A Descriptive Study of Grain Production, Consumption, and Storage in Virginia

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ABSTRACT

Agriculture is an important industry in Virginia, with an array of crops grown and animals produced. Virginia's crop, livestock, and poultry sectors sold agricultural products worth $1.4 billion and $2.4 billion, respectively, in 2012. One of the products, grain, serves as an important input for raising livestock and poultry. Virginia needs to import grain from other states (Eastern Corn Belt states) to meet current livestock feed requirements, an expense that raises the cost of production over locally sourced grains . Further, such movements of grain from producing-areas to demand-areas rely on the efficient and timely interaction of grain storage and transportation. Describing the details of the grain supply chain provides insights into the interplay and relationships among production, storage, transportation, and end users of grains and oilseeds in Virginia. Results of a state-wide survey of Virginia grain producers shed light on the following topics: current cropping practices; current grain storage practices; available farm-level storage and its use, age, and expected life; and future storage plans and constraints. Overall findings include, grain production in Virginia has generally increased over the last decade, yet storage capacity remains constant and continues to age; livestock and poultry populations are declining leading to less demand for feed grains and oilseeds; grain farmers report satisfaction with their current storage situation and higher returns to stored grain may encourage "non-storers" to build storage; and the majority the grain leaving the farm is hauled by truck over short distances (25 miles or less). Overall, the results provide a foundation for understanding the grain supply chain in Virginia and offer useful information to Virginia's agricultural stakeholders.

Dedicated to the memories of

Norita Frenning
(1927 – 2011)

Who inspiringly took "one day at a time"

Mary Frenning
(1925 – 2013)

Whose work with (the University of Maine)
Cooperative Extension means I wasn't the first

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Research of any magnitude hardly goes untouched by others. My work is certainly no different. I am grateful to the many suggestions and contributions from colleagues that have made the work not only more accurate, but more relevant to Virginia's agricultural stakeholders. First, I express my thanks to my committee, namely Drs. Gustavo Ferreira, Gordon Groover, and Kathryn Boys. Their guidance, efforts, and feedback helped bring a relatively open-ended project to fruition. Also, their exceptional patience and support are noteworthy, particularly given the various challenges encountered during the process. We didn't give up.

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I also appreciate the involvement, interest, and support of our project from the Virginia Grain Producers Association, the Virginia Soybean Association, Virginia Cooperative Extension, and Virginia Farm Bureau (Jonah Bowles' interest in and enthusiasm for our project was inspiring, and the humor in his weekly *Commodity Comments* still makes me smile to this day).

I also extend my deep and humble appreciation to Virginia's farmers for their participation in our research and every day work that supports Virginia's agricultural economy.

In addition, I would like to thank Smithfield Foods who, through Virginia Tech's Educational Foundation, funded needed research of the grain supply chain in the Mid-Atlantic and made this all possible. It was a privilege to work on the project, and I would not be where I am today without it.

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Table of Contents

Abstract ... ii
Dedication ... iii
Acknowledgements ... iv
Table of Contents ... v
List of Figures ... vii
List of Tables ... ix
Preface ... x
Chapter 1: Introduction ... 1
Chapter 2: Grain and Soybean Production and Storage in Virginia: A Summary and Spatial Examination ... 3
Introduction ... 3
Results ... 3
Production: Types and How Much ... 3
Locations of Production ... 7
Storage: Types and Capacity ... 11
Location of Storage ... 15
Joint Consideration of Grain Production and Storage Across Time ... 16
Conclusions and Discussion ... 19
References ... 21
Chapter 3: Grain Consumption and Production in Virginia: A Trend and Spatial Examination ... 22
Introduction ... 22
Literature Review ... 23
Trends in Virginia Grain Consumption and Production ... 24
Data Sources and Methodology ... 24
Grain Production ... 25
Grain Consumption ... 25
Results ... 28
Grain Production ... 28
Grain Consumption ... 29
Grain Consumption and Production ... 32
Spatial Distribution of Virginia Grain Consumption and Production ... 35
Data Sources and Methodology ... 35
Grain Production ... 36
Grain Consumption: Animal Populations, GCAUs, Grain Consumed Per GCAU, and Total Grain Consumption ... 36
Results ... 37
Grain Production ... 37
Grain Consumption ... 38

Grain Consumption and Production 39

Conclusions and Discussion **40**

References **43**

Chapter 4: Describing Grain and Soybean Production and Storage in Virginia: Results of a 2013 Farm Survey ***47***

Introduction **47**

About the Survey **48**

Results **50**
General Characteristics of the Sample and Grain Producers in Virginia 50
Characteristics of Virginia's On-Farm Storage 53
Storage Constraints in Grain Operations 57
Plans to Alleviate Storage Constraints 58
Economic Incentives to Encourage Storage Building 60
Characteristics of Grain Transportation in Virginia 60

Conclusions and Discussion **62**

References **64**

Chapter 5: Conclusion ***66***

Appendix A: Additional State-Level Methodology and Results ***67***
Additional Methodology 67
Grain Consumption: Cattle Population (Dairy Cows, Dairy Heifers, Beef Cattle on Feed, Other Beef Cattle) 67
Grain Consumption: Poultry Population (Broilers, Turkeys, Layers, and Pullets) 67
Grain Consumption: Hogs Population 68
Grain Consumption: Sheep (and Lambs) Population 68
Grain Consumption: Horses Population 69
Additional Results 70
Graphs of Populations (Number of "Head") Fed in Virginia 70
Graphs of Consumption Shares 75

Appendix B: Additional County-Level Methodology and Results ***78***
Additional Methodology 78
Grain Consumption: Cattle Population (Dairy Cows, Beef Cattle on Feed, Other Beef Cattle) 78
Grain Consumption: Poultry Population (Broilers, Turkeys, Layers, and Pullets) 79
Grain Consumption: Hogs Population 80
Grain Consumption: Sheep (and Lambs) Population 81
Grain Consumption: Horses Population 82
Additional Results 84
Consumption (Livestock Population) Maps 84
Production Maps 87

Appendix C: Survey Recruitment Letter and Instrument ***90***

Appendix D: Additional Data Tables ***104***

List of Figures

Figure 1: Average Contribution (%) to Total Production of Virginia Grains, 1920s-2010s 5
Figure 2: Virginia Grain Production by Grain Type, 1988-2012 6
Figure 3: Map of Virginia Barley Production by County, 2007 9
Figure 4: Map of Virginia Corn Production by County, 2007 10
Figure 5: Map of Virginia Soybean Production by County, 2007 10
Figure 6: Map of Virginia Wheat Production by County, 2007 11
Figure 7: Virginia Off-Farm and On-Farm Storage Capacity, 1988-2012 13
Figure 8: Number of Commercial Facilities in Virginia, 1988-2012 14
Figure 9: Map of Virginia On-Farm Storage Capacity by County, 2007 16
Figure 10: Virginia Storage Capacity and Grain Production, 1988-2012 17
Figure 11: Surplus or Shortage in Virginia Storage Capacity, 1988-2012 18
Figure 12: Tons of Feed Consumed per Grain Consuming Animal Unit, 1992-2014................. 28
Figure 13: Grain Production in Virginia, 1992-2014 (Million Tons) 29
Figure 14: Number of Grain Consuming Animal Units in Virginia, 1992-2014.......................... 30
Figure 15: Estimated Grain Consumption in Virginia by Livestock and Poultry, 1992-2014 31
Figure 16: Grain Consumption (by Livestock and Poultry) and Production in Virginia, 1992-2014 33
Figure 17: Map of Total Grain Production in Virginia by County, 2012 38
Figure 18: Map of Total Grain Consumption (by Livestock and Poultry) in Virginia by County, 2012... 39
Figure 19: Map of Virginia's Grain Deficits and Surpluses (Production Less Consumption by Livestock and Poultry) by County, 2012 40
Figure 20: Counties with the Highest Number of Surveys Received 50
Figure 21: Shares of Survey Respondents Growing 1 or More Crops 51
Figure 22: Number of Farmers with a Given Number of Bins 55
Figure 23: Number (and Share) of Virginia's On-Farm Structures by Age 56
Figure 24: Share of Virginia's On-Farm Structures by Remaining Useful Life........................... 57
Figure 25: Number of Respondents by Wait Time 62
Figure 26: Population of Broilers in Virginia, 1992-2014.. 70
Figure 27: Populations of Turkeys, Layers, and Pullets in Virginia, 1992-2014 71
Figure 28: Population of Hogs in Virginia, 1992-2014 72
Figure 29: Populations of Dairy Cows and Beef Cattle on Feed in Virginia, 1992-2014 73
Figure 30: Population of Sheep in Virginia, 1992-2014... 74
Figure 31: Shares of Total Grain Consumption in Virginia by Poultry, Cattle, Hogs, and Other, 1992-2014 75
Figure 32: Recent Shares within Poultry Grain Consumption in Virginia, ... 76
Figure 33: Recent Shares within Cattle Grain Consumption in Virginia, ... 77
Figure 34: Map of Virginia's Broilers by County, 2012 84
Figure 35: Map of Virginia's Turkeys by County, 2012 84
Figure 36: Map of Virginia's Hogs by County, 2012 85
Figure 37: Map of Virginia's Dairy Cattle by County, 2012... 85
Figure 38: Map of Virginia's Beef Cattle on Feed by County, 2012 86
Figure 39: Map of Virginia's Sheep by County, 2012.. 86

Figure 40: Map of Virginia’s Horses by County, 2006 87
Figure 41: Map of Barley Production in Virginia by County, 2012 87
Figure 42: Map of Corn Production in Virginia by County, 2012 88
Figure 43: Map of Soybean Meal in Virginia by County, 2012 88
Figure 44: Map of Wheat Production in Virginia by County, 2012 89

List of Tables

Table 1: Annual Acreage Panted and Harvested for Virginia's Primary Grain Crops, ... 4
Table 2: Production Levels of Virginia Grains, 2008-12, in Bushels 4
Table 3: Proportion (%) of Total Production by Crop for Different Productivity Years, 1988-2012 7
Table 4: Top Grain-Producing Counties and Independent Cities in Virginia, by Grain Type, 2007 8
Table 5: Storage Capacity in Virginia, 2008-12, in Bushels 12
Table 6: Regions in Virginia with the Most On-Farm Storage, 2007 15
Table 7: Two-Period Comparison of Virginia's Storage Shortages and Surpluses under Normal Grain Production Years 19
Table 8: Factors to Convert Grain in Bushels to Tons 25
Table 9: Livestock and Poultry Considered in Assessment of Virginia Grain Consumption 26
Table 10: Grain Consuming Animal Unit Factors for Different Animals 27
Table 11: Comparison of Annual and Census Data for Virginia Grain Production 36
Table 12: Variables for the State-Level and County-Level Grain Consumption Estimates 37
Table 13: Response Statistics of 2013 Farmer Survey 48
Table 14: Acreage Statistics 51
Table 15: Crop Production Statistics of Sample 52
Table 16: Breakdown and Number of Respondents Falling Into Each Group 53
Table 17: On-Farm Storage Size Characteristics 55
Table 18: Number of Operations with a Storage Limitation by Group 57
Table 19: Storage Issues Faced by Constrained Operations 58
Table 20: Future Storage Plans of "Constrained" Operations 59
Table 21: Future Storage Plans of "Non-Constrained" Operations 59
Table 22: Conditions under Which Virginia's Grain Farmers (Without Storage) Would Consider Building Storage 60
Table 23: Volume of Bushels Transported Various Distances from Farm in Virginia 61
Table 24: Comparison of Annual and Census Data for Cattle 79
Table 25: Comparison of Annual and Census Data for Poultry 80
Table 26: Comparison of Annual and Census Data for Pigs 81
Table 27: Comparison of Annual and Census Data for Sheep 82
Table 28: Information on County-Level Data for Horses 83
Table 29: Number of Grain Crops Grown 104
Table 30: Number of Farmers with a Given Number of Bins 104
Table 31: Number of Bins by Age 105
Table 32: Number of Bins by Remaining Useful Life 105

Preface

The work outlined in this thesis was submitted in partial fulfilment of the requirements for a Master of Science degree in Agricultural an Applied Economics from Virginia Polytechnic Institute and State University. The material in this thesis is submitted purely for a degree or diploma and has not previously been submitted for any such qualification. The first manuscript has been published through Virginia Cooperative Extension. All three papers were my own words, unless otherwise documented, with helpful comments, suggestions, and recommendations from Gustavo Ferreira, Gordon Groover, and Kathryn Boys.

Chapter 1: Introduction

A kernel of corn, a granule of wheat, a single soybean. Though minute and practically insignificant in size, these products operate in a large, complex, world supply chain. At the macro -level, grain production (or supply) in the United States serves as an input in domestic livestock production, and is also exported abroad. Farm and off-farm storage, and the transportation system, are critical to the efficient and timely flow of grain from farms to final users. Transportation, including a wide network of trains, trucks, and barges, moves grain where it needs to go, and grain storage facilitates delivery of grain, a seasonal product, at the right time.

At a local level, Virginia is home to significant livestock and poultry operations, which rely on grain for feed. There is a perceived shortfall of feed grains to support the livestock and poultry sectors. Shipping grain from the Midwest to the Mid-Atlantic States to supplement the shortfall is expensive and increases the costs of production for raising livestock and poultry.

The following objectives provided the basis for describing and identifying the factors that influence Virginia's grain supply chain: 1) current volumes and location of grain production and consumption; 2) current grain storage capacity and transportation infrastructure; 3) plans for future building of on-farm and commercial storage; 4) existing constraints in the grain marketing channels; and 5) possible economic incentives to reduce these constraints. Results are presented in three papers (organized as chapters) on Virginia grain production, storage, and consumption.

The first paper (Chapter 2) examines the characteristics and trends of Virginia grain production and storage. Results show that grain production in Virginia is mainly characterized by corn, soybeans, and wheat, with a growing share of soybeans. Production (and storage) mainly occurs in the counties east of Interstate 95 and in the Shenandoah Valley. Most of Virginia's grain storage is on the farm (as opposed to commercial). Grain production has generally increased over the years, but with relatively flat grain storage capacity, the system appears to be more constrained in recent years.

The second paper (Chapter 3) couples grain production with Virginia's important livestock and poultry sectors to analyze both the overall magnitude and distribution of grain consumption in Virginia. Specifically, the chapter describes the sources and trends over time of grain production and consumption; identifies grain surplus/deficit areas across Virginia's counties; quantifies livestock and poultry consumption requirements at the state- and county-levels; and provides an updated assessment of Virginia's ability to meet its grain needs. Important results of the analysis reveal that grain consumption in Virginia is mainly by poultry (primarily broilers or chickens). Furthermore, grain consumption in Virginia has generally declined over the last twenty years, due to decreasing livestock population numbers. Coupled with an upward trend in grain production, Virginia appears to be increasingly capable of meeting its grain needs. Importantly, there is an east-west divide in the state, with western counties requiring more grain than they produce (most of the grain consumption and resulting "deficit" is in the Shenandoah Valley). Since grain does not appear to move from the relatively "production-rich" eastern counties, transportation infrastructure is important to bring in grain from outside the state.

Lastly, the third paper (Chapter 4) presents the results of a state-wide survey of Virginia grain producers, which was conducted to gain more specific insights into possible storage constraints. This paper assesses grain growers' production (in terms of type of crop and volume); investigates growers' decision-making at harvest; studies the amount and quality of grain storage (e.g., age and remaining useful life); identifies economic incentives that might encourage storage building; and examines a few attributes of grain transportation in Virginia. Findings demonstrate that that many grain producers in Virginia grow three crops (corn, soybeans, and wheat). Further, producers exhibit different behavior at harvest, with most either delivering all their grain to market at harvest or storing a portion in owned on-farm structures. Survey results show that grain storage in Virginia appears to be aging; however many respondents believe their structures will remain useful for another decade or more. Interestingly, whether they have storage or not, a majority of respondents believe that the storage set-up on their operations are sufficient. However, within the group that does face a storage limitation, many report an issue with “total capacity.” In terms of transportation, most of the respondents haul their own grain to buying stations and over relatively short distances (25 miles or less).

Chapter 2: Grain and Soybean Production and Storage in Virginia: A Summary and Spatial Examination

Introduction

Grain and soybean production is a critical component of Virginia agriculture—the state's No. 1 industry (VDACS, 2013). Virginia's farmers produced more than half a billion bushels of grain and soybeans over the span of 2006 to 2012 (USDA-NASS, 2013b).[1] The objectives of this publication are to characterize the market for grain production and storage in Virginia. Specifically, this paper will:

1. Highlight and examine the current characteristics and trends of Virginia grain and soybean production and storage;
2. Provide an overview of the types, volume, and location of Virginia grain production;
3. Show how much storage existed across time and where it is located;
4. Identify future constraints and opportunities in production and storage in Virginia; and
5. Offer market insight for industry stakeholders.

Results

Production: Types and How Much

Varying substantially in acres planted and bushels produced, seven grain crops (barley, corn, grain sorghum, oats, rye, triticale, and wheat) and soybeans are grown in Virginia (USDA-NASS, 2009). Although technically an oilseed, for the purpose of this discussion, soybeans will be included in the "grains" category. Table 1 displays data from the U.S. Department of Agriculture's National Agricultural Statistics Service (NASS) for the average number of acres planted and harvested from 2008 to 2012 for Virginia's primary grain crops.[2] These data are for Virginia grain grown conventionally as opposed to organic grain. According to the latest available numbers from the Economic Research Service (2011), little organic grain is produced in Virginia (USDA-ERS 2014).[3]

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[1] The crops included in the calculation are barley, corn, soybeans, and wheat.

[2] According to the most recent and available NASS survey reports (USDA-NASS 2013b), in 2004, 5,000 acres of grain sorghum were planted and 2,000 acres were harvested for grain. In 1999, 80,000 acres of rye were planted and 8,000 acres were harvested. Rye is primarily planted as a cover crop in Virginia. In 2012, 11,000 acres of oats were planted and 4,000 acres were harvested for grain. Planting data for triticale are not available.

[3] In 2011, Virginia had 369 acres of organic barley, 1,252 acres of organic corn, 676 acres of organic soybeans, and 34 acres of organic wheat (USDA-ERS 2014).

Table 1: Annual Acreage Panted and Harvested for Virginia's Primary Grain Crops, 2008-12

	Barley	Corn	Soybeans	Wheat
Total acres planted	72,000	488,000	574,000	258,000
Acres harvested for grain/seed Share (%)	46,800 65%	334,000 68%	562,000 98%	227,000 88%
Acres harvested for silage Share (%)	Not reported	139,000 29%	Not applicable	Not reported
Acres harvested remaining Share (%)	25,200 35%	15,000 3%	12,000 2%	31,000 12%
Total production (bushels)	3,730,400	35,378,000	19,946,000	14,663,000

Source: USDA-NASS (2013b) and authors' calculations.
Values reflect averages over production from 2008-12.

NASS only reports the acres of corn and grain sorghum (a relatively insignificant crop grown in Virginia) that are harvested for silage. However, given barley's large remaining share of 35 percent, it can be implied that a substantial proportion of barley is grown for forage. Soybeans and wheat, on the other hand, are primarily harvested for seed and grain, respectively, in Virginia.

The most recent annual production data (2008-12) for Virginia's four main grain crops is shown in Table 2.

Table 2: Production Levels of Virginia Grains, 2008-12, in Bushels

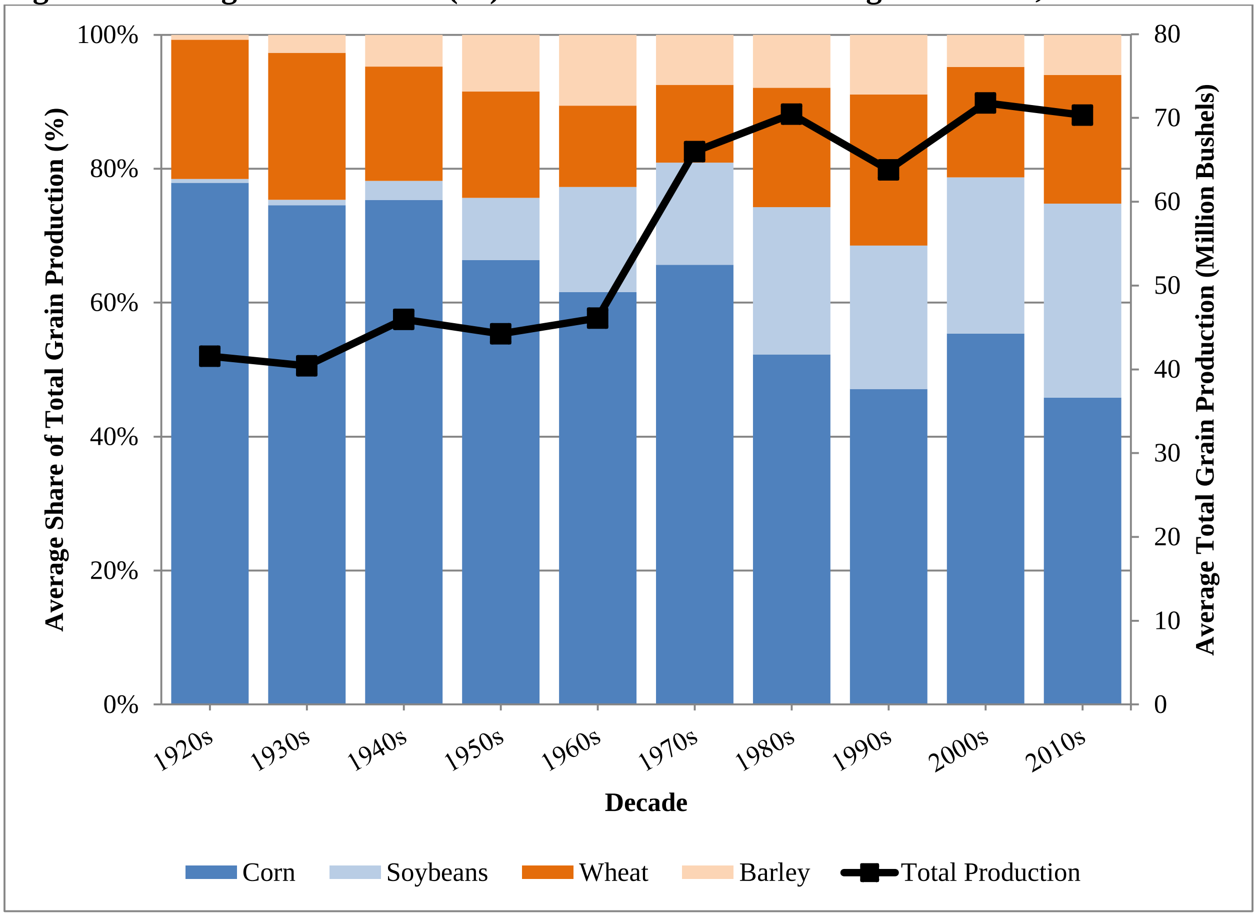
Year	Barley	Corn	Soybeans	Wheat	Total
2012	3,034,000	36,050,000	24,360,000	15,600,000	79,044,000
2011	6,160,000	40,120,000	22,000,000	17,750,000	86,030,000
2010	3,216,000	20,770,000	14,040,000	7,905,000	45,931,000
2009	3,182,000	43,230,000	21,090,000	12,180,000	79,682,000
2008	3,060,000	36,720,000	18,240,000	19,880,000	77,900,000

Source: USDA-NASS (2013b).

Although Virginia produced a record high 86 million bushels of grain in 2011, total grain output decreased by 8 percent in 2012. In the last 20 years, grain output came close to 2011's peak production level in only two years, with 85.4 million bushels produced in 2000 and 85.7 million bushels produced in 2004.

Figure 1 illustrates the movements in total grain production and the relative shares of barley, corn, wheat, and soybean production in Virginia by decade.

Figure 1: Average Contribution (%) to Total Production of Virginia Grains, 1920s-2010s



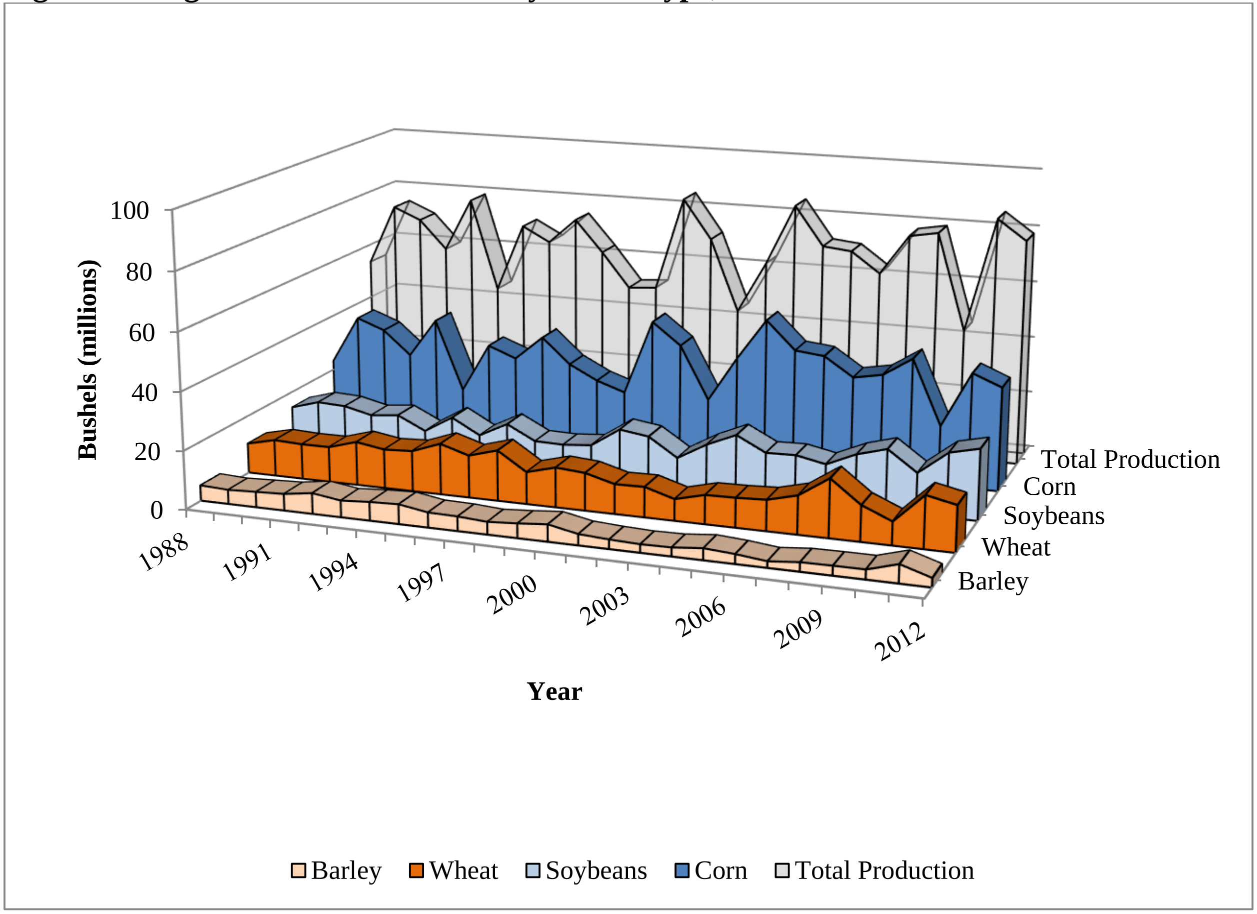
Source: USDA-NASS (2013b).

Figure 1 reveals that Virginia saw a generally positive trend in total grain production during the period examined. Due to increased production levels of corn, soybeans, and wheat, notable production expansion occurred during the 1970s and into the 1980s. This shift is mainly composed of higher corn yields (despite substantially lower harvested corn acreage compared to earlier decades) and more harvested acres of soybeans and wheat.

Also, the same figure reveals that, from the 1920s to the 1940s, the share of corn in total production was more than 70 percent. Despite a reduction over time, corn's share was still a leading 45.6 percent in 2012. Corn and wheat were the prominent grains produced in Virginia from the 1920s to the 1950s. However, displacing the proportions of other grains, soybeans experienced a widening share since the 1920s. Finally, the proportion of barley increases until the 1960s, declines slightly, and steadies thereafter.

Figure 2 displays recent annual production levels of different grain types to showcase current trends in the state's grain sector.

Figure 2: Virginia Grain Production by Grain Type, 1988-2012



Source: USDA-NASS (2013b).

Though production levels certainly vary annually, there is a slight upward trend in total production across the 25-year time span considered. Over the last five years (2008-12), the average shares of total production for these four grain crops are as follows: (1) 47.8 percent corn, (2) 27.4 percent soybeans, (3) 19.7 percent wheat, and (4) 5.2 percent barley.[4]

It is useful to consider these production responses in light of relevant environmental conditions. Table 3 presents the proportions of the examined crops in years of low (drought) and normal production. Wiebold (2012) claims that "crop productivity" or yield is a good "indicator of drought intensity." Drought years were determined by looking at the average corn yield in Virginia from 1988 to 2012, computing quartiles, and selecting years when Virginia's corn yield was at or below the first quartile. Considering the entire period, relatively low-production years due to drought demonstrate different shares of barley, corn, soybeans, and wheat compared to normal years.

[4] Due to rounding, the total adds to 100.1 percent.

Table 3: Proportion (%) of Total Production by Crop for Different Productivity Years, 1988-2012

	Barley	**Corn**	**Soybeans**	**Wheat**
Low production (drought) years (1988, 1991, 1993, 1998-99, 2002, 2010)	9.0%	44.3%	24.5%	22.2%
Normal production years (1989-90, 1992, 1994-97, 2000-01, 2003-09, 2011-12)	6.0%	52.8%	22.9%	18.3%
All years (1988-2012)	6.9%	50.4%	23.4%	19.4%

Source: USDA-NASS (2013b) and authors' calculations.
The proportions were averaged over the selected years.

In drought years, barley, soybeans, and wheat increased in their share of total production at the expense of corn. On the other hand, years with relatively normal production levels witnessed a higher proportion of corn. These results suggest that, in Virginia, corn yields are more vulnerable to drought than the other considered crops.

Locations of Production

According to the 2007 Census of Agriculture, Virginia's corn, soybeans, wheat, and barley had a combined market value of $268.3 million in 2007, with individual contributions of $115.3 million, $98 million, $51.2 million, and $3.9 million, respectively (USDA-NASS 2009). Using county-level information from the same census, Table 4 shows the top five producing counties for barley, corn, soybeans, and wheat in 2007.[5] Westmoreland County and Rockingham County were the largest producing areas for barley, while Accomack County and Augusta County ranked first and second for corn, respectively (USDA-NASS 2009). Notably, Northumberland, Accomack, and Essex counties rank among the top five producing counties for multiple grains.

[5] In the Census, NASS collects agricultural data on 95 counties and an additional three independent cities (Chesapeake, Suffolk, and Virginia Beach). NASS still collects data on an annual basis, but does not publish the results for all of Virginia's agricultural counties and independent cities. For instance, in its annual release, NASS published data on 72 counties for corn production and 16 counties for barley production. This stands in contrast to NASS' Census which offers agricultural production data for all 98 areas. Thus, though less recent than annual NASS survey data, the 2007 census was used for its county-level coverage.

Table 4: Top Grain-Producing Counties and Independent Cities in Virginia, by Grain Type, 2007

Barley		
Rank	**County/city**	**Volume (bu)**
1	Westmoreland	194,825
2	Rockingham	173,112
3	Essex	143,805
4	Augusta	136,852
5	Northumberland	95,218
	Total	**743,812**
Total barley production (Va.)		**2,008,416**
Top five share of total		**37.0%**

Corn		
Rank	**County/city**	**Volume (bu)**
1	Accomack	3,902,761
2	Augusta	2,001,675
3	Rockingham	1,701,405
4	Chesapeake	1,391,272
5	Northampton	1,365,312
	Total	**10,362,425**
Total corn production (Va.)		**34,811,582**
Top five share of total		**29.8%**

Soybeans		
Rank	**County/city**	**Volume (bu)**
1	Accomack	1,166,566
2	Chesapeake	886,279
3	Northampton	760,208
4	Southampton	622,541
5	Hanover	534,365
	Total	**3,969,959**
Total soybean production (Va.)		**12,624,547**
Top five share of total		**31.4%**

Wheat		
Rank	**County/city**	**Volume (bu)**
1	Northampton	1,324,268
2	Accomack	980,123
3	Northumberland	816,833
4	Westmoreland	593,349
5	Essex	538,426
	Total	**4,252,999**
Total wheat production (Va.)		**12,345,217**
Top five share of total		**34.5%**

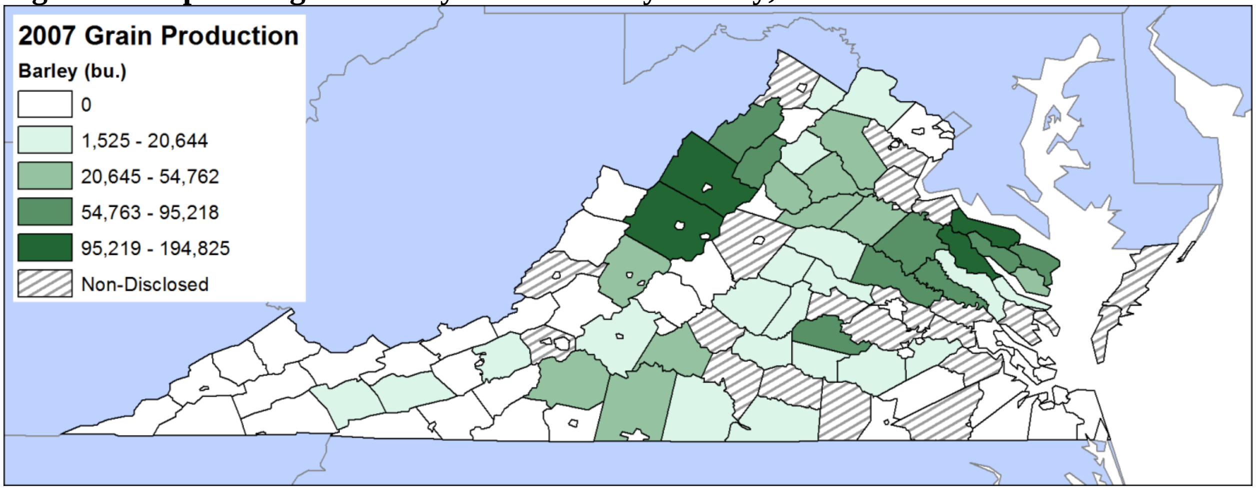
Source: USDA-NASS (2009).
Rankings do not take into account nondisclosed counties and independent cities.

