics to determine any clear patterns. In a qualitative study, Malin (2013) found that farmers discuss the natural gas developments as inevitable and that they have no real choice but to accept

them. She further argues that the economic reasoning in support of development is so powerful that farmers feel a lack of agency and lack the capacity to articulate an alternative. Data from surveys and other secondary data will be needed to determine the dynamic influences and relationships between drilling activities and changes in farming operations, quality of life, and decisions related to land-use and availability.

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The authors maintain responsibility for any errors.

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## Appendix A: Unconventional Wells Drilled by County and Year, 2005-2014

County	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Total, county
Allegheny	0	0	0	1	3	0	5	13	9	35	66
Armstrong	0	3	2	7	18	37	37	44	34	30	212
Beaver	0	0	0	0	1	1	6	17	9	12	46
Bedford	0	0	0	0	0	1	0	0	0	0	1
Blair	0	0	0	0	0	4	2	0	0	0	6
Bradford	1	2	2	24	159	377	397	164	108	96	1330
Butler	0	3	12	11	10	35	35	69	92	126	393
Cambria	0	0	0	0	2	1	3	1	0	2	9
Cameron	0	0	0	3	2	3	7	0	5	26	46
Centre	0	1	1	4	7	41	8	2	0	1	65
Clarion	0	0	3	1	3	3	10	4	1	5	30
Clearfield	0	0	0	6	23	39	58	19	3	0	148
Clinton	0	0	0	4	9	35	39	10	3	3	103
Columbia	0	0	0	0	0	1	2	0	0	9	12
Crawford	0	0	0	0	0	0	0	3	0	0	3
Elk	1	1	5	7	5	16	22	1	9	55	122
Erie	0	0	0	0	0	0	0	0	0	27	27
Fayette	0	2	6	20	57	44	54	47	23	17	270
Forest	0	0	0	0	5	1	0	12	4	0	22
Greene	0	2	14	67	101	102	121	108	117	255	887
Huntingdon	0	0	0	0	0	1	0	0	0	0	1
Indiana	0	0	0	5	6	7	21	2	7	0	48
Jefferson	0	0	0	3	3	8	15	9	3	16	57
Lackawanna	0	0	0	0	1	0	1	0	0	0	2
Lawrence	0	0	0	0	0	0	2	17	13	34	66
Luzerne	0	0	0	0	0	2	0	0	0	0	2
Lycoming	0	0	5	12	23	120	304	203	163	86	916
McKean	0	2	1	4	7	22	19	5	13	11	84
Mercer	0	0	0	0	0	0	0	5	21	12	38
Potter	0	0	8	6	8	36	12	1	0	0	71
Somerset	0	0	1	0	7	4	7	6	1	0	26
Sullivan	0	0	0	0	0	22	19	27	14	34	116
Susquehanna	0	1	2	33	88	125	204	192	206	238	1089
Tioga	0	0	0	15	124	276	273	122	33	30	873
Venango	0	0	0	1	0	0	2	3	1	0	7
Warren	0	0	2	0	0	0	1	1	1	0	5
Washington	5	19	45	66	101	167	156	195	220	140	1114
Wayne	0	0	0	1	0	3	0	0	0	0	4
Westmoreland	1	0	4	33	39	49	60	42	28	4	260
Wyoming	0	0	0	0	2	25	72	15	67	44	225

## Appendix B. Marcellus Activity County Typology Definitions for Pennsylvania<sup>a</sup>

Category	Geological Definition	Activity level	Counties
<b>Core Counties with High Drilling Activity<sup>b</sup></b> (N=7)	More than 50% of the land area is in the core Marcellus formation	Annual average 64 or more Marcellus wells 2005 to 2010	Bradford, Fayette, Greene, Lycoming, Susquehanna, Tioga, Washington
<b>Core Counties with Low Drilling Activity</b> (N=12)	More than 50% of the land area is in the core Marcellus formation	Annual average less than 64 Marcellus wells 2005 to 2010	Armstrong, Cambria, Cameron <sup>c</sup> , Clearfield, Clinton, Elk, Indiana, Jefferson, Potter <sup>c</sup> , Somerset, Sullivan <sup>c</sup> , Wyoming
Counties in the <b>Marcellus 2<sup>nd</sup> Tier</b> (N=19)	1%-50% land area is in the core <u>and</u> 25% or more land area is in the less viable areas (2 <sup>nd</sup> tier or gray areas in Figure 2)	Not applicable	Bedford, Blair, Butler, Carbon, Centre, Clarion, Columbia, Crawford, Forest <sup>c</sup> , Lawrence, McKean, Mercer, Monroe, Montour <sup>c</sup> , Pike, Schuylkill, Venango, Warren, Wayne
Urban Counties in the Marcellus Shale-- <b>Core or 2<sup>nd</sup> Tier</b> (N=6)	Marcellus Core or 2 <sup>nd</sup> Tier <u>and</u> identified as urban by the Center for Rural Pennsylvania	Not applicable	Allegheny, Beaver, Erie, Lackawanna, Luzerne, Westmoreland
Counties with No Marcellus Shale (N=23)	25% or less viable Marcellus land area or no Marcellus land area	Not applicable	Adams, Berks, Bucks, Chester, Cumberland, Dauphin, Delaware, Franklin, Fulton <sup>c</sup> , Huntingdon, Juniata, Lancaster, Lebanon, Lehigh, Mifflin, Montgomery, Northampton, Northumberland, Perry, Philadelphia, Snyder, Union, York

<sup>a</sup>See McLaughlin, et al. 2012.

<sup>b</sup>Note this category includes all four study counties.

<sup>c</sup>These counties are excluded from those analyses that use American Community Survey (ACS) three-year estimates, as their populations are too small to be estimated.

\*For more on maps, see the Penn State University Marcellus Center for Outreach and Research (<http://marcellus.psu.edu>) and Dell, Lockshin, and Guber (2008).

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