Regional food security in south-central Appalachia: Connecting diet, land requirement, and agricultural carrying capacity

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ABSTRACT

Local communities and regional networks are currently exploring the strategy of developing local and regional food systems in order to enhance food security. The relationship between food consumption and production must be tested at various scales and across geographies in order to describe how place-based diets influence agricultural land use and the degree to which a discrete agricultural land base can feed a population. This thesis used two models to integrate data from across the agricultural and nutritional sciences to test the capacity of regional food systems to meet complete diet food need in the south-central Appalachian foodshed. First, a complete diet approach was applied to the entire foodshed to test the influence of animal product and fat consumption on the land requirements of food production. The quantity of specific regionally-adapted food commodities for six diet patterns were estimated following USDA recommendations and compared to county-based Census of Agriculture land use data to determine agricultural carrying capacity. Second, a sub-regional geospatial foodshed model used site-specific soil and current land cover datasets to estimate the spatial distribution of food production capacity relative to the per capita food needs determined by the complete diet model. Together, these studies contribute information from a data-user perspective for stakeholders and planners interested in quantifying the capacity of regional food systems to meet total food needs.

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"Food is more than itself. It is not everything, but it is touched by almost everything: memory, weather, dirt, hunger, chemistry, the universe. It is identity, and culture, and history. It is science, and nature, and botany. It is the earth. It is our family, our philosophy, our past. It is the most important matter in our lives. It is more than its ingredients. But it is also just dinner. It means nothing. It is serious, and not."

Bill Buford

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CHAPTER 1

INTRODUCTION

Food is a basic provisioning ecosystem service provided by agricultural systems (MEA 2005). The stability, sustainability and nutritional quality of the food supply impacts human health and the economy. Globally, food systems must address a host of intersecting challenges, namely trends of increasing populations, increasing demand for animal food products, increasing environmental pressures such as limited arable land, water scarcity and reducing non-renewable inputs. These challenges are further complicated by the seemingly paradoxical reality of both persistent hunger and increasing incidence of chronic disease such as obesity (AMA, 2013; CDC 2013; Popkin 2006). While nutrition and agriculture are obviously interconnected, the goals of their representative fields and the implementation of policy often do not align. Agricultural sciences are typically more invested in productivity and efficiency- particularly of a handful of key commodity crops- while nutritional sciences typically focus on nutrient deficiencies and balanced diets (Peters et al. 2003).

In pre-World War II America, food systems were much more local and regional in nature and diets were largely determined by the changing seasons. At this time, almost 40 percent of Americans lived on a farm (Martinez et al. 2010). In the past half-century after World War II, agronomy and technological advances dramatically increased yields and contributed to increased food production around the world. These advances have fed the appetite of a growing global population. Despite the success these increased yields have had in decreasing the overall proportion of hungry people, currently more than one in seven people lack access to adequate protein and calories and over two billion people are malnourished from some type of deficiency in micronutrients (Godfray et al. 2010; WHO 2006).

The concept of food security emerged in the 1970s mainly as a response to global hunger and describes a situation where an individual has enough food to eat. More recently, this concept has evolved into the more comprehensive, prevention-oriented approach of community food security, or the ability of populations to systemically meet food and nutritional needs. Hamm and Bellows (2003) provide a widely accepted definition of community food security as:

> "A situation in which all community residents obtain a safe, culturally acceptable, nutritionally adequate diet through a sustainable food system that maximizes community self-reliance and social justice"

This definition extends the concept of food security past that of the single individual or household and highlights the environmental, social, and economic dimensions of food systems. Community food security attempts to describe the degree to which food is accessible, available and affordable (Cohen et al. 2002). The concept of food access is determined by two factors. First, the proximity and prevalence of physical locations where healthy foods may be purchased and, second, the transportation and other essential infrastructure that enables community members to reach these locations. Food availability deals with temporal and geographic fluctuations in food supply. Food affordability highlights community residents' economic capacity to purchase sufficient nutritious food (USDA 2009). According to a recent USDA-ERS study, almost 15% of American households were food insecure at least some time during the year in 2012, meaning they lacked access to enough food to meet USDA nutrition recommendations for all household members (Coleman-Jensen et al. 2013).

This evolution of the concept of food security as a systemic issue emerged as consumer preferences shifted to support a significant growth in local food systems or a "relocalization" (Guptill and Wilkins 2002; Martinez et al. 2010). Growing environmental awareness, cultural interest food that is rooted in a sense of place and that supports regional farmers and economies have all contributed to the burgeoning domestic community food security movement. Many communities and regional bodies are interested in measuring the degree to which strong, integrated regional food systems enhance environmental quality, local economies and quality of life (Connor et al. 2013; Kantor 2001; Lohr, et al. 2011). The rise in interest in local and regional food systems as an alternative to the global food system requires producers and consumers to ask: to what degree can regional agriculture meet the food demand of the regional population? And to what degree can local and regional food systems enhance food security in its multiple dimensions.

There is no universally-accepted definition specifying geographic or distance requirements in the idea of what constitutes as "local" food. The term carries a variety of geographic connotations including food originating within the confines of a specific locality, to anywhere within a 100 radius, while others consider any foods from within a 500 mile radius or within state lines to qualify as "local foods." (Darby et al. 2008; Ostrum 2007). Further complicating the ambiguous concept of local food is that consumers often consider one food local and another not local for different reasons based on production method and type of product (fresh vegetables short distances, milk, eggs, and meat longer distances, for example) and whether it is fresh or processed (Durham et al. 2009). A definition used for federally-funded rural development loan programs by the U.S. Congress in the Food, Conservation, and Energy Act of 2008 highlights the elusive nature of a definition for 'local foods':

> "[A locally produced agricultural food product is] any agricultural food product that is raised, produced, and distributed in (1) the locality or region in which the final product is marketed, so that the total distance the product is transported is less than 400 miles from the origin of the product, or (2) the State in which the product is produced."

The concept of "local" must accommodate a wide range of perspectives and definitions. In order to steer clear of the confusion this term can carry, the concept of a foodshed is introduced.

Foodshed analysis

Peters et al. (2008) describe the origin of the foodshed concept, which they compare to a watershed. A foodshed is a distinct geographical boundary containing flows of food production and consumption. Unlike watersheds, foodsheds are more of a semi-permeable boundary in that they allow some external flows, describe the capacity of local and regional lands and resources to contribute to food security for the contained population. First used by Walter Hedden in 1929, the term "foodshed" describes the food system from producer through transport and distribution channels to retailers and consumers (Peters et al. 2008). Hedden was concerned with the effect of potential system disruptions such as labor and transportation strikes, natural disasters and other threats to the ability of the food system to supply populations, particularly the urban population of New York City, with food (Hedden 1929). Contemporary researchers extended Hedden's concept of a foodshed to describe local food systems as alternative, sustainable networks of production and consumption (Kloppenburg et al. 1996). The concept of a foodshed carries all of these connotations, but for clarity, the definition of a "foodshed" in this thesis is taken from Peters et al. (2008) to describe a discrete geographic area of food production used to feed the population therein contained, in this case, the entire 109 county area of south-central Appalachia.

Any debate of the sustainability of agricultural systems and the potential for a regionalized food system to increase food security at the household and community levels must be grounded in biophysical reality. William Rees introduced the concept of an ecological footprint of a city that is now widely used as a metric of human's use of ecological services and the biosphere's ability to sustain these demands. An ecological footprint describes the inputs and outputs of energy, resources, and waste on a per capita basis to determine if the impact on ecosystems is positive, negative or neutral (Reese 1992). The ecological footprint is metric describing the carrying capacity of an area or even the entire planet (Wackernagel and Rees 1996). In the same vein, a foodshed analysis quantifies the biophysical capacity and production potential, or biocapacity, of a region compared to the nutritional food needs of a given population.

This biocapacity is determined by how the natural resources and land base of a foodshed align with the food demand of a population. A foodshed analysis must be able to address three challenges for aligning regional nutritional and agricultural goals and needs. First, the food need and land requirements of diets must be calculated. Second, place-based estimates of soil productivity must be collected and integrated. Third, land use and land available for agricultural production must be determined (Hu et al. 2011; Peters et al. 2009).

Research questions

This research explores tools that can aid communities and regional planners shaping food policy and inform farmers interested in producing for local and regional markets. This thesis combines the results of a complete-diet model, a geospatial model and a seasonality model as a part of an overall foodshed analysis. Central research questions are as follows:

1. What is the relationship between food need (diet) and agricultural land requirements? How does biocapacity limit or enhance the number of people a region can feed? How does dietary choice affect this?
2. What is the relationship between the distribution of agricultural land and soil productivity? Are high-productivity soils currently in agricultural production?
3. Does the current distribution of perennial crop and annual crop agriculture align with soil production capacity? Are we using our limited agricultural land for its best use, i.e. getting the best yields to feed the most people while optimizing for sustainable land use?
4. What are the upper bounds to food system regionalization in a given foodshed?

Addressing these questions as a part of an overall foodshed analysis requires two approaches used in subsequent chapters: a complete diet approach and a geospatial framework.