Table 4 also reports the top producing counties' share of total state production for each grain. These numbers indicate that the state's grain production is concentrated in a few regions rather than evenly spread across the state. For each of the examined grains, 30 percent or more of the production output is concentrated in just five counties. It is worth noting that in 2007, 9.8 percent of Virginia's total grain production originated in Accomack County.[6]

Figures 3 through 6 depict the location and volume of county-level grain production. Categories in all subsequent maps were developed using the Jenks' optimization method, a technique that minimizes the variance within groups and maximizes the variance between groups.[7]

Overall, corn, soybean, and wheat production is concentrated in Eastern Virginia (east of Interstate 95). Figure 3 summarizes Virginia's barley production and shows its concentration in the Shenandoah Valley, Northern Neck, and Middle Peninsula.

Figure 3: Map of Virginia Barley Production by County, 2007



Source: USDA-NASS (2009).

As shown in Figure 4, much of the state's corn production is generated in the Eastern Shore, Shenandoah Valley, Tidewater region, Northern Neck, and Middle Peninsula. Of note, Augusta and Rockingham counties in the Shenandoah Valley are two of the top five producing counties for both barley and corn, with much of the corn acreage harvested for silage (table 1). Accomack County, on the Eastern Shore, is particularly intensive in corn production, producing almost 2 million bushels more than the second-highest corn-producing county.

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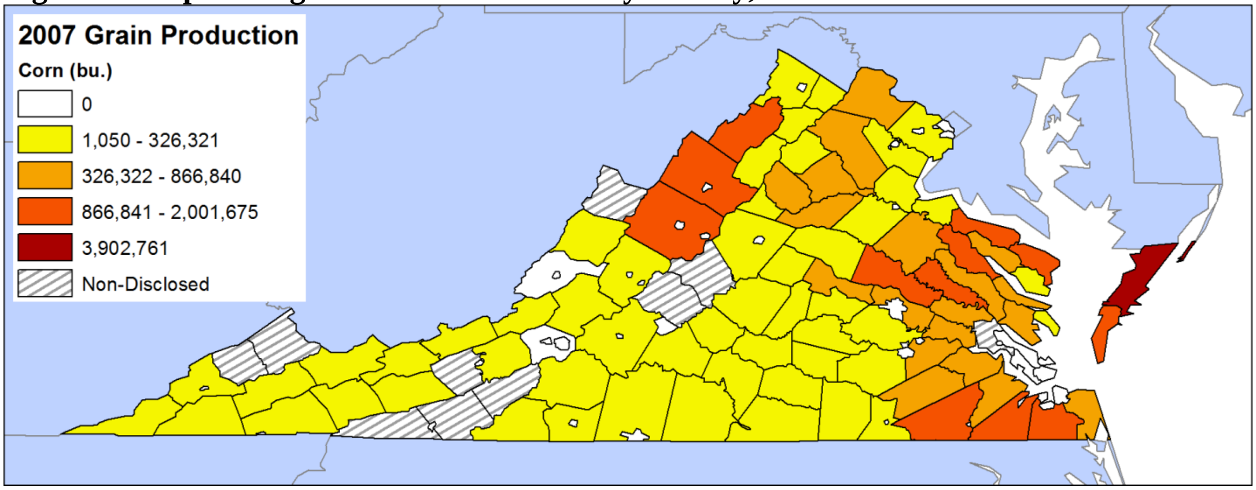
[6] This metric was computed by adding the corn, soybean, and wheat production in Accomack County (3,902,761 bu.; 1,166,566 bu.; and 980,123 bu., respectively) and dividing by the total grain production in Virginia (61,789,762 bu.). Accomack County's barley production was not disclosed.

[7] ESRI GIS Dictionary (online), s.v. "Jenks' optimization," accessed July 10, 2013; http://support.esri.com/en/knowledgebase/Gisdictionary/browse.

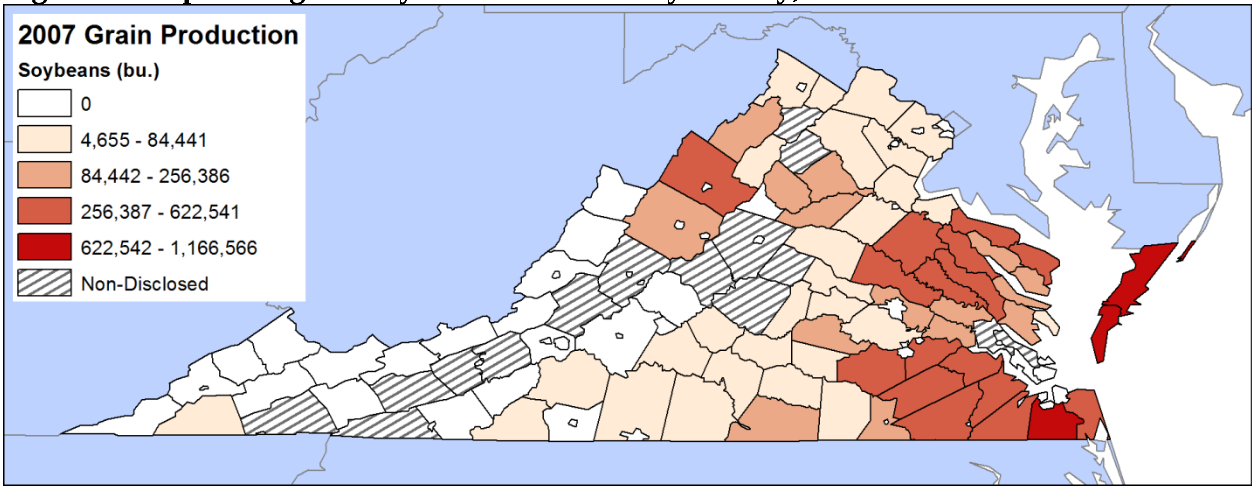
Figure 4: Map of Virginia Corn Production by County, 2007



Source: USDA-NASS (2009).

As would be expected given the pattern of corn production, much of the state's soybean production is concentrated in the Eastern Shore and counties east of Interstate 95 (Figure 5). In particular, Accomack and Northampton counties and the City of Chesapeake are major production areas for both corn and soybeans.

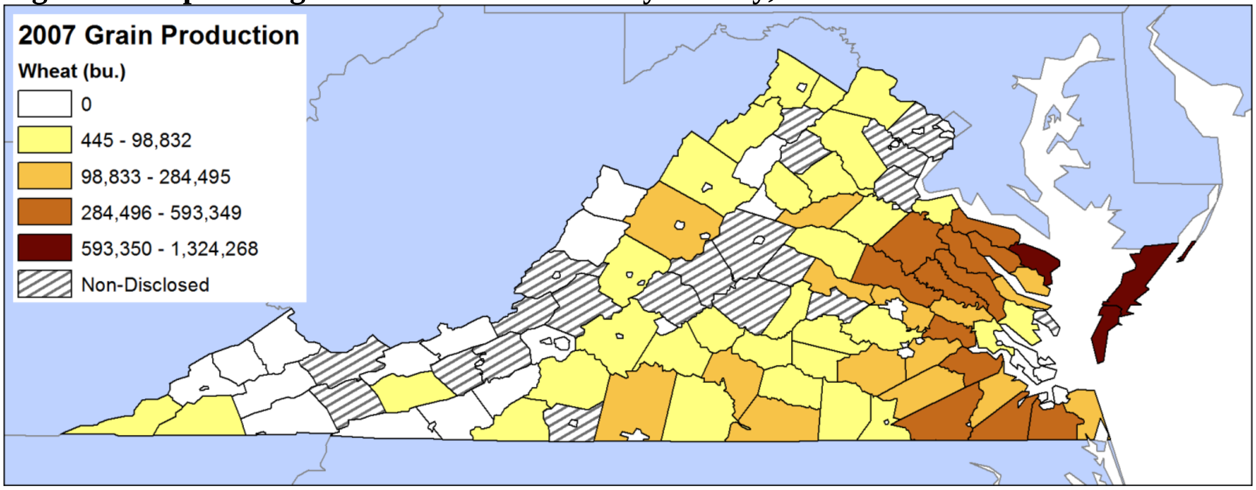
Figure 5: Map of Virginia Soybean Production by County, 2007



Source: USDA-NASS (2009).

Finally, akin to corn and soybeans, the Eastern Shore and counties east of I-95 are important areas for wheat production (fig. 6). Three counties in the Northern Neck and Middle Peninsula (Essex, Northumberland, and Westmoreland) are among the top five producing regions for both wheat and barley.

Figure 6: Map of Virginia Wheat Production by County, 2007



Source: USDA-NASS (2009).

Areas of concentration of the examined grains also reflect the local agriculture requirements. For instance, production in the Shenandoah Valley is dominated by the need to provide forage and grain for livestock herds and poultry. On the other hand, grain in Eastern Virginia serves export markets and the regional demand of the poultry and swine industries.

Storage: Types and Capacity

A comprehensive examination of grain production also requires consideration of the capacity and location of grain storage. Storage facilities allow grain to move according to signals in the market rather having it all enter the system at harvest (Kohls and Uhl, 1997). For producers, advantages include capturing higher prices later in the marketing year, increased flexibility in where and when grain is sold, faster harvest times, and the ability to withdraw grain throughout the year for animal feed (Edwards, 2010).

Normally, grain is held and stored in two different ways: on-farm storage structures and off-farm (commercial) facilities (Dhuyvetter, 1999). These two broad categories may be subdivided into four options: (1) investment in on-farm storage, (2) renting on-farm storage, (3) investment in condominium storage built by a commercial elevator, and (4) renting commercial storage. Each of these alternatives comes with advantages and disadvantages to grain producers (Edwards, 2010).

1. An investment in on-farm storage gives a producer greater flexibility in deciding when and where to market the crops, guaranteed available storage space, convenient management of stored grains, quicker transportation times during harvest, and financing available from the Farm Service Agency.

2. Renting on-farm storage also offers certain advantages, including more efficient harvest due to more convenient storage capacity, rental rates that may be lower than those from commercial facilities, rental agreements that are usually only for one year at a time, and flexibility in deciding when and where to market crops.

3. The advantages of investment in storage at a commercial elevator include: the elevator may be able to build storage capacity at a lower cost per unit, the elevator handles the grain and guarantees quality, no additional transportation and handling is required if the elevator merchandises the grain, and storage capacity can be sold if it is no longer needed.

4. The advantages to renting commercial storage include: the producer pays only for the exact amount of capacity needed, the producer pays for storage only for as long as it is needed, the elevator handles the grain and guarantees quality, the elevator can dry the grain, and no additional transportation and handling is required if the elevator merchandises the grain (Edwards, 2010).

Table 5 contains NASS off-farm and on-farm storage capacity numbers for Virginia from 2008 to 2012. According to NASS, off-farm grain storage capacity consists of "all elevators, warehouses, terminals, merchant mills, other storage, and oilseed crushers" and farm grain storage capacity includes "all bins, cribs, sheds, and other structures located on farms that are normally used to store whole grains, oilseeds, or pulse crops" (USDA-NASS, 2013).

Table 5: Storage Capacity in Virginia, 2008-12, in Bushels

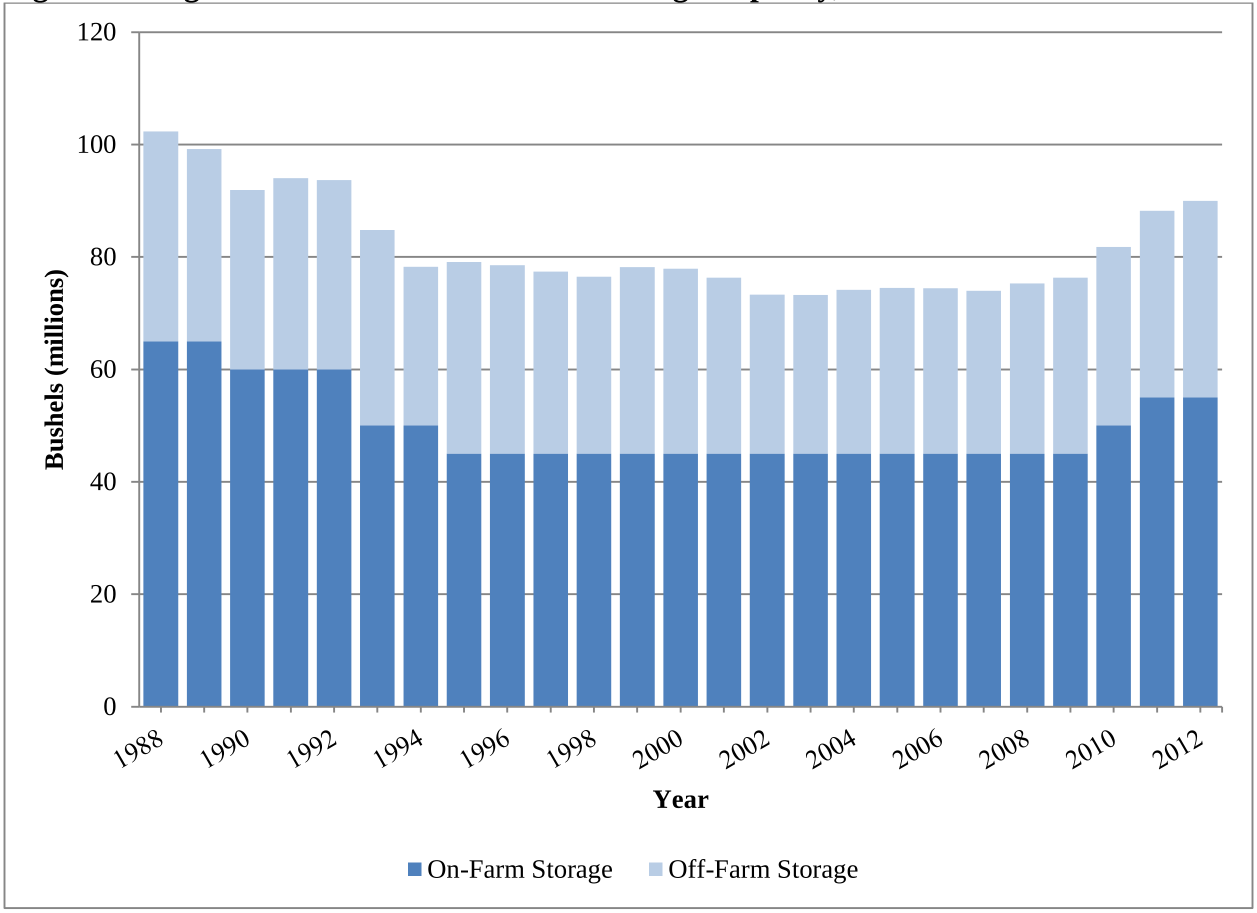
Year	Off-farm storage capacity	On-farm storage capacity	Total storage capacity
2012	35,000,000	55,000,000	90,000,000
2011	33,200,000	55,000,000	88,200,000
2010	31,800,000	50,000,000	81,800,000
2009	31,300,000	45,000,000	76,300,000
2008	30,300,000	45,000,000	75,300,000

Source: USDA-NASS (2013b).

Virginia's total grain storage capacity in 2012 was 90 million bushels and was composed of 35 million bushels of off-farm storage and 55 million bushels of on-farm storage. The data also reveal that overall storage has increased annually from 2008 to 2012. Historically, with record amounts of on-farm storage, Virginia's greatest combined storage levels averaged 96.2 million bushels from 1988 to 1992.[8] To illustrate the storage trends graphically, Figure 7 shows Virginia's on- and off-farm capacity numbers from 1988 to 2012.

[8] NASS does not have storage data for Virginia prior to 1988.

Figure 7: Virginia Off-Farm and On-Farm Storage Capacity, 1988-2012



Source: USDA-NASS (2013b).

Several characteristics are worth noting in Figure 7.

1. From 1988 to about 1994, total capacity decreased.

2. Capacity then remained relatively constant from 1994 to 2009. On average, grain storage capacity was 76.1 million bushels during this 16-year span.

3. Since 2007, total capacity has increased every year.

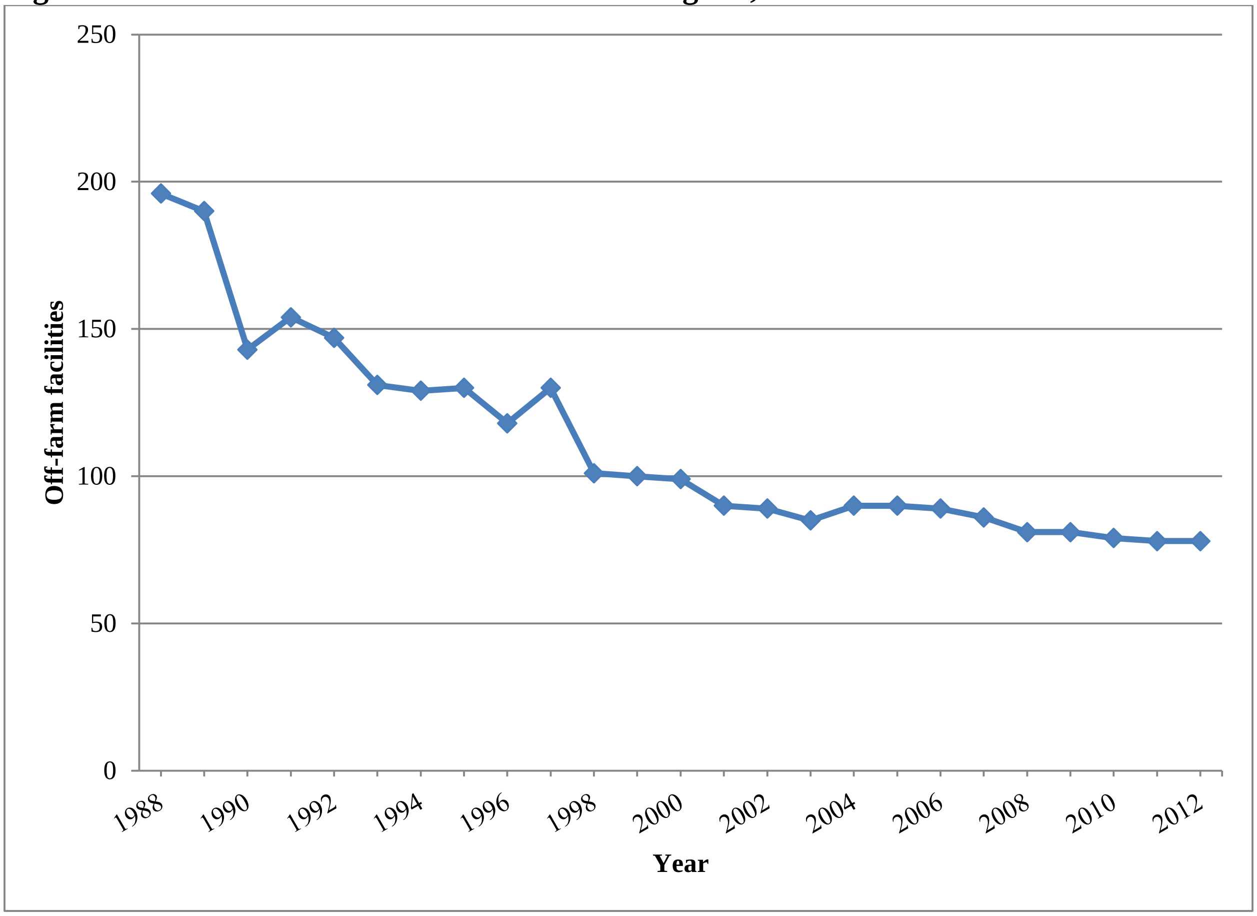
4. Grain storage in Virginia is largely characterized by on-farm storage. Specifically, for recent years (2008-12), the on-farm share of total storage is 60.7 percent compared to 39.3 percent held commercially.[9] In the 25-year period of analysis, commercial storage reached a maximum of 43.1 percent of total state storage in 1995.

While off-farm storage capacity has remained relatively constant, the number of commercial facilities has undergone significant changes. Figure 8 plots the number of off-farm

[9] These results are similar to the overall span from 1988 to 2012 where the proportions are 60.8 percent for on-farm and 39.2 percent for off-farm storage.

facilities during the period of study (1988-2012).[10] Notably, from a high of 196 facilities in 1988 to a low of 78 in 2011 and 2012, the number of off-farm facilities has generally declined over the last 25 years, with decreases slowing in more recent years. This information, coupled with data indicating relatively stable off-farm capacity (Figure 7), suggests that Virginia's commercial grain facilities have consolidated and each now possesses a greater share of the available storage. The average capacity of a commercial facility in 1988 was 332,000 bushels, compared to 705,000 bushels in 2012—an increase of 112 percent.

Figure 8: Number of Commercial Facilities in Virginia, 1988-2012



Source: USDA-NASS (2013b).

Finally, it is useful to assess where Virginia's capacity levels fit in terms of larger national trends. Overall, Virginia's total storage capacity is small relative to other states (USDA-NASS 2013b). More specifically, out of 40 states reporting off-farm storage in 2012, Virginia ranked 32nd in commercial grain storage and 27th in the number of commercial grain storage facilities. Virginia was tied for 27th out of 29 reporting states for on-farm storage capacity in 2012. Though

[10] A more detailed examination of developments in commercial storage across the South Atlantic states (including Maryland, Virginia, North Carolina, and South Carolina) is presented in the article "Commercial Storage in the South Atlantic: A Summary of Four States" from the February/March 2013 issue of Farm Business Management Update, available at http://pubs.ext.vt.edu/AAEC/AAEC-46/AAEC-46_PDF.pdf.

these rankings suggest that capacity is small compared to other states, Virginia's storage volume closely resembles its production levels. This matter is further explored later on.

Location of Storage

In addition to analyzing trends across time, this study considers the geographic distribution of grain storage capacity.[11] Table 6 displays the five counties with the greatest on-farm storage and their combined percentage of Virginia's total on-farm capacity. Just over 24 percent of Virginia's on-farm storage is concentrated in five counties. This presents evidence of some degree of geographic concentration of on-farm storage.

Table 6: Regions in Virginia with the Most On-Farm Storage, 2007

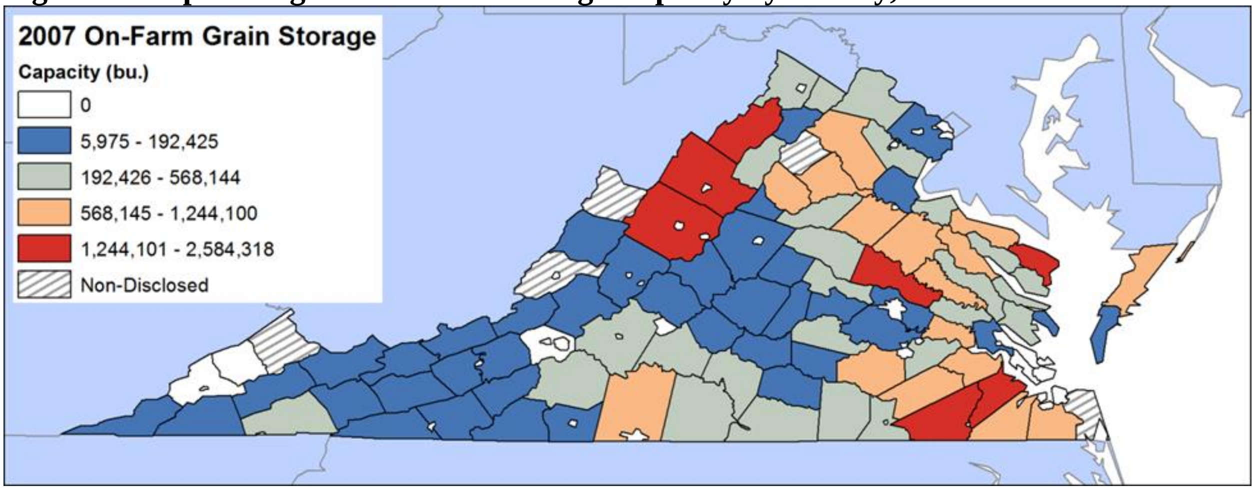
On-farm storage		
Rank	**County**	**Volume (bu)**
1	Rockingham	2,584,318
2	Southampton	2,502,411
3	Isle of Wright	1,775,212
4	Shenandoah	1,558,499
5	Augusta	1,515,255
	Total	**9,935,695**
Total on-farm storage (Va.)		**40,970,443**
Top five share of total		**24.3%**

Source: USDA-NASS (2009).
Rankings do not take into account nondisclosed counties.

Figure 9 presents on-farm grain storage capacity for Virginia counties in 2007 and indicates that farm storage is particularly concentrated in the Shenandoah Valley and Tidewater region. These areas reflect some of Virginia's primary grain-producing areas. It is important to note, however, that much of the storage capacity in the Shenandoah Valley is used in support of the state's poultry production and is unavailable for use in distribution channels outside the valley.

[11] Estimates used in this discussion are drawn from the 2007 Census of Agriculture for Virginia (USDA-NASS 2009). It is important to note that, while this data source offers on-farm storage capacity disaggregated at the county level, off-farm capacity is only reported at the state level. More than 50 percent of the state's capacity is on-farm (Figure. 7); the distribution of on-farm storage capacity is assumed to be a suitable proxy for the distribution of off-farm storage.

Figure 9: Map of Virginia On-Farm Storage Capacity by County, 2007

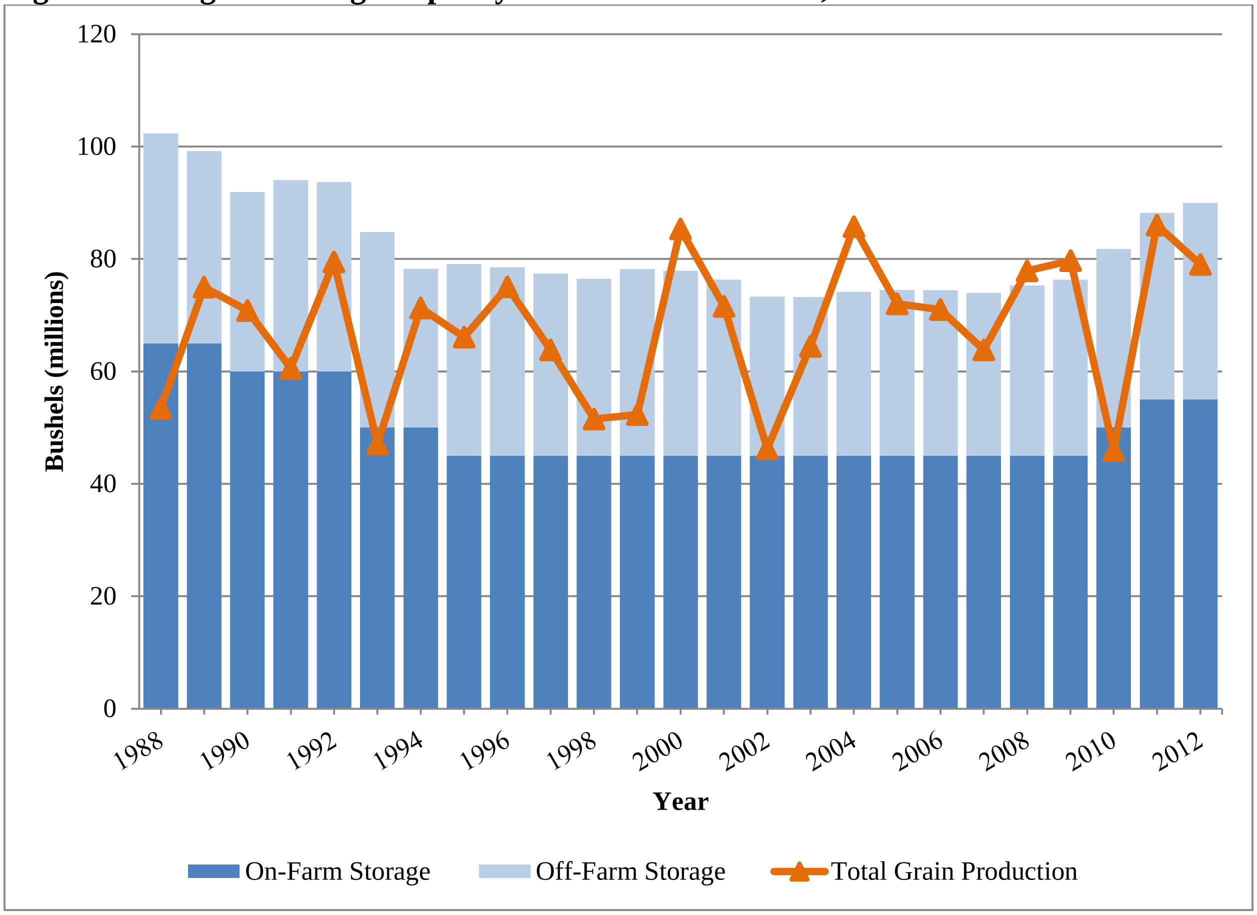


Source: USDA-NASS (2009).

Joint Consideration of Grain Production and Storage Across Time

In practice, production and storage are not separate decisions. On-farm storage allows producers to capture profit opportunities through timely sales of grain (O'Brien 2000). In off-farm storage facilities, elevators buy and store grain, facilitate its transportation, and connect buyers and sellers (Henderson and Fitzgerald 2008). Given the link between production and storage, it is important to compare levels of Virginia grain production and total storage capacity. Figure 10 considers this relationship by overlaying the depiction of Virginia's total grain production (fig. 2) and total storage capacity (fig. 7) from 1988 to 2012. As shown in the graph, although Virginia has lower levels of grain storage compared to other states (Section III), the capacity appears to meet and often exceed production. Across the 25-year span, there was an average storage capacity surplus of 13.9 million bushels. Figure 10 shows that 21 years had excess storage with surpluses averaging 17.8 million bushels per year, and four years had deficit storage with shortages averaging 6.3 million bushels per year.

Figure 10: Virginia Storage Capacity and Grain Production, 1988-2012



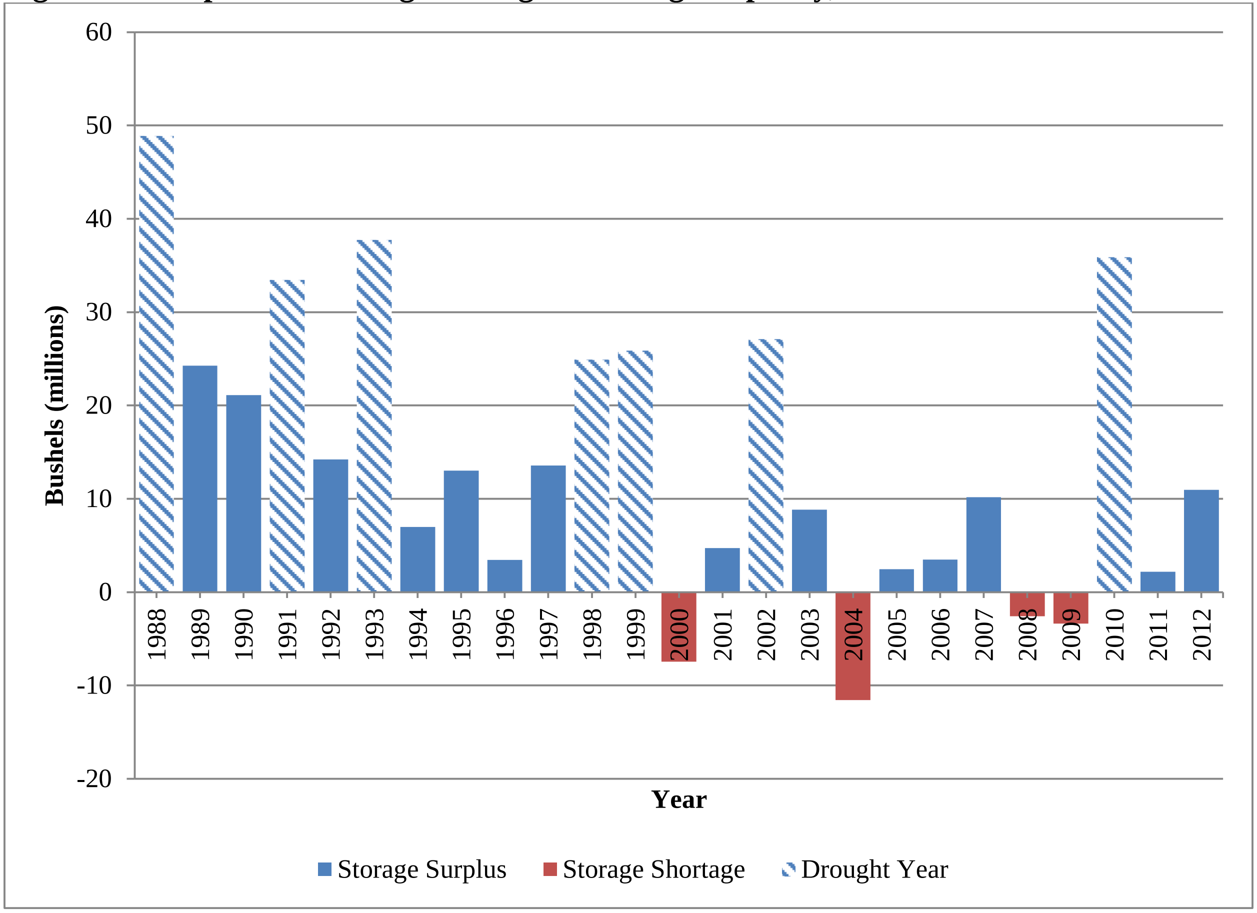
Source: USDA-NASS (2013b).

While figure 10 offers a useful snapshot of total grain production and capacity, it masks the important movements in these markets. In reality, grain rarely enters the marketing channels all at once, and not all of it moves directly into storage once harvested. Another limitation is that some grain flows into Virginia's storage from outside the state and vice versa.[12]

It is useful, however, to compare grain production volume relative to storage potential. In order to obtain a more intuitive view of the relationship between storage and production, figure 11 portrays the years of excess and deficit grain storage. As shown in the graph, from 1988 to 1993, Virginia's storage capacity considerably exceeded the state's grain production. In fact, total grain production exceeded capacity in only four years (2000, 2004, 2008, and 2009) and some recent surpluses (2005, 2006, and 2011) were relatively small.

[12] A more detailed examination of grain imported into Virginia by rail is presented in the article "Virginia's Grain 'Imports' by Rail: A Summary" from the August/September 2013 issue of Farm Business Management Update, available at http://news.cals.vt.edu/fbm-update/2013/08/07/virginias-grain-imports-by-rail-a-summary/.

Figure 11: Surplus or Shortage in Virginia Storage Capacity, 1988-2012



Source: USDA-NASS (2013b) and authors' calculations.

These observations suggest that Virginia's grain storage has become more constrained in recent years. This outcome is supported by the results in Table 7, which presents findings of a two-period analysis that considers the storage shortages and surpluses of normal production years.[13] The periods were developed by splitting Virginia's 18 nondrought years into two periods of nine years each. When compared, the second period experienced not only more years with a storage deficit than the first period, but also a smaller average surplus in years of storage excess. Importantly, these measures suggest that storage has likely been hampered to a larger degree in recent years compared to the past. They also imply that if production experiences periods of significant growth, the current capacity levels for storing grain may not be sufficient and more shortage years may occur.