Study area

South-central Appalachia is a rural, mountainous region extending from West Virginia to North Carolina. Both the rates of poverty and household food insecurity are above the national average (Table 1). In a region characterized by historical subsistence farming, there has been a decrease in the number of farms, farmers and farm revenue in the past decade (U.S. Census of Agriculture 2012). In this foodshed analysis, a complete diet model calculates the food need and land requirements for the 109 counties within this south-central portion of the greater Appalachian region as defined by the Appalachian Regional Commission and referenced as the south-central Appalachian foodshed throughout this thesis (Fig 1). A geospatial model and a seasonality model are also developed for a subset of this region, the 54 counties of Virginia and North Carolina. Due to lack of spatially explicit productivity and yield data, the 55 West Virginia counties are not included in the spatial model.

This thesis aims to inform the current discussion of community food security among a coalition of community organizations and academic researchers alike, known as the Appalachian Foodshed Project[1]. The mission of this USDA NIFA-AFRI project is to enhance community food security by addressing regional farming, nutrition, and food access. This thesis is an effort to quantify the relationship between the biophysical capacity of the South-Central Appalachian agricultural land base and the food needs of the regional population using a foodshed analysis.

[1] The Appalachian Foodshed Project is funded through the USDA's Agriculture, Food and Research Initiative (AFRI) grants program. Award Number: *2011-68004-30079. See Web site* http://appalachianfoodshedproject.org *for more information.*

Table 1. Poverty Rates in South-central Appalachia, 2007-2011.

	Persons for Whom Poverty Status is Determined, 2007–2011	Persons Below Poverty Level, 2007–2011	Poverty Rate, 2007–2011	Poverty Rate, Percent of U.S. Average, 2007–2011
Appalachian North Carolina	1641745	276940	16.90%	117.90%
Appalachian Virginia	734458	133191	18.10%	126.80%
Appalachian West Virginia	1794220	313363	17.50%	122.10%

Source: ARC 2012.

A foodshed analysis is warranted for this study area for a number of reasons. First, the global and national trends of increasing consumer demand for animal products and high fat diets have important regional health and environmental implications in Appalachia. While increasing levels of diet related diseases are problematic across the U.S., the Appalachian study area features both ends of the malnutrition spectrum, with high rates of obesity and diet-related mortality and morbidity on one side and persistent hunger on the other. The Appalachian Regional Commission reports that Appalachian residents experience higher morbidity and mortality rates than non-Appalachian residents. The prevalence of diabetes is 13.9% for Appalachian residents, significantly higher than persons living in non-Appalachian regions (7.4%). Nationally, over one-third of adults are obese, costing the U.S. an estimated $147 billion in health care in 2008 (Ogden et al. 2014; Finkelstein et al. 2009). In 2012, the CDC reported that the three states in the Appalachian Foodshed had high levels of obesity- North Carolina had a rate of 29.6%, Virginia 27.4% and West Virginia 33.8% (CDC, 2013).

Secondly, a foodshed analysis is suited for the study area to better understand the capacity of a rural, mountainous region to feed its population. Previous foodshed analyses focus primarily on urban locations, however, rural areas high in food insecurity also warrant the attention of this methodological framework. Moreover, the unique topography and soils of the Appalachian Foodshed create a discontinuous patchwork of arable lands amongst the sloping mountain range, making it a unique region to study. Steep slopes and shallow soils limit the areas available to successful agricultural production primarily to valley floors and eroded plateaus (Gardener and Sevon 1989; Kaliz 1986). The mountains are also physically isolating and there is limited infrastructure in the region, either creating or fostering the Appalachian culture of self-reliance. This combination of natural and social factors has led to a preponderance of small farms, hobby farming, and a notable absence of large industrial farms in most locations. Larger farms in the study area tend to focus on production of beef cattle and supporting crops such as pasture, hay, and silage (USDA 2012). With limited quality agricultural land in the region, decreasing numbers of farms, farmers, and farm revenue in the past decade, a foodshed analysis provides important information relating to the need for farmland conservation awareness of regional connections between consumption and production (USDA, 2007).

Figure 1. The South-central Appalachian study region.

Community organizations and regional planning networks are all interested in the potential of local and regional food systems to contribute to enhanced sustainability and food security within Appalachia on three fronts: economy, environment, and quality of life (Matson et al. 2013; Peters et al. 2012). First, the historically weak economy of Appalachia and its dependence on extractive industries have many considering the benefits of regional agriculture to bring employment and revenue to the region. Local dollars spent on local products keep more money within the region by traveling through shorter supply chains (Marsden et al. 2002; Renting et al. 2003; Woods et al. 2013). Second, people in Appalachia are interested in the potential of agricultural regionalization to benefit the environment through the use of sustainable management practices and reducing the distance of food transport. Third, the potential for regional food systems to improve health outcomes and strengthen social ties through emphasis on traditional Appalachian foods and the heritage of community production and processing offers prospective improvements for the quality of life for Appalachian people.

However, the reality of food system regionalization is not as clear cut as many advocates of local food may purport. A key USDA review of research highlights the complications that arise when attempting to determine causation and correlation within local food systems. The review showed that since 2010, empirical evidence does support the hypothesis that local food systems can increase employment and income within the community (Martinez et al. 2010). It also revealed that local and regional food systems can be less detrimental to the environment, but that they are not inherently more environmentally sustainable. Though regionalized systems can reduce greenhouse gas emissions, net energy use, and food waste, it cannot yet be unequivocally stated that this is significantly different from the conventional, global food system. Finally, the review found that the data are insufficient to support a clear cut link between local foods and improved diet quality or food security. Clearly, bold claims supporting relocalization and regional food systems must be investigated as tradeoffs of the risks and benefits are weighed (Bellows and Hamm, 2001).

For all of the many environmental, economic and social reasons regional coalitions are exploring a relocalization of the food system, deeper questions of regional production capacity and the links between diet and agricultural land use in Appalachia must be explored.

Measuring food need and land requirements: The complete-diet approach

If better and more balanced nutrition is a current concern of advocates of community food security, approaches are needed that explicitly test the biocapacity of agricultural production systems to meet human nutritional needs. Early efforts to characterize the adequacy of food production in terms of food consumption commonly assessed the adequacy of food production solely in terms of overall caloric availability per capita (Foster and Leathers, 1999). This calorie-centric approach does not take into account the proper serving sizes, nutritional differences or seasonal availability amongst the wide variety of foods available for human consumption. In an effort to inform the public on balanced nutrition, the USDA and Department of Human Health and Services (HHS) has since 1980 regularly released official dietary recommendations that describe adequate diets in terms of those comprised of different types of foods. These Dietary Guidelines for Americans led to the development of the Food Pyramid in 1992 (Davis and Saltos 1999). The Pyramid gave specific recommendations for five major food groups- grains, vegetables, fruits, dairy, and protein (meat, poultry, fish, eggs, dry legumes, nuts)- as well as added sugars and fats. The Pyramid was developed in response to the growing public health concern of increasing diet-related chronic disease and to give the public a daily tool to create healthy, balanced diets that meet basic nutritional needs. The Pyramid served as a baseline of daily consumption targets for the first assessment of the national food supply in terms of availability of foods within different food groups (Kantor 1998).

It is important to acknowledge the somewhat contentious history of the Food Pyramid and subsequent iterations of federal dietary recommendations. The Pyramid was not a completely objective, scientific document, but is by its very nature a policy document and therefore influenced by politics. The relevance and accuracy of the Pyramid is disputed amongst nutrition scientists and the politicized nature of its development is well documented (Nestle, 2002). Though the influence of powerful agricultural lobbyists, political interest groups, and the questionably high allowance for animal products must be taken into consideration, the Food Pyramid nonetheless offers a valuable baseline to compare the food need of the population to agricultural yield need. Moreover, there is a general consensus by nutrition researchers that it offers a versatile framework that is easily generalizable to entire populations (Peters et al. 2003).

In order to assess food systems in more nuanced terms than simply counting calories, Christian Peters and colleagues developed a novel method to assess not only how food production and consumption align, but defined the relationship between the two based on the Food Pyramid recommendations (Peters et al. 2007). This complete-diet framework takes a more nuanced view of consumption and therefore a hopefully more realistic impact on production need by considering the impacts of diet choice on production. To do so, nutrient, serving, and food group recommendations are all taken into account to study different dietary patterns composed of varying levels of animal product and fat intake in relation to overall caloric intake. This requires using data on the nutritional composition, consumer preference, estimates of food loss and waste through the supply chain, and expected agricultural yields of a number of specific food commodities. Thus, the complete-diet approach links diet to the land requirements and biocapacity of regional agriculture.

Peters et al. (2007) use the entire state of New York in their preliminary complete-diet model. The complete-diet approach has since been applied by several other studies in different regions across the U.S. Its value lies in its ability to modify the foods included to those that are able to be produced within a given foodshed and applied to the given population at any scale of interest. Desjardins et al. (2010) apply a complete-diet analysis to current and future food needs of the population of the Waterloo Region of Canada. Giombolini et al. (2010) apply foodshed analysis to a region of several counties within the state of Oregon. Hu et al. (2011) apply a foodshed analysis to the state of Iowa but also include data from surrounding states in their calculations. In this case, the researchers chose to adapt the methods presented by Peters et al. (2007) in order to make them more relevant to the rural nature of the foodshed of interest, accounting for the lower population total and density of Iowa's population compared to total and density of Iowa's population that of New York.

Mapping the Appalachian Foodshed: spatial distribution of agriculture

Food system localization is a geographic concept that readily transfers to spatial analysis of the distribution of farmland and the production capacity of soils. Results from the complete-diet model can be applied to spatial tools that relate the calculated food consumption need and expected yield need across the topography and soils to add another important component of foodshed analysis.