[13] The table seeks to compare production and storage levels to uncover possible storage capacity constraints when output is as high as possible (achieved during normal production years). Years of drought were ignored because they naturally lead to above-average storage surpluses, and they bias conclusions about Virginia's storage capacity.

Table 7: Two-Period Comparison of Virginia's Storage Shortages and Surpluses under Normal Grain Production Years

	Period 1	**Period 2**
Years in period (9)	1989, 1990, 1992, 1994, 1995, 1996, 1997, 2000, 2001	2003, 2004, 2005, 2006, 2007, 2008, 2009, 2011, 2012
Shortage years		
Number of years with shortage	1 (11.1%)	3 (33.3%)
Average amount of shortage (bushels)	−7.5 million	−5.9 million
Surplus years		
Number of years with surplus	8 (88.9%)	6 (66.7%)
Average amount of surplus (bushels)	12.7 million	6.3 million

Source: USDA-NASS (2013b) and authors' calculations.

Conclusions and Discussion

From poultry, cattle, and hog operations to tobacco, tomatoes, grain, and soybeans, Virginia offers a wide agricultural portfolio. Within this collection, Virginia produces a number of grains, including barley, corn, sorghum, oats, rye, triticale, soybeans, and wheat. Of these, corn and soybeans dominate grain production, followed by wheat and barley. Much of Virginia's grain production comes from the Shenandoah Valley, Northern Neck, Middle Peninsula, Tidewater region, and Eastern Shore. Overall, Virginia's grain growers produced a record high 86 million bushels in 2011 and generated an average of 73.7 million bushels over the last five years (2008-12).

With respect to Virginia's grain storage capacity, data reveal that capacity levels have been fairly consistent over time and on-farm storage capacity is approximately 61 percent of total storage. The number of commercial facilities decreased considerably since 1988, but this decline has slowed in recent years. Overall, in comparison to other states, Virginia's storage capacity is relatively low, which may present opportunities for expansion.

Combining the production and storage data reveals that capacity has been more challenged in recent years than in the past when storage consistently met grain output levels. This information is important because it implies that if Virginia grain production increases substantially, storage may also need to increase to facilitate its distribution at the desired time. The majority of this increase might come from farms if on-farm storage levels remain around 60 percent of total capacity.

The information presented offers policy-relevant insight that will be useful for several stakeholder groups. For instance, in the event of increasing grain production and subsequent storage shortages, a series of questions would need to be addressed concerning the financing of future storage construction, the location of future storage facilities, the type of future capacity (on-farm versus commercial), the creation of economic incentives conducive to the expansion of storage capacity, and an aging farming population that may be unwilling to invest in new storage facilities. Private enterprises, state and local governments, producer associations, industry boards, cooperatives, and farmers should be actively involved and have a role in these decisions.

This study suggests several areas for potential future research.

1. A study that examines where and how much commercial storage exists and conducts a spatial analysis of the state’s production and storage areas would offer important and geographically refined insight into likely locations of future storage constraints.

2. Research examining the flow of grain in, out, and within Virginia and considering the stocks of grain at various times during the year in different geographic areas would help to further understand and resolve possible storage capacity constraints.

3. Understanding of this sector would be further enhanced by examining two additional and integral components of the supply chain — the grain transportation network and the demand for grain by Virginia’s livestock industries.

Combined, this information would offer additional insights into both the current function and expansion potential of Virginia’s grain sector.

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Chapter 3: Grain Consumption and Production in Virginia: A Trend and Spatial Examination

Introduction

Agriculture is Virginia's most important industry, with an estimated yearly economic impact of $52 billion (Rephann, 2013). The grain, poultry, and livestock sectors are critical contributors to this industry. Though ranked 31 out of 50 in terms of the market value of all agricultural products sold in 2012, Virginia was fourteenth in the U.S. for poultry and eggs sales (Virginia NASS Field Office, 2015a). In 2013, cash receipts for Virginia's major grains (barley, corn, and wheat) and soybeans totaled $583 million (VDACS, 2015). These grains and soybeans help support the state's livestock and poultry sectors, which generated over $2.1 billion in cash receipts in 2013 (VDACS, 2015).[14]

This study analyzes both the overall magnitude and distribution of grain production and consumption in Virginia. More specifically, it describes the sources of grain production and consumption, identifies trends over time, and shows the resulting grain production surplus/deficit areas across Virginia's counties. A county-level examination is important because it leads to new insights and implications, particularly concerning transportation. Overall, the research provides an updated assessment of Virginia's ability to meet its grain needs, identifies constraints and opportunities in the current system, and sheds light on Virginia's grain, livestock, and poultry sectors. Highlights of this study are:

- Corn, soybeans, and wheat are the main sources of Virginia grain production;
- Grain production has shown year-to-year variability, due primarily to drought affecting corn production;
- Poultry industry is the largest consumer of grain in the state;
- Generally, the demand for grain by the livestock and poultry sectors exceeds the amount produced in the state, making Virginia a net "importer" of grain from outside the state;
- However, the grain production deficit is decreasing due to declining livestock populations and increasing feeding efficiency;
- Most of Virginia's grain is grown in the in the Shenandoah Valley and counties east of I-95;
- Due to substantial poultry operations, Virginia's greatest feed requirements are in the Shenandoah Valley area;
- Though the Shenandoah Valley grows a large amount of grain, the region experiences the most severe grain shortages;

[14] The commodities included in the calculation are broilers, cattle/calves, milk, turkeys, and eggs.

- Transportation is crucial to move grain to demand areas to supplement the grain shortages, both within the state and from out of the state; and,
- Grain storage is important because it connects seasonal production with yearlong consumption by poultry and livestock.

Overall, the results provide market insight and foundational knowledge to address the needs of Virginia's grain, livestock, and poultry sectors. In addition, this study helps to uncover and quantify constraints in the grain production market. Finally, the study applies a methodology to estimate the animal feed requirements at the state- and county-levels, which can be replicated for approximation in other states. Following sections review relevant literature and previous research, present state-level trends of grain consumption and production in Virginia, and include the methodology used and the results of the spatial distributions of these two components in Virginia. Concluding remarks, discussion, and policy implications are presented in the last section. Appendices A and B provide additional trends, maps, and descriptive methods concerning grain consumption and production in Virginia.

Literature Review

A number of studies have examined grain consumption or feed requirements using different estimation methods and geographical scopes (e.g. national or state). Meilke (1975) proposed a six-equation simultaneous model (incorporating feed, food and industrial use, exports, previous stocks, and animal units) to calculate and predict levels of feed demand at national level in the United States. More recently, Dikshit and Birthal (2010) take a different approach by developing animal population numbers and using amount fed per animal-type to estimate grain consumption in India. Others studies have used similar procedures as Dikshit and Birthalb (2010), but applied the methodology to a more local level. For instance, Lammers, Hart, and Honeyman (2012) used animal population numbers and corn used per type of livestock to calculate corn consumption in Iowa in 2010. A limitation of this study may be that it is not wholly representative of grain consumption since corn is just one of the major row crops fed to livestock (Capehart, 2015). Others also invoke the approach of aggregating the rations fed to livestock, but include more crops and a wider regional coverage (Lazarus, 1980). Huffman and Kenyon (1999) developed estimates of consumption for Virginia using animal population quantities and the amount fed per animal-type to calculate corn and soybean consumption from 1965 to 1997. While that study is limited by the narrow portfolio of feed grains considered, it offers additional insight by taking the analysis beyond the state to the agricultural district level.[15] In another study, Tiffany and Fruin (2002) examined grain (including corn, oats, and soybean meal) consumption and distribution patterns at the county-level in Minnesota in 1999 using similar procedures to Huffman and Kenyon.

Differing in method from the aforementioned studies, the Economic Research Service (ERS) of the United States Department of Agriculture (USDA) has been estimating variables related to grain consumption at the national level for over a hundred years (USDA-ERS, 1963). This method includes a series of steps: 1) obtaining population numbers for livestock fed during the year; 2) developing animal units by weighting the animals according to their relative feed

[15] The National Agricultural Statistics Service divides a state into several "agricultural districts," so it provides more in-depth information in terms of location.

consumption (e.g. one broiler does not consume the same as one dairy cow); and 3) multiplying the number of animal units by the tons of grain consumed per animal unit to achieve total annual grain consumption (Capehart, Allen, and Bond, 2013; Capehart, 2013). At least two studies have used the ERS procedures to investigate grain consumption at the state-level, one by Conley, Nagesh, and Salame (2012) at the University of Nebraska and another by the Agricultural Marketing Service (AMS) of the USDA (Prater and O'Neil, 2013). The AMS computed the average number of animal consuming units from 2006 to 2010 for all states (Prater and O'Neil, 2013), while Conley et al. (2012) calculated corn consumption by grain consuming animal units as well as the total corn utilization (including other avenues for grain such as industrial use and seed) for each state over the 2004-2010 period.

The present study largely applies a method developed and used by the ERS, and makes additional steps to develop spatial insights at the county-level. Such steps, particularly include identification of sufficient proxy variables since state-level variables are not always available at the county-level, and a brief discussion of ways to increase the spatial accuracy of the data on a map. Combining the ERS' approach with these additional steps leads to new insights and provides a methodology that may be applied in other regions.

Trends in Virginia Grain Consumption and Production

Data Sources and Methodology

Analysis encompassed in this paper focuses on the major components of the grain supply chain in Virginia: grain production and consumption by livestock and poultry. These variables are intended to measure "grain supply" and "grain demand"[16] in Virginia from 1992 to 2014. The research primarily makes use of publically available data from USDA's National Agricultural Statistics Service (NASS).[17] Unlike production data, which is readily available, additional steps are needed to estimate Virginia's grain consumption. This study applies procedures developed by the ERS and AMS to calculate the consumption or demand for grain by Virginia's livestock sector. The procedure requires the following general steps: obtain animal population numbers that are fed, examine how much each animal consumes, and aggregate all consumption (per year) to arrive at a total (in tons[18]).

Grain production or supply is derived from aggregating barley, corn, soybeans, and wheat production for the twenty-three year period of study. Eleven animal groups including various types of cattle and poultry, hogs, sheep, and horses were used in the calculation of grain consumption in Virginia. Following the ERS methodology, livestock and poultry population numbers were converted (where applicable) to a September-August year to match the crop production and marketing cycle (Capehart, Allen, and Bond, 2013; Capehart, 2013). The following two

[16] For the sake of simplicity, the terms "grain supply"/"grain production" and "grain demand"/"grain consumption" are used interchangeably.

[17] Data are available via NASS' online retrieval program, "Quick Stats" (USDA-NASS, 2015), and the official reports posted on their website. The names of the relevant NASS reports for each commodity are provided in the report and appendices. For example, information on broilers and turkeys are published NASS' *Poultry Production and Value*.

[18] As shown later, the amount consumed per animal unit is provided by the ERS in tons, so "tons" is an easy unit to compare both variables.

subsections briefly describe the variables collected and used to represent the different crop and animal groups.

Grain Production

Virginia's grain production consists of four main crops: barley, corn, soybeans, and wheat.[19] Crop production data at the state-level were obtained from the *Crop Production, Annual Summary* reports, released by NASS. In order to compare grain production against grain consumption, production is converted from bushels to tons using the conversion factors shown in Table 8. The conversion is done by multiplying the bushels produced in a given year for each grain by their respective weights (see equation below).

Basic principle: *"Crop (Production in Bushels)" * "Crop's Pounds per Bushel" / "2,000 Pounds per Ton" = "Crop (Production in Bushels)" * "Conversion Factor"*

For example: *"2014 Grain Production (in tons)" = "2014 Barley Production (in bushels)" * 0.0240 + "2014 Corn Production (in bushels)" * 0.0280 + "2014 Soybean Production (in bushels)" * 0.0237 + "2014 Wheat Production (in bushels)" * 0.0300*

As noted in the equation, an important step must be taken to convert soybeans to soybean meal—the portion relevant to animal feeds. Specifically, a 60-pound bushel of soybeans generates 47.3 pounds of soybean meal (Huffman and Kenyon, 1999). The production (in tons) of barley, corn, soybean meal, and wheat is then aggregated for each year to arrive at "total grain production."[20]

Table 8: Factors to Convert Grain in Bushels to Tons

Crop	Pounds/Bushel	Conversion Factor (Tons/Bushel)
Barley	48	0.0240
Corn	56	0.0280
Wheat and soybeans	60	0.0300
Soybean meal	47.3	0.0237

Source: Prater and O'Neil, 2013.

Grain Consumption

The ERS provides the following steps to generate grain consumption: 1) obtain animal population numbers that are fed; 2) weight the animals according to their relative feed consumption; and 3) multiply the number of animal units by the tons of grain consumed per animal unit (Capehart, Allen, and Bond, 2013; Capehart, 2013). Thus, the initial steps involve identifying the relevant livestock groups and collecting their population numbers from 1992 to 2014. With its wide agricultural portfolio, Virginia livestock include cattle (dairy, beef on feed, other beef), poultry (broilers, turkeys, layers, and pullets), hogs, sheep, and horses. Table 9 lists the eleven livestock commodities and their respective variable type (e.g., "inventory," "production," etc.).

[19] Although technically an oilseed, soybeans are grouped in the "grains" category because of its importance and similar role in the grain supply chain.
[20] Total production is used because grain consumption cannot be separated into individual components (i.e., "the amount of *corn* consumed").

The ERS and AMS procedures include ten of the variables, but leaves out horses. Since horses are a sizeable part of Virginia agriculture (Rephann, 2011), they are also included with the previous ten variables to follow the ERS methodology and capture all major animal groups of Virginia grain consumption. Specific details pertaining to the consumption calculations such as where the data may be found in the NASS reports, which variables were converted to a September-August marketing year, and any additional steps taken are provided in Appendix A.

Table 9: Livestock and Poultry Considered in Assessment of Virginia Grain Consumption

Livestock/Poultry Type	Variable Type	Estimated 2014 "Population"
Cattle, dairy cows	Inventory on January 1	93,000
Cattle, dairy heifers	Inventory on January 1	43,000
Cattle, beef, cattle on feed	Inventory on January 1	20,000
Cattle, beef, other	Inventory, derived (see Appendix A)	1,314,000
Poultry, broilers	Production (head) during year	258,900,000
Poultry, turkeys	Production (number raised) during year	16,000,000
Poultry, layers	Inventory, average, derived (see Appendix A)	2,949,167
Poultry, pullets	Derived (see Appendix A)	9,998,286
Hogs	Pig crop	70,000
Sheep	Inventory on January 1	75,000
Horses and mules	Derived (see Appendix A)	215,000

Sources: Prater and O'Neil, 2013; USDA-NASS, 2015; authors' calculations.
See text for an explanation of authors' calculations.

After animal population numbers are gathered or estimated, the next steps to calculate total grain consumption involve developing "animal units" and aggregating all the animal units for each year. Then, animal units are multiplied by the amount of grain consumed per animal unit.

The concept of "animal units" addresses the need for comparable units—different animals have different environmental impacts and feed requirements (MDA, 2015). Thus, ERS developed the "grain consuming animal unit" (GCAU) to weight the livestock groups appropriately. The weights were estimated by comparing the grain consumption of different livestock species to the dry-weight grain consumption of one dairy cow. Table 10 shows the weights or factors for the different livestock groups, which were last developed in 1969-71 from a survey of feeding data (Capehart, 2013; Hollis, 2002). The factors imply that, the annual grain feed requirements of one dairy cow are equivalent to approximately 524 broilers, 68 turkeys, or 4.6 hogs.[21] To estimate the number of grain consuming animal units (GCAU), the population for a given species is multiplied by its respective GCAU factor shown in Table 10.[22] Then, total (annual) grain consuming animal units in Virginia are calculated by summing all the livestock GCAUs (e.g. cattle GCAUs, poultry GCAUs, etc.) for the respective year.

[21] For example, the broiler factor is 0.0020 and the dairy cow factor is 1.0475. 1.0475/0.0020 = 524.
[22] For example, to generate GCAUs, the number of dairy heifers is multiplied by 0.1761, the number of broilers by 0.0020, the number of hogs by 0.2285, and so on for the remaining livestock commodities.

Table 10: Grain Consuming Animal Unit Factors for Different Animals

Animal Group	GCAU Factor
Cattle, Dairy Cows	1.0475
Cattle, Dairy Heifers	0.1761
Cattle, Beef, Cattle on Feed	1.5323
Cattle, Beef, Other	0.0547
Poultry, Broilers	0.0020
Poultry, Turkeys	0.0155
Poultry, Layers	0.0217
Poultry, Pullets	0.0054
Hogs	0.2285
Sheep	0.0194
Horses and Mules	0.2043

Source: Prater and O'Neil, 2013.

The last step in estimating grain consumption is to multiply the total yearly GCAUs by the amount of grain consumed per animal unit (Figure 12). An equation of these steps is provided below.

Basic principle: *"Livestock/Poultry Type's Population" * "GCAU Factor" * "Amount Fed per GCAU"*

For example: *"2014 Grain Consumption (in tons)"* = [*"2014 Dairy Cow Population" * 1.0475 + "2014 Dairy Heifers Population" * 0.1761 + … + "2014 Horse Population" * 0.2043*] * *"2014 Tons Fed per Grain Consuming Animal Unit (2.345 tons/GCAU)"*

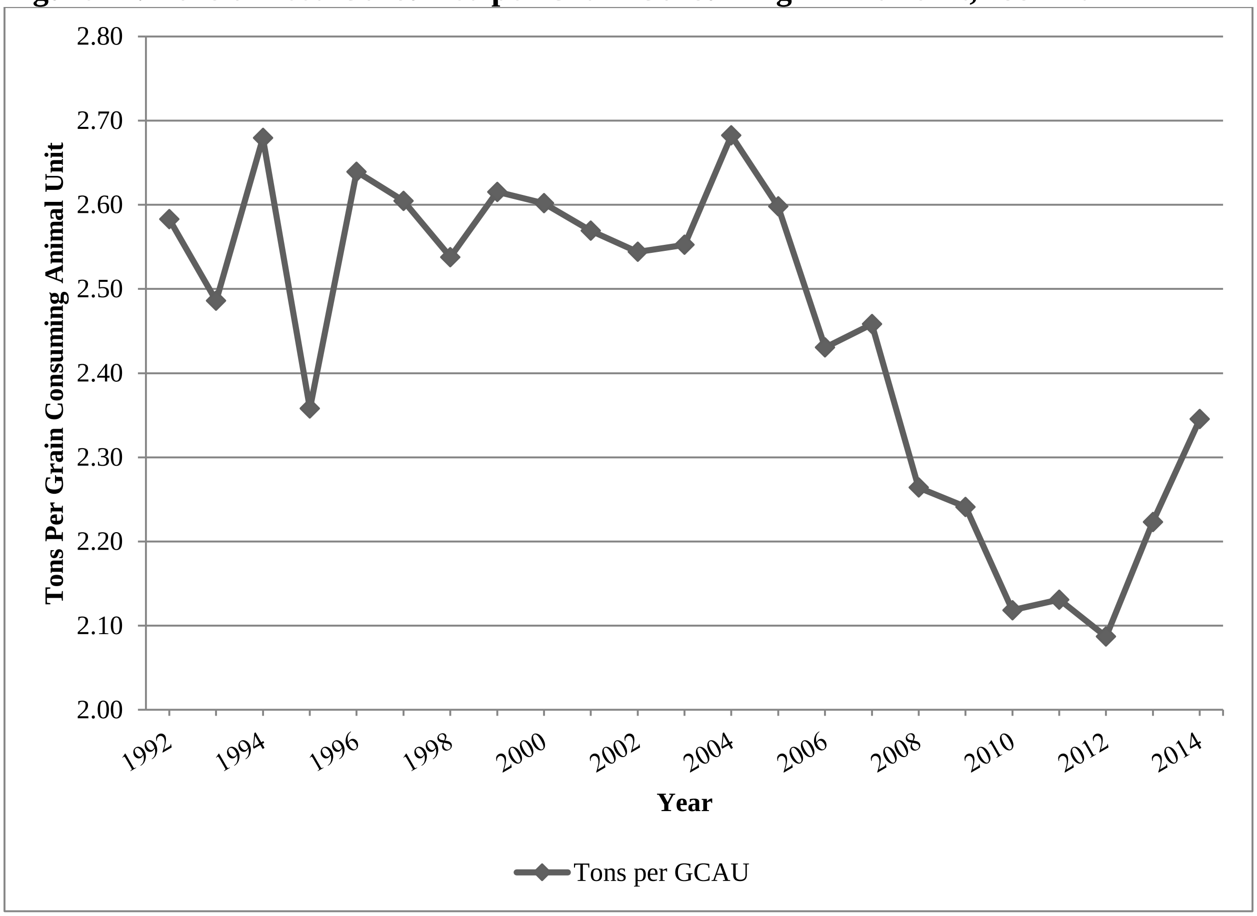
Data on feed per animal unit is obtained from ERS on a marketing year basis (such as 2012/13, which corresponds to 2012 in this analysis). The numbers represent all feeds, including the major energy feeds (corn, wheat, etc.) and oilseed meals. Figure 12 shows that the amount of grain fed per grain consuming animal unit has varied from about 2.1 tons to 2.7 tons (USDA-ERS, 2015a). Importantly, these numbers correspond roughly to the grain rations fed to livestock and poultry.[23] According to the ERS, the amount of feed per grain consuming animal unit reflects changes in feeding efficiency and grain prices over time (Capehart, 2013).[24] Rising feed prices

[23] 2.1 to 2.7 tons of feed is between 4,200 and 5,400 pounds. According to Jacob and Pescatore (2012), 10 to 11 50-pound bags of feed are needed to produce fifty 5-pound commercial-type broilers (more bags are required to produce heavier chickens). One GCAU of broilers is 500 chickens. Therefore, about 105 50-pound bags are needed for 500 chickens, or 5,250 pounds of feed (6,750 pounds are needed to produce 500 6-pound chickens). Layers require about four 50-pound bags of feed per month to feed 25 hens (Jacob and Pescatore, 2012), which is about 4,423 pounds of feed for one GCAU of layers (4 bags for 25 hens * 50 pounds per bag * 12 months * 46.08 layers per GCAU / 25 hens). As an approximation of the grain consumption by a dairy cow (which is about one GCAU), the normal lactation period is between 290 and 310 days, with an average of 296 days (Adams, Hutchinson, and Ishler, 2015). According to Huffman and Kenyon (1999), a lactating cow is fed 17 pounds of grain concentrates daily, which is about 5,032 pounds during the period. Fisher and Hutjens (2007) estimate that the diet for a dairy cow could include 25 pounds of grain mix per day (in addition to substantially higher wet feed such as forage).

[24] For example, grain faced a severe price shock in 1995 and 1996, which caused a decrease in the amount fed to livestock (Light and Shevlin 1998). In addition, Karlin (2014) finds a good fit between the amount fed per grain consuming animal unit and the price (at least for corn).

can alter short-term trends of feed per GCAU as higher feed prices push livestock producers to slaughter at lower weights and put more animals (such as cattle) on pasture (Capehart, 2013). Conversely, when feed prices decline, feed use per GCAU increases as more animals are fed for a longer period and moved to feedlots (Capehart, 2013). Generally, the amount of grain consumed per animal unit has declined over the period, but increased the past two years.

Figure 12: Tons of Feed Consumed per Grain Consuming Animal Unit, 1992-2014



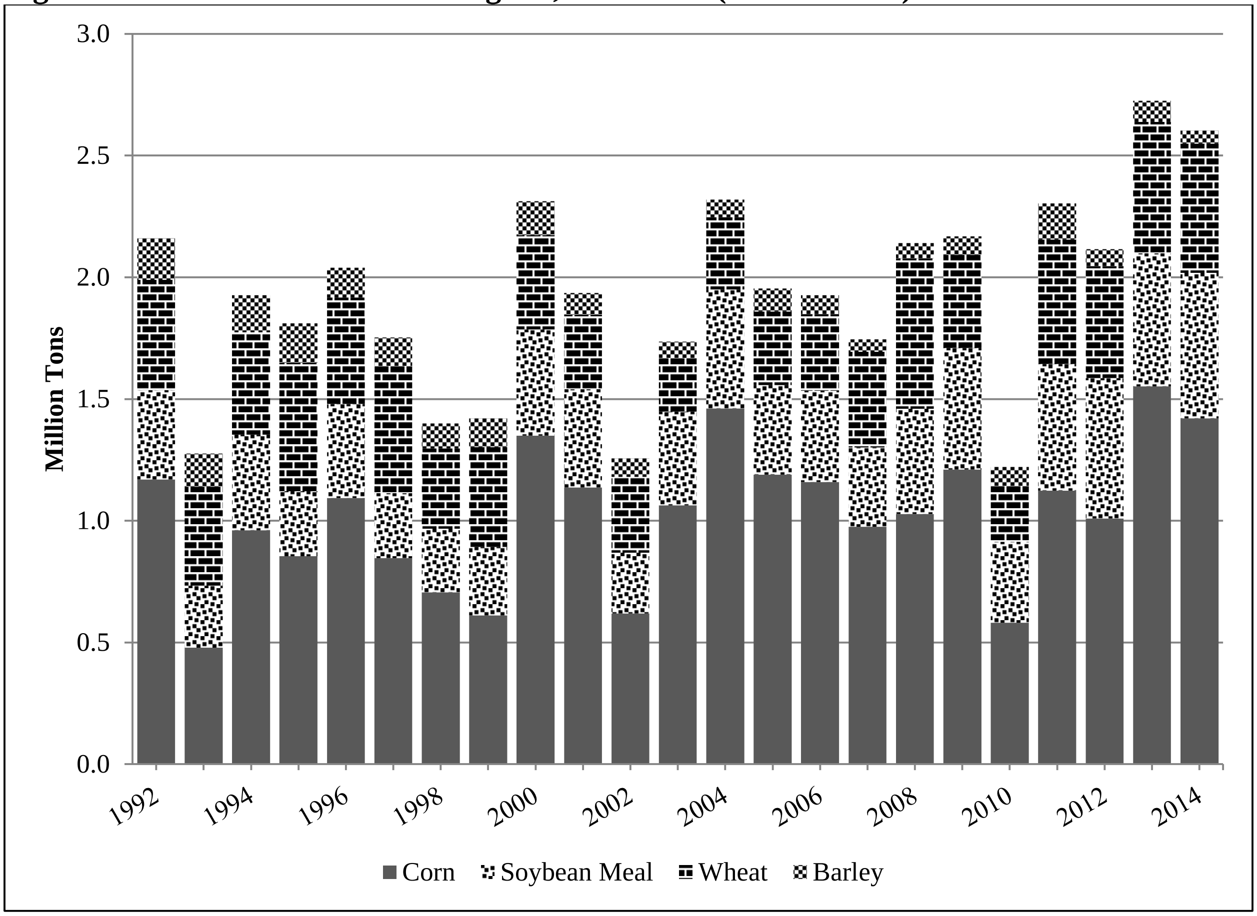
Source: USDA-ERS (2015).

Results

Grain Production

Virginia was ranked 29th in the nation for sales of grains and oilseeds in 2012 (Virginia NASS Field Office, 2015a). Grain production in the state is mainly characterized by corn, soybean (converted to soybean meal for this analysis), and wheat production, with relatively smaller amounts of barley production (Figure 13). The respective shares of total grain production in 2014 were 2.0 percent for barley, 54.6 percent for corn, 23.0 percent for soybean meal, and 20.4 percent for wheat. Year-to-year fluctuations in total grain production are mainly due to low productivity (yields) of Virginia's corn crop (Caffarelli et al., 2014b). Nevertheless, grain production in Virginia has experienced a slight positive increase over the period from 1992 to 2014. In fact, grain production in 2013 and 2014 reached amounts comparable to the peak levels only achieved in the 1980s.[25] For a more detailed examination of Virginia's grain production, see Caffarelli et al. (2014b).

Figure 13: Grain Production in Virginia, 1992-2014 (Million Tons)



Source: USDA-NASS; authors' calculations.

Grain Consumption

In terms of "number of head" or population, poultry accounts for the largest share of Virginia livestock production with 287.8 million units fed out of a total of 289.7 million animals in 2014.[26] However, the conversion of livestock populations into comparable units based on feed consumption changes the relative weight of different animal populations. For instance, grain consuming animal units appropriately increase the weight of cattle while lessening that of poultry. This is important because the grain consuming animal units show the overall trends in grain

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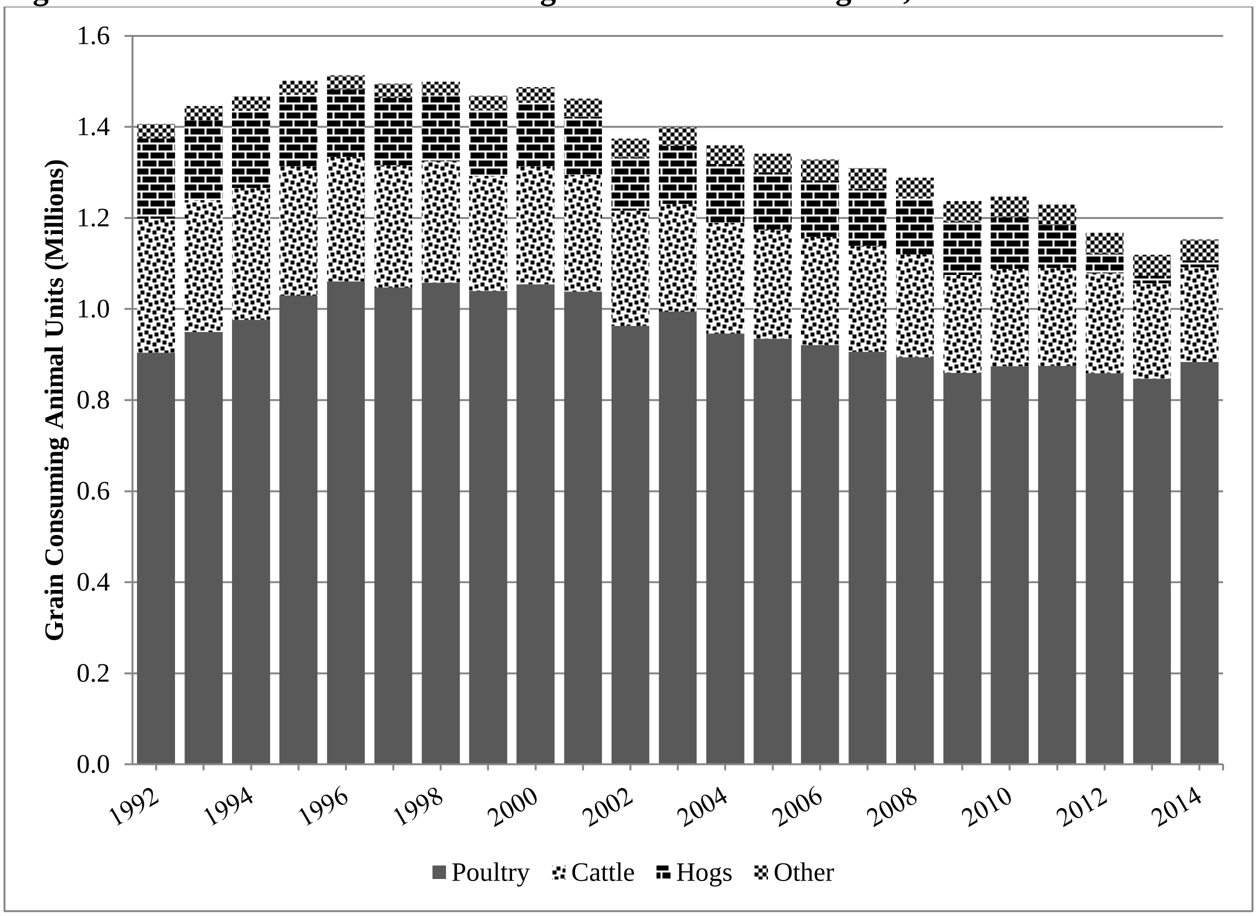
[25] For example, peak grain production levels prior to 2012 were in 1982, 1981, and 1984 with 100,905,000, 97,107,000, and 95,830,000 bushels (respectively) of barley, corn, soybeans, and wheat. Grain production in Virginia was 100,128,000 and 95,922,000 bushels in 2013 and 2014, respectively.

[26] The calculation for "poultry" includes broilers, turkeys, layers, and pullets.

consumption that are due to changes in the different animal populations.[27] According to Prater and O'Neil (2013), Virginia was ranked 22nd in the nation based on the average number of grain consuming animal units from 2006 to 2010.[28] In Virginia, the number of grain consuming animal units has generally declined over the period of 1992 to 2014, as shown in Figure 14. This downward trend is mainly due to generally declining populations of broilers, turkeys, layers, hogs, and dairy cows.[29] (Appendix A contains figures that plot Virginia's livestock populations over time). The reduction in the number of hogs raised in Virginia is particularly notable from 2010 to 2014.[30]

Figure 14: Number of Grain Consuming Animal Units in Virginia, 1992-2014



Source: USDA-NASS; authors' calculations.

As previously explained, estimates of total grain consumption by livestock are obtained by multiplying the number of GCAUs by the amount of grain consumed per unit. Due to the combined

[27] For example, to say that Virginia's livestock "declined by 10,000 head" is meaningless in terms of a discussion on grain consumption as animals of different species do not consume the same amount of grain. Instead, it is useful to convert all animals to the same unit and discuss changes in that comparable unit.

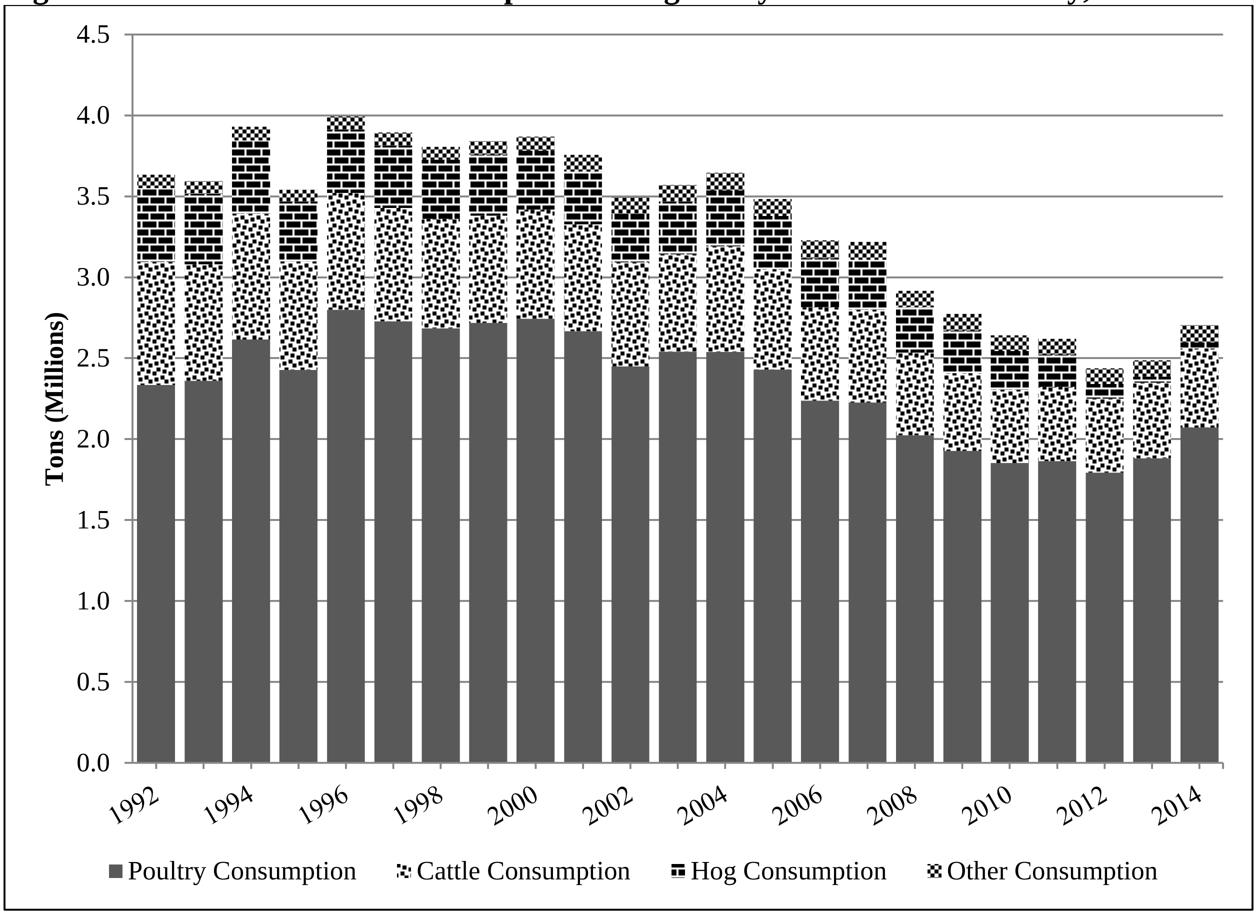
[28] The five leading states in terms of GCAUs over this period was Texas, Iowa, North Carolina, Nebraska, and Kansas.

[29] In terms of the other livestock and poultry populations, pullets and beef cattle on feed have generally declined, and, while sheep numbers have declined earlier in the period, some of the population has returned.

[30] Interestingly, a fall in Virginia's hog production in 2014 was not due to the porcine epidemic diarrhea virus (PEDv), which devastated hog production in other states (Murphy, 2014).

effects of declining livestock populations (reflected in Figure 14) and generally increasing feeding efficiency (Figure 12), the total amount of grain consumed in Virginia has decreased (Figure 15). As a note, the proportions of feed required for poultry, cattle, hogs, and other remain constant in figures reflected in Figure 14 and Figure 15; incorporating changes in tons fed per GCAU simply changes the height of the columns.

Figure 15: Estimated Grain Consumption in Virginia by Livestock and Poultry, 1992-2014



Source: USDA-NASS; USDA-ERS; authors' calculations.

In a past study of grain consumption in Virginia, Huffman and Kenyon (1999) examined corn and soybean consumption from 1965 to 1997. Their approach made use of animal population numbers and the specific rations of corn and soybeans fed to each animal commodity. For the comparable years of 1992 to 1997, Huffman and Kenyon identified increasing corn and soybean consumption. Though their results are not directly analogous, a comparison is useful. Huffman's findings are mostly in accordance with the observations found in this analysis, with the exception of 1995—a marketing year that the ERS saw a significant drop in the amount consumed per GCAU.[31] Interestingly, current estimates showing decreasing demand for grain contradict Huffman and Kenyon's (1999) prediction that growth in corn and soybean consumption would continue.

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[31] Grain faced a severe price shock in 1995 and 1996, which caused a decrease in the amount fed to livestock (Light and Shelvin 1998).

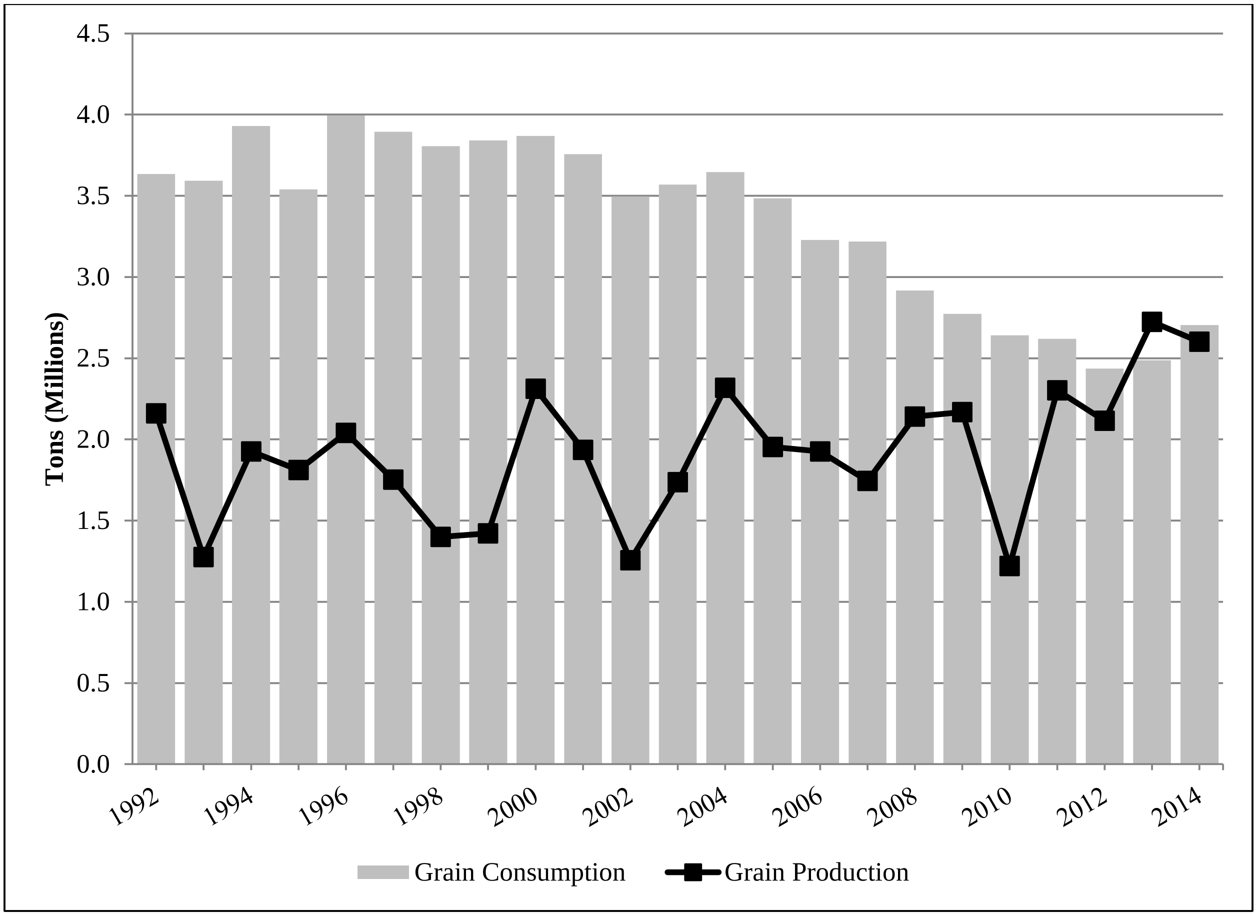
Indicated in previous figures, poultry comprises the largest share of Virginia grain consumption.[32] Specifically, from 2009 to 2014, the average share of total grain consumption was 72.8 percent for poultry, 17.9 percent for cattle, 5.5 percent for hogs, and 3.8 percent for other. In recent years, poultry's share of total consumption has increased while the share of hogs has decreased (see Appendix A, which contains additional charts breaking out the shares within the poultry and cattle groups).

Grain Consumption and Production

Figure 16 presents the aggregate grain production and consumption by livestock and poultry for Virginia from 1992 to 2014. The decline in grain consumption has been accompanied by generally increasing grain production levels. Consequently, Virginia's grain production deficit has been diminishing over time, even turning to a surplus in 2013. From 2009 to 2014, Virginia's livestock and poultry required an average of 2.61 million tons of grain, while grain production averaged 2.19 million tons. When combined, these two measures resulted in an average grain production shortage of 422 thousand tons (or 15.1 million bushels[33]). Comparing the average production deficit in 2003-2008 to 2009-2014, the shortage in Virginia fell by 952 thousand tons or 69.3 percent.

[32] Virginia was ranked fourteenth in the U.S. for poultry and eggs sales in 2012 (Virginia NASS Field Office 2015a).
[33] Using the metric of 56 pounds/bushel.

Figure 16: Grain Consumption (by Livestock and Poultry) and Production in Virginia, 1992-2014



Source: USDA-NASS; USDA-ERS; authors' calculations.

Importantly, the grain production deficit is underestimated as it is influenced by additional uses of Virginia grain such as grain exports and quantities used for seed, industrial use, and human consumption (Lazarus, Hill, and Thompson, 1980). While it is more difficult to estimate the amount of Virginia-grown grain that goes to human consumption,[34] it is possible to roughly estimate the amount of Virginia's grain exports. The ERS has data on the value of Virginia's grain exports, including corn, soybeans, soybean meal, and wheat, from 2000 to 2014 (USDA-ERS, 2015b). Comparing the "value of grain exported" to the "value of grain produced" shows that, from 2009 to 2014, Virginia exported an average of 16 percent of its corn (149 thousand tons), 65 percent of its soybeans (417 thousand tons), and 63 percent of its wheat (223 thousand tons), for a combined 790 thousand tons. Grain exports experienced fluctuations from 2000 to 2010 (with an average of 652 thousand tons), but have increased every year from 2010 on.

Combining this result with the 422 thousand ton grain shortage due to livestock and poultry consumption (over the same period) suggests that Virginia requires about 1,212 additional tons. Interestingly, Virginia does bring in a substantial amount of grain by railroad from the Midwest, including the states of Ohio, Illinois, Indiana, and others (Caffarelli et al., 2013). From 2006 to

[34] For instance, most of Virginia's wheat fields are soft red winter wheat, which is used to make cakes, pastries, and crackers. Other wheats for bread and pasta (for human consumption) must be imported into Virginia from other states.

2010, Virginia took in an average of 2.48 million tons of grain that originated in the Midwest (Caffarelli et al., 2013).[35]

Timing is another important issue that merits more detailed discussion. Grain production is seasonal, yet grain consumption occurs year-round. In Virginia, barley and wheat are harvested in June and early July, and corn and soybeans are harvested in the fall (USDA-NASS, 2010). As a result of this timing disparity, grain storage and transportation are important to keep a supply of grain available outside harvest times and to move grain when and where it is needed. Virginia's grain stocks held by commercial facilities are highest in December following the corn and soybean harvest (Caffarelli et al., 2014a).[36]

[35] During that time (2006 to 2010), Virginia's grain production deficit averaged 1.12 million tons, and exports averaged 655 thousand tons, for a combined 1.77 million tons. Note: the analysis does not include product that is used for industry/human or quantities that move across state lines by truck.

[36] For more information on how grain production compares to grain storage in Virginia, see Caffarelli et al. (2013b). Interestingly, fall grain stocks and production compared against storage capacity (examining potential storage shortfalls at harvest) show that Virginia's storage is not as limited as other states (Caffarelli and Gastelle, 2015).

Spatial Distribution of Virginia Grain Consumption and Production

Data Sources and Methodology

To further assess the situation of grain production and consumption in Virginia, the same methods used in the state-level estimates are now applied at the county-level to gain spatial insights. On the supply-side, once again, grain production includes barley, corn, soybeans, and wheat (where soybeans are converted to soybean meal and the amounts of each crop are converted to tons and aggregated). In terms of the demand-side or grain consumption, the same general steps are applied: obtain animal population numbers for each commodity per county; convert populations to animal units by weighting the livestock according to their relative feed consumption; and multiply the number of animal units in each county by the tons of grain consumed per animal unit (in 2012) to generate total grain consumption. County-level data was obtained from the 2012 *Census of Agriculture* (USDA-NASS, 2014). County-level estimates are just generated for 2012 to correspond to the most recent *Census* available.

Importantly, though the methods used to estimate grain consumption and production at the county-level parallel those used in the state-level calculations, there are two unique issues to be aware of: 1) the degree to which Census data resemble the "expected" production or livestock population numbers developed in the previous annual calculations, and 2) the "accuracy" of the production and population distributions displayed on a map of Virginia's counties. The first issue arises because NASS does not collect all of the same variables in the periodic Census that it gathers annually (which are used in the state-level calculations). For example, the ERS methodology uses "broiler production" and the "pig crop" as a proxy for broiler and hog feed consumption, respectively. However, NASS does not collect data on the pig crop or broiler production in the Census so adjustments are required. The second issue is due to the fact that NASS does not publish data for every county as a means to avoid disclosing information on individual operations.[37]

In order to simplify the language, the first issue is termed "magnitude accuracy"—how close the aggregate county-level (Census) estimate resembles the state-level estimate for a particular variable. The second issue is referred to as "distribution accuracy"—how exact the spread is across Virginia's counties. The issue of magnitude accuracy is mitigated, first, by the fact that most of the variables in the Census are the same (or reasonably similar) to those used in the annual state-level calculations and, second, because county-level data from the Census estimate 97.7 percent of the expected 2012 grain consumption. In the absence of a similar match, variables are selected that most closely reflect the expected 2012 state-level population for the given animal-type. The second issue of distribution accuracy is not a substantial problem since most of the county data are disclosed (often 90 percent or more) for the production and livestock consumption categories. As a general procedure, the non-disclosed data are distributed equally across non-disclosed counties. However, wherever possible, additional measures are taken and explained to enhance the distributional accuracy of certain livestock groups (see Appendix B).

[37] For example, NASS does not release the information if a county contains less than three operations.

Grain Production

As in the annual calculations, grain production at the county-level consists of barley, corn, soybeans (meal), and wheat. Since the variables used to estimate the grain supply at the state- and county-levels both represent "production" for the year, the issue of "magnitude accuracy" issue is not present (Table 11).[38] In addition, the issue of "distribution accuracy" is small since 94.6 percent of the grain production at the county-level is disclosed. Thus, it is reasonable to believe that the quantities reflected on the maps (in the Results section) are the expected amount and in the appropriate location.

To obtain tons of grain produced in each county, final steps include converting bushels to tons (by multiplying the amount of each crop by its respective factor in Table 8) and aggregating the tons of barley, corn, soybean meal, and wheat.

Table 11: Comparison of Annual and Census Data for Virginia Grain Production

	Barley	Corn	Soybeans	Wheat
State-Level Variable:				
Type	Production (bushels)	Production (bushels)	Production (bushels)	Production (bushels)
Time Frame/Date	2012	2012	2012	2012
Amount	2,870,000	36,050,000	24,360,000	15,360,000
County-Level Variable:				
Type	Production (bushels)	Production (bushels)	Production (bushels)	Production (bushels)
Time Frame/Date	2012	2012	2012	2012
Amount	2,905,047	33,984,647	22,680,879	14,804,947
Percentage Difference	1.2%	-5.7%	-6.9%	-3.6%
Amount Disclosed	2,607,902	33,703,317	22,552,678	14,578,900
Amount Non-Disclosed	297,145	281,330	128,201	226,047
Percent Disclosed	89.8%	99.2%	99.4%	98.5%
Percent Non-Disclosed	10.2%	0.8%	0.6%	1.5%

Source: USDA-NASS, 2014; authors' calculations.
Soybeans are not yet converted to soybean meal in the table.
The variable "types" for grain production at the state- and county-levels are the same. This is not true for all livestock and poultry.

Grain Consumption: Animal Populations, GCAUs, Grain Consumed Per GCAU, and Total Grain Consumption

Akin to the annual grain consumption calculations, the first step is identifying the variables to represent the various livestock groups. However, as mentioned previously, an important consideration to bear in mind is that the same variables used in the annual estimates (following ERS and AMS procedures) are not collected in the Census. For comparison purposes, Table 12

[38] In fact, due to the comprehensiveness and effort involved in conducting the Census, the county-level data are likely a more accurate representation of the "true" production numbers in Virginia. Even so, the annual production values are not replaced by Census numbers in order to maintain a consistent variable to observe year-to-year changes.

lists the variables used in the state- and county-level estimates for each animal group. Notably, some variables such as those used to represent horses, cattle, and sheep are the same (or essentially the same) in both calculations, while "most representative" proxies are used for others like for poultry and hogs. Further details comparing the selected Census variables to the annual ones and describing any issues related to magnitude or distribution accuracy (as well as additional steps to mitigate) are provided in Appendix B.

Table 12: Variables for the State-Level and County-Level Grain Consumption Estimates

Animal Group	State-Level (Annual) Variable	County-Level (Census) Variable
Cattle, Dairy Cows	Inventory on Jan. 1, 2013	Inventory on Dec. 31, 2012
Cattle, Dairy Heifers	Inventory on Jan. 1, 2013	Not available
Cattle, Beef, Cattle on Feed	Inventory on Jan. 1, 2013	Inventory on Dec. 31, 2012
Cattle, Beef, Other	Derived (see Appendix A)	Derived
Poultry, Broilers	Production (head) in 2012	Sold/moved in 2012
Poultry, Turkeys	Production (head) in 2012	Sold/moved in 2012
Poultry, Layers	Inventory (average) in 2012	Inventory on Dec. 31, 2012
Poultry, Pullets	Derived (see Appendix A)	Inventory on Dec. 31, 2012
Hogs	Pig crop in 2012	Inventory on Dec. 31, 2012
Sheep	Inventory on Jan. 1, 2013	Inventory on Dec. 31, 2012
Horses and Mules	Inventory on Nov. 1, 2006	Inventory on Nov. 1, 2006

As described previously, after population numbers are obtained, the remaining steps are to 1) convert the livestock numbers to grain consuming animal units (GCAUs) in each county; 2) aggregate the grain consuming animal units; and 3) multiply the GCAUs by the amount consumed per GCAU. More specifically, in order to calculate GCAUs of step 1, the animal populations are multiplied by their respective GCAU factor shown in Table 10. Next, to complete the second step, the GCAUs of all the different livestock groups are summed to estimate the total GCAUs for each county. Third, the number of grain consuming animal units in each county is then multiplied by 2.087 (Figure 12)—the number of tons of feed consumed per GCAU in 2012. This final calculation yields the total grain consumption in each county (in tons).

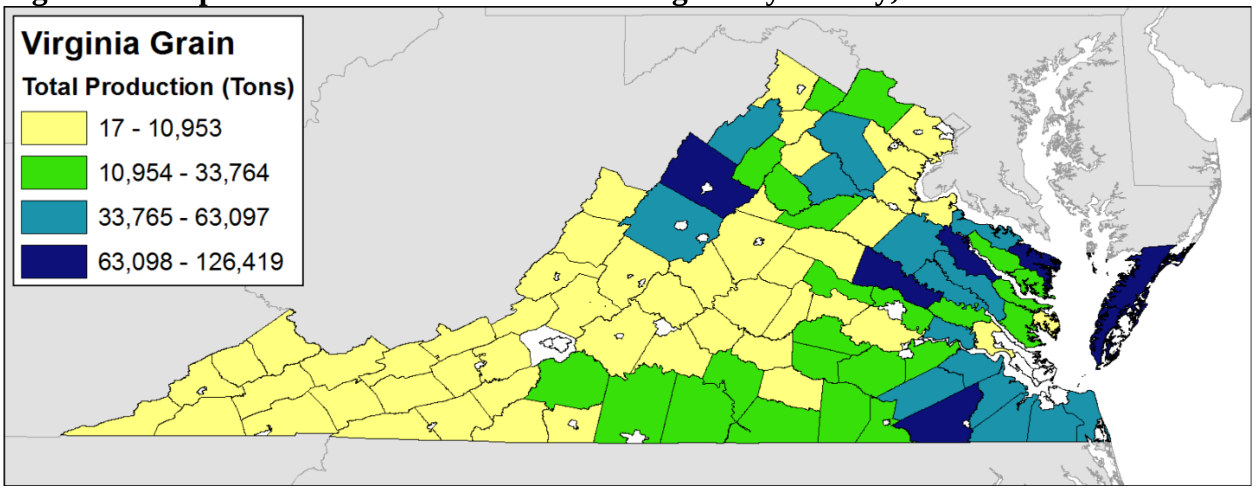
Results

The following subsections provide a series of maps to show the location and levels of grain consumption, production, and their resulting difference. Categories displayed in all maps applied the Jenks' optimization method, a procedure automatically calculated in the software which minimizes the variance within groups and maximizes the variance between groups (Esri, 2015).

Grain Production

Virginia's grain production encompasses almost every county and three independent cities: Chesapeake, Suffolk, and Virginia Beach. The state produced an estimated 2.1 million tons of grain in 2012, from 69.7 thousand tons of barley, 951.6 thousand tons of corn, 680.4 thousand tons of soybeans, and 444.1 thousand tons of wheat (USDA-NASS 2014). For purposes of comparing production against consumption, soybeans are converted to soybean meal.[39] As shown in Figure 17, most of the grain in Virginia is grown and harvested in the Shenandoah Valley and eastern counties. Individual crop distribution maps for barley, corn, soybean meal, and wheat are provided in Appendix B. Large levels of all four crops are produced in the Eastern Shore (Northampton and Accomack counties). These two counties produced a combined 200 thousand tons or 10.0 percent of the state's total grain supply in 2012.

Figure 17: Map of Total Grain Production in Virginia by County, 2012



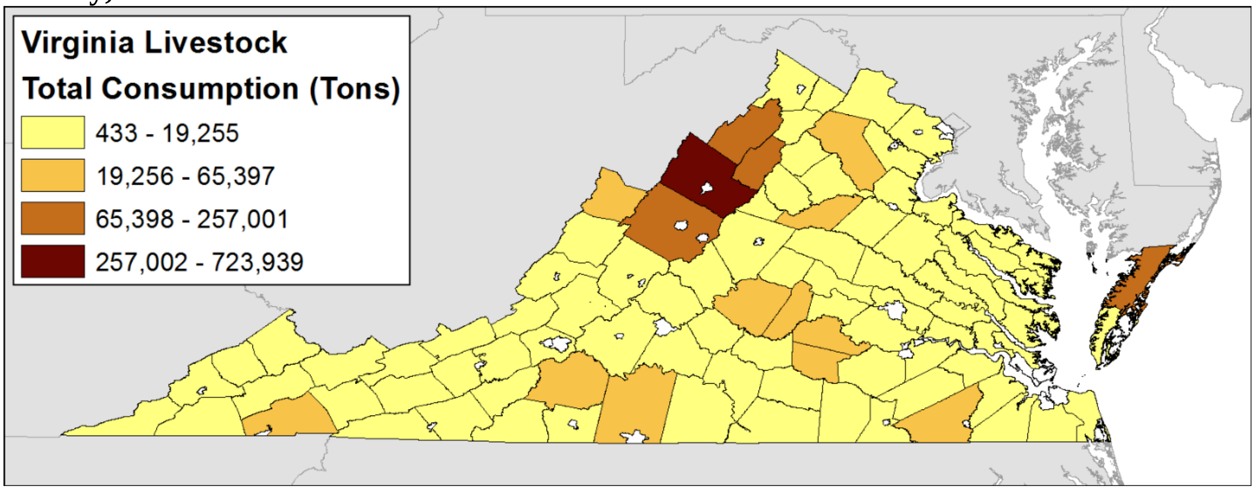
Source: USDA-NASS, 2014.

Grain Consumption

Similar to grain production, feed requirements are spread throughout the state. Figure 18 displays the total grain consumption by livestock and poultry in each of Virginia's counties (in tons). Because most of Virginia's poultry operations are located in the Shenandoah Valley and with poultry's substantial portion of the state's total demand of the feed grains, the Shenandoah Valley is naturally home to some of the largest amounts of grain consumption. The top-five counties requiring the most grain in 2012 include Rockingham (724 thousand tons), Augusta (257 thousand tons), Page (243 thousand tons), and Shenandoah (147 thousand tons) of the Shenandoah Valley region and Accomack (152 thousand tons) of the Eastern Shore (which also houses significant broiler populations). With over 1.5 million tons of the state's total grain consumption of 2.4 million tons, these five counties accounted for 64.0 percent of Virginia's grain needs (up from 62.8 in 2007). For additional details underlying total grain consumption in each county, maps depicting the individual distributions of the population of most livestock groups are included in Appendix B.

[39] As a linear transformation, the relative distribution remains the same.

Figure 18: Map of Total Grain Consumption (by Livestock and Poultry) in Virginia by County, 2012

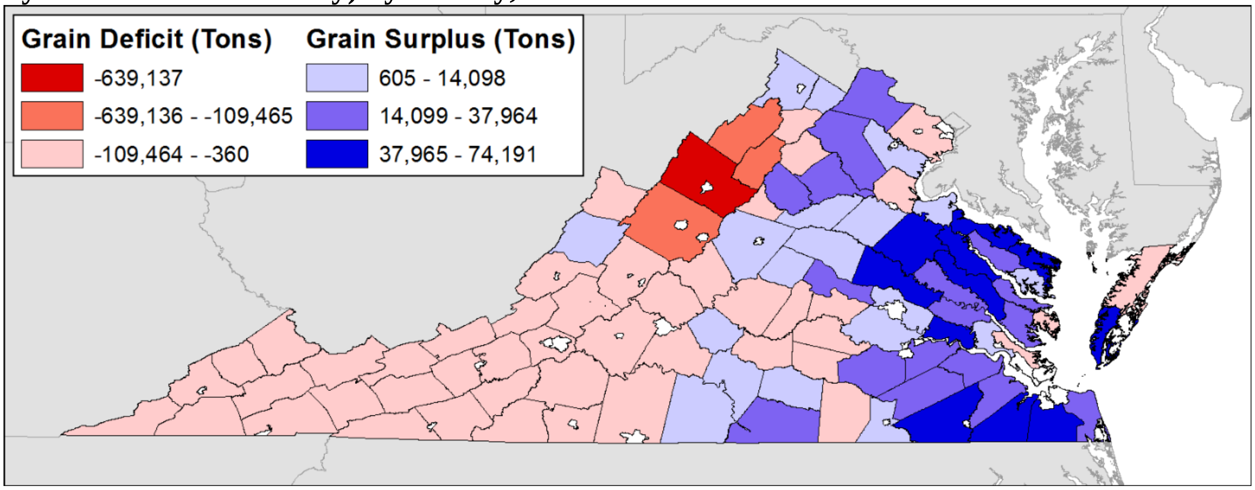


Source: USDA-NASS, 2014.

Grain Consumption and Production

In order to gain additional insight by examining grain surplus and deficit areas in Virginia, grain consumption is subtracted from grain production. Results reveal that the state is primarily divided east-west, with western counties experiencing grain shortages and eastern counties having excess grain (Figure 19). These results are due to the aforementioned fact that eastern Virginia grows large quantities of grain, especially relative to its livestock needs. A notable exception is Accomack County on the Eastern Shore, which, despite producing the most grain in Virginia with 126 thousand tons in 2012, still requires an additional influx of grain. Home to a substantial amount of Virginia's poultry operations, the counties in the Shenandoah Valley have the state's greatest grain shortages. The four counties of Rockingham, Page, Augusta, and Shenandoah have grain shortages of 639 thousand tons, 228 thousand tons, 195 thousand tons, and 109 thousand tons, respectively. With a combined grain deficit of 1.2 million tons, these four counties account for 73.9 percent of Virginia's total grain shortage in 2012 (up from 70.1 percent in 2007). In addition to those four, nine other counties had a grain shortfall of at least ten thousand tons in 2012.

Figure 19: Map of Virginia's Grain Deficits and Surpluses (Production Less Consumption by Livestock and Poultry) by County, 2012



Source: USDA-NASS, 2014.

Interestingly, at the more aggregated agricultural district level, Huffman and Kenyon (1999) reached similar conclusions: the northern agricultural district (which includes Rockingham and Shenandoah counties) experiences the greatest grain shortages while the eastern agricultural district generates the highest grain surpluses.[40] It is important to recognize that the locational snapshot of grain supply and demand in Virginia is limited by the omission of flows of grain from one county to another, and it does not include grain destined for the export market or industry/human use. Consequently, county-level deficits may be underestimated or overestimated. Nevertheless, this analysis identifies the areas that are comparatively more constrained or, conversely, well-supplied with grain for livestock and poultry production.

Conclusions and Discussion

Virginia is a state with a rich diversity of crops grown and products produced. Virginia's agricultural producers raise poultry, cattle, hogs, sheep, and horses and, combined with their related products, the sector generated over $2.1 billion in cash receipts in 2013 (VDACS, 2015). On the grain supply-side, Virginia's important crops include barley, corn, soybeans, and wheat. Naturally, these groups are connected since much of the grain is converted to animal feed and serves as an important input in livestock production.

Generally, the needs of Virginia's livestock sector have consistently exceeded the state's grain production (especially when grain exports and grain for human consumption are considered) thus, Virginia is a grain deficit state. Grain production is dominated by corn, soybeans, and wheat. On the other side of the equation, grain consumption is mainly characterized by poultry (specifically, broilers and turkeys). Moreover, across the period of study, feed consumption in Virginia is generally declining. This is due to 1) decreasing livestock populations (primarily declining broilers, turkeys, hogs, and dairy cattle) and 2) increased feed efficiency by livestock producers in the U.S. (Capehart, 2013). Combined with a slight positive trend in grain production,

[40] Their deficit in the northern agricultural district may even be understated because Augusta County, the county with the second highest grain shortage, is included in the "western" agricultural district.

the gap is narrowing and the shortages of grain production for livestock and poultry consumption in Virginia are falling.

Declining grain consumption by the livestock and poultry sectors and increasing grain production at the state-level may present opportunities for the grain export sector because there is reduced competition for grain from livestock producers. In fact, evidence suggests that this is likely the case as grain exports have increased every year in Virginia since 2010. Increasing grain production may encourage local sourcing, which would help maintain dollars in the Virginia economy as opposed to being sent to other states for grain imports (Huffman and Kenyon, 1999). Increasing local sourcing, however, would require an assessment of the impact and risk associated with variable levels of grain supplies. In addition, declining livestock and poultry populations in Virginia is noteworthy because USDA's Office of the Chief Economist (OCE) predicts increasing U.S. poultry and pork production through 2014 (USDA-OCE, 2015). Coupling these observations suggests that vital pieces of Virginia's agricultural economy are shrinking, particularly relative to other states.

At a local level, Virginia's grain shortages and surpluses show an east-west divide, with western counties generally needing more grain than they grow. Due to substantial poultry operations (the largest share of total consumption), most of the state's grain consumption is in the Shenandoah Valley. Grain production is significant in that region as well as in the state's eastern counties. An examination of grain consumption and production together reveals that grain shortfalls are most notable in the Shenandoah Valley.

The analysis yields several other important implications, particularly with respect to transportation. Broadly, as a grain deficit state, transportation is critical since grain must come into the state to meet the residual needs of the livestock sector in excess of grain production. Much of Virginia's grain shortfall is supplemented by inter-state grain supplies shipped by railroad (Caffarelli et al., 2013). More specifically, transportation is crucial to areas such as the Shenandoah Valley (and other western counties) that rely on moving the grain they grow to storage to ensure that the grain is ultimately available where and when it is needed. This is especially pertinent because a limitation is still hypothesized to exist where the relative grain surpluses in the east do not move back west. Despite their geographic proximity, the Valley has generally found it more economical to import grain by rail from the Midwest rather than grain hauled by truck from the east (Huffman and Kenyon, 1999).[41] While Accomack County on the Eastern Shore is a grain deficit county, it can meet its grain needs from its nearby surplus neighbor, Northampton county (or grain from Maryland). In contrast, Virginia's counties in the west face two issues: they need more grain than they have and that additional grain is not available nearby. Transportation must be efficient and timely to move grain from farm, to storage, to demand areas. In the event of limited transportation, a series of questions would need to be addressed concerning: the financing, location, and type(s) (e.g. rail, truck, etc.) of future transportation infrastructure. Private enterprises, state and local governments, producer associations, industry boards, cooperatives, and farmers should be actively involved and have a role in these decisions.

Furthermore, the study presents the opportunity for geographically targeted agricultural policy. For instance, Virginia's counties in the Shenandoah Valley are identified as the area facing the most severe grain shortages. Poultry production—Virginia's most significant livestock group—is concentrated in the Shenandoah Valley. Importantly, the magnitude of the grain shortfall leaves livestock and poultry producers in the area subject to forces not always in their

[41] Excess grain beyond the state's livestock requirements in the east could enter Virginia's ports for export and supply feeding operations in North Carolina.

control. For one, a deficit of 1.2 million tons is equivalent to 46,164 large semi-trucks (Iowa Department of Transportation, 2014), which implies some of the shortage can only be reasonably supplied by rail. This leaves “receivers” subject or “captive” to railroad service, prices, and infrastructure. Further, any area is affected by local supplies, but counties in the Valley are particularly tied to outside supplies, including their availability and price. If outside supplies were to become unavailable or more costly, the Valley would be impacted (Piggott, Shumaker, and Curtis, 2005). Finally, livestock and poultry producers in the Valley are dependent on grain storage to ensure grain is available when needed; these producers are tied to the capacity, quality, and location of on- and off-farm grain storage. Thus, the amount, location, availability, and condition of grain supplies, transportation, and storage are important to profitability of the industry.

This study suggests several areas for potential future research. First, investigation is needed to explore the reasons why Virginia’s livestock and poultry populations have declined from the late 1990s and early 2000s to make a more complete assessment of the industry. Next, research examining grain transportation, the flows of grain in, out, and within Virginia, and the economic factors behind those flows would increase the understanding of issues related to grain production and consumption and offer information for policymakers (e.g. explore the incentives for Virginia grain to move west). Moreover, the three areas of production, consumption, and transportation must be integrated with data on Virginia’s grain storage to more fully understand the nature of and opportunities and constraints in the state’s grain supply chain. Combined, this information would offer insights into both the current function and expansion potential of Virginia’s valuable grain and livestock sectors.