Peters et al. (2009) linked the results of the initial complete-diet model to a spatial model in a geographic information system (GIS). An explicit goal of this process was to meet consumer food demand within the shortest possible distance by including an optimization calculation. The researchers were operating under the assumption that reducing the total distance all food traveled within the foodshed was a desirable outcome. This stems from the concept of food miles, or the attempt to increase food sustainability by reducing the environmental cost of transportation of foods over long distances. The supposed environmental benefits derived from a reduction in this distance food travels is used as a justification for many other foodshed optimization studies (Thompson 2008; Brown 2003; Lea 2005; Peters et al. 2009; Hu et al. 2011). However, recent studies have published results that question the validity of the assumption that local production is inherently more environmentally sound due to a reduction in food miles alone (Martinez et al. 2010; Edwards-Jones et al. 2008).

According to a thorough review of research, the USDA currently finds that the general preponderance of evidence does not conclusively prove that foods with fewer food miles are inherently more sustainable, use less total energy to produce, or result in healthier ecosystems than those with higher food miles (Martinez et al. 2010). Saunders et al. (2006) published research revealing that higher food miles do not necessarily translate to higher fuel consumption of greenhouse gas emissions Distance can be an important factor in sustainability and resource use, but it does not factor in the complete environmental impact throughout the entire food system (Coley et al. 2009; Weber and Matthews 2008; Saunders and Hayes 2007). Such findings do not erase the important place of regional food systems, but they do frame the need to critically approach some claims made by local food proponents. Quantifying the bounds of regional systems based on natural constraints is therefore essential to this process.

This research uses a geospatial model to map current agricultural land use to compare to total food needs in the aggregate. It does not attempt to connect consumers to the closest possible producer but rather, aims to measure how much land area is available to contribute to the dietary demand of these aggregate food needs for people throughout the region. However, joining the complete-diet model results are inputted into in to a spatial model in order to test upper bounds of regional production supplying local consumption. The optimization goal can be changed or excluded from the analysis depending on research goals. Excluding this optimization allows the spatial model to consider that any food produced within the boundary of a foodshed could theoretically be consumed by any member of the given population.

To map a foodshed in a GIS, it is necessary to collect a range of soil, land cover, yield, and population data relating to the geographic extent of the area. The Appalachian Foodshed is comprised of 109 counties with a total population of 4,315,690 (ACS, 2012). The population of each county can be mapped in addition to layers representing the extent and distribution of defined soil productivity groups and agricultural land cover for a more complete picture of the Appalachian Foodshed (Donahue et al. 1994). Using the findings of a place-based complete-diet model within a GIS allows localities and regions to more fully understand the upper and lower bounds of production capacity to answer the question, 'How local can we go?' within a spatial context. Insights gained from this process include the number of people a foodshed can feed on a fully regional diet or the degree to which the current population can meet current food needs from within the region.

Prior studies using mapping techniques to describe geographically discrete areas of food production, distribution, and consumption tend to focus on the nation as a whole or else densely populated urban areas such as New York City, San Francisco, Chicago and others (Conrad et al. 2011; Thompson et al. 2008; Hu et al. 2011). This thesis posits that spatially relating the requirements of complete-diets have applications that can benefit rural populations as well.

Key drivers of agricultural production in Appalachia

This thesis focuses on two key drivers of agricultural production: diet, productivity, and land availability. Dietary choice represents consumer demand for agricultural food products and will ultimately determine what and how much producers grow. Soil productivity is a foundational biophysical determinant of the yield potential of agricultural lands and shape when, where, and how much producers are able to grow.

Chapter 2 presents results from a complete-diet model that tests the relationship between diet and land requirements. Methods from previous research are applied to the Appalachian foodshed in order to connect regional consumption patterns to overall regional yield needs.

Chapter 3 presents results from both a geospatial model of the distribution of soil productivity and agricultural land cover in a foodshed matrix. The results are discussed in relation to their on the overall production potential and food security within the study area.

Chapter 4 synthesizes the results from the complete-diet and geospatial models presented in Chapters 2 and 3 and presents conclusions in the form of a complete foodshed analysis of south-central Appalachia. Implications for regional food security are discussed.

This analysis of the Appalachian foodshed focuses on quantifying the relationship between diet and land use as well as the distribution of regional agriculture. It does not attempt to measure the economic impacts or specific health outcomes. Rather, this thesis is interested in describing food system behavior in relation to dietary choice as but one key driver of regional food demand. This analysis will hopefully be of use to regional practitioners and policy makers interested in leveraging diet and agriculture to enhance community food security and economic development in Appalachia.

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CHAPTER 2

TESTING A COMPLETE-DIET MODEL FOR ESTIMATING AGRICULTURAL LAND REQUIREMENTS OF SIX DIET TYPES IN THE SOUTH-CENTRAL APPALACHIAN FOODSHED

Introduction

This study aims to determine the extent to which regional food production can enhance food security in south-central Appalachia. Community food security describes a system in which all people can adequately and healthfully meet their dietary needs (Hamm and Bellows 2003). Localities and regions strategizing for enhanced food security must include an analysis of human nutritional needs and the capacity for agricultural lands to provide adequate yields to meet these needs. Aligning agricultural production with diet needs is a key consideration for regional food systems to address (Buzby et al. 2006; Martinez et al. 2010). However, the food supply does not align with recommended amounts for balanced nutrition and moreover most Americans do not follow federal nutrition recommendations (Putnam et al. 2000; Kantor 1998).

South-central Appalachia, like many other regions throughout the U.S., must cope with the challenges of rising populations, increasing demand for animal products, the proliferation of diets exceeding recommended intakes of both fat and animal products, high instances of diet-related morbidity and mortality, and mitigating the environmental impacts of agriculture (ARC 2012; CDC 2013; Peters et al. 2003). If better and more balanced nutrition is indeed a current concern of advocates of community food security, approaches are needed that explicitly express human nutritional needs in the biophysical terms of agricultural production systems situated in specific geographies. Complete-diet approaches relate the food need of a given population to the biocapacity- the production potential based on the biophysical factors of the system- of the agricultural land base at a regional scale (Peters et al. 2007).

The concept of a foodshed describes a geographic unit within a distinct boundary containing flows of food production and consumption (Peters 2007). This paper models the rural south-central Appalachian foodshed, which is composed of the entire state of West Virginia along with the mountainous, western portions of Virginia and North Carolina (Figure 1). The 109 counties included in this foodshed have a total population of 4,315,690 (U.S. Census Bureau 2012). This study area was selected in order to provide information to an ongoing community food security research effort, the

Appalachian Foodshed Project (AFP)[2] in regards to the leverage points for promoting regional production and consumption.

The AFP emerged in a context of a poor rural economy, decline in regional agriculture, and an alarming rise in diet-related disease such as obesity and diabetes (ARC 2012; U.S. Census Bureau 2012). This joint effort between community stakeholders with academic

Figure 2. The south-central Appalachian Foodshed.

Source: www.appalachianfoodshedproject.org

researchers reflects the growing interest in community food systems and the need to measures of the upper bounds of regional resources to meet the food needs of the contained population.

Estimates of consumption, or food need of the population, are compared with estimated levels of food production, or expected regional crop yields. Average human nutritional needs are quantified in terms of both caloric intake and recommended servings of food groups. These nutritional needs by food group are then linked to specific regionally-adapted crops, assigned a consumer preference value, average food loss calculated, and expected yield determined. Therefore, a complete-diet model tests the relationship between human dietary choices and the associated agricultural land requirements. Soils, current land use, productivity, human dietary need, and food loss are all used to estimate

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[2] The Appalachian Foodshed Project is funded through the USDA's Agriculture, Food and Research Initiative (AFRI) grants program. Award Number: *2011-68004-30079. See Web site* *http://appalachianfoodshedproject.org* *for more information.*

regional land requirements of different diet types. These land requirements are used to determine the regional biocapacity of a foodshed, that is, how human food need compares with the regional ecosystems to supply this need.