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Chapter 4: Describing Grain and Soybean Production and Storage in Virginia: Results of a 2013 Farm Survey

Introduction

Agriculture is an important industry in Virginia, with an estimated yearly economic impact of $52 billion (Rephann, 2013). The grain sector is a critical and necessary component of Virginia agriculture, providing inputs to the state's livestock sector and generating farm income through domestic and international markets. Virginia's major grains (barley, corn, and wheat) and soybeans generated $583 million in cash receipts in 2013 (VDACS, 2015). Virginia produced near-record levels of barley, corn, soybeans, and wheat in 2013 and 2014, and is predicted to harvest 87.6 million bushels in 2015, the sixth best year in the state's history (USDA-NASS, 2015).[42]

The current study presents the results of a state-wide survey of Virginia grain producers conducted in the summer of 2013. The objectives of the study are to describe and identify 1) on-farm storage capacity in Virginia; 2) storage constraints and issues; 3) possible economic incentives to reduce these constraints; and 4) transportation characteristics of Virginia's grain producers. Specifically, the survey explores grain growers' production, decision-making at harvest, amount and quality of grain storage, economic incentives that might encourage storage building, and transportation characteristics. Overall, this information can be used to identify constraints and opportunities in Virginia's grain sector, inform policymakers, and identify areas for future research. Highlights of the study include:

- Virginia's grain producers grow a number of different grains, but mainly corn, soybeans, and wheat;
- Thirty-one percent of the grain producers grow 1 or 2 crops, but most (44 percent) grow three crops, typically corn, soybeans, and wheat;
- Producers exhibit different behavior at harvest. Some growers bring it all to market immediately, some store a portion in their own storage, while others chose to store a share in rented commercial or on-farm structures;
- The average on-farm bin size is 10,345 bushels;
- On-farm grain storage in Virginia is relatively old—65 percent of the structures are 21 or more years old;
- Most farmers believe their bins will last another 11 to 20 years, if not longer;
- A majority (62 percent) of grain producers deem their storage situation (whether they have it or not) to be acceptable;

[42] Although technically an oilseed, soybeans are grouped in the "grains" category because of its similar role in the grain supply chain.

- Of the operations that are limited in their storage capacity, or who do not have on-farm storage, 64 percent stated that they are adding or replacing storage in the near future;
- For producers that neither have storage nor plan to build any, most report that “higher returns to stored grain” may induce them to build storage;
- A majority of producers (78 percent) indicate that they haul their own grain;
- Most (48 percent) of the grain from the farm gate is hauled 25 miles or less; and
- Farmers typically wait over fifty minutes at buying stations before their grain is unloaded.

About the Survey

In 2013 a survey was conducted to collect information about Virginia farmers’ production, storage, and transportation practices. The target audience was Virginia farmers that produce and sell cash grains. The survey was conducted using Virginia Tech’s mailing list for the state’s annual Ag Expo. The original list contained 2,156 entries and includes members of the Virginia Grain Producers Association as a subset. After general clean-up procedures were performed, which included eliminating duplicates and obvious non-farm entities, a mailing list of 1,765 names was generated. It was assumed that the mailing list contained more than just grain producers, so an opening question filtered cash grain farmers from other farmers and non-farmers (Appendix C provides a copy of the survey and participant recruitment letter). After further clean-up (removing deceased farmers, retired farmers, entries connected to the same operation, and undeliverable surveys) the final list contained 1,291 names (Table 13). Deceased and retired farmers were identified by a note on a returned letter or survey. In addition, respondents either directly indicated that they were part of the same operation or were presumed to be part of the same operation if their last name, location, and company name matched a returned survey.

Table 13: Response Statistics of 2013 Farmer Survey

Total Number in List	**1765**
Number of Deceased	32
Number of Non-Farmers (Retired, Not in Virginia, etc.)	224
Number of Farmers, Not Cash Grain	107
Elected Not to Respond	16
Connected to an Operation	8
Presumably Connected to an Operation	69
Undeliverable	18
Total	**474**
Completed Surveys	**347**
“Relevant List” (1765 less 474)	**1291**
Response Rate	**26.9%**

Source: Caffarelli et al., 2015.

The survey contained 26 questions that covered the areas of grain production, storage, transportation, and farm business characteristics (Appendix C). Briefly, the questionnaire examined:

- Farm location (represented by county and zip code of the farm operations);
- Production information, including the total acreage typically under grain production, the types of crops grown, and the typical volume harvested;
- Decision-making at harvest, including if any crop is stored commercially, in owned on-farm storage, and/or rented on-farm storage;
- Storage, including the amounts stored, if any portion is retained for on-farm use like feed, and how long (in months) grain remains in storage until later sale;
- On-farm storage, including how many bins are owned as well as their capacity, approximate age, and expected remaining useful life;
- Constraints, including if and how operations were constrained by their current storage situation (or lack of storage) as well as when these issues were most limiting
- Future storage plans, including type (e.g., adding storage or replacing storage), amount (e.g., number of bins and bushels), and when (e.g., "within the next 5 years");
- Economic incentives that were either important to the farms already storing or the factors under which non-storage owners would consider building; and
- Transportation, including how grain is delivered to buying stations, the distance(s) the grain is hauled, and wait times at buying stations

Procedures for implementing the survey followed the method prescribed by Dillman et al. (2014), which involved the sending of an initial mailing of a cover letter and a survey form. A reminder postcard was mailed one week later, and a second letter and survey form was mailed two weeks after the postcard. Seven weeks after the initial mailing, a third and final letter and survey were mailed.

A total of 347 completed and usable surveys were returned, yielding a response rate of 27 percent (Table 13). As shown and explained later, a comparison of the total bushels harvested by the respondents' farms to the expected production in Virginia suggests that the questionnaire respondents reflects about 42 percent of Virginia's grain production. Data were entered into a Microsoft Excel spreadsheet. Additional clean-up measures included taking a simple average if a respondent provided a range of values, noting "non-responses" when values were expected for applicable questions, and converting production numbers to bushels if either acres or yield was provided instead.[43]

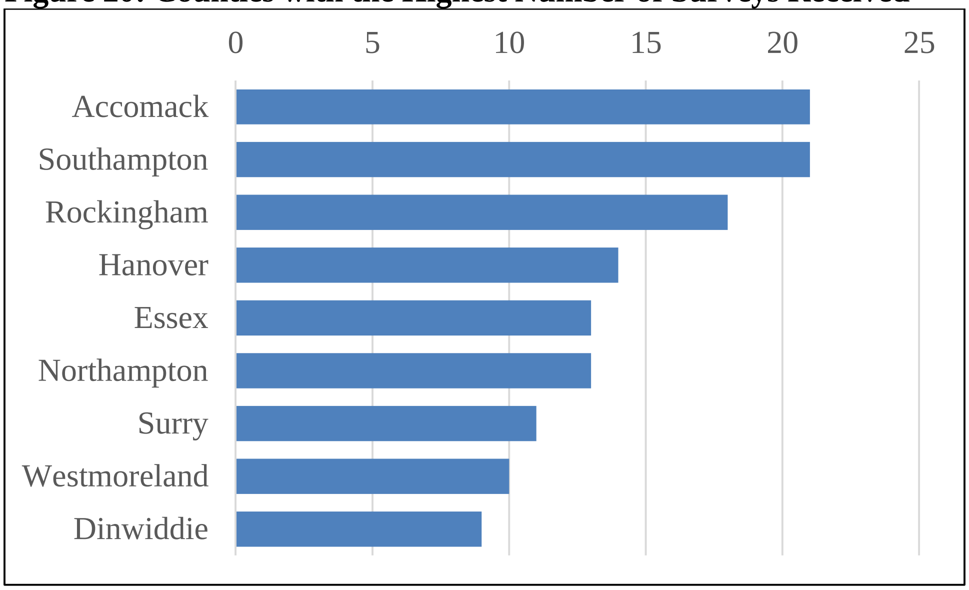
[43] When a respondent did not specify if they reported acres or yield by crop, unrealistically high yields were assumed to be reported acres. Twenty respondents reported yield, which required estimating acres. "Splits" were designed to take into account timing (barley and wheat harvested in the summer; corn and soybeans harvested in the fall) and possible double-cropping. For farms growing corn and another crop (e.g., soybeans), the total reported acreage was split equally. For farms growing corn and two other crops, the total reported acreage was split 60 percent to corn and 40 percent to each of the others (e.g., corn, soybeans, and wheat; corn, soybeans, and barley). For the farms growing corn and three other crops, the acreage was split 60 percent to corn, 40 percent to soybeans, 20 percent to wheat, and 20 percent to barley (as if wheat and barley were double-cropped with soybeans). In the thirteen instances where acres were reported by crop, yields were estimated using county-level yield from the *2012 Census of Agriculture* for Virginia. When yields were not disclosed for a crop in a particular crop, state yields from the *Census* were used (grain sorghum = 63.8 bushels/acre; oats = 69.1 bushels/acre; rye = 36.8 bushels/acre).

Results

General Characteristics of the Sample and Grain Producers in Virginia

Responses include surveys from grain growers operating in 60 different counties, including the agriculturally-relevant independent cities of Chesapeake, Suffolk, and Virginia Beach.[44] Figure 20 shows the top counties and, not surprisingly, the counties with the most respondents are also Virginia's main grain-producing counties. Ranked in decreasing order of total grain production, Accomack, Southampton, Rockingham, and Hanover were Virginia's largest producers in 2012 (USDA-NASS, 2014), which corresponds directly to the number of surveys received.[45]

Figure 20: Counties with the Highest Number of Surveys Received



Source: Caffarelli et al., 2015.

Overall, the responses reflect over 335 thousand acres under grain production in Virginia (Table 14). Small farms harvested grain in the tens of acres, while large farms had thousands of acres under production. The average acreage per reporting farm was approximately 1,031 acres, which suggests that the survey responses reflect larger-than-average grain operations as the average oilseed and grain farm (NAICS 1111) in Virginia was 569 acres in 2012 (USDA-NASS, 2014). In addition to growing row crops, about 29 percent of respondents (99 out of 347) indicate that they have some form of livestock operations since they retain a portion of their grain for feed. However, results from the survey show that respondents are largely grain producers since only 2 respondents retain 75 percent or more of their grain on-farm for feed.

[44] Virginia has a total of 95 counties.

[45] Total grain production is measured as the combined production of barley, corn, soybeans, and wheat.

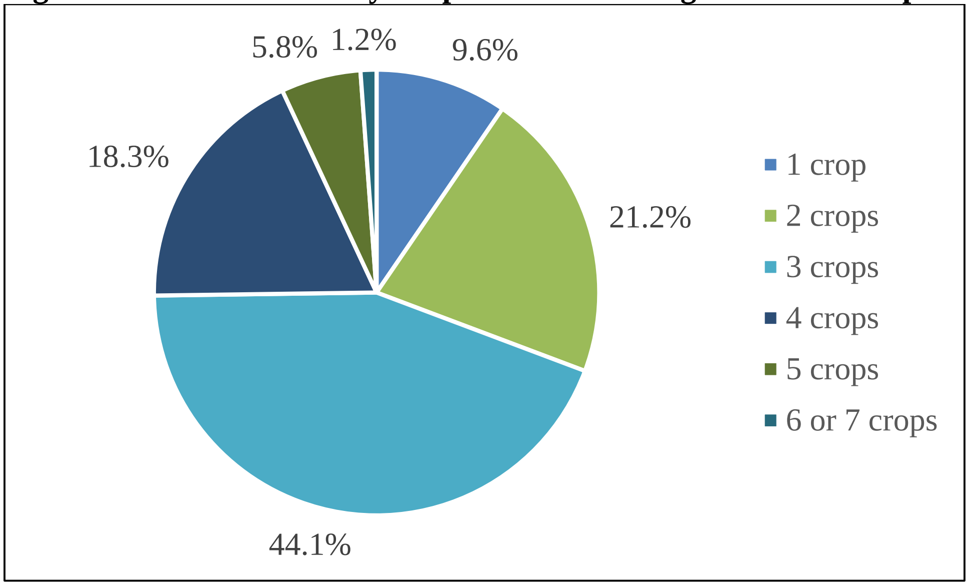
Table 14: Acreage Statistics*

Farm Size (Acreage) Statistics	
Reported Acreage	335,045 acres
Largest Farm	8,000 acres
Smallest Farm	15 acres
Average Acreage per Reporting Farm	1,031 acres

Source: Caffarelli et al., 2015.
* *n* = 325, out of 347, 94%

Virginia farmers grow several different grains, with total production characterized by barley, corn, soybeans, and wheat (Caffarelli et al., 2014). Many farmers produce more than one grain as most grow two or three types, while some grow four or more (Figure 21; data is provided in Table 29, included in Appendix D). Most of the farmers (85 percent) with three crops grow corn, soybeans, and wheat.

Figure 21: Shares of Survey Respondents Growing 1 or More Crops*



Source: Caffarelli et al., 2015.
* *n* = 345, out of 347, 99%

Table 15 presents the number and share of farmers growing each crop, and the average number of bushels produced per farm. Most respondents reported that they grew soybeans (94 percent), followed by corn (83 percent) and wheat (75 percent). Corn is produced in the largest amount on each farm, followed by wheat and soybeans. Using the 2012 *Census of Agriculture* for Virginia as a proxy of total production in the state, the data in the surveys reflect approximately 48 percent of Virginia's corn production, 33 percent of the soybean production, and 41 percent of the wheat production.[46] In total, the surveys reflect about 42 percent of grain production in

[46] Since the survey was sent out in the summer of 2013 and asked about "typical" production behavior, 2012 grain production numbers offer a good basis of comparison.

Virginia, which is higher than the 27 percent representation based on the survey response rate alone. This is important because it suggests that the surveys are particularly reflective of the characteristics of larger-than-average grain producers in the state.

Table 15: Crop Production Statistics of Sample[a]

Crop	Number of Growers (% of Sample[b])	Total Bushels Reported	Average Bushels per Grower	Total Bushels in Virginia (2012)[c]	Percentage Represented
Barley	81 (23%)	1,164,162	14,372	2,905,047	40.1%
Corn	285 (83%)	16,207,298	56,868	33,984,647	47.7%
Grain Sorghum	25 (7%)	205,678	8,227	258,000	79.7%
Oats	17 (5%)	58,700	3,453	238,928	24.6%
Rye	19 (6%)	21,860	1,151	157,851	13.8%
Soybeans	324 (94%)	7,575,570	23,381	22,680,879	33.4%
Triticale	3 (1%)	Not Disclosed[d]	Not Disclosed	Not Disclosed	Not Disclosed
Wheat	259 (75%)	6,131,849	23,675	14,804,947	41.4%
Total		**31,367,217**	**90,919**	**75,061,784**	**41.8%**

Source: Caffarelli et al., 2015.
[a] *n* = 345, out of 347, 99%
[b] Percentages do not add to 100 because farmers often grow more than one crop.
[c] Total production numbers per crop come from the 2012 Census of Agriculture for Virginia (USDA-NASS, 2014).
[d] Not disclosed to protect individual information.

Analysis of the survey data reveals that respondents generally fall into one of four categories regarding their behavior at harvest (Table 16). Some grain producers sell everything at harvest; they do not own on-farm storage nor do they store any grain ("Group 1"). The largest group, "Group 2," may sell some at harvest, but their key characteristics are owning on-farm storage and using it by storing a portion of their output at harvest. "Group 3" does not own storage, but they store at least a portion in either commercial structures or rented on-farm storage. Finally, "Group 4" is similar to "Group 2" in that they own storage; however, the important difference remains that the storage is not used (likely due to the poor quality of the bins).[47] Most of the respondents fall into Group 2 and Group 1, with smaller proportions in Groups 3 and 4 (Table 16). Thus, in general, most grain producers in Virginia either sell everything at harvest or store a portion in the bins they own.

[47] Some of the respondents in Group 4 store commercially.

Table 16: Breakdown and Number of Respondents Falling Into Each Group*

Group #	Count	Percentage	Description of Group
Group 1	81	23.3%	No on-farm storage, sells everything at harvest
Group 2	234	67.4%	Owns on-farm storage, stores some *on-farm* at harvest
Group 3	16	4.6%	No on-farm storage, stores some *commercially* at harvest
Group 4	16	4.6%	Owns on-farm storage, does not store on-farm[48]
Total	**347**	**100%**	

Source: Caffarelli et al., 2015.
* *n* = 347, out of 347, 100%

Characteristics of Virginia's On-Farm Storage

Grain storage has an important role in the grain supply chain, and provides for the efficient and timely flow of grain from farms to final users. For grain growers, grain storage serves several functions such as helping farmers capture higher prices later in the marketing year, offering farmers flexibility on where and when grain is sold, and contributing to a more timely harvest (Edwards and Johanns, 2015). For livestock growers and processors, storage helps ensure that supply is available throughout the year, not just at harvest (Alexander and Kenkel, 2012). There are two types of permanent storage, on-farm and off-farm, as well as a variety of temporary storage options.

The National Agricultural Statistics Service (NASS) of the US Department of Agriculture (USDA) collects data annually on the capacity of on- and off-farm grain storage. Total grain storage capacity in the U.S. was 23.8 billion bushels (bbu)—10.7 bbu off-farm and 13.1 bbu on-farm (USDA-NASS, 2015). Storage varies state-to-state in terms of total capacity and composition (i.e., share of off-farm versus on-farm).[49] The states with the most permanent storage capacity in 2014 were Iowa (3.4 bbu), Illinois (2.9 bbu), Minnesota (2.2 bbu), Nebraska (2.1 bbu), and Kansas (1.4 bbu) (USDA-NASS, 2015). Out of forty states, Virginia ranked 30th with 90 million bushels of storage capacity in 2014. Next, while the share of off-farm and on-farm storage in the United States was 45 percent and 55 percent, respectively in 2014, some states have greater (and smaller) shares of off-farm storage. For instance, over 73 percent of the storage in the states of Texas, Oklahoma, Washington, and Kansas was characterized as off-farm in 2014 (USDA-NASS, 2015).[50] Conversely, states like Kentucky, New York, Pennsylvania, and Montana had 73 percent or more of their storage on-farm in 2014 (USDA-NASS, 2015).[51] Virginia falls in the middle, with on-farm storage accounting for a 61 percent share of total storage in 2014 (USDA-NASS, 2015).

On- and off-farm storage present different storing options to farmers. For instance, farmers can invest in on-farm storage or rent on-farm storage space from other farmers. Advantages of owning storage include guaranteed available storage space, convenient management of stored grain, and low cost financing available from the Farm Service Agency (Edwards and Johanns,

[48] It is not known if this unused storage is rented to others; presumably it is left empty due to its poor quality.
[49] Dhuyvetter (1999) admits that why these differences exist is not really clear, but suspects that a number of factors are contributing, including transportation infrastructure, climate, livestock operations, intensity of production, and type of crops stored.
[50] The analysis excludes Arizona, California, Delaware, Florida, Louisiana, Maryland, New England, New Mexico, South Carolina, Utah, and Wyoming whose on-farm storage capacity numbers are not disclosed.
[51] *Ibid*.

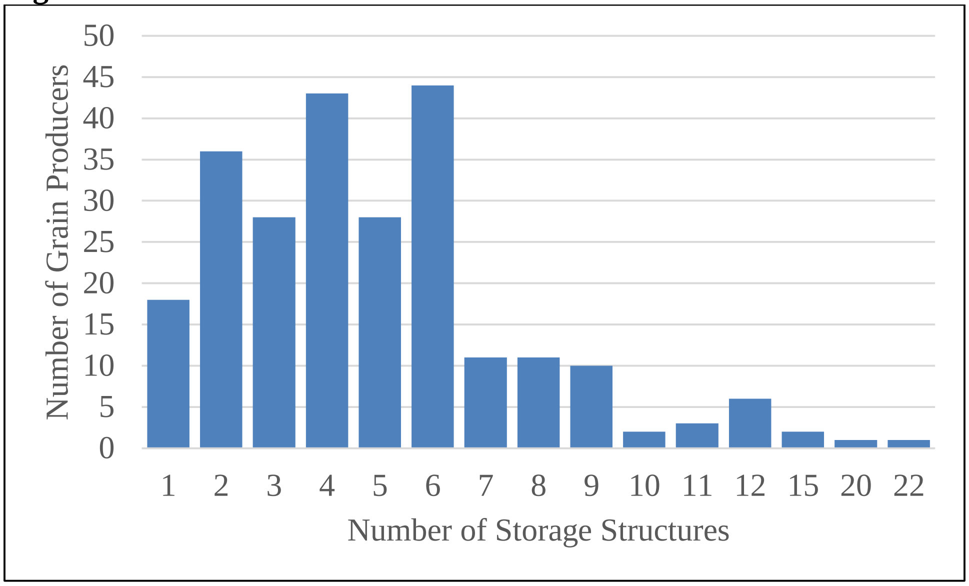
2015). These benefits would have to be weighed against possible disadvantages such as the size of the initial investment, the need to monitor grain throughout the storage period, and the difficulty of disposing storage structures if no longer needed (Edwards and Johanns, 2015). Different commercial storage options for farmers include investing in condominium storage at an elevator or renting commercial storage space. Advantages of these off-farm options include the elevator handles the grain and guarantees quality, the elevator can dry the grain, and no additional transportation and handling is required if the elevator merchandises the grain (Edwards and Johanns, 2015). Nevertheless, storing grain commercially may present some of its own disadvantages such as possible longer travel distances and wait times to unload grain at harvest, and it may be uneconomical to market the grain to another buyer or processor (Edwards and Johanns, 2015).

In the five-year Agricultural Census, NASS collects more specific information from farmers about their on-farm storage, such as the county-level locations, amount, and number of operators with on-farm storage. However, no other comprehensive information is readily available that describes the state and quality of on-farm grain storage. In that vein, this survey sheds light on a valuable part of the grain supply chain and offers more details pertaining to on-farm storage in Virginia.

Overall, a majority of respondents (72 percent) report having on-farm storage.[52] Of these, 244 (98 percent) of the farmers indicated that they have a combined 1,202 storage structures or bins (Table 30 in Appendix D provides a numeric breakout of the bins). The number of bins per farmer ranges from 1 to 22, though many have between 4 and 6 structures (Figure 22). The average number of bins per grower is about 4.9.

[52] This calculation includes the 250 members of Groups 2 and 4, which own storage. Interestingly, the percentage likely comes close to its "population" percentage in Virginia; that is of grain producers that have a market value of $10,000 or more, which corresponds to earlier results showing that respondents are "larger-than-average" farms. According to the *Census*, 1,233 of Virginia's crop producers (NAICS 111; as compared to NAICS 112 which represents animal producers and aquaculture) had storage in 2012. Further, 1,771 farms were classified as NAICS 1111 ("oilseed and grain farming") and in an "economic class" of $10,000 or greater. (Economic class refers to the combined dollar value of a farm's market value of agricultural products sold and government payments. It is assumed that farms with less than $10,000 in value are of too small a scale to invest in permanent storage.) Thus, it appears that 70 percent (1,233/1,771) of Virginia's moderate to large grain farms have storage.

Figure 22: Number of Farmers with a Given Number of Bins*



Source: Caffarelli et al., 2015.
* *n* = 244, out of 250, 98%

Furthermore, another important measure of grain storage is their total volume or capacity. The received surveys accounted for over 11.6 million bushels of capacity, which is about 37 percent of Virginia's total on-farm storage possessed by crop producers (Table 17).[53] The average capacity per bin is slightly over 10 thousand bushels.

Table 17: On-Farm Storage Size Characteristics

	Capacity
Number of bins with capacity information	1,118
Number of bins with no response	84
Total number of bins	1,202
Total capacity reported (bushels)	11,565,644
Average capacity per bin (bushels)	10,345
2012 on-farm capacity in Virginia for crop producers (NAICS 111)	31,327,512
Percentage of Virginia on-farm storage capacity reflected by survey respondents	37%

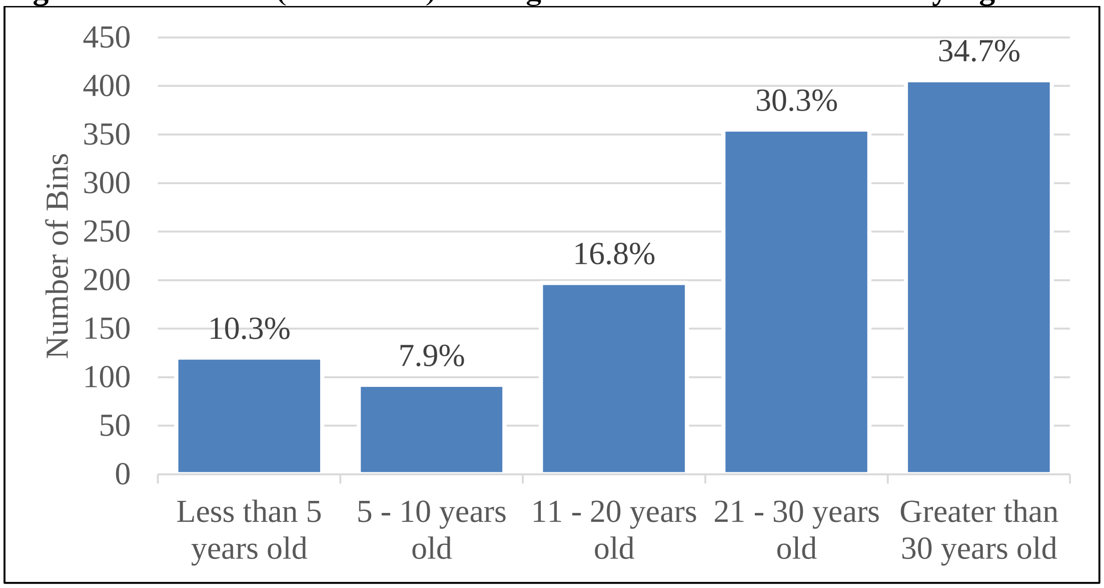
Source: Caffarelli et al., 2015.

Next, the "age" and "remaining useful life" of the structures are considered to assess the quality and longevity of on-farm storage in Virginia. Studies estimate that the useful life of a grain bin is between 15 and 30 years.[54] Thus, on-farm storage in Virginia appears to be relatively old as grain producers indicated that many (over 60 percent) of their structures were "21 to 30 years old" or more than 30 years old (Figure 23; Table 31 in Appendix D provides a numeric breakout). More

[53] Virginia had 42,645,073 bushels of on-farm storage capacity in 2012, 31,327,512 bushels (73.5 percent) by crop producers and 11,317,561 bushels (26.5 percent) by animal producers and aquaculture (USDA-NASS, 2014).
[54] According to Miller and Jose (2009) and Edwards (2014), the useful life of a grain bin is 15 to 25 years. Dhuyvetter et al. (2007) cite 30 years as the useful life.

specifically, about 30 percent of the bins were characterized as "21 to 30 years old" and 35 percent were deemed "greater than 30." However, there does appear to be some relatively newer bins, as 10 percent of structures are described as "less than five years old." In 1991, research found that the average storage bin was 27 years old in Kansas, with 33 percent of structures "30 years or older" and 50 percent "less than 20 years" old (Kadir et al., 2005). The age of on-farm storage in Kansas today or in other states is not known.

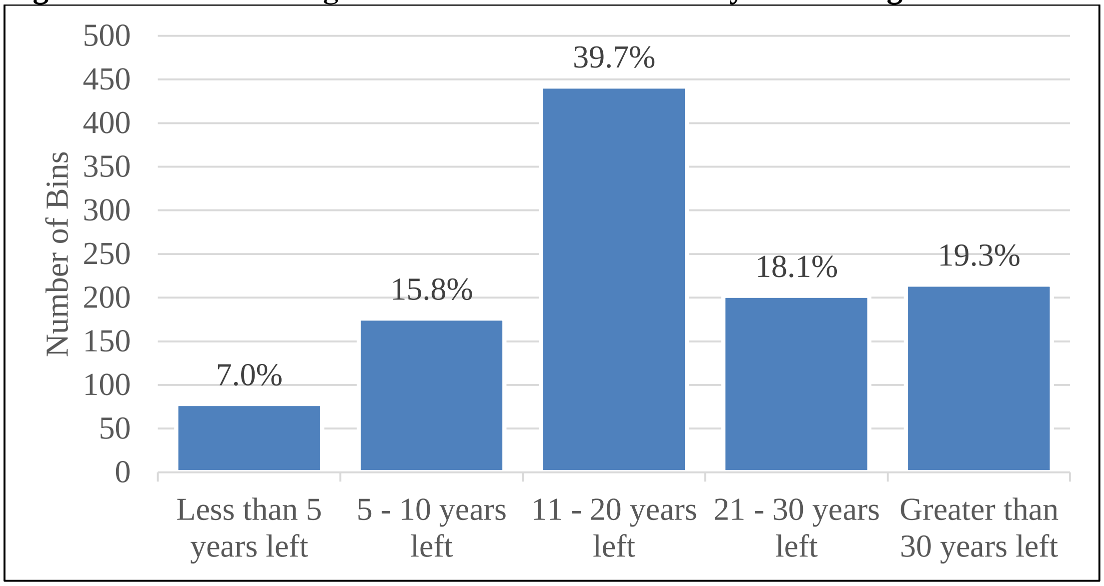
Figure 23: Number (and Share) of Virginia's On-Farm Structures by Age*



Source: Caffarelli et al., 2015.
* Results do not include bins without a response.

Equally as important as age of on-farm storage is the remaining useful life. Most of the respondents (77 percent) anticipate having at least 11 years of useful life remaining in their structures (Figure 24; Table 32 in Appendix D provides a numeric breakout). However, respondents predict about 7 percent of their bins will reach the end of their useful life in less than five years.

Figure 24: Share of Virginia's On-Farm Structures by Remaining Useful Life*



Source: Caffarelli et al., 2015.
* Results do not include bins without a response.

Storage Constraints in Grain Operations

As described previously, grain producers fall into different groups depending on their storing behavior and infrastructure on the farm. Naturally, farmers in each group face specific issues and challenges. Thus, one of the goals of this survey was to identify the issues that impact growers with storage as well as observe if farms are limited without grain storage. Table 18 contains the number of respondents that report if their operations are constrained by their current (or lack of any) storage situation. Overall, a majority of grain producers (62 percent)[55] indicate that their operations are not negatively affected by an aspect of their storage or by not having any.

Table 18: Number of Operations with a Storage Limitation by Group

Group	Operations Not Constrained	Operations Constrained	No Response	Total
1 (Sells everything)	48 (59.3%)	20 (24.7%)	13 (16.0%)	**81**
2 (Owns and uses on-farm storage)	134 (57.3%)	99 (42.3%)	1 (0.4%)	**234**
3 (No on-farm storage, stores commercially)	11 (68.8%)	3 (18.8%)	2 (12.5%)	**16**
4 (Owns on-farm storage, does not use)	10 (62.5%)	5 (31.3%)	1 (6.3%)	**16**
Total	**203 (58.5%)**	**127 (36.6%)**	**17 (4.9%)**	**347**

Source: Caffarelli et al., 2015.

[55] This calculation (203/330) includes the 202 "non-constrained" operations and 127 "constrained" operations, and excludes the 17 non-responses.

Of the groups that do not have storage (Groups 1 and 3), 72 percent (59/82) of those grain growers say their operations are not impacted by the lack of storage. Similarly, 58 percent (134/233) of grain growers that own and use on-farm storage (Group 2) report not having an issue with their storage situation that limits operations. Importantly, these results suggest that, in general, most grain farmers are satisfied with their current storage infrastructure setups; however, some on-farm storage issues are revealed.

For those respondents that store on-farm (Group 2) and indicated that their operations were somehow constrained by their storage, a majority (73 percent) indicated that they have (at least) a "total capacity" issue (Table 19). Further, some of those farmers stated that they remain unable to store multiple crops. Many of these farmers grow more types of crops than they have bins. Several respondents also cited "other" reasons explaining how their storage limited their farming operations such as "drying capacity," "age" of farmer, "drying equipment" and lack of dryer, and "location of storage."

Table 19: Storage Issues Faced by Constrained Operations*

Issue	Number "Yes"
Total capacity	72 (72.7%)
Ability to store multiple crops	47 (47.5%)
Age of some existing structures	34 (34.3%)
Quality of some existing structures	19 (19.2%)
Other	17 (17.2%)

Source: Caffarelli et al., 2015.
* n = 99, out of 99, 100%

Plans to Alleviate Storage Constraints

Though most grain producers in Virginia do not appear to be hindered by their current storage situation (all groups), a portion (38 percent; 127/330) of operations are impacted in some way by their storage. Taking these situations as given and presently fixed, farmers' future plans are explored, particularly concerning any proposals to expand storage in the future and relieve the storage constraints. For instance, 64 percent (81/127) of the farmers who reported that their operations were constrained plan to add or replace capacity (or both) in the future (Table 20).

Table 20: Future Storage Plans of "Constrained" Operations

Group	Plans to Modify On-Farm Storage (Add or Replace Capacity)	No Plans to Modify On-Farm Storage (Add or Replace Capacity)	Total
1 (Sells everything)	8 (40.0%)	12 (60.0%)	**20**
2 (Owns and uses on-farm storage)	68 (68.7%)	31 (31.3%)	**99**
3 (No on-farm storage, stores commercially)	3 (100.0%)	0 (0.0%)	**3**
4 (Owns on-farm storage, does not use)	2 (40.0%)	3 (60.0%)	**5**
Total (%)	**81 (63.8%)**	**46 (36.2%)**	**127**

Source: Caffarelli et al., 2015.

Conversely, Table 21 contains survey response data regarding the future plans of farmers whose operations are not constrained by on-farm storage. This explores if farmers are adding structures for some other reason than a storage-limitation with their operation (since they do not reporting having one). The numbers overwhelmingly show that "non-constrained" farmers who do not use on-farm storage (Groups 1, 3, and 4) are satisfied with the state of their operation; 100 percent of these respondents are not planning to build any storage in the future. On the other hand, a small portion (30 percent or 40/133, excluding the one non-response) of "non-constrained" growers with on-farm storage are planning to add or replace capacity in the future. This suggests a different motivation for increasing storage other than trying to relieve a storage constraint. As a note, this 30 percent share is in contrast to 69 percent (68/99) of storage-constrained operations who are planning to change their storage situation.

Table 21: Future Storage Plans of "Non-Constrained" Operations

Group	Plans to Modify On-Farm Storage (Add or Replace Capacity)	No Plans to Modify On-Farm Storage (Add or Replace Capacity)	No Response	Total
1 (Sells everything)	0 (0.0%)	48 (100.0%)	0 (0.0%)	**48**
2 (Owns and uses on-farm storage)	40 (29.9%)	93 (69.4%)	1 (0.7%)	**134**
3 (No on-farm storage, stores commercially)	0 (0.0%)	11 (100.0%)	0 (0.0%)	**11**
4 (Owns on-farm storage, does not use)	0 (0.0%)	10 (100.0%)	0 (0.0%)	**10**
Total	**40 (19.7%)**	**162 (79.8%)**	**1 (0.5%)**	**203**

Source: Caffarelli et al., 2015.