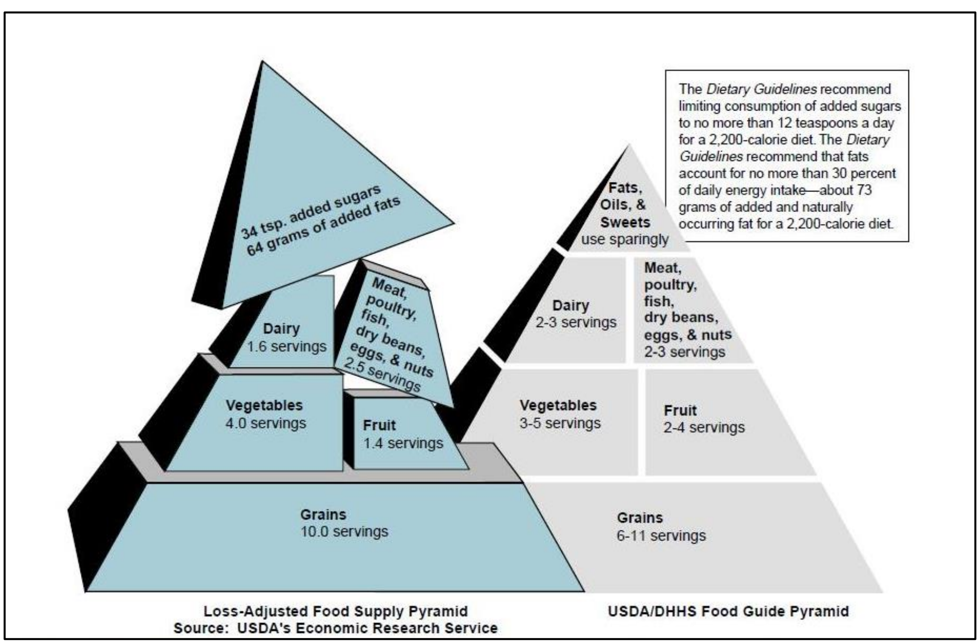
Diet and health

Diet and physical activity are two of the most important factors determining individual health (USDA and USHHS 2010). Since 1980, the USDA and the Department of Human Health and Services (HHS) have regularly released official dietary recommendations that describe adequate diets for health in an effort to inform the public on balanced nutrition. These dietary recommendations are organized around food groups composed of specific food items and led to the development of the Food Pyramid in 1992 (Davis and Saltos 1999). The Pyramid gave specific recommendations for five major food groups- grains, vegetables, fruits, dairy, and protein (meat, poultry, fish, eggs, dry legumes, nuts)- as well as added sugars and fats. The Pyramid served as a baseline of daily consumption targets for the first assessment of the national food supply in terms of availability of foods within different food groups (Kantor 1998). Multiple other studies have used national food guides as a baseline for calculating agricultural production need in various ways and determined that there is a persistent mismatch between human nutritional needs based on a balanced diet and agricultural output (Cowell and Parkinson 2003; Peters et al. 2003; Buzby et al. 2006). Figure 2 illustrates some of these disparities.

In 2011, the Pyramid was replaced with the MyPlate recommendations, which attempt to address the growing public health concern of increasing diet-related chronic disease and mortality. MyPlate serves as a daily tool for constructing complete diets that meet nutritional needs and improve health (USDA and USDHHS 2010).

These recommendations for balanced, complete diets are important because diseases linked to unhealthy diet choices include obesity, diabetes, hypertension, coronary heart disease, cancer, and stroke (Mela 2005). Nationally, over one-third of adults are obese

Figure 3. The mismatch between the U.S. food supply and food recommendations.



Source: Putnam et al. 2000.

(34.9%), costing the U.S. an estimated $147 billion in 2008 (Ogden et al. 2014; Finkelstein et al. 2009). In 2012, the CDC reported that the three states in the south-central Appalachian Foodshed had high levels of obesity- North Carolina had a rate of 29.6%, Virginia 27.4% and West Virginia 33.8% (CDC 2013). Diets high in meat and fat intake are also correlated with diet related disease (Mela 2005). Typical American diets are high in meat and fat intake exceeding daily recommended amounts, consuming 184g (6.5oz) of cooked meat and eggs per day based on the five-year average from 2008-2012 of the loss-adjusted federal food supply data (USDA 2012). Globally, this preference for high-meat and high-fat diets is increasing as developing nations see increases in income, leading to an expected increase in meat consumption of 65% between 1993 and 2020 (Delgado et al. 2001). Agricultural production should support good human health and it is clear that increasing demands of animal products pose an enormous challenge to food systems and health.

Diet and the environment

Changes in diets result in changes in production requirements and land use. Trends of increased demand for animal products and fat-rich diets are expected to continue and will have marked impacts on ecosystem services (Delgado et al. 2001). Livestock requires heavy inputs of land and water resources to produce needed feed and forage. Many researchers argue that this global shift in preferences for diets high in meat and animal products is unsustainable in the long run (Heitschmidt et al. 1996; Peters et al. 2007; Pimentel and Pimentel 2003). However, in south-central Appalachia, much of the land base is unsuitable for the cultivation of annual crops, whereas grass-based animal production provides a reliable source of income. Thus, it is essential that areas planning for regionalized production better understand and quantify resource and land requirements of different animal products specifically and diet types in general.

Diet occupies the unique position between people, agriculture, and the environment. As such, consumer diet choice stands out as an important leverage point to improve or degrade not only human and environmental health, but also community food security and sustainability more broadly. Community food security is the degree to which enough food that meets basic nutritional and cultural needs is available, accessible, and affordable to all residents of a discrete population (Cohen et al. 2002; Hamm and Bellows 2003). Similar to using the Pyramid in a nationwide assessment of the food supply, the MyPlate recommendations can be used as a part of a foodshed analysis of a community or region.

The complete diet approach

Place-based analyses are needed that consider the impact of different dietary patterns to test the regional land and resource requirements of varying intakes of foods, especially, meat and fat in the human diet. Peters et al. (2007) present the complete-diet model as a method to test the relationship between diets and land requirements of New York State foodsheds. This framework allows individual foods to be organized by food group into diets that are then linked back to per capita land requirements. This measure is then compared to the current population of a foodshed. Though the land requirements for all food groups were calculated, the key variables in the New York study were meat and fat intake. Diets tested in the New York study were meant to meet the caloric and nutritional needs of the average American and reflect a wide range of eating habits- from lacto-vegetarian to high-meat omnivorous and low to high fat intakes. Caloric intake was held constant at 2308 kcal/day, while meat intakes ranged from 0 to 381 grams/day (0 to 12 ounces/day) of meat products and fat intakes ranged from 52 to 117 grams/day (20 to 40 percent of total daily calories). Remaining nutrient and caloric needs were met by other food groups as recommended by the USDA Food Pyramid.

The complete-diet methods presented in the New York study have been replicated in other studies from many other regions of the United States and at various scales. One study uses the state of Iowa as a foodshed but also includes data from seven nearby states the researchers determined as having a significant impact on Iowan consumption (Hu et al. 2011). Another study based out of Oregon confines its analysis to the ten counties of the Willamette Valley (Giombolini et al. 2010).

These more recent applications of the complete-diet approach are situated within study areas that are predominantly rural and do not have to accommodate one of the largest metropolitan areas in the nation as did the New York study. In this way, these more recent iterations of the complete-diet approach provide evidence of its the suitability to a rural foodshed such as the south-central Appalachian foodshed in this study. This framework is used in this study due to its flexibility to suit different assumptions, contexts, and definitions of local food or foodsheds.

Methods

This study adapts methods from these previous studies in order to accommodate the climate, population, topography, and other biophysical factors affecting food production in the south-central Appalachian foodshed. Following the complete diet approach, six unique diets were created in a spreadsheet model using the parameters listed in Table 2. These diets reflect the complete-diet needs of the average, moderately active adult person and contain the same amount of daily energy (calories) while varying in intakes of animal products and total fat.

Though diets are affected by weight, gender and age, this analysis aggregates average dietary needs for the population, as we are aiming to look at total land requirements. Previous research has shown little value in separating diet needs of various population cohorts when only considering the total land demand (Peters et al. 2003; Desjardins et al. 2010; Hu et al. 2011; Kantor 1998). Diets in this study represent a wide range of eating habits, from those rich in animal products to those completely free of animal products to those with recommended fat intake to those rich in fat. The model then tests the relationship between animal product and fat intake and agricultural land requirement on the number of people that can be fed from within the foodshed.

Table 2. Assumptions and parameters for diet treatments.

Parameter	Assumption/treatment
Meat	0-190 g/day (0-8 oz/day)
Fat	25% and 40% total calories from fat/day
Protein	6.6-10 equivalents/day[3]
Energy	2308 kcal/day
Geography	Excludes all foods that cannot be produced in the Appalachian Foodshed
Seasonality	Assumes seasonal limitations on fruits and vegetables
Nutrition	Meets USDA MyPlate recommendations where possible: • Grains, vegetables, fruits meet or exceed recommendations (unless daily kcal limit would be exceeded) • Dairy meets recommendations except for two animal product-free diets • Protein meets or exceeds recommendations • Sugar added to diets to meet daily kcal limit • 25% and and 40% daily kcal from fat tested
Food preferences	Relative preferences for specific food items within a food group is based on ratios derived from national intake data, as regional intake data unavailable for the Appalachian Foodshed
Fat sources	Contain a mixture of regular and reduced fat foods • Diets with recommended fat intake (25% kcal/day from fat) contain more skim milk and lean meats • Diets with higher fat intake (40% kcal/day from fat) contain more whole milk and regular meats with additional added fats to meet treatment limit

The diet types are composed of servings of food items within seven overarching food groups: grains, vegetables, fruits, protein foods (meat, eggs, pulses, nuts and seeds), dairy, added fats and added sugars (Table 2). Since the publication of the original New York study, updated dietary recommendations have been released. This study uses the MyPlate recommendations based of the 2010 Dietary Guidelines for Americans, the most recent version available upon publication. As with the Food Pyramid, the MyPlate recommendations outline general guidelines for creating balanced daily meals. Key

[3] According to the USDA MyPlate web site: "In general, 1 ounce of meat, poultry or fish, ¼ cup cooked beans, 1 egg, 1 tablespoon of peanut butter, or ½ ounce of nuts or seeds can be considered as 1 ounce equivalent from the Protein Foods Group." See Web site http://www.choosemyplate.gov/food-groups/protein-foods-counts.html.

differences from the Food Pyramid include increased servings for fruits and vegetables and fewer servings of grains. The MyPlate guidelines also recommend that consumers meet at least half of daily grain servings with whole grains, obtain meat and dairy requirements with a mix of whole and low fat varieties, and to select a variety of protein foods (USDA and USDHHS 2010). There is also a lacto-vegetarian version of the MyPlate recommendations available, but not a completely animal product-free version. The diets tested in this study use the MyPlate recommendations as a baseline for nutritional requirements and health.

This study follows the complete-diet framework presented by Peters et al. (2007), but differs on several accounts. Firstly, the New York study tests the influence of two key variables on land requirements: meat and fat. However, the overall influence of individual animal products such as dairy, eggs and animal fats are not discussed along with meat. These food items are important foods in the south-central Appalachian foodshed and like meat require significant land and resource inputs (Delgado et al. 2001). A complete-diet model concerned with measuring the land demands of different diets must consider not only the land requirements of meat, but animal products more broadly. This paper uses the term animal products to refer to all meat, dairy, eggs and animal-based fats. Therefore, this study expands upon the New York study by varying overall animal product intake and fat intake.

Secondly, the New York researchers state that the model was designed with the purpose of estimating the land requirements of diets sourced from entirely within the geographic bounds of a foodshed. However, their inclusion of sugarbeet and canola does not meet this parameter. Moreover, their exclusion of animal-based fats in the diet design is notable. Researchers in the New York study chose to include sugarbeet as their sole source of added sugars and canola oil as one of the sources of added fats in all diets tested despite the fact that these food commodities are not suited for production in New York State (Peters et al. 2007). A foodshed analysis must consider regionally-adapted crops available to include in the diets of the population.

This study of the south-central Appalachian foodshed only includes crops that are regionally adapted for production in the region based on productive yields and frost dates in order to get the most realistic land requirements possible. Table 3 provides a complete list of food commodities included in the spreadsheet model. Crops such as sugarbeets and canola are excluded from this model as they are also not well-suited for production in this study area either. Instead, corn syrup and honey are used as added sweeteners in the diets. The New York study fills all added fat servings with plant-based oils with the implication that portions of animal fats are wasted by the food system. This study includes animal-based fats (butter, lard, chicken fat, beef tallow) in the model in addition to a regionally-suited plant-based oil (soybean oil), with added fat servings being met by a mixture of plant and animal-based sources for all diets except the animal product-free diets. Added fat servings for these animal product-free diets were derived solely from plant-based oils.

Table 3. Foods included in the design of Appalachian diets, by food group.

Food group	Food crops
Grains	Corn meal, oats, rye flour, wheat flour
Vegetables	Asparagus, broccoli, cabbage, carrots, cauliflower, collard greens, cucumbers, eggplant, green beans, green peas, kale, lima beans, onions, peppers, potatoes, romaine lettuce, spinach, summer squash, sweet corn, sweet potatoes, tomatoes, winter squash and pumpkin
Fruits	Apples, blackberries, blueberries, cantaloupes, cherries, grapes, honeydew melons, nectarines, peaches, pears, raspberries, strawberries, watermelons
Dairy	Skim and whole milk
Protein foods	Dry beans, eggs, regular and lean chicken, regular and lean beef, regular and lean pork, soybeans (tofu), sunflower seeds
Added fats	Beef tallow, butter, chicken fat, lard, soybean oil
Added sugars	Corn syrup, honey

In the same vein, forage and feed rations for beef cattle were adjusted from those used in the New York study and met with a more regionally-suited mix of grass hay, and pasture. Dairy cattle feed and forage requirements were designed to reflect the more southerly climate by including less alfalfa than in the New York study and instead making use of more fescue, orchardgrass hay, and pasture as per regional recommendations and farm budgets.

Thirdly, if a regional population is reliant on regionally-adapted crops, seasonality is a necessary consideration. The complete diet approach assumes that regionally adapted crops are harvested and brought to market at different times throughout the year and that some of these crops must be consumed fresh (i.e. lettuce), while others may be stored or processed for use throughout the year (i.e. frozen or canned peaches). Following the methods of Peters et al. (2007), annual diets were broken down into crops available during the summer and winter months. For the study area, the duration of the ‘summer’ diet is extended in this model to account for the more southerly climate. The spreadsheet model assumed a seven month ‘summer diet’ and a five month ‘winter diet.’ This allowed fruits and vegetables that were only available fresh to be included in summer diets and excluded fruits and vegetables that were not available fresh in winter, adjusting the nutritional content for various processing methods needed for storage during the winter months (i.e. freezing, cold storage, canning). The division of the fruit and vegetable food groups into summer and winter diets is highlighted in Table 4.

An implicit assumption of this approach is that there is adequate storage and processing capacity readily available within the foodshed. A more detailed investigation of the impacts of seasonality on regional production will be considered in Chapter 3. As most of the harvest of regional foods occurs during the summer months, only processed and storable foods were included in the model during the winter months (Table 4).

Table 4. Assignment of vegetable and fruit food group products to seasonal availability classes.

Food group	**Summer, 7-months (fresh products)**	**Winter, 5 months (fresh or stored)**
Vegetable	Asparagus, broccoli, cabbage, carrots, cauliflower, collard greens cucumbers, eggplant, green beans, green peas, kale, lima beans, onions, peppers, potatoes, romaine lettuce, spinach, summer squash, sweet corn, sweet potatoes, tomatoes, winter squash and pumpkin	Frozen broccoli, fresh cabbage, frozen carrots, frozen cauliflower, fresh collard greens, canned and frozen green beans, fresh kale, canned lima beans, onions, canned and frozen green peas, fresh potatoes, frozen spinach, canned and frozen sweet corn, fresh sweet potatoes, canned tomatoes, fresh winter squash and pumpkin
Fruit	Apples (fresh and juice), blackberries, blueberries, cantaloupes, cherries, grapes (juice), honeydew melons, nectarines, peaches, pears, raspberries, strawberries, watermelons	Apples (fresh and juice), frozen blackberries, frozen blueberries, frozen cherries, grapes (juice), canned peaches, fresh pears, frozen raspberries, frozen strawberries

Design of diets

A spreadsheet model was used to design six unique diet types varying in animal product and fat intake. First, 48 food crops and 5 animal products suited for production within the study area were selected to develop the diets (Table 2). Second, to ensure compliance with complete-diet nutritional standards, nutritional information for each of these selected food commodities included in the six diet types were collected from the Nutrient Database for Standard Reference (USDA 2013). This data source lists standardized amounts of calories, fat, energy density, and serving weights for each food. Changes in serving weights and nutritive value due to the preparation technique of each food were accounted for to represent the standard values of the prepared food on the plate of the average consumer given the average food product of interest (Peters 2007).

Third, in order to account for the fact that not all servings of any one food group will be met equally by all included food commodities, consumer relative preference values were created. There was no regional source of data describing the breakdown of relative preferences of specific food items within each food group and subgroup for south-central Appalachian consumers. Therefore, according to methods presented by Peters et al. (2007), preference ratios were calculated for each food commodity using nationally-representative loss-adjusted food availability amounts from the USDA Food consumption (per capita) data system (USDA 2012). This data source provides the total weight of over 250 plant and animal food items available in the national food system divided out on a per capita basis after accounting for exports and other standardized demand considerations. This data is commonly used by agronomists and food system researchers as representative of domestic consumer demand for different foods (Desjardins et al. 2010; Giombolini et al. 2010; Hu et al. 2011; Peters et al. 2007; USDA 2012). The per capita weight available for each regionally-adapted food item included were recorded and used to calculate ratios of consumer preferences of each food item within their given food group or subgroup. These ratios were then converted into percentages to represent the consumer preference of each food item in order to assign servings of each specific food item within each food group and subgroup.

For fat intake, the Dietary Guidelines for Americans recommends 25% of total daily energy coming from fat and gives 30% of total daily energy from fat as an upper bound. However, the average American exceeds recommended fat intake, with 41% of daily calories coming from fat (Peters et al. 2007). For animal product intake, the USDA MyPlate guidelines recommend 6-7 daily protein ounce-equivalents that are derived from a variety of sources- meat, eggs, pulses, nuts and seeds. The MyPlate diet for this calorie range recommends that only 2-3 of these protein ounce-equivalents come from meat and eggs. For the caloric range tested, the MyPlate guidelines recommend three servings of dairy. Table 5 lists food group servings for each diet type.

Table 5. Daily Servings of food from food groups and selected food subgroups, by diet type[4].

	Diet type					
Food group	**AFR**	**AR**	**FR**	**MP**	**FRV**	**V**
	-------------------------------*servings*---------------------------------					
--						
Grain	8.7	8.7	8	9	9.4	9.5
Vegetable	3	3	3	5	6.1	6.1
Fruit	2	2	2.5	4	5	5
Dairy (skim)	1	3	0	1.5	0	0
Dairy (whole)	3	2	3	1.5	0	0
Pulses & seeds	0	0	1.5	2	6.6	6.6
Lean meat	3	5	0	2	0	0
Regular meat	5	3	3.1	1.1	0	0
Eggs	2	2	1.5	1.5	0	0
Fats	2.6	0.6	3.7	1.8	6	3.06
Sugars	1.29	4.2	14.65	7.17	6.6	9.18
	---------------------------------*g/day*----------------------------------					
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Animal products	290	290	138	138	0	0
Fat	104	65	104	65	104	65

To design the diets for this study, a diet was created that followed the recommended MyPlate guidelines, with other treatments ranging from meat intake of 0 to 63 g/day (0 to

[4] MP= MyPlate diet, AR= Animal product-rich diet, FR= Fat-rich diet, AFR= Animal product- and fat-rich diet, FRV= Fat-rich and animal product-free diet, V= Animal product-free diet. See text for details.