Economic Incentives to Encourage Storage Building

Given that not all grain producers in Virginia have storage or plan to build any, the survey attempted to identify possible conditions (if any) that would incentivize individuals (from Groups 1 and 3) to build storage. Examples of different incentives could include "higher returns to stored grains," increased "wait times" at elevators, more "government incentives," and others. To that end, 63 percent (71 respondents) acknowledge that there are factors that would cause them to consider building storage.[56] For the 71 respondents that stated that they would build storage under different conditions, many of them (78 percent) reported that, in order to do so, returns to stored grain would have to be higher (Table 22). This implies that higher prices are needed later in the year relative to prices immediately after harvest. The next leading factors include "government incentives to build on-farm storage" (49 percent) and "increased production levels and/or acreage" (47 percent).

Table 22: Conditions under Which Virginia's Grain Farmers (Without Storage) Would Consider Building Storage

Condition	Number "Yes"	Number "No"
Higher returns to stored grain	35 (77.8%)	10 (22.2%)
Increased production levels and/or acreage	21 (46.7%)	24 (53.3%)
Longer wait times at buying facilities (e.g., grain elevators)	20 (44.4%)	25 (55.6%)
Information on storage builders and designs	3 (6.7%)	42 (93.3%)
Government incentives to build on-farm storage	22 (48.9%)	23 (51.1%)
Access to infrastructure (e.g., three-phase electrical power, roads)	4 (8.9%)	41 (91.1%)
Access to financing	9 (20.0%)	36 (80.0%)
Access to information on grain storing and drying practices	7 (15.6%)	38 (84.4%)

Source: Caffarelli et al., 2015.

Characteristics of Grain Transportation in Virginia

Grain production and storage are two facets of a complex, interconnected, supply chain. One of the links between growers and buyers is transportation. After harvest, grain moves to market or storage by a variety of methods such as truck, railroad, barge, and ocean vessel (Casavant et al., 2010). These modes have different advantages under different conditions. For example, trucks offer the most flexibility and timeliness for shipments, but they are also the most expensive per mile (Meyer, 2004). Trucks typically have the advantage for distances under 250 miles (Frittelli, 2005). Rail delivery is generally more cost effective to move grain over longer distances,

[56] The 71 respondents come from Groups 1 and 3—12 from the "constrained" operations not adding storage and 59 "non-constrained" operations not adding storage.

when available (Frittelli, 2005). Given their substantial carrying capacities, barge tows are even more cost effective than railroads over long distances, but routes are limited to waterways, which are subject to seasonal and weather effects (Meyer, 2004).

Importantly, these modes compete and complement each other, with a bushel of grain often using more than one mode before reaching its final destination (Sparger and Marathon, 2015). Agriculture depends on transportation; a competitive and efficient system results in lower shipping costs, smaller marketing margins for middlemen, and more competitive export prices, which ultimately results in lower food costs for U.S. consumers and higher market prices for U.S. producers (Sparger and Marathon, 2015).

While more investigation is needed to make an assessment of transportation infrastructure, capacity, the survey captured a few different attributes of grain transportation in Virginia, such as hauling methods by farmers, traveling distances out of the farm gate, and typical wait times for grain producers at buying stations. These initial movements typically occur by truck (Casavant, 2010), which moved 64 percent of the grain tonnage in the United States in 2013 (Sparger and Marathon, 2015). Seventy-eight percent of respondents report that they haul their own grain to a buying station, 40 percent say they hire out the delivery of their grain, and 9 percent specify another method of grain delivery (such as the buyer picking up).[57] In addition, 10 percent of Virginia's grain farmers indicate that they haul grain other than their own.

In terms of distance to first buyers (e.g., elevators), most of Virginia's grain production reported in the survey is transported over relatively short distances as 48 percent is moved 25 miles or less (Table 23). This data represents the first trip for the grain, a product that makes multiple movements along the supply chain (Casavant, 2010). It is interesting to note that some producers have to ship different crops different distances. For example, a farmer may have a buying station or elevator for corn closer than one for soybeans.

Table 23: Volume of Bushels Transported Various Distances from Farm in Virginia

Distances	Bushels	Percentage
1 - 25 miles	14,075,282	48.3%
26 - 50 miles	5,889,872	20.2%
51 - 75 miles	3,520,158	12.1%
76 - 99 miles	2,047,369	7.0%
100 or more miles	3,629,821	12.4%
Total	**29,162,502**	**100%**

Source: Caffarelli et al., 2015.

Finally, many grain producers in Virginia typically wait thirty minutes or less at buying stations before their grain is unloaded (Figure 25), with an average wait time of 53 minutes. On average, growers report that they would be willing to wait no more than 93 minutes before switching to another buying facility; however, many may not have the option to do so.[58]

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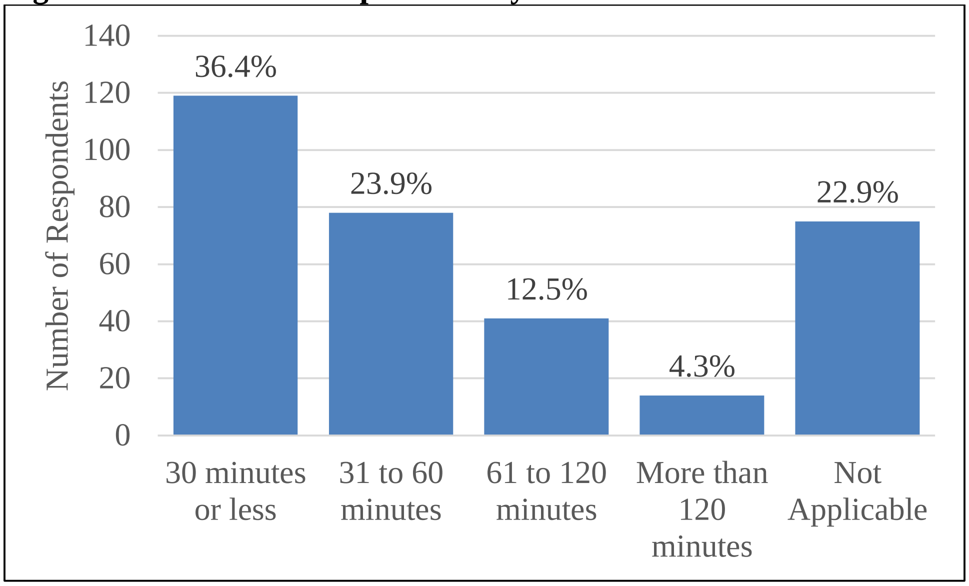
[57] The total adds up to more than 100 percent because many farmers use more than one method to haul their grain.

[58] While the survey did not explore this directly, some respondents reported "no choice" to the question asking about maximum time willing to wait before switching to another buying station. This suggests that the economic costs of switching are too high. For instance, they may not have another buyer within a reasonable driving distance to justify switching.

Figure 25: Number of Respondents by Wait Time*



Source: Caffarelli et al., 2015.
* Results do not include bins without a response.
Many respondents in the "not applicable" category do not haul their own grain.

Conclusions and Discussion

Grain production spans many of Virginia's counties. Survey respondents reported farming a little over a thousand acres used to produce feed grains and oilseeds, including barley, corn, grain sorghum, oats, rye, soybeans, triticale, and wheat. Specifically, Virginia farmers largely grow corn, soybeans, and wheat, and many farms grow all three. Virginia grain producers differ in how they market their grain and oilseeds; some sell all their crop immediately at harvest, while others store for later sales.

Storage has a functional role in the merchandising of grain, allowing farmers to benefit by moving sales beyond harvest gluts to capture potentially higher prices later in the year (Edwards and Johanns, 2015).[59] Grain producers have several available storage alternatives such as storing in their own structures or renting space at a commercial elevator. Almost three-quarters of Virginia's medium- to large-sized grain farms (as measured by a market value of the products greater than $10,000) own storage. Respondents with storage in Virginia each have about five bins, with a bin holding on average 10,000 bushels. Virginia respondents describe their grain storage as "aging," with a majority of structures 21 years or older. However, there might not be a need for immediate concern as 77 percent of the bins are reported to have at least a useful life of 11 or more years.

Whether they have grain storage or not, a majority of grain producers in Virginia are satisfied with the state of their operations. Farmers that report some issue with storage (including those that do not have storage), a majority are planning to do something about it by adding or

[59] According to Edwards and Johanns (2015), "Grain prices tend to be higher later in the marketing year than at harvest. Storing grain can help [growers] capture the 'carry' in the market."

replacing storage. Farmers that do not have storage and are not planning to build new storage, report that returns to stored grains need to be higher to consider building storage.

More than three-quarters of Virginia's grain growers reported that they haul their own grain, while fewer farmers reported using other methods such as hiring out delivery of their grain or letting the buyer pick it up. On average, producers wait a little over 50 minutes to have their grain unloaded at buying stations, though many wait thirty minutes or less. At least for the first leg of the grain's journey, most of the grain (roughly 50 percent) was hauled 25 miles or less.

Results of this study indicate that the current system is working well, at least in aggregate. For instance, 62 percent of grain producers indicate that their operations are not hindered by their grain storage system, including those that do not have storage. Sixty-four percent of operations that report a storage constraint indicate that they are planning to address it by adding or replacing storage. In addition, much of Virginia grain leaving the farm is hauled over relatively short distances and many farmers face relatively short waiting times at elevators. However, the typical observations do not highlight the issues faced by some Virginia grain producers, with 36 percent of Virginia's operators reporting constrains because of storage issues (e.g., not enough capacity, unable to store multiple crops, aging structures, etc.). In addition, some grain requires a great deal of time to move into the supply chain as approximately 20 percent of Virginia grain transported from the farm to its first stop in the supply chain is hauled more than 76 miles, and 17 percent of respondents wait more than an hour at a buying station. Moreover, as Virginia continues to produce historically high volumes of grain and oilseeds, the state's aging on-farm storage infrastructure will have to be addressed. Private enterprises, state and local governments, producer associations, industry boards, cooperatives, and farmers should be actively involved and have a role in decisions regarding the financing and location of future storage and buying stations that improve grain movement thus reducing farm-level constraints and wait times.

This study suggests several areas for potential future research. First, an econometric analysis can be conducted to explore if statistically different relationships exist. For example, the connection between age of storage and reporting that the operation is "constrained" could be explored. More specifically, one may observe that the operations that grow multiple crops are more likely to report an inability to store all crops. In addition, one could examine if a relationship exists between size of farm and whether they own storage or not. Further, this study presented results at the state-level, but future research can explore regional differences based on county or region (e.g., "Shenandoah Valley" versus Tidewater). Finally, this research can be integrated with other grain production, storage, consumption, transportation, and price data to understand the nature of and opportunities and constraints in the state's grain supply chain.

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Chapter 5: Conclusion

Characterized by a variety of products, agriculture is an important component of Virginia's overall economy. Along with other states in the Southeast, Virginia agriculture is mainly known for its livestock production, primarily poultry and smaller amounts of cattle and hogs. Grains, including corn, wheat, and barley as well as soybeans help support the state's livestock operations. With generally increasing grain production and declining livestock population numbers, the grain deficit in Virginia has been decreasing. However, a regional analysis shows that substantial geographic differences exist, with the Shenandoah Valley experiencing the greatest shortages. As a result, transportation and storage are critical to move grain where and when it is needed. At one level, trucking is important to haul grain from local producing-areas to storage and local feed operations (most production out of the farm gate travels 25 miles or less). Areas like the Shenandoah Valley that require significantly more grain (especially in times of drought) are dependent on outside grain supplies and an efficient and cost-effective railroad network.

Like transportation, grain storage contributes to the timely flow of grain from producers to end users. The majority of storage in Virginia is on-farm. While grain consumption in Virginia is mostly decreasing, grain production has generally gone up, which puts pressure on an already aging infrastructure. Many farmers report that their operations are not presently limited by an issue with their storage or the fact that they do not have any. If production continues to expand and returns to storing grain are higher, Virginia may see subsequent growth in on-farm storage. Though many farmers appear to be satisfied, some farmers face long wait times and travel lengthy distances to bring their product to market.

Naturally, there are issues and topics not covered in these papers that merit future investigation. Specifically, a deeper examination of the transportation infrastructure such as location (to measure availability in different areas), type (rail, truck), and quality would yield useful information on another critical link among production, consumption, and storage. In addition, a comparison of consumption against storage could reveal additional constraints as higher levels of storage in high-consumption areas may reduce pressure on the transportation system. Finally, a study of prices (of grain and transportation), particularly including a location-component, would further an understanding of grain flows in Virginia. Those efforts, combined with the aforementioned observations would shed light on valuable components of agriculture in Virginia.

Appendix A: Additional State-Level Methodology and Results

Appendix A describes the state-level procedures in more detail and presents selected graphs of Virginia's livestock populations (broilers, turkeys, layers, pullets, hogs, dairy cows, beef cattle on feed, and sheep). It also provides graphs that depict trends in the shares of total grain consumption in Virginia by different livestock groups as well as breakouts of the shares among the poultry and cattle groups.

Additional Methodology

Grain Consumption: Cattle Population (Dairy Cows, Dairy Heifers, Beef Cattle on Feed, Other Beef Cattle)

Cattle data were obtained from NASS' *Cattle, Final Estimates* and January *Cattle* publications, which provide annual January 1 inventories for four major cattle types: dairy cows, dairy heifers, beef cattle on feed, and other beef cattle. These cattle inventory numbers are used by the ERS as a proxy for the number fed during the year. In *Cattle*,[60] dairy cow inventory for Virginia includes "Milk cows that have calved" (of the "Cattle Inventory by Class" table). Dairy heifer inventory is represented by "Milk cow replacement" from the "Heifers 500 pounds and over" grouping. On the other hand, beef cattle on feed inventory is retrieved from the "Total Number of Cattle on Feed" table. Finally, other beef cattle numbers are calculated by subtracting the previous three cattle categories from the "All cattle and calves" category. Since these inventory variables reflect a single point in time, they do not need to be converted to a September-August marketing year. Importantly, inventory on January 1, 2013, for example, corresponds to the 2012-year in the analysis.

Grain Consumption: Poultry Population (Broilers, Turkeys, Layers, and Pullets)

Estimates of grain consumption by poultry are based on four major groups: broilers, turkeys, layers, and pullets. NASS' *Poultry—Production and Value* (an annual summary) and *Poultry—Production and Value, Final Estimates* publications are the data sources for broilers and turkeys and represent the number of animals fed during the year. Since the broiler population comes from the number produced from December 1 to November 30, a conversion is needed to adjust to a September-August marketing year. This is achieved by combining 25 percent of the prior year's production and 75 percent of the current year's production (Capehart, Allen, and Bond, 2013). The turkey population, however, represents the number of head raised from September 1 to August 31, and no data transformation is needed.

NASS' *Chicken and Eggs, Annual Summary* and *Chicken and Eggs, Final Estimates* publications contain data on the average number of layers on hand in Virginia every month

[60] The *Final Estimates* contain similar names for column and tables in which to locate data. This is the case for other animals as well.

("Average Number of All Layers on Hand During the Month—States and United States" table). Following procedures set by the ERS (Capehart et al. 2013), the layer population fed during the year is calculated by averaging the September through August months (e.g. September 2010 to August 2011 for the 2011 marketing year).[61]

Data for pullets come from NASS' monthly *Chicken and Eggs*. The ERS calculation for pullets is one-half the egg-type chick hatch plus the pullets placed in the broiler supply flocks for the September-August marketing year (Capehart, Allen, and Bond, 2013). The egg-type chick hatch comes from the "Egg-Type Chicks Hatched by Month—United States" table and the pullets placed in the broiler supply flocks comes from the "Intended Placements of Broiler-Type Pullet Chicks for Hatchery Supply Flocks by Month and Total" table. Since this only calculates yearly totals of pullets for the entire United States, the AMS takes an additional step to calculate shares of pullets at the state-level. For instance, to calculate the number of pullets in Virginia, total U.S. pullets are multiplied by Virginia's percentage share of the combined U.S. broiler and layer populations (Prater and O'Neil, 2013).

Grain Consumption: Hogs Population

Information on hog population is found in NASS' December issue of *Quarterly Hogs and Pigs* and *Hogs and Pigs, Final Estimate*. The ERS estimates the number of hogs fed annually through a variable titled the pig crop, which is found in the "Annual Sows Farrowing, Pigs per Litter, and Pig Crop—States and United States" section. Since the data are collected quarterly, the ERS combines quarters to create two groups: the "spring pig crop" (December to May) and the "fall pig crop" (June to November). The computation for pigs requiring feed is 20 percent of the prior year's spring pig crop, 100 percent of the prior year's fall pig crop, and 80 percent of the current year's spring pig crop (Capehart, Allen, and Bond, 2013). For example, for the 2011 marketing year, the total number of hogs fed is equal to 20 percent of the 2010 spring pig crop, 100 percent of the 2010 fall pig crop, and 80 percent of the 2011 spring pig crop. For Virginia, the pig crop is only disclosed for the entire year (December to November) so it is assumed that half of the yearly pig crop is "spring" and the other half is "fall."[62]

Grain Consumption: Sheep (and Lambs) Population

NASS presents sheep data in its *Sheep and Goats* and *Sheep and Goats, Final Estimates* reports. Similar to cattle, the ERS uses the January 1 inventory to approximate the sheep population that was fed during the year (Capehart, Allen, and Bond, 2013). Data come from the "All Sheep and Lambs" column of the *Sheep and Goats* publication ("Sheep and Lamb Inventory by Class—States and United States" table). As with cattle, inventory on January 1, 2013, for example,

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[61] Due to data availability limitations, the calculation for years 1992 to 1994 is somewhat different. Prior to 1994, NASS collected average monthly layer data on 20 states; of which, Virginia was not included. For 1992 and 1993, the variable "average number of layers" (in the "Layers and Egg Production: Annual Average Number of Layers" table of the 1989-93 *Final Estimates*) was used. Layers were then calculated by repeating the ERS procedure for broilers: taking 25 percent of the previous year with 75 percent of the current year. 1994 is a combination of the two with 25 percent of the 1993 average layer inventory and 75 percent of the 1994 December to August months.

[62] Prior to 1993, NASS collected data on Virginia's pig crop every quarter. These additional data points were used to make the estimate for 1992 more accurate.

corresponds to 2012 in the analysis. It is important to note that the ERS does not include goats in their grain consumption calculations.

Grain Consumption: Horses Population

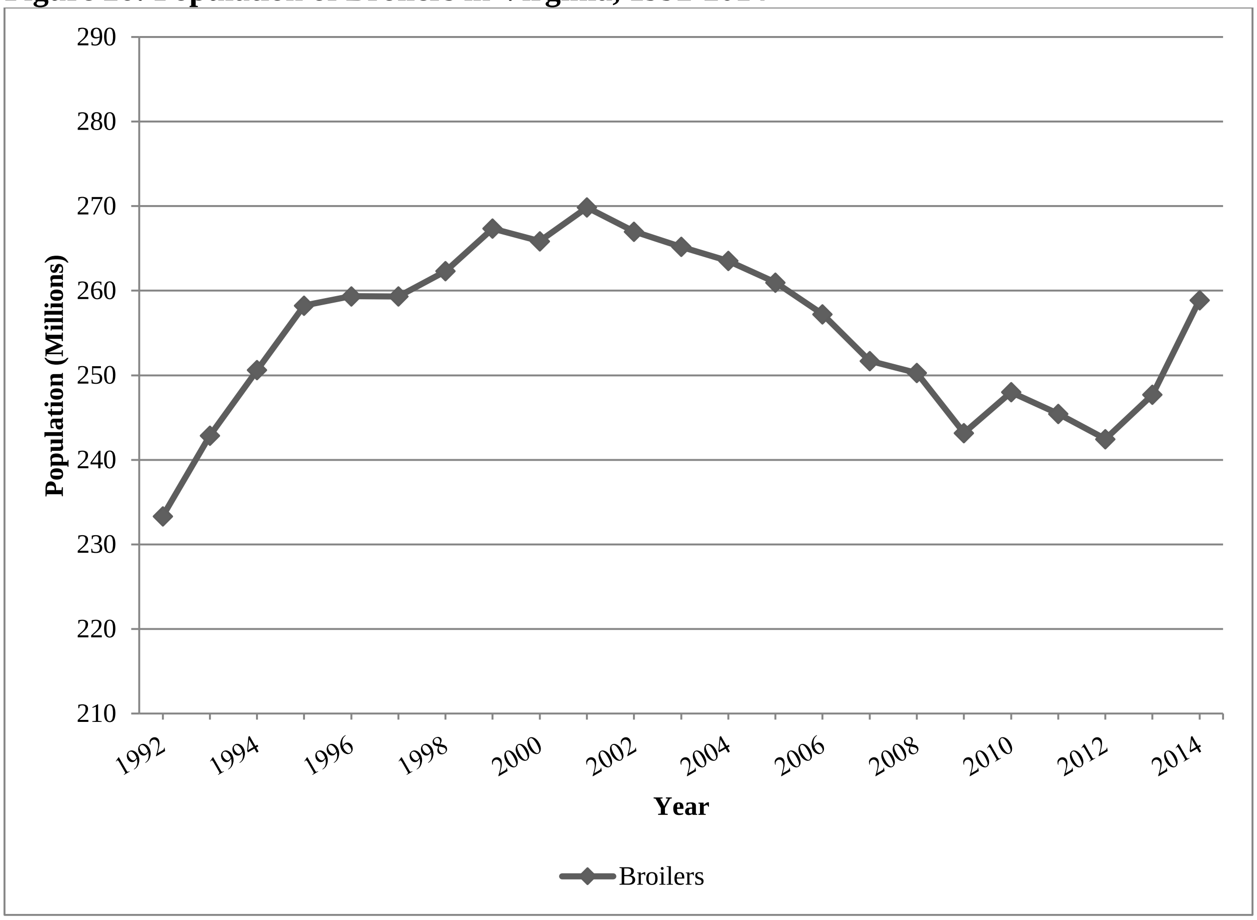
Since NASS does not collect yearly numbers on horses, the AMS does not estimate horse population and its contribution to feed demand at the state-level. However, Virginia's horse industry had a total sales impact of $1.2 billion in 2010 (Rephann, 2011). Thus, horses are a relevant part of the state's agriculture and merit inclusion in the feed consumption estimates. In terms of potential data sources, NASS gathers information on the inventory of horses (and mules) in the Census of Agriculture, which gives data points exist for 1997, 2002, 2007, and 2012. However, these inventories are only the number of horses on farms, which likely underestimates Virginia's total horse population.[63] On the other hand, NASS did conduct a full-scale equine survey in 1998 and 1999, and the NASS Virginia Field Office conducted their own surveys in 2001 and 2006. Data from these reports are used in the current study. For the years without data, the horse population in Virginia is approximated by using the 1998 value for 1992-97 period; the average of the 1999 and 2001 values for 2000; the average of the 2001 and 2006 values for 2002-05 period; and the 2006 value for 2007-14 period.

[63] For example, the 2007 Census estimated that Virginia had 97,112 horses and mules (on farms), while the 2006 report from the NASS Virginia Field Office estimated that the entire state of Virginia had 215,000 horses and mules.

Additional Results

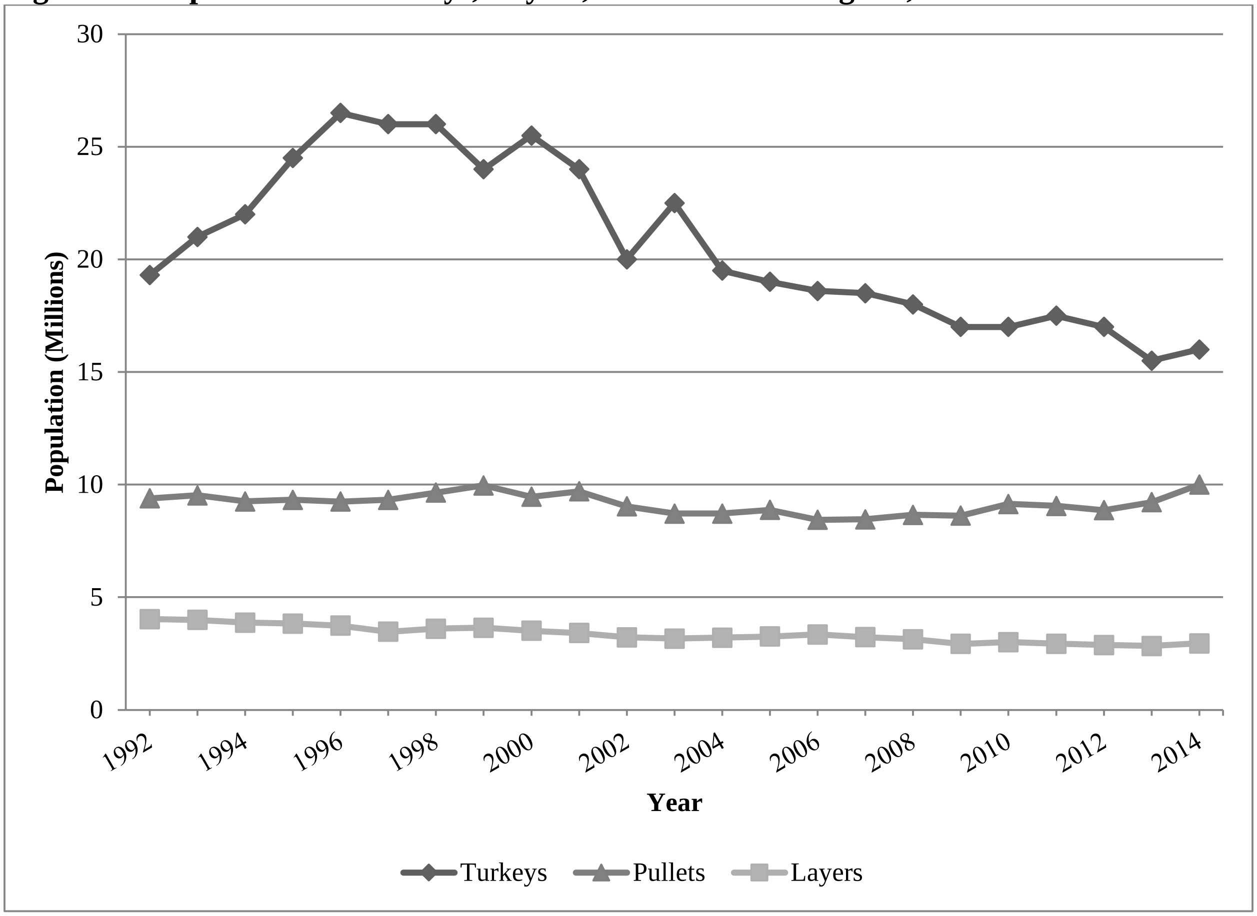
Graphs of Populations (Number of "Head") Fed in Virginia

Figure 26: Population of Broilers in Virginia, 1992-2014



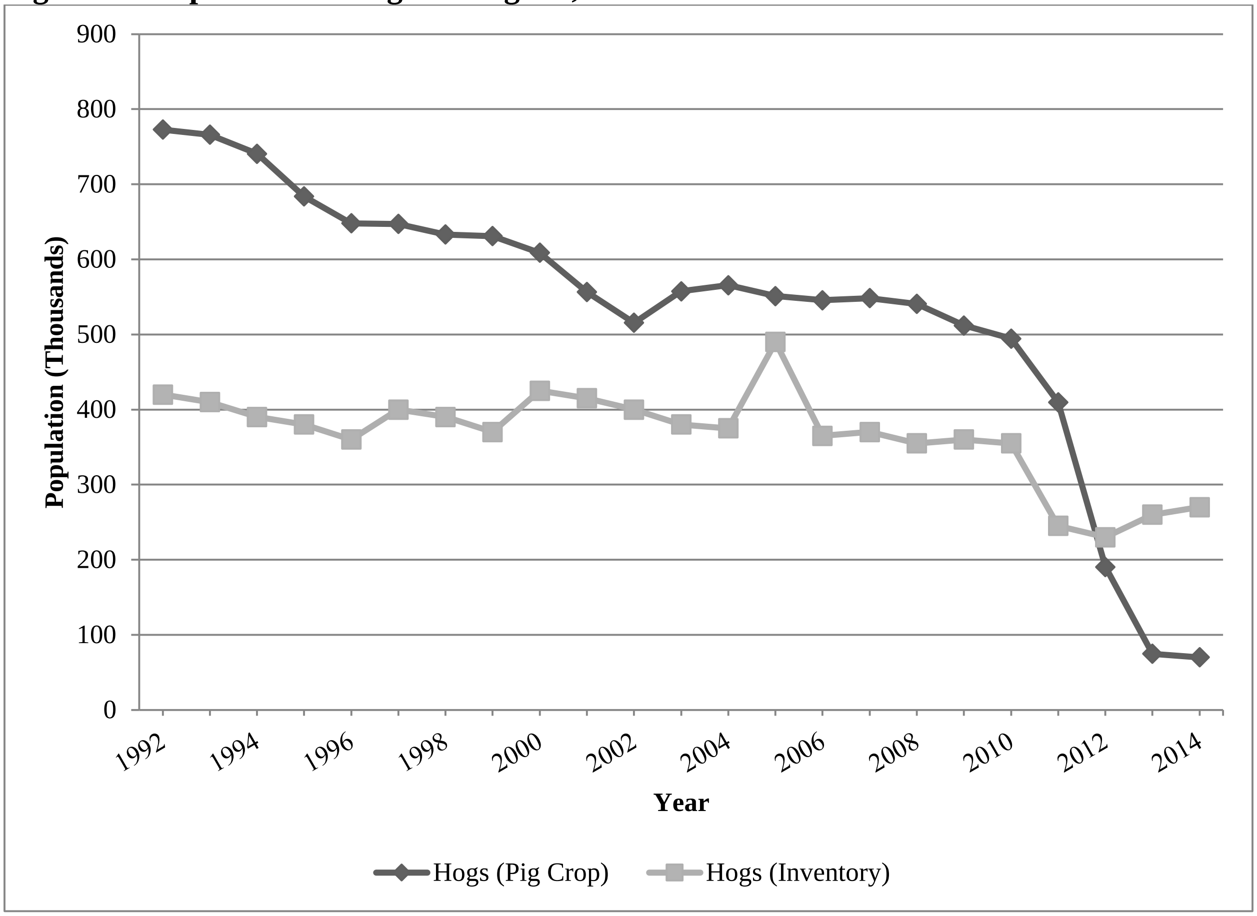
Source: USDA-NASS, 2015; authors' calculations.

Figure 27: Populations of Turkeys, Layers, and Pullets in Virginia, 1992-2014



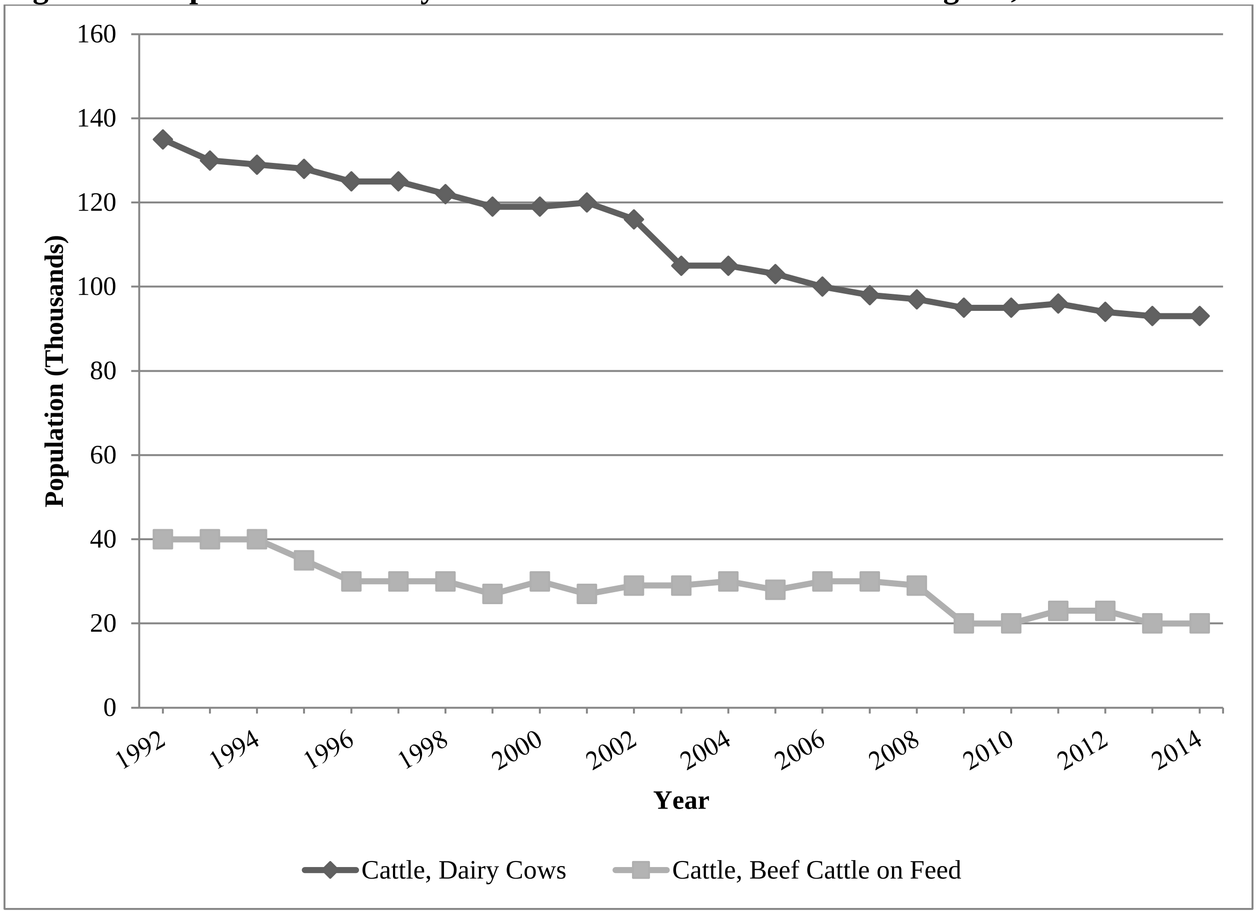
Source: USDA-NASS, 2015; authors' calculations.