8 oz/per day) and intervals of 0, 138 and 290 g/day of total animal product intake. For total fat, intakes ranged from the recommended amount of 25% to 40% of total daily calories per day following the methods of Peters et al. (2007). First, the allotted treatment of animal products was assigned to each diet type. Second, servings of each food group were determined by prescribing the minimum amount of recommended servings of plant products. Added fats were included only as needed to bring each diet to the target value of overall fat intake. Added sugars were included only as needed to bring diets to the target caloric content of 2308 kcal/day. Table 6 details the diet design process.

Table 6. Designing six complete diets to test in the model.

1. MyPlate diet (**MP**): Contains recommended levels of fat (25% kcal/day from fat) and recommended protein food servings. Derives recommended protein food servings ,and eggs. Contains recommended dairy servings split between whole and skim options. Contains added fat servings derived from both animal and plant sources of fat. Contains foods from all food groups.

2. Animal product-rich diet (**AR**): Contains recommended levels of fat (25% kacal/day from fat) and exceeds recommended protein food servings. Derives protein food servings entirely from animal sources: meat and eggs. Contains dairy servings split between whole and skim options. Contains added fat servings derived from both animal and plant sources of fat. Contains foods from all food groups but excludes the pulses and seeds subgroup of the protein foods.

3. Fat-rich diet (**FR**): Exceeds recommended levels of fat (40% kcal/day from fat) and contains recommended protein food servings. Derives recommended protein food servings between animal and plant sources of protein: regular cuts of meat, pulses, seeds, and eggs. Contains recommended dairy servings derived entirely from whole milk. Contains added fat servings derived from both animal and plant sources of fat. Contains foods from all food groups but excludes the skim subgroup of the dairy foods and the lean meat subgroup of the protein foods.

4. Animal product- and fat-rich diet (**AFR**): Exceeds recommended levels of fat (40%kcal/day from fat) and exceeds recommended protein food servings. Derives protein food servings entirely from animal sources: regular and lean cuts of meat and eggs. Contains dairy servings split between whole and skim potions. Contains added fat servings derived from both animal and plant sources of fat. Contains foods from all food groups but excludes the pulses and seeds subgroup of the protein foods.

5. Fat-rich and animal product-free vegan (**FRV**): Exceeds recommended levels of fat (40%kcal/day from fat) and contains recommended protein food servings. Derives recommended protein food servings entirely from plant sources: pulses and seeds. Contains no meat, eggs, dairy or animal-based fats. Added fat servings derived entirely from plant sources of fat.

6. Animal product-free vegan (**V**): Contains recommended levels of fat (25% kcal/day from fat) and recommended protein food servings. Derives recommended protein food servings entirely from plant sources: pulses and seeds. Contains no meet, eggs, dairy or animal-based fats. Added fat servings derived entirely from plant sources of fats.

Calculating food need "on the plate" and "at the farm-gate"

The diet types give us daily per capita food needs of both plant and animal products in terms of servings of food groups and subgroups, which can then be converted into total annual weight of specific food items needed to meet this demand, or weight of food "on the plate" (Eqn. 1). The annual per capita food need "on the plate" (*P*) of each plant or animal food item (*i*) by diet type (*d*) is the product of the number of annual servings (*S*) of each food group or subgroup (*g*) prescribed to each diet type, the relative consumer preference (*C*) of each food item within each food group or subgroup, and the weight (*W*) of a single serving of each food item in grams.

[Eqn. 1] $P_{di} = S_{gd} \times C_{ig} \times W_i$

This annual consumer demand of specific food items was next used to calculate the total annual weight needed by agricultural commodities "at the farm gate" after accounting for losses throughout the stages of processing, distribution, retail, purchasing and cooking of the items (Eqn. 2a-b). Two separate equations for plant and animal food products are included to account for the additional need of supporting crops consumed by livestock.

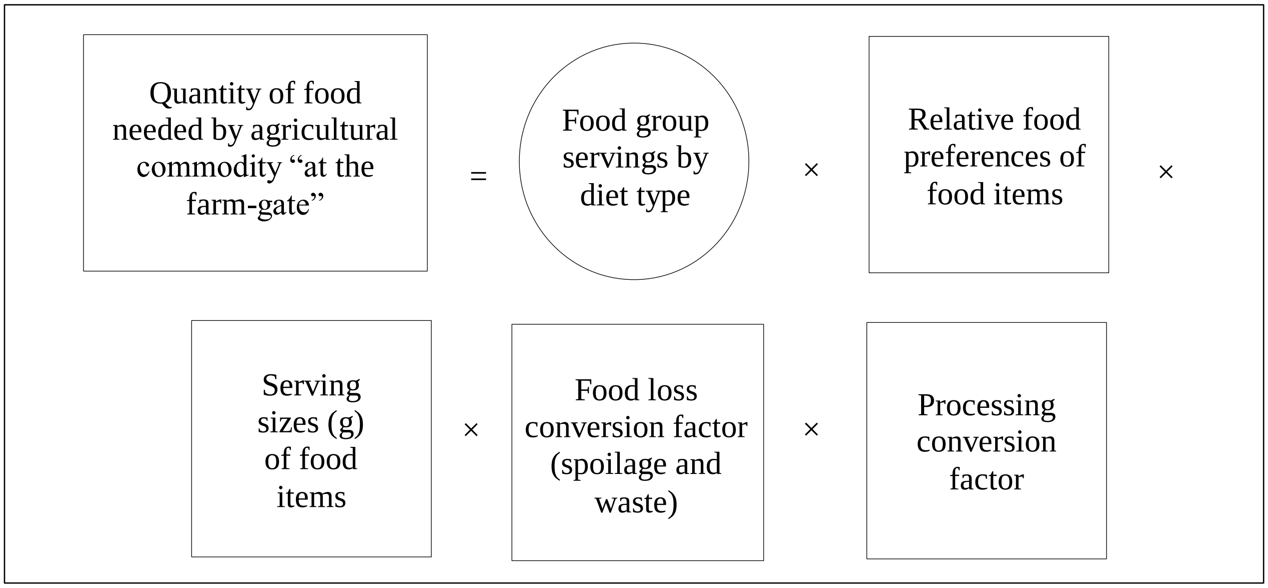
The annual per capita weight of farm product (*F*) for each plant (*v*) or animal (*j*) food item required by diet type is the product of the weight "on the plate" of each item by diet type, a loss conversion factor (*L*) to account for food waste and spoilage of each item throughout the food chain, a processing conversion factor (*G*) to account for weight gain or loss due to processing of each item, and for animal food items (dairy, meats, and animal-based fats) feed and forage requirements (*R*) for each ingredient (*k*) in the ration to determine the annual per capita weight of feed grains, silage, hay, and pasture needed. This results in the total annual weight needed of 54 agricultural commodities (food commodities, feed crops, and pasture land). Figure 4 summarizes this process.

[Eqn. 2a] $F_{vd} = P_{vd} \times L_v \times G_{vf}$

[Eqn. 2b] $F_{jd} = P_{jd} \times L_j \times G_{jf} \times R_{jk}$

Standardized amounts of losses from primary weight to retail weight, retail loss, cooking loss, inedible portions of the foods and foodservice and consumer losses published by the USDA were used in accordance to the methods of Peters et al. (2007). These food loss figures take into account each preparation type of the specific foods, whether they are canned, frozen, fresh or otherwise stored (Kantor 1998; USDA 1992).

Figure 4. Simplified diagram of complete-diet procedure to calculate per capita food needs for the south-central Appalachian foodshed. Adapted from Peters 2007.[1]



1- Quantity of food needed by agricultural commodity "at the farm-gate" relates to Eqn. 2a and Eqn. 2b. Food group servings by diet type, relative food preferences of food items, serving sizes of food items, food loss conversion factor, and processing conversion factor relate to Eqn. 1. See text for details.

Calculating land requirements

The previous steps determined the quantity of each food and agricultural commodity needed by diet type. Annual per capita food production need of each commodity (weight "at the farm-gate") and regional crop yields were used to calculate the land requirements of annual (Eqn. 3a) and perennial (Eqn. 3b) crops by diet type. Land requirements for animal products include only land used to raise supporting feed and forage crops and not any other uses. The area (*D*) per capita of annual (*a*), perennial (*p*) crops, and total (*t*) crops for each diet (*d*) was calculated as the sum of land required for all plant and animal food crops by each and across land use types. Land demand by food item was calculated as the production weight required "at the farm-gate" (*F*) for each food item (*i*) divided by its yield (*Y*).

[Eqn. 3a] $D_{ad} = \sum(F_a / Y_a)$

[Eqn. 3b] $D_{pd} = \sum(F_p / Y_p)$

[Eqn. 3c] $D_{td} = D_{ad} + D_{pd}$

Within the study region, annual yield estimates on agricultural food commodities are only available for a handful of commodity crops, whereas detailed numbers on horticultural fruit and vegetable production are not regularly reported in a consistent manner. This research therefore relies on existing yield data where reported and filled in the gaps using data from nearby geographies or expert estimates (Straw 2014). For this analysis we assume production under good agricultural management on average productivity soils (Donahue et al. 1994). A more detailed geospatial analysis including soil productivity is reported separately.

Current agricultural land use

Land requirements were next compared to available arable land in the foodshed. Land use data from the 2007 and 2012 USDA Census of Agriculture (2014) was used to calculate hectares of total land in farms, cropland, pastureland, and woodland (Table 7). Following the methods of Peters et al. (2007), these categories of land use were used to determine land use limits for the spreadsheet model.

Table 7. Comparing actual agricultural land use in south-central Appalachia with land use limits.

Land use[1]	**Land area (ha)**		
	2007	**2012**	**Average**
Actual land use			
Cropland	869,351	769,640	819,496
Harvested Cropland	624,622	659,471	642,047
Field crops	598,731	629,607	614,169
Hay and haylage	505,507	515,723	510,615
Cereals, beans, potatoes[2]	86,928	108,312	97,620
Other field crops[3]	6,296	5,572	5,934
Vegetable crops, total	883	839	861
Fruit crops, total	4,744	3,688	4,216
Pastured cropland, total	1,404	736	1,070
Idle cropland, total[4]	50,360	47,257	48,808
Other cropland, total	192,965	62,175	127,570
Pastureland, total	1,450,282	1,411,022	1,430,652
Permanent pasture	175,077	50,165	112,621
Non-permanent pasture	1,275,205	1,360,857	1,318,031
Woodland, total	1,044,995	1,082,110	1,063,553
Non-pastured woodland	727,543	777,301	752,422
Pastured woodland	314,879	302,446	308,663
Other lands[5]	68,740	157,528	113,134
Total land in farms	3,433,368	3,420,300	3,426,834
Land use limits in model[6]			
Productive land available	2,391,187	2,373,676	2,382,432
Usable for any crop	644,406	639,687	642,047
Limited to perennial crops or pasture	1,746,781	1,733,989	1,740,385

1- Values and categories of actual land use from the 2007 and 2012 USDA National Agricultural Statistics Service Census of Agriculture (USDA 2014).
2- Includes corn silage.
3- Residual value after accounting for hay, cereals, beans, and potatoes. Includes haylage and greenchop.
4- Includes land in cover and soil-improvement crops, unplanted cropland, and cropland enrolled in the Federal Conservation Reserve Program (CRP) and Wetland Reserve Program (WRP). Model assumes that some cropland is idle each year for soil management and economic management.
5- Includes land in house lots, water cover (ponds, rivers, streams, etc.), roads, waste, etc.
6- Assumes that all harvested or pastured cropland and all permanent pasture are available for productive use. For soil management and economic reasons, it is assumed that some cropland is in perennial crop or pasture production at any given time. Proportion of land limited to production of perennial crops or pasture is based on the current ratio of pastured cropland, pastureland, and pastured woodland to the total of harvested cropland and all pastureland (73.1%).

Average figures for land categories were taken from the 2007 and 2012 censuses, the two most recent available at the time of publication. The model assumes that this average value of annual and perennial land represents a reasonable use of available south-central Appalachian cropland. There is a total of 2,391,187 ha of productive land available, which is the sum of all harvested cropland, pastured cropland and woodland, and all pastureland. Based on the average distribution of annual and perennial crops, of the total productive land, 1746781 ha is limited to perennial or pasture production and 644406 ha is usable for any crop.

Calculating food biocapacity

The number of people sustained by the foodshed's agricultural land base describes the food biocapacity. Following the methods of Peters et al. (2007), the annual per capita land requirements and land use data were used to determine if there was a limiting class of land to overall agricultural carrying capacity. Holding diet type (d) constant, a conditional If/Then statement was created to calculate the population fed by each of the six diets tested (Eqn. 4).

[Eqn. 4] $$C = \text{If } \{(D_a/D_t > L_a/L_t), (L_a/D_a), \text{ if } [D_p/D_t > L_p/L_t), (L_p/D_p), (L_t/D_t)\}$$

The biocapacity was calculated as the agricultural carrying capacity (*C*) to compare land requirements by diet (*D*) for annual (*a*), perennial (*p*), and total land for all land types (*t*) to land available (*L*) in each class. Agricultural carrying capacity in this equation is either limited by the capacity of regional lands to produce either annual or perennial crops if the entire population were to follow one of the six diet types designed for this study. It is assumed that no land conversion can occur between the land use categories used as limits in the model.

Results

Land requirements per capita

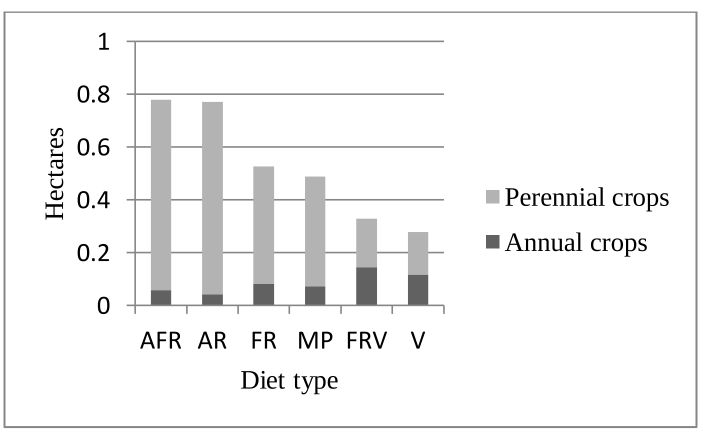
The complete diet model uses the food need of specific crops determined by diet type, regional crop yields, and regional livestock feed rations to calculate annual per capita land requirements. The six diet types exhibited almost a fivefold difference in land requirements per capita. Table 8 breaks down the total land requirements of each diet. Average annual per capita land requirements ranged from 0.16 ha (0 g animal products, 64 g fat) to 0.73 (227 g animal products, 64 g fat). Increases in animal product intake correlated with higher land requirements. Increases in fat, however, intake did not always correlate with higher land demands. The proportion of land in perennial crops increased with animal product intake (Fig. 5).

Per capita, there are 0.55 ha (1.36 acres) of total current productive land in the foodshed. The animal product-rich diets (AFR and AR diets) exceed this total land demand and are therefore limited by the regional food biocapacity.

Table 8. Model output: Total annual per capita land requirements by diet type.

Diet type[5]	Hectares (acres) of annual cropland required	Hectares (acres) of perennial cropland required	Hectares (acres) of total productive land required
AFR	0.058 (0.14)	0.663 (1.64)	0.721 (1.78)
AR	0.042 (0.10)	0.686 (1.69)	0.728 (1.8)
FR	0.082 (0.20)	0.363 (0.90)	0.445 (1.1)
MP	0.073 (0.18)	0.342 (0.85)	0.415 (1.02)
FRV	0.144 (0.36)	0.040 (0.10)	0.184 (0.46)
V	0.116 (0.26)	0.047 (0.12)	0.163 (0.4)

Figures 5. Annual per capita land requirements of annual and perennial crops by diet type.



[5] MP= MyPlate diet, AR= Animal product-rich diet, FR= Fat-rich diet, AFR= Animal product- and fat-rich diet, FRV= Fat-rich vegan diet, V= Vegan diet. See text for details.

Land requirements by food

The required area of agricultural land was calculated for each agricultural commodity. Table 9 displays this land requirement for different types of food on a caloric basis, illustrating how much land is needed to produce a unit of energy in the edible portions of each crop. Results ranged from 0.9 m^2Mcal^{-1} (grains) to 68 m^2Mcal^{-1} (lean beef). Plant-based sources of proteins (pulses and seeds) and plant-based sources of fat (plant oils) required 1.3 and 2.6 times as much land per unit of edible energy as grains respectively. Due to the high land requirement of feed and forage crops, beef required 73.3 times as much land per unit of edible energy as grains. Chicken required the least amount of land among all meat products, while eggs and whole milk required the least among all animal products overall.

Table 9. Land requirements per unit edible energy for selected foods and food groups based on crop yields in the south-central Appalachian foodshed.

Food	Land requirement
Animal products[1]	*(m^2Mcal^{-1} edible product)*
Meat & eggs	
Beef, lean cuts	68.0
Beef, all cuts	38.7
Chicken, lean cuts	11.3
Chicken, all cuts	6.8
Eggs	5.2
Pork, lean cuts	14.3
Pork, all cuts	15.6
Animal fats[2]	13.9
Dairy	
Milk, skim	7.7
Milk, whole	4.2
Plant products[3]	
Fruits	2.1
Grains	0.9
Plant oils	2.4
Pulses[4] and seeds	1.2
Sugar	4.5
Vegetables	3.0

1- Assumes the following rations for each class of livestock: Beef cattle require 1.26 ha pasture, 5.4 Mg grass hay, 1.77 Mg corn grain, 3.06 Mg corn silage, and 138.2 kg soy per animal to reach market weight of 545.2 kg (1202 lbs). Value includes feed requirements of all supporting cattle and calves needed to bring one animal to market. Hog (pork) ration is 70% corn grain, 23% soy, 7% mineral supplements, requiring

309.5 kg corn grain and 101.7 kg soy per animal to reach market weight of 113.4 kg (250 lbs). Value includes feed requirements of all feeder pigs, sows, boars and piglets needed to bring one animal to market. Broiler chicken ration is 60% corn grain, 35% soy, 5% mineral supplements, requiring 140.4 kg corn grain and 46.1 kg soy per animal to reach market weight of 2.27 kg (5 lbs). Value includes feed requirements for all pullets, hens, roosters and chicks needed to bring one animal to market. Layer chicken (eggs) ration is 60% corn grain, 30% soy, 10% mineral supplements, requiring 27.5 kg corn grain and 13.7 kg soy per animal to produce 300 eggs for market. Dairy cattle require 0.51 ha pasture, 2.97 Mg alfalfa hay, 1.43 Mg orchardgrass hay, 2.03 Mg corn grain, 15.1 Mg corn silage, and 1.2634 Mg soy per animal for 9.53 Mg (21000 lbs) fluid milk production.
2- Weighted average based on animal fats included in the model.
3- Weighted average based on the crops included in the model.
4- Pulses are leguminous crops such as beans harvested for dry seed. Pulses do not include crops harvested for fresh seed (green beans and peas) or oil production (soybeans).