Figure 28: Population of Hogs in Virginia, 1992-2014



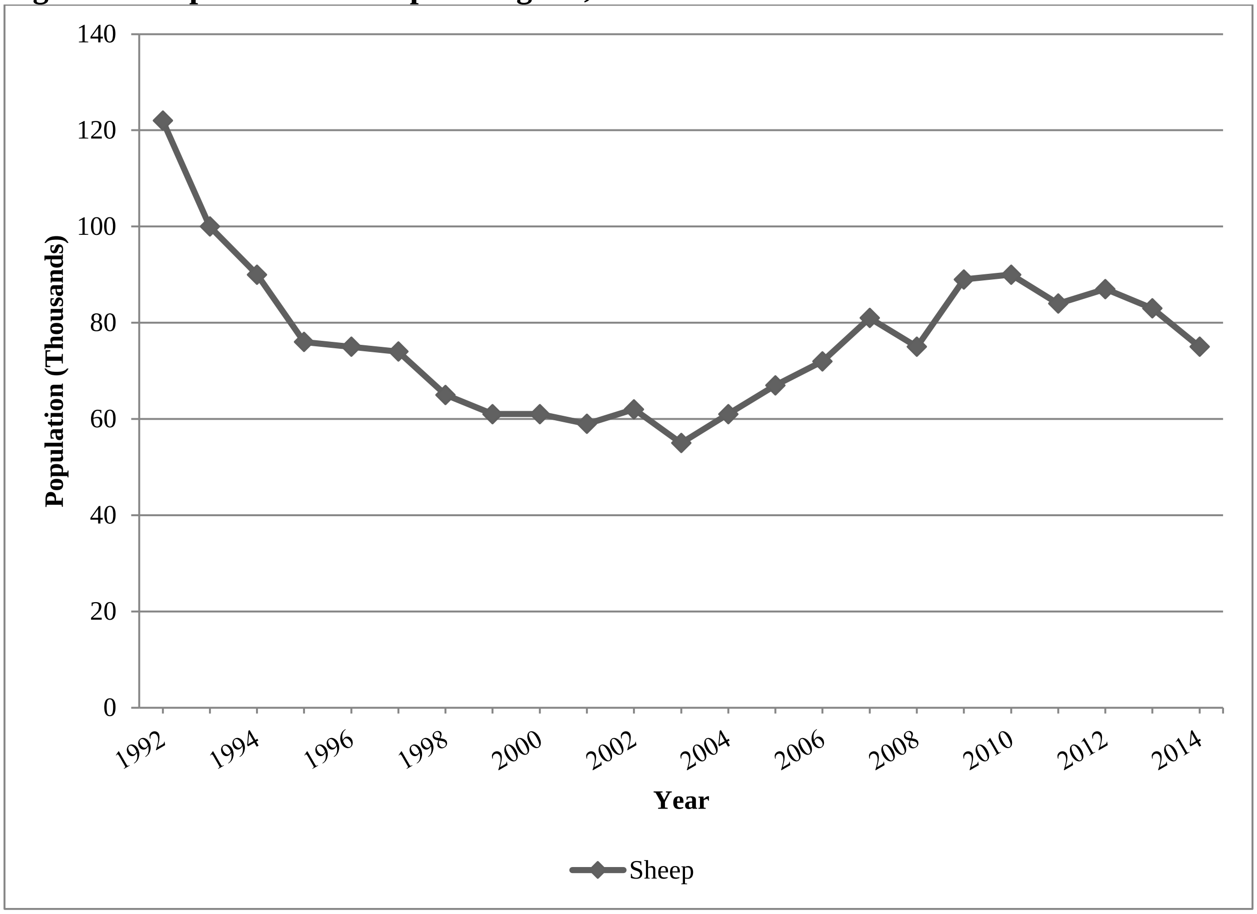
Source: USDA-NASS, 2015; authors’ calculations.

Figure 29: Populations of Dairy Cows and Beef Cattle on Feed in Virginia, 1992-2014



Source: USDA-NASS, 2015.

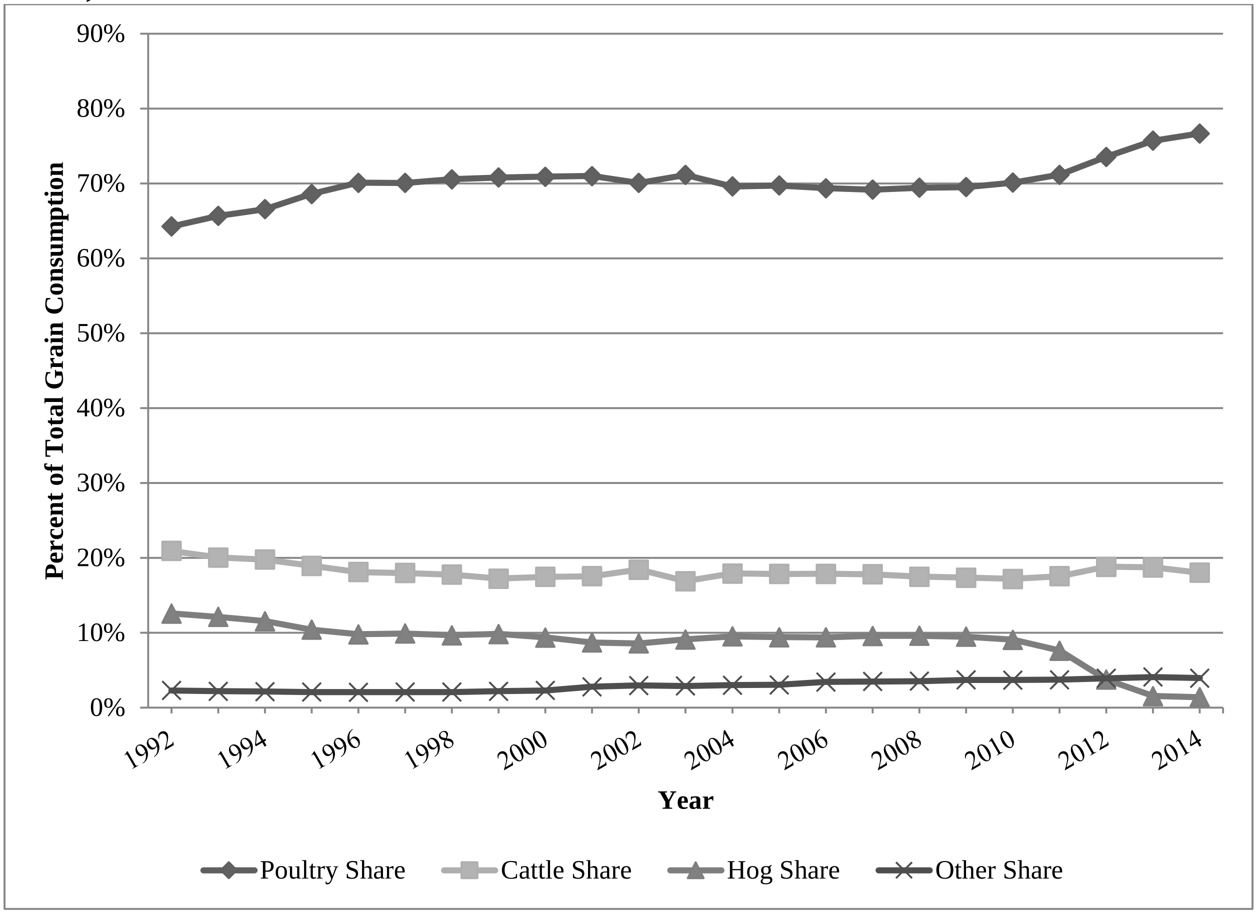
Figure 30: Population of Sheep in Virginia, 1992-2014



Source: USDA-NASS, 2015.

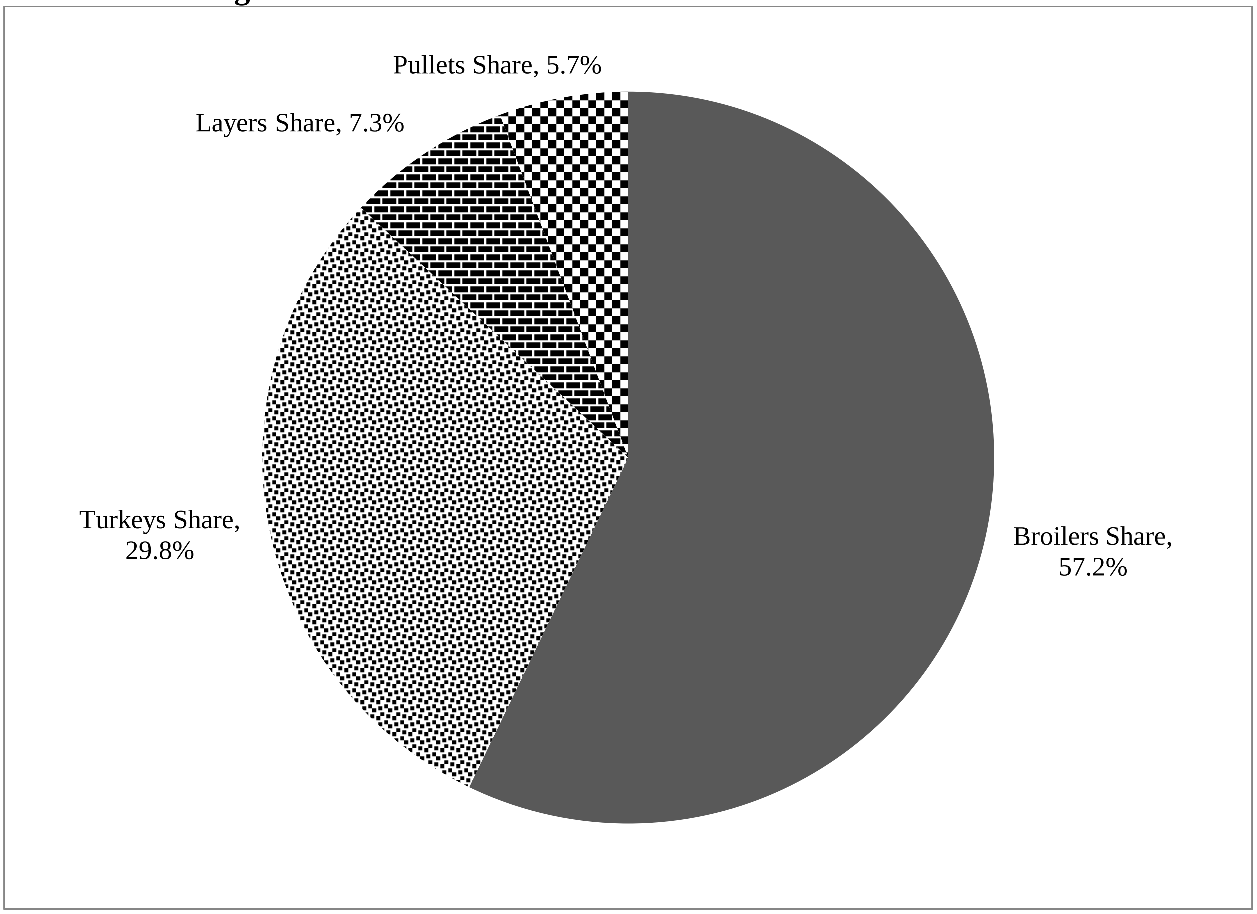
Graphs of Consumption Shares

Figure 31: Shares of Total Grain Consumption in Virginia by Poultry, Cattle, Hogs, and Other, 1992-2014



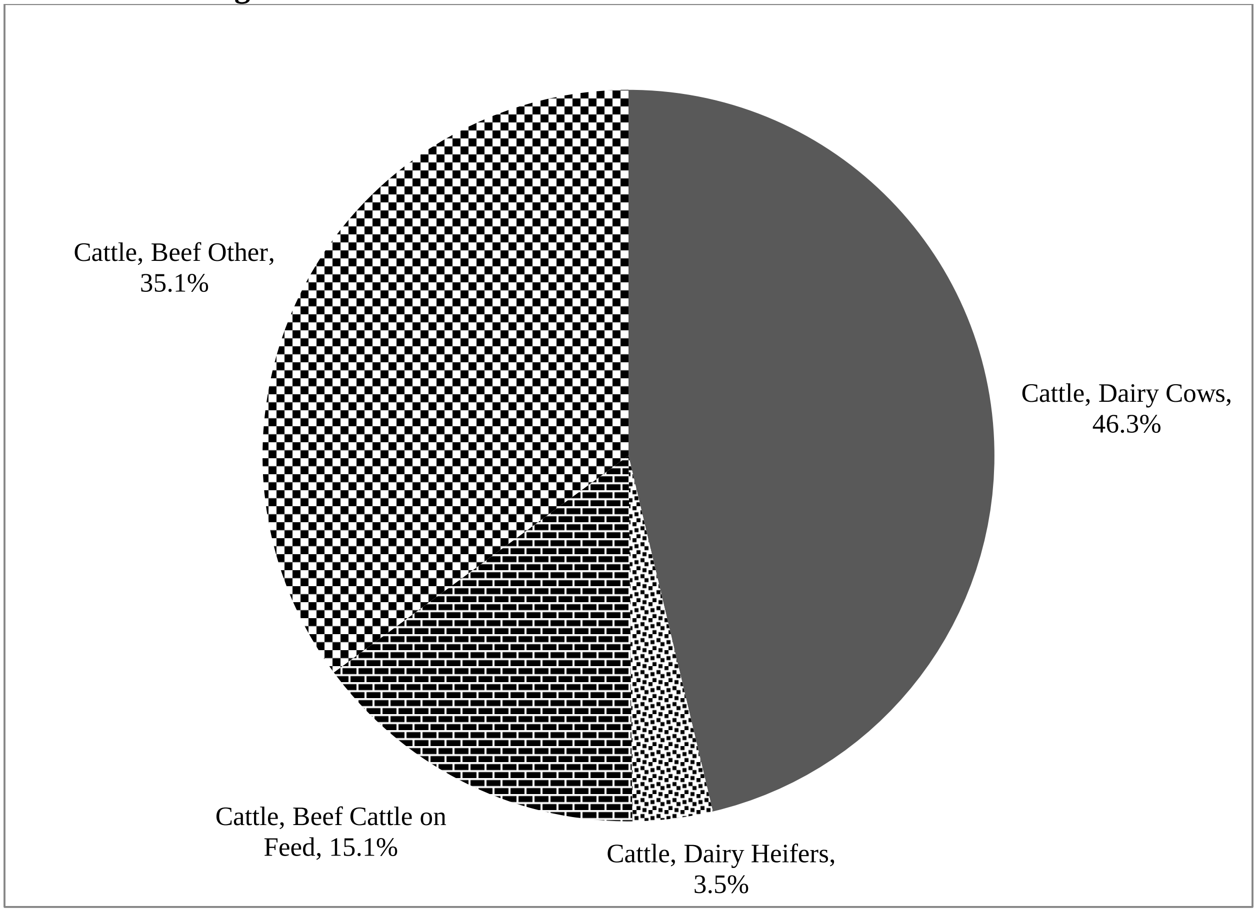
Source: USDA-NASS, 2015; authors' calculations.

Figure 32: Recent Shares within Poultry Grain Consumption in Virginia, 2009-2014 Average



Source: USDA-NASS, 2015; authors' calculations.

Figure 33: Recent Shares within Cattle Grain Consumption in Virginia, 2009-2014 Average



Source: USDA-NASS; authors' calculations.

Appendix B: Additional County-Level Methodology and Results

Appendix B describes the county-level procedures in more detail and includes additional maps showing the distribution of Virginia's livestock populations (broilers, turkeys, hogs, dairy cattle, beef cattle on feed, sheep, and horses) and grain production (barley, corn, soybean meal, and wheat). All maps display data from 2012 except for horses, where the most recent information is from 2006.

Additional Methodology

Grain Consumption: Cattle Population (Dairy Cows, Beef Cattle on Feed, Other Beef Cattle)

County-level data for cattle come from the "Cattle and Calves – Inventory and Sales" table of the Census, which provides the cattle inventories in Virginia as of December 31, 2012. Inventories of dairy cows and beef cattle on feed are available. "Other beef cattle" is normally calculated by subtracting dairy cattle, dairy heifers, and beef cattle on feed from the variable representing all of Virginia's cattle. However, since the Census does not collect information on dairy heifers, those cattle are part of the "other" category.[64]

Table 24 shows a summary of the cattle information available at the state- and county-levels, and the degree to which Census variables match the expected population (magnitude accuracy) and the amount of disclosed information (distribution accuracy). Since inventory is a variable collected in both the Census and on an annual basis, the estimated county-level grain consumption by cattle should be accurate; "magnitude accuracy" is not an issue. Moreover, the distribution should be relatively accurate because much of the data is disclosed.

[64] Since the GCAU factor is lower for "other beef cattle" than for "dairy heifers," grain consumption may be underestimated.

Table 24: Comparison of Annual and Census Data for Cattle

	Dairy Cattle	Beef Cattle, On Feed	All Cattle
State-Level Variable:			
Type	Inventory	Inventory	Inventory
Time Frame/Date	Jan. 1, 2013	Jan.1, 2013	Jan. 1, 2013
Amount	94,000	23,000	1,610,000
County-Level Variable:			
Type	Inventory	Inventory	Inventory
Time Frame/Date	Dec. 31, 2012	Dec. 31, 2012	Dec. 31, 2012
Amount	94,105	20,010	1,631,882
Percentage Difference	0.1%	-13.0%	-1.4%
Amount Disclosed	89,068	14,195	1,631,882
Amount Non-Disclosed	5,037	5,815	0
Percent Disclosed	94.6%	70.9%	100.0%
Percent Non-Disclosed	5.4%	29.1%	0.0%

Note: "Other cattle" is derived from these three and is, therefore, not included.
Source: 2012 Census of Agriculture for Virginia (USDA-NASS, 2014).

Grain Consumption: Poultry Population (Broilers, Turkeys, Layers, and Pullets)

Broilers, turkeys, layers, and pullets make up Virginia's poultry population. As stated in Appendix A, the ERS annual population estimations use production (in head) for broilers and turkeys; average monthly inventory for layers; and a lengthier derivation for pullets. Though NASS collects these variables on a yearly basis, it does not gather the same data in the Census. Instead, three variables for (all) livestock are gathered: 1) number in inventory (on December 31 in the Census year); 2) number produced under a production contract in the Census year; and 3) number moved or sold by the operation in the Census year.[65]

Given the relatively quick cycle in broiler and turkey production (Penn State Extension 2015),[66] the number moved or sold is likely to better proxy for expected broiler and turkey populations. Therefore, this measure is assumed to be a more accurate reflection at the county-level than inventory. Next, since the annual layer population is derived from inventory data, the inventory variable for layers in the Census is a satisfactory proxy to examine the population at the county-level. Finally, inventory was selected to conservatively represent the number of pullets at the county-level.[67]

Table 25 contains a summary of the poultry information in the annual calculations and Census, which reflects any bias due to the magnitude and distributional accuracy issues. In terms

[65] More specifically, inventory generally refers to the number on-hand. A "production contract refers to "an agreement between a producer or grower and a contractor (integrator) setting terms, conditions, and fees to be paid by the contractor to the operation for the production of crops, livestock, or poultry" and is included as part of total inventory and total moved. Total moved/sold refers to the number sold or moved from the operation (which may result in one being sold twice).
[66] For example, a broiler can reach its market weight in five weeks (Penn State Extension 2015).
[67] The number of pullets in inventory includes those in inventory on production contracts and is a more conservative variable than those "moved or sold" where several may be moved two or more times.

of the former, three of the selected Census variables (broilers, turkeys, and layers) strongly resemble their annual counterparts, which imply that they are good approximations of the expected populations (though turkeys appear to be overestimated). However, with a percentage difference of 85.3 percent, the number of pullets seems to be substantially underestimated. Even so, as previously mentioned, the number of available variables is limited in the Census and inventory still serves as a reasonable and adequate proxy of Virginia's pullet population.

In terms of distributional accuracy across counties, large shares of broilers and turkeys moved/sold are disclosed, but portions of the layer and pullet populations are non-disclosed, which impacts exactness of the distribution. However, these the layer and pullet poultry groups account for a small share of grain consumption relative to broilers and turkeys (see Figure 32) and, as a result, do not present a significant issue. In terms of location, the four selected variables accurately portray Virginia's poultry populations and, hence, their grain consumption at the county-level.

Table 25: Comparison of Annual and Census Data for Poultry

	Broilers	**Turkeys**	**Layers**	**Pullets**
State-Level Variable:				
Type	Production (head)	Production (head)	Inventory	Calculation
Time Frame/Date	2012	2012	Monthly, 2012	2012
Amount	242,450,000	17,000,000	2,883,750	8,862,281
County-Level Variable:				
Type	Sold/Moved	Sold/Moved	Inventory	Inventory
Time Frame/Date	2012	2012	Dec. 31, 2012	Dec. 31, 2012
Amount	237,669,378	18,223,608	2,897,238	1,301,917
Percentage Difference	-2.0%	7.2%	0.5%	-85.3%
Amount Disclosed	231,854,347	17,877,630	1,630,571	961,103
Amount Non-Disclosed	5,815,031	345,978	1,266,667	340,814
Percent Disclosed	97.6%	98.1%	56.3%	73.8%
Percent Non-Disclosed	2.4%	1.9%	43.7%	26.2%

Source: 2012 Census of Agriculture for Virginia (USDA-NASS, 2014).

Grain Consumption: Hogs Population

Applied in the annual calculations, the Economic Research Service uses the "pig crop" to estimate the number of feeding hogs and their overall grain consumption. However, NASS does not collect information on the "pig crop" in the Census. In its place, inventory is used to estimate Virginia's pig population at the county-level.

Providing insight with respect to the issues of magnitude and distribution accuracy, Table 26 contains a summary of the hog information in the Census and annual calculations. First, though inventory overestimates the expected hog population by 26 percent, it is arguably the best variable available in the Census.[68] Second, since 63.4 percent of the hog population is non-disclosed, the distributional accuracy of the estimates is impacted. Thus, in order to distribute the non-disclosed inventory and increase accuracy, an additional data source for hog inventory in Virginia is used.

[68] Those under a production contract are included in inventory and the number moved or sold (of 559,658) exceed the expected population by 193.9 percent. This suggests that some are moved or sold more than once during the year.

NASS and the NASS Virginia Field Office have hog inventory data at the agricultural district level from 1988 through 2009 (see Virginia NASS Field Office 2015b). Virginia has seven agricultural districts so, while not as precise as counties in the Census, the data provide more information than just at the state-level. The basic idea requires weighting the non-disclosed counties according to their agricultural district as some districts have larger amounts of hogs than others.

More specifically, the steps include 1) calculate the percentage of Virginia's hogs in each agricultural district level from the 2009 Virginia Field Office report, the latest one available (this consists of dividing each district's inventory by the total population of hogs in Virginia); 2) calculate the percentage of Virginia's hogs in each agricultural district from disclosed ("known") Census values (which will naturally be smaller due to non-disclosed counties); 3) obtain the difference between the "expected" district percentage and the Census district percentage (for each district) to determine how much more is needed to have the percentages be equivalent; 4) determine how much of the non-disclosed hog information needs to go into each district to match percentages described in Step 3; and 5) divide the required amount per district equally across non-disclosed counties in that district. Overall, this procedure translates into increased accuracy at the county-level since amounts are no longer spread equally across non-disclosed counties.

Table 26: Comparison of Annual and Census Data for Pigs

	Pigs
State-Level Variable:	
Type	Pig Crop
Time Frame/Date	2012
Amount	190,400
County-Level Variable:	
Type	Inventory
Time Frame/Date	Dec. 31, 2012
Amount	239,899
Percentage Difference	26.0%
Amount Disclosed	87,799
Amount Non-Disclosed	152,100
Percent Disclosed	36.6%
Percent Non-Disclosed	63.4%

Source: 2012 Census of Agriculture for Virginia (USDA-NASS, 2014).

Grain Consumption: Sheep (and Lambs) Population

Akin to cattle, NASS collects inventory data for sheep in the Census, which matches the variable used in the annual calculations. Specifically, county-level sheep data come from the "Sheep and Lambs – Inventory, Wool Production, and Number Sold" table, which provides the inventory of sheep and lambs on December 31, 2012. Table 27 contains a summary of the sheep information and indicates how closely Census variables match the expected population (magnitude accuracy) and the amount of disclosed information (distribution accuracy). Since inventory is the variable available in both the state and Census reports, it is an adequate measure to estimate grain consumption by sheep at the county-level. In addition, the location or spread across the counties is also accurate with almost all data being disclosed.

Table 27: Comparison of Annual and Census Data for Sheep

	Sheep
State-Level Variable:	
Type	Inventory
Time Frame/Date	Jan. 1, 2013
Amount	87,000
County-Level Variable:	
Type	Inventory
Time Frame/Date	Dec. 31, 2012
Amount	84,983
Percentage Difference	-2.3%
Amount Disclosed	84,718
Amount Non-Disclosed	265
Percent Disclosed	99.7%
Percent Non-Disclosed	0.3%

Source: 2012 Census of Agriculture for Virginia (USDA-NASS, 2014).

Grain Consumption: Horses Population

As mentioned in Appendix A, NASS does not collect information for horses on an annual basis. County-level data are available from two sources: the Census of Agriculture and the Virginia NASS Field Office. Data on horses from the Census is limited in Virginia because a large portion of the state's equine population is found off farms; the Census underestimates the total horse population in the state. Instead, information collected in a 2006 survey from the NASS Virginia Field Office is used because it is the most accurate and recent data available on the total population and distribution of Virginia's horses.[69] The selected variable represents the number of horses, ponies, and mules in inventory in Virginia on November 1, 2006.

Table 28 provides summary data on Virginia's horses to examine the accuracy of its distribution on a map. In this case, "magnitude accuracy" is not a problem because the annual estimates use the same data. Also, since much of the data is disclosed (almost 93 percent), the distribution is accurate. Further, since the Virginia NASS Field Office provides information on the non-disclosed quantities in each agricultural district, the accuracy of the distribution can be enhanced.

[69] For example, according to the 2007 Census of Agriculture, the number of horses and mules on Virginia's farms was 97,112. The Virginia NASS Office estimated that Virginia had a population of 215,000 horses in 2006—a 121 percent difference.

Table 28: Information on County-Level Data for Horses

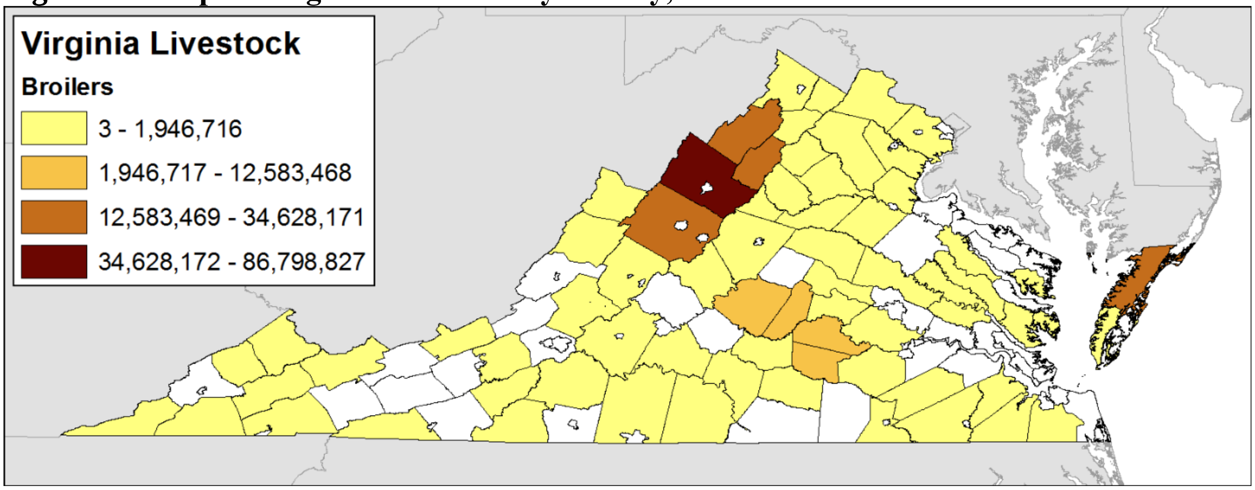
	Horses
County-Level Variable:	
Type	Inventory
Time Frame/Date	Nov. 1, 2006
Amount	215,000
Amount Disclosed	199,200
Amount Non-Disclosed	15,800
Percent Disclosed	92.7%
Percent Non-Disclosed	7.3%

Source: Virginia NASS Field Office (2008).

Additional Results

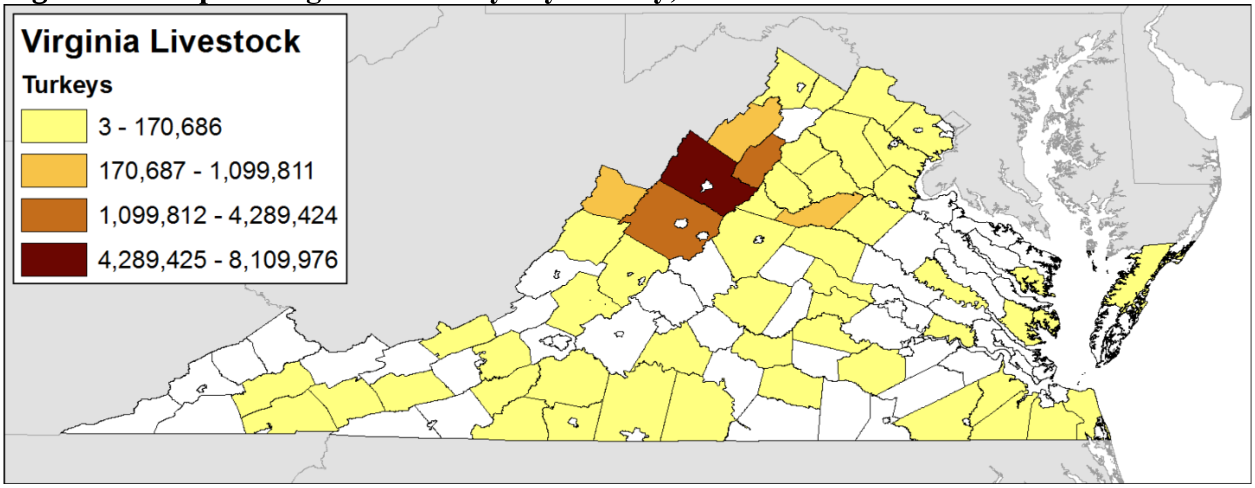
Consumption (Livestock Population) Maps

Figure 34: Map of Virginia's Broilers by County, 2012



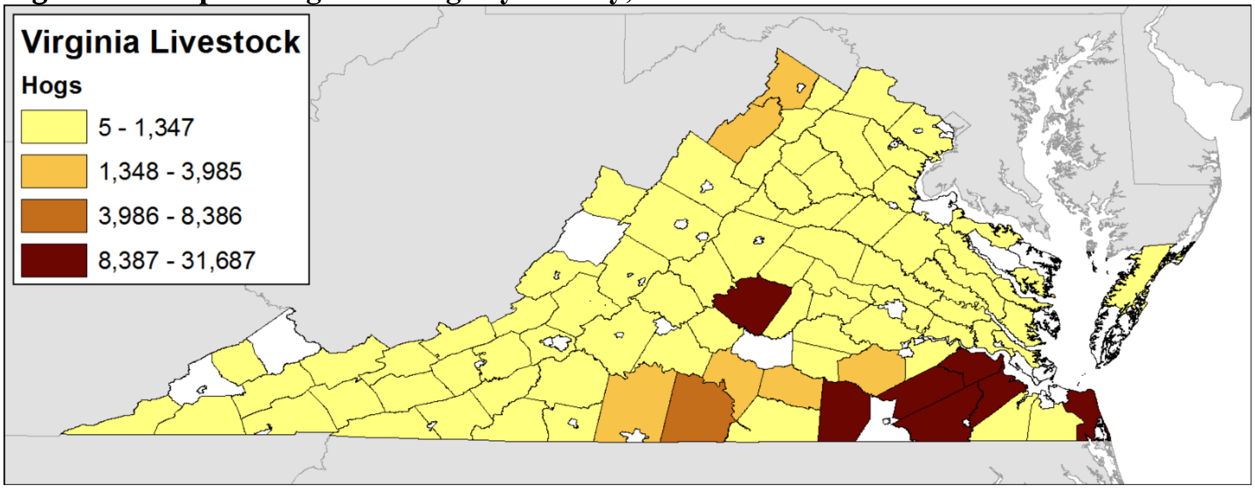
Source: USDA-NASS, 2014.

Figure 35: Map of Virginia's Turkeys by County, 2012



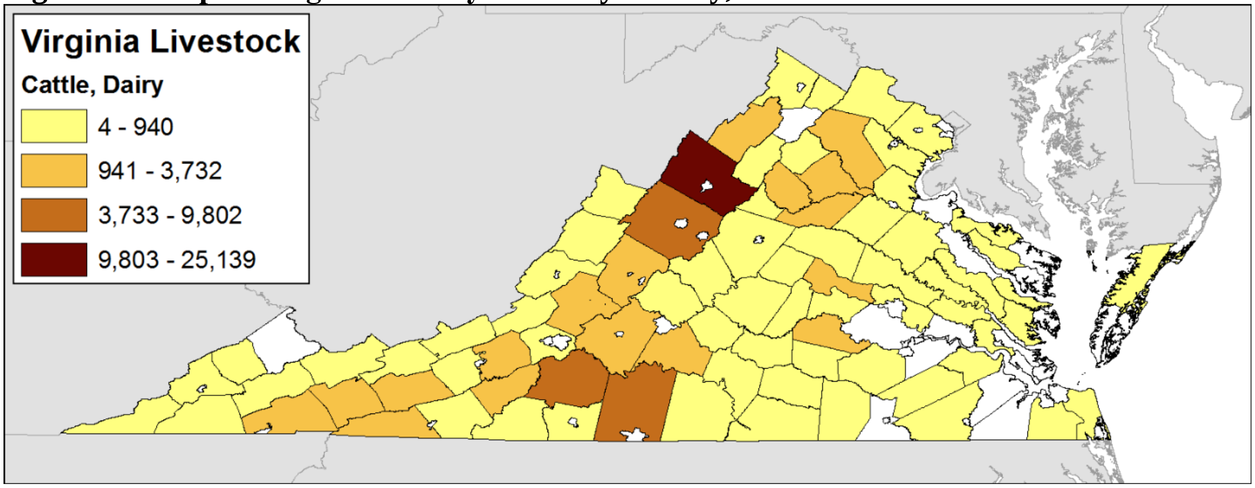
Source: USDA-NASS, 2014.

Figure 36: Map of Virginia's Hogs by County, 2012



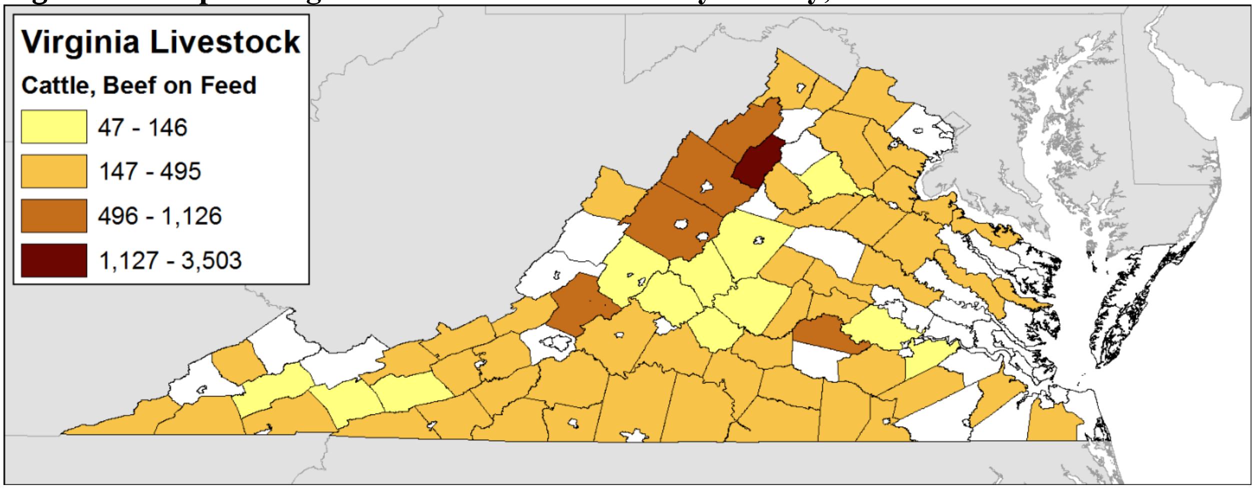
Source: USDA-NASS, 2014.

Figure 37: Map of Virginia's Dairy Cattle by County, 2012



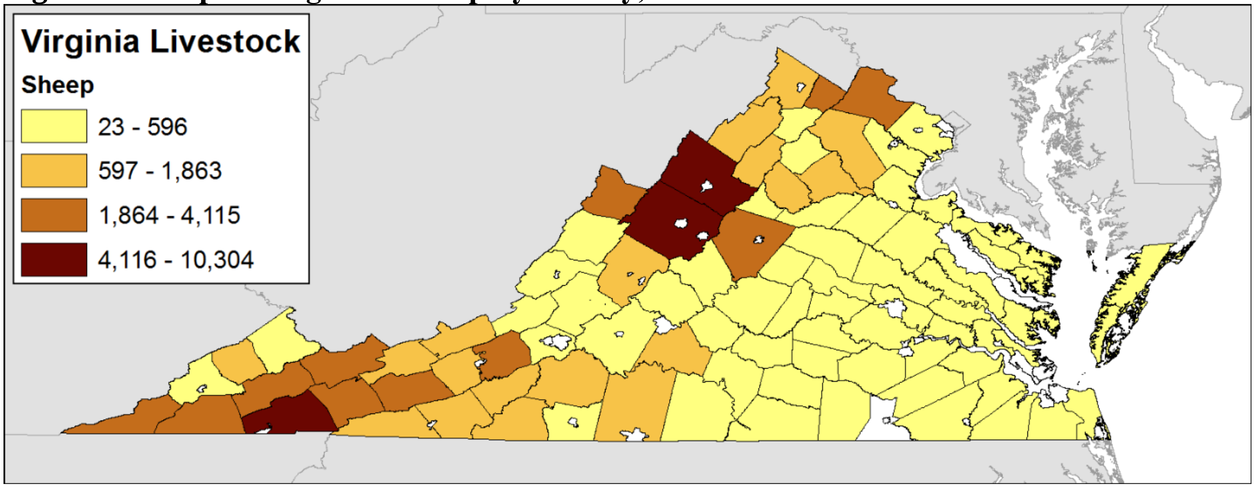
Source: USDA-NASS, 2014.

Figure 38: Map of Virginia's Beef Cattle on Feed by County, 2012



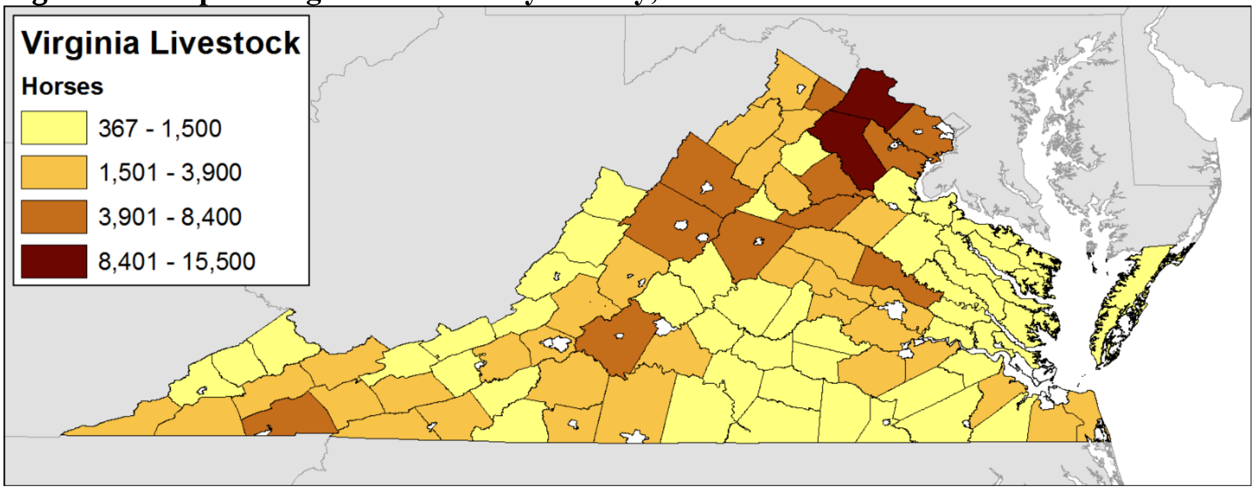
Source: USDA-NASS, 2014.

Figure 39: Map of Virginia's Sheep by County, 2012



Source: USDA-NASS, 2014.

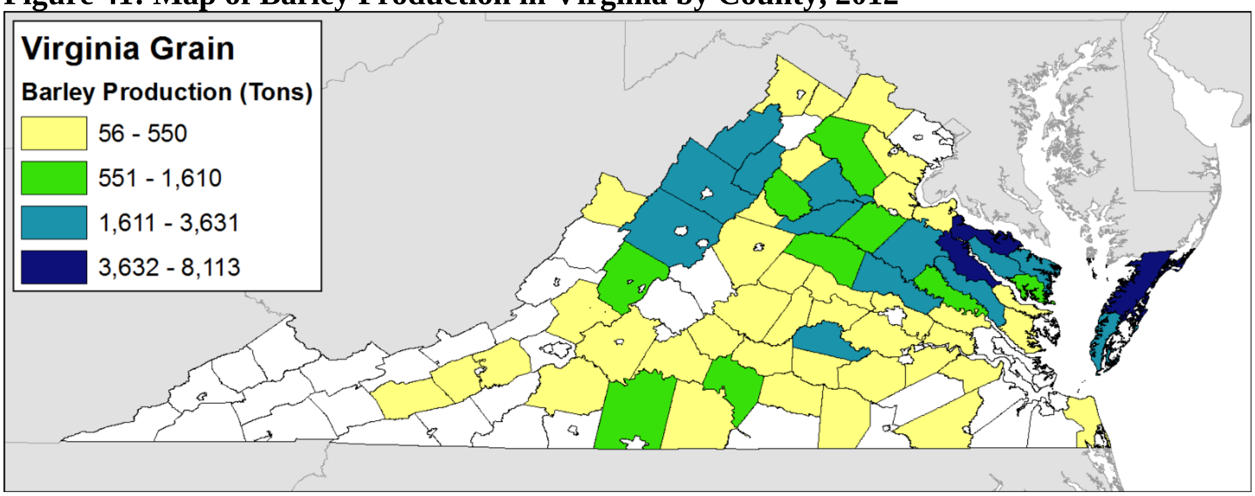
Figure 40: Map of Virginia's Horses by County, 2006



Source: Virginia NASS Field Office (2008).

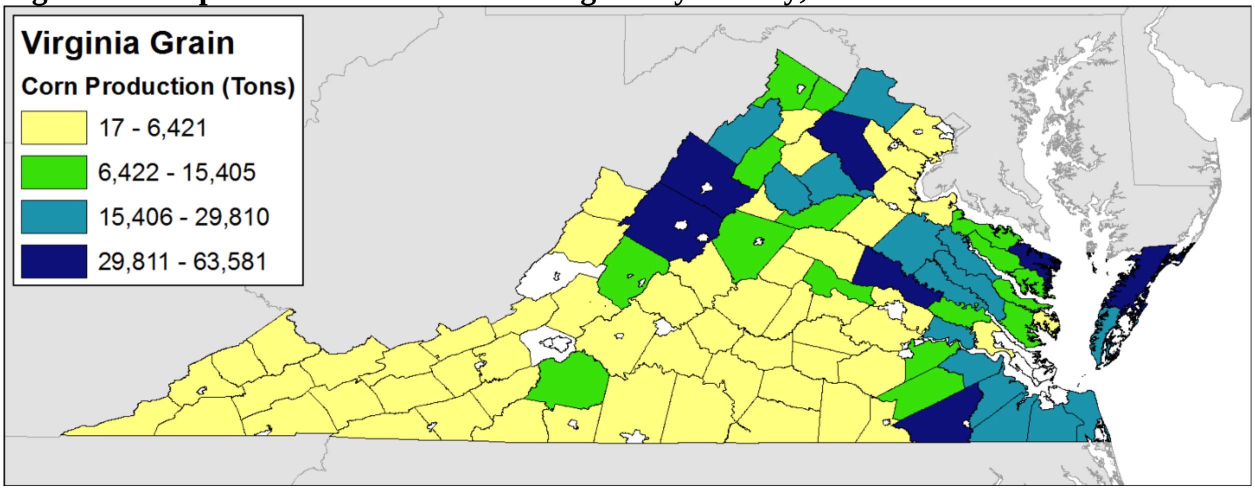
Production Maps

Figure 41: Map of Barley Production in Virginia by County, 2012



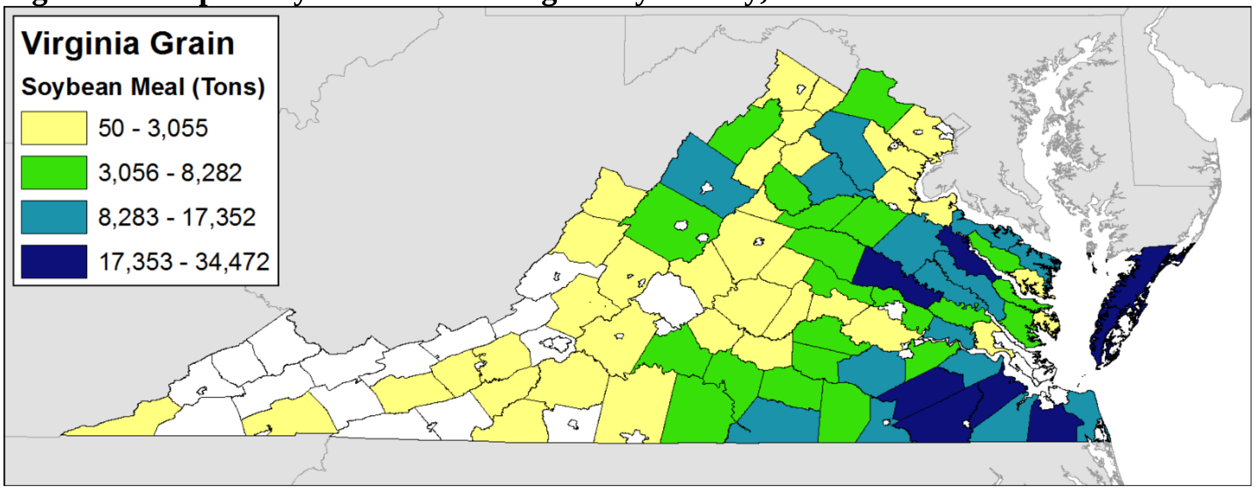
Source: USDA-NASS, 2014.

Figure 42: Map of Corn Production in Virginia by County, 2012



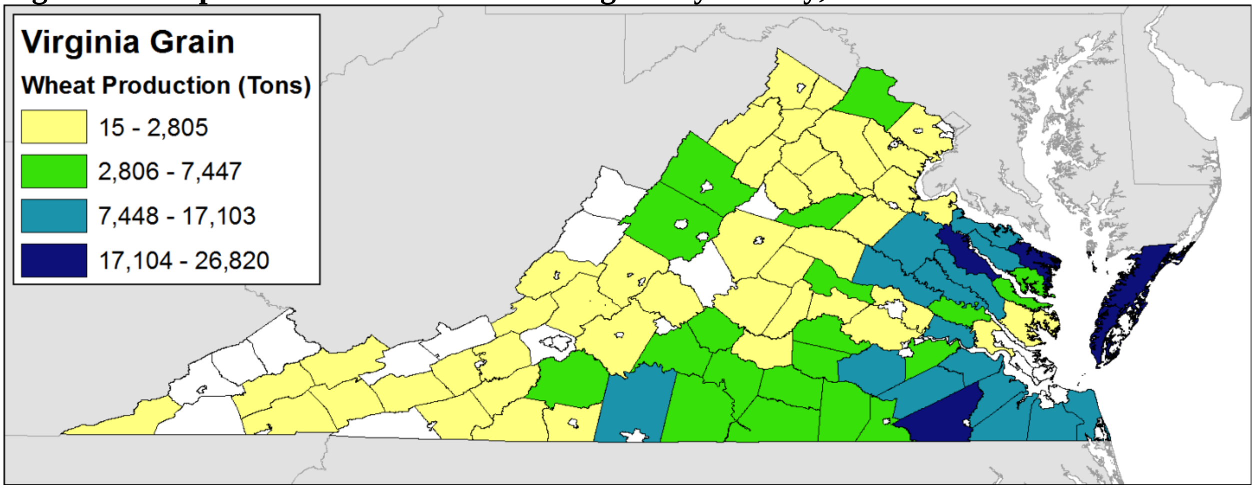
Source: USDA-NASS, 2014.

Figure 43: Map of Soybean Meal in Virginia by County, 2012



Source: USDA-NASS, 2014.
The distribution of soybean meal is equivalent to total soybeans harvested for beans even though the amounts are not the same.

Figure 44: Map of Wheat Production in Virginia by County, 2012



Source: USDA-NASS, 2014.

Appendix C: Survey Recruitment Letter and Instrument

VirginiaTech
College of Agriculture
and Life Sciences

Department of Agricultural and Applied Economics
208 Hutcheson Hall (0401)
Blacksburg, Virginia 24061
540/231-5850 Fax: 540/231-7417
www.aaec.vt.edu/

[[DATE]]

[[FIRST]] [[LAST]] [[SUFFIX]]
[[ADDRESS]]
[[CITY]], [[STATE]] [[ZIP+4]]

Dear [[FIRST]] [[LAST]] [SUFFIX]]:

We are writing to ask for your assistance in cooperating on a survey of Virginia's grain production, storage, and transportation practices. We are examining critical issues and constraints faced by growers and the commercial supply chain. (A list of specific objectives is included on the back.)

Survey instructions: If you grow cash grain in Virginia, we ask that you (or another primary decision-maker) complete the enclosed survey. The questionnaire should take about ten minutes. Please return it in the postage-paid self-addressed envelope. While the surveys are numbered for mailing purposes, you can be assured that **your responses will be kept strictly confidential with no disclosure of individual information**. **Only summaries of the results will be published**. (If you do not grow cash grain in Virginia and/or do not farm in Virginia, please mark the appropriate box in Question #1 and return the survey in the postage-paid envelope.)

Importantly: Due to the possibility that more than one individual from the same farm receives a survey request, we ask that only one survey be completed per farm. In addition, many individuals were contacted through email and previous correspondence to an online version of this survey. If you completed the "Virginia Grain Production and Storage Survey" electronically, thank you for your response. Please do not complete the questionnaire a second time. If you grow cash grain crops in Virginia and have not completed the survey, please consider doing so today.

Thank you for your time and assistance. Please continue to the back to read other important information before beginning the survey.

Sincerely,

Gordon Groover, Extension Economist, Virginia Tech
Kathryn Boys, Assistant Professor, Virginia Tech
Wade Thomason, Extension Grains Specialist, Virginia Tech
Gustavo Ferreira, Extension Economist, Virginia Tech
Peter Caffarelli, Research Assistant, Virginia Tech
Bryan Tallaferro, President, Virginia Grain Producers Association

Enclosure

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Additional Information

Background/relevance: Grain production and its allied industries are a leading part of Virginia's agricultural economy. Farm and off-farm storage, and the transportation system, are critical to the efficient and timely flow of grain from farms to final users. This study is focused on identifying "bottlenecks" in grain storage capacity and transportation systems from farm to final users.

Specific objectives of the research: To describe and identify: 1) current grain storage capacity and transportation infrastructure; 2) plans for future building of on-farm and commercial storage; 3) the impact of a more diverse supply of grain; 4) existing constraints in the grain marketing channels; and 5) possible economic incentives to producers and commercial elevators to reduce these constraints.

Benefits: Summaries of results will be published as Extension Publications and made available through http://www.ext.vt.edu/. Additional benefits consist of an enhanced ability to address the needs of area grain producers and commercial facilities, including but not limited to offering policy recommendations, proposing solutions to alleviate constraints, and providing educational programs.

Risks: There are no foreseeable risks.

Confidentiality: All information gathered will be anonymous. You will **not** be asked to disclose your name or the name of your operation during the survey. We will ask only for the zip code of your operation. Your responses will be kept strictly confidential with no disclosure of individual information. Only summaries of the survey results will be distributed.

Voluntary participation: Your participation in this study is voluntary. However, you can help us very much by taking a few minutes to share your experiences in Virginia grain production and storage. If for any reason you prefer not to respond, please let us know by returning the blank questionnaire in the enclosed stamped envelope.

Contact Information: If you have questions, please contact Peter Caffarelli (email: caffarep@vt.edu, phone: 716-480-2763) or Gordon Groover (email: groover@vt.edu, phone: 540-231-5850).

Importantly, by beginning this survey, you agree that you are at least 18 years old, voluntarily participating in this study, and understand the study's information provided above.

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1. Did you grow cash grain in Virginia in the past year (2012)? *(Put an "X" in the box that applies.)*

   ☐ Yes, I produce and sell cash grains
   ☐ No, I farm, but did not grow cash grain
   ☐ No, I do not farm or am no longer farming

   } *If "No," please return the survey in the postage-paid return envelope.*

2. Please write the county and zip code where your primary grain farm operations are located:

   County: ______ Zip code: ______

3. What is the typical acreage under grain production?

   ______ acres

4. Approximately how many bushels of each grain are harvested during a typical year?

Field Crop	Number of Bushels Harvested
Barley	bu.
Corn	bu.
Grain sorghum	bu.
Oats	bu.
Rye	bu.
Soybeans	bu.
Triticale	bu.
Wheat	bu.
Other grain crop: ________	bu.

5. What happens to your grain at harvest? *(Put an "X" in the boxes to all that apply.)*

   ☐ I sell my grain at harvest.
   ☐ I store my grain in commercial (off-farm) structures at harvest.
   ☐ I store my grain in owned on-farm structures at harvest.
   ☐ I store my grain in rented on-farm structures at harvest.

<u>DIRECTIONS</u>: If you store grain by any of the above methods, continue on to Question 6 (Page 2). If you do <u>not</u> store any grain, please skip to Question 15 (Page 6).

6. In the table below, please write 1) the number of bushels that are typically stored at harvest at the applicable location(s); 2) the number of bushels retained for farm use (if any); and 3) how many months grain for later sale usually sits in storage. *(If a grain does not apply, feel free to leave the boxes blank.)*

Field Crop	Bushel Stored Commercially	Bushels Stored On-Farm (Own)	Bushels Stored On-Farm (Rented)	Bushels Retained for On-Farm Use or Feed	How Many Months Does Grain for Later Sale Typically Remain in Storage?
Barley	bu.	bu.	bu.	bu.	months
Corn	bu.	bu.	bu.	bu.	months
Grain sorghum	bu.	bu.	bu.	bu.	months
Oats	bu.	bu.	bu.	bu.	months
Rye	bu.	bu.	bu.	bu.	months
Soybeans	bu.	bu.	bu.	bu.	months
Triticale	bu.	bu.	bu.	bu.	months
Wheat	bu.	bu.	bu.	bu.	months
Other	bu.	bu.	bu.	bu.	months

7. Do you own storage? *(Put an "X" in the box that applies.)*

☐ Yes

☐ No → *If "No," please skip to Question 15 (Page 6).*

8. In the table below, please report the approximate capacity (in bushels), age, and expected remaining useful life for each bin of your current usable storage.

	Approximate Capacity *(Write number of bushels.)*	**Approximate Age** *(Check one box.)*	**Approximate Remaining Useful Life** *(Check one box.)*
Bin 1	bu.	☐ < 5 years old ☐ 5-10 years old ☐ 11-20 years old ☐ 21-30 years old ☐ > 30 years old	☐ < 5 years left ☐ 5-10 years left ☐ 11-20 years left ☐ 21-30 years left ☐ > 30 years left
Bin 2	bu.	☐ < 5 years old ☐ 5-10 years old ☐ 11-20 years old ☐ 21-30 years old ☐ > 30 years old	☐ < 5 years left ☐ 5-10 years left ☐ 11-20 years left ☐ 21-30 years left ☐ > 30 years left
Bin 3	bu.	☐ < 5 years old ☐ 5-10 years old ☐ 11-20 years old ☐ 21-30 years old ☐ > 30 years old	☐ < 5 years left ☐ 5-10 years left ☐ 11-20 years left ☐ 21-30 years left ☐ > 30 years left
Bin 4	bu.	☐ < 5 years old ☐ 5-10 years old ☐ 11-20 years old ☐ 21-30 years old ☐ > 30 years old	☐ < 5 years left ☐ 5-10 years left ☐ 11-20 years left ☐ 21-30 years left ☐ > 30 years left
Bin 5	bu.	☐ < 5 years old ☐ 5-10 years old ☐ 11-20 years old ☐ 21-30 years old ☐ > 30 years old	☐ < 5 years left ☐ 5-10 years left ☐ 11-20 years left ☐ 21-30 years left ☐ > 30 years left
Bin 6	bu.	☐ < 5 years old ☐ 5-10 years old ☐ 11-20 years old ☐ 21-30 years old ☐ > 30 years old	☐ < 5 years left ☐ 5-10 years left ☐ 11-20 years left ☐ 21-30 years left ☐ > 30 years left

[Note: If you have more than 6 bins, please find the Appendix (Page 10).]

9. Are your operations somehow constrained by your current on-farm storage? *(Put an "X" in the box that applies.)*

☐ Yes

☐ No → *If "No," please skip to Question 12 (bottom of page).*

10. What are the storage issues that limit your operations? *(Put an "X" in the boxes to all that apply.)*

☐ Total capacity of current storage

☐ Ability to store multiple crops

☐ Age of some of my existing storage structures

☐ Quality of some of my existing storage structures

☐ Something else not listed above: ______________________________

11. When does your storage most limit your operations? *(Put an "X" in the boxes to all that apply.)*

☐ January	☐ May	☐ September
☐ February	☐ June	☐ October
☐ March	☐ July	☐ November
☐ April	☐ August	☐ December

12. Do you anticipate changing your on-farm storage in the future? *(Put an "X" in the box(es) to what applies.)*

☐ Yes, I plan on **adding to** existing capacity.

☐ Yes, I plan on **replacing** existing capacity.

☐ No, I am not planning to change my on-farm storage. → *If "No," please skip to Question 14 (Page 5).*

13. Can you provide further details of your future storage plans (how much and when)? *(Put an "X" in the appropriate boxes.)*

Build to ADD TO Capacity *(If Applicable)*	**Build to REPLACE Capacity** *(If Applicable)*
How Many Bins? (*Check one box.*)	**How Many Bins?** (*Check one box.*)
☐ 1 bin ☐ 2 bins ☐ 3 bins ☐ 4 bins ☐ 5 or more bins	☐ 1 bin ☐ 2 bins ☐ 3 bins ☐ 4 bins ☐ 5 or more bins
How Much Capacity (Combined)? (*Check one box.*)	**How Much Capacity (Combined)?** (*Check one box.*)
☐ 1 – 10,000 bushels ☐ 10,001 – 20,000 bushels ☐ 20,001 – 30,000 bushels ☐ 30,001 – 40,000 bushels ☐ 40,001 or more bushels	☐ 1 – 10,000 bushels ☐ 10,001 – 20,000 bushels ☐ 20,001 – 30,000 bushels ☐ 30,001 – 40,000 bushels ☐ 40,001 or more bushels
When Do You Plan to Act? (*Check one box.*)	**When Do You Plan to Act?** (*Check one box.*)
☐ Within the next 5 years ☐ In the next 6 to 10 years ☐ More than 10 years from now	☐ Within the next 5 years ☐ In the next 6 to 10 years ☐ More than 10 years from now

14. What factors were important in your decision to have on-farm storage and are they currently at satisfactory levels? *(Put an "X" in the boxes to all that apply.)*

	Important Factor in Decision-Making?	**Satisfied at Current Levels?**
Higher returns to stored grains	☐ Yes	☐ Yes ☐ No
Increased production levels and/or acreage	☐ Yes	☐ Yes ☐ No
Wait times at buying facilities (e.g. grain elevators)	☐ Yes	☐ Yes ☐ No
Information on storage builders and designs	☐ Yes	☐ Yes ☐ No
Government incentives to build on-farm storage	☐ Yes	☐ Yes ☐ No
Access to infrastructure (e.g. three-phase electrical power; roads)	☐ Yes	☐ Yes ☐ No
Access to financing	☐ Yes	☐ Yes ☐ No
Access to information on grain storing and drying practices	☐ Yes	☐ Yes ☐ No
Something else not listed here: ____________	☐ Yes	☐ Yes ☐ No
Something else not listed here: ____________	☐ Yes	☐ Yes ☐ No

DIRECTIONS: Please skip to Question 21 (Page 8).

15. Does not having on-farm storage constrain your farm operation? *(Put an "X" in the box that applies.)*

☐ Yes

☐ No → *If "No," please skip to Question 17 (bottom of page).*

16. When are your operations most limited by not having storage? *(Put an "X" in the boxes to all that apply.)*

☐ January	☐ May	☐ September
☐ February	☐ June	☐ October
☐ March	☐ July	☐ November
☐ April	☐ August	☐ December

17. Do you anticipate building any on-farm storage in the future? *(Put an "X" in the box that applies.)*

☐ Yes, I plan on building on-farm storage structures (e.g. grain bins).

☐ No, I am not planning to build on-farm storage. → *If "No," please skip to Question 20 (Page 7).*

18. Can you provide further details of your future storage plans (how much and when)? *(Put an "X" in the appropriate boxes.)*

How Many Bins? (*Check one box.*)	**How Much Capacity (Combined)?** (*Check one box.*)	**When Do You Plan to Act?** (*Check one box.*)
☐ 1 bin	☐ 1 – 10,000 bushels	☐ Within the next 5 years
☐ 2 bins	☐ 10,001 – 20,000 bushels	☐ In the next 6 to 10 years
☐ 3 bins	☐ 20,001 – 30,000 bushels	☐ More than 10 years from now
☐ 4 bins	☐ 30,001 – 40,000 bushels	
☐ 5 or more bins	☐ 40,001 or more bushels	

19. What factors were important in your decision to build on-farm storage and are they currently at satisfactory levels? *(Put an "X" in the boxes to all that apply.)*

	Important Factor in Decision-Making?	Satisfied at Current Levels?
Higher returns to stored grains	☐ Yes	☐ Yes ☐ No
Increased production levels and/or acreage	☐ Yes	☐ Yes ☐ No
Wait times at buying facilities (e.g. grain elevators)	☐ Yes	☐ Yes ☐ No
Information on storage builders and designs	☐ Yes	☐ Yes ☐ No
Government incentives to build on-farm storage	☐ Yes	☐ Yes ☐ No
Access to infrastructure (e.g. three-phase electrical power; roads)	☐ Yes	☐ Yes ☐ No
Access to financing	☐ Yes	☐ Yes ☐ No
Access to information on grain storing and drying practices	☐ Yes	☐ Yes ☐ No
Something else not listed here: ______________	☐ Yes	☐ Yes ☐ No
Something else not listed here: ______________	☐ Yes	☐ Yes ☐ No

DIRECTIONS: Please skip to Question 21 (Page 8).

20. What are the conditions under which you would consider building on-farm storage? *(Put an "X" in the box(es) to what applies.)*

Higher returns to stored grains	☐
Increased production levels and/or acreage	☐
Wait times at buying facilities (e.g. grain elevators)	☐
Information on storage builders and designs	☐
Government incentives to build on-farm storage	☐
Access to infrastructure (e.g. three-phase electrical power; roads)	☐
Access to financing	☐
Access to information on grain storing and drying practices	☐
Something else not listed here: ______________	☐
Something else not listed here: ______________	☐

None of the above	☐

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21. How is your grain delivered to a buying station?

- ☐ We haul our grain
- ☐ We hire out delivery of our grain
- ☐ Other not listed above: ____________________

22. Do you haul grain other than your own? *(Put an "X" in the box that applies.)*

- ☐ Yes
- ☐ No

23. What percentage of your grain is transported the following distances (one-way)? *(Please write the appropriate percentages in the boxes. Total should sum to 100%.)*

Distances	Percentage
1 – 25 miles	%
26 – 50 miles	%
51 – 75 miles	%
76 – 99 miles	%
More than 100 miles	%

24. What is the typical wait time at a buying station before your grain is unloaded? *(If applicable, please write a time in minutes; if not, leave blank.)*

minutes

25. What is the maximum acceptable time you are willing to wait to unload your grain before switching to another buying station? *(If applicable, please write a time in minutes; if not, leave blank.)*

minutes

26. Do you have any additional comments or concerns about the constraints you encounter in your farm operation? Please elaborate below.

Thank you for completing the survey.
Your help in this effort is greatly appreciated.

Please return the survey in the postage-paid return envelope provided.

These results will be used to investigate and address the needs of Virginia's grain industry. If you would like additional information or have questions about the study, please contact Peter Caffarelli (email: caffarep@vt.edu, phone: 716-480-2763) or Gordon Groover (email: groover@vt.edu, phone: 540-231-5850) of the research team.

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APPENDIX

Please use the table to below to record details on any remaining storage structures.

	Approximate Capacity *(Write number of bushels.)*	**Approximate Age** *(Check one box.)*	**Approximate Remaining Useful Life** *(Check one box.)*
Bin 7	bu.	☐ < 5 years old ☐ 5-10 years old ☐ 11-20 years old ☐ 21-30 years old ☐ > 30 years old	☐ < 5 years left ☐ 5-10 years left ☐ 11-20 years left ☐ 21-30 years left ☐ > 30 years left
Bin 8	bu.	☐ < 5 years old ☐ 5-10 years old ☐ 11-20 years old ☐ 21-30 years old ☐ > 30 years old	☐ < 5 years left ☐ 5-10 years left ☐ 11-20 years left ☐ 21-30 years left ☐ > 30 years left
Bin 9	bu.	☐ < 5 years old ☐ 5-10 years old ☐ 11-20 years old ☐ 21-30 years old ☐ > 30 years old	☐ < 5 years left ☐ 5-10 years left ☐ 11-20 years left ☐ 21-30 years left ☐ > 30 years left
Bin 10	bu.	☐ < 5 years old ☐ 5-10 years old ☐ 11-20 years old ☐ 21-30 years old ☐ > 30 years old	☐ < 5 years left ☐ 5-10 years left ☐ 11-20 years left ☐ 21-30 years left ☐ > 30 years left
Bin 11	bu.	☐ < 5 years old ☐ 5-10 years old ☐ 11-20 years old ☐ 21-30 years old ☐ > 30 years old	☐ < 5 years left ☐ 5-10 years left ☐ 11-20 years left ☐ 21-30 years left ☐ > 30 years left
Bin 12	bu.	☐ < 5 years old ☐ 5-10 years old ☐ 11-20 years old ☐ 21-30 years old ☐ > 30 years old	☐ < 5 years left ☐ 5-10 years left ☐ 11-20 years left ☐ 21-30 years left ☐ > 30 years left

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Office of Research Compliance
Institutional Review Board
North End Center, Suite 4120, Virginia Tech
300 Turner Street NW
Blacksburg, Virginia 24061
540/231-4606 Fax 540/231-0959
email irb@vt.edu
website http://www.irb.vt.edu

MEMORANDUM

DATE: July 2, 2015

TO: Gordon Groover, Gustavo Ferreira, Peter Anthony Caffarelli

FROM: Virginia Tech Institutional Review Board (FWA00000572, expires April 25, 2018)

PROTOCOL TITLE: Virginia Grain Production and Storage Project

IRB NUMBER: **15-677**

Effective July 2, 2015, the Virginia Tech Institution Review Board (IRB) Chair, David M Moore, approved the New Application request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report within 5 business days to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at:

http://www.irb.vt.edu/pages/responsibilities.htm

(Please review responsibilities before the commencement of your research.)

PROTOCOL INFORMATION:

Approved As:	**Exempt, under 45 CFR 46.110 category(ies) 2**
Protocol Approval Date:	**July 2, 2015**
Protocol Expiration Date:	**N/A**
Continuing Review Due Date*:	**N/A**

*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

FEDERALLY FUNDED RESEARCH REQUIREMENTS:

Per federal regulations, 45 CFR 46.103(f), the IRB is required to compare all federally funded grant proposals/work statements to the IRB protocol(s) which cover the human research activities included in the proposal / work statement before funds are released. Note that this requirement does not apply to Exempt and Interim IRB protocols, or grants for which VT is not the primary awardee.

The table on the following page indicates whether grant proposals are related to this IRB protocol, and which of the listed proposals, if any, have been compared to this IRB protocol, if required.

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Appendix D: Additional Data Tables

Table 29: Number of Grain Crops Grown*

Number of Crops Grown	Number of Farmers	Percentage
1	33	9.6%
2	73	21.2%
3	152	44.1%
4	63	18.3%
5	20	5.8%
6 or 7	4	1.2%

* *n* = 345, out of 347, 99%

Table 30: Number of Farmers with a Given Number of Bins

# of Bins	# of Respondents	Percentage
1	18	7.2%
2	36	14.4%
3	28	11.2%
4	43	17.2%
5	28	11.2%
6	44	17.6%
7	11	4.4%
8	11	4.4%
9	10	4.0%
10	2	0.8%
11	3	1.2%
12	6	2.4%
15	2	0.8%
20	1	0.4%
22	1	0.4%
No Response	6	2.4%
Total	**250**	**100%**

Table 31: Number of Bins by Age

Age of Bins	Number of Bins
Less than 5 years old	120
5 to 10 years old	92
11 to 20 years old	197
21 to 30 years old	355
Greater than 30 years old	406
No response	32
Total	**1,202**

Table 32: Number of Bins by Remaining Useful Life

Remaining Useful Life of Bins	Number of Bins
Less than 5 years left	78
5 to 10 years left	176
11 to 20 years left	442
21 to 30 years left	202
Greater than 30 years left	215
No response	89
Total	**1,202**