Regional land requirements and food biocapacity

The annual per capita land requirements for each diet type were compared to land use limits in the model and the total population to determine an agricultural carrying capacity for the south-central Appalachian foodshed. The different annual per capita annual and perennial land requirements of each diet reveal different demands on the total productive land available. Classification of land use into annual and perennial production determined whether one of these land categories was limiting to production and thus to the regional agricultural carrying capacity for each diet type (Table 10). Figure 6 displays the carrying capacity, or the number of people fed by each diet type in the south-central Appalachian foodshed based on the complete diet model output.

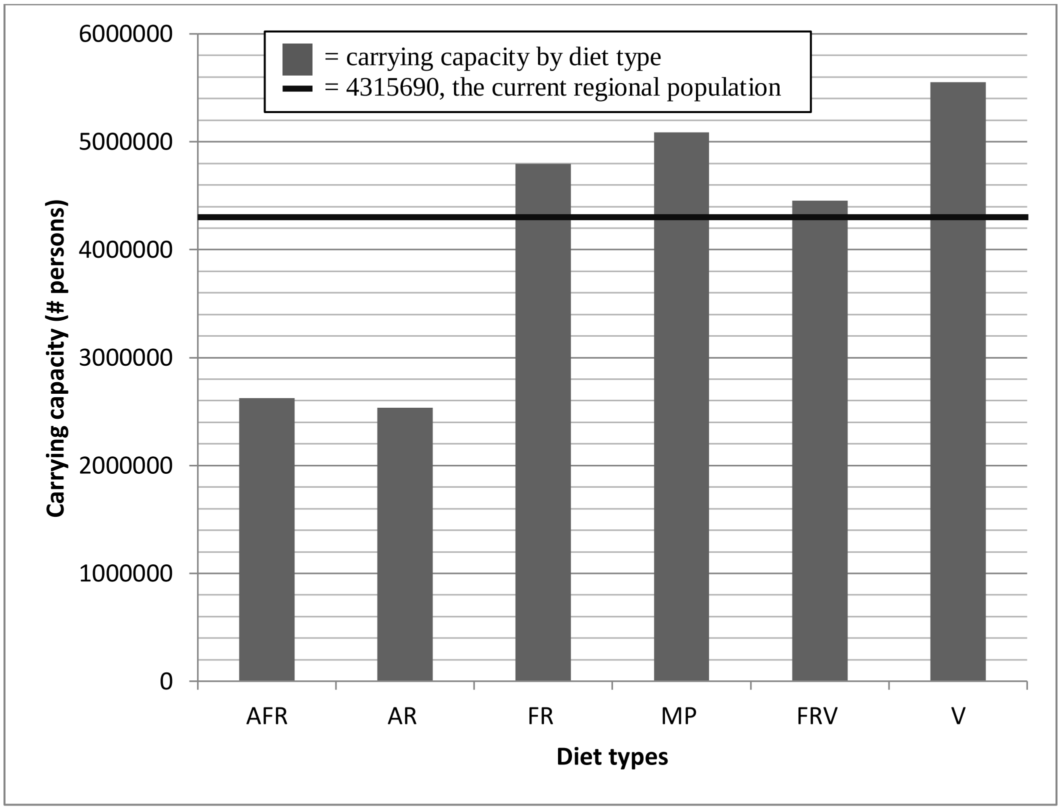
Though the model shows around a fivefold difference in total land requirements among the six diet types tested, it reveals only slightly over a twofold difference in the total human population supported by the south-central Appalachian foodshed.

Table 10. Estimated agricultural carrying capacity (C) of the south-central Appalachian foodshed by diet type.

Diet type	C	$(D_a/D_t):(L_a/L_t)$	$(D_p/D_t):(L_p/L_t)$	Limiting crop type[1]
AFR	2626108	0.30	1.26	Perennial
AR	2537383	0.22	1.29	Perennial
FR	4793449	0.68	1.12	Perennial
MP	5087794	0.65	1.13	Perennial
FRV	4455357	2.90	0.30	Annual
V	5551814	2.64	0.40	Annual

1- Limiting crop type to human carrying capacity assuming total regional population follows given diet type. Spreadsheet model assumes no land conversion between annual and perennial cropland (Peters et al. 2007).

Figure 6. Comparing estimated agricultural carrying capacity (food biocapacity) of six diet types in the south-central Appalachian foodshed[1] to current population[2].



1- Based on average estimated crop yields with good management practices (Straw 2014).

2- USDA Census Bureau, American Community Survey 5-Year Estimates (2008-2012).

Discussion and Conclusions

Animal product intake did not consistently relate to overall regional food biocapacity. The diets exceeding USDA daily intake recommendations of meat, fat, dairy, and animal fats (AFR and AR diet types) have the highest land requirements due to their increased demand for supplemental livestock feed and forage crops. This is in many ways expected, but a more complicated picture emerges when comparing the agricultural carrying capacities of the diet types receiving the recommended treatment amount of 138 g/day of animal products (FR and MP diet types) to those receiving no animal products and deriving all protein equivalents from plant sources (FRV and V diet types). While the V diet type does estimate the highest agricultural carrying capacity of all tested diets, both the FR and MP diet types estimate higher carrying capacities than that of the FRV diet.

While this may seem counterintuitive, this is a result of the limited annual cropland in the study area by land use type. The FRV diet requires higher amounts of plant-based oils which are relatively land intensive on a $m^2 Mcal^{-1}$ edible product basis. Therefore, as this model assumes no land use conversion, the FR and MP diets are able to support a higher regional population than the FRV due to the fact that they are not limited by annual cropland but rather by perennial cropland which is more abundant in the foodshed. As in the New York study, the influence of fat intake on south-central Appalachian land requirements appears to vary with animal product intake.

These findings relate to those found in other complete diet studies, including the seminal New York example, which found an overall trend of increased land requirement for meat-rich diets (Peters et al. 2007; Hu et al. 2011; Delgado et al. 2001; Desjardins 2010; Giombolini 2010). However, interpreting the relevance of these land requirements is complicated by their overall influence on regional agricultural carrying capacity, which is uniquely constrained by land use in south-central Appalachia. This study does not conclude that increased animal product intake consistently limits human carrying capacity, but rather is a complex interaction between regional biocapacity and land availability.

The animal product-rich (AR) diet stood out as the highest land demand of all diets, surpassing even that of the both animal product- and fat-rich (AFR) diet type. This is explained by the way total daily fat intake was a determined as the sum of the fat content of each grain, vegetable, fruit, protein, and dairy food items along with the supplementation of added fats. For the diets containing animal products, added fats were derived from both animal and plant sources. The high fat treatments that included animal products (diets AFR and FR) were assigned more regular cuts of meat and whole fat dairy before including added fats to bring each diet to its prescribed treatment of overall daily fat intake. The AFR and FR diets assumed that the fat content of included meat and dairy foods were not wasted by the food system in the same way that the diets depending on lean cuts of meat and skim dairy products (diets AR and MP).

Therefore, the higher land demand of the AR when compared to the AFR diet can be explained by the more efficient use of land resources for the fat sources included in the diets. This reasoning does not hold for the animal product-free (FRV and V) diets. While total daily fat intake is determined in the same way, these diet types contain no cuts of meat or dairy products and contain no animal-based sources of added fats. Only plant-based added fats were included (soybean oil) in the FRV and V diets. Therefore, the FRV diet has a higher per capita land requirement and lower regional carrying capacity than that of the V diet. This is explained by the results in Table 8, showing the higher land requirements per unit of energy of edible product of plant-based added fats (2.4 m^2Mcal^{-1}) compared to grains (0.9 m^2Mcal^{-1}) , pulses and seeds (1.2 m^2Mcal^{-1}), and fruits (2.1 m^2Mcal^{-1}). This highlights one of many challenges embedded in regional food systems attempting to align healthy diets with regional land resources.

This model tests the upper thresholds of what is possible as far as how regional resources align with dietary demand. It assumes that all agricultural lands are used for food system uses, when in reality they might be put to other uses. In particular, the assumption that all animal products consumed by the regional population would be raised consuming only food rations produced on regional lands through their entire life cycle is most certainly unrealistic. Currently, most supplemental grains for livestock are imported to the region or else stocker animals are sold and exported to feed lots outside this foodshed. The Appalachian Foodshed can clearly support more people on diets with fewer or no animal products; however, certain lands are limited to perennial and pasture production, making them well-suited grazing or pastureland. Reduced animal production on such lands would limit land use to non-provisioning services, or if converted to annual crop production, have serious environmental impacts, especially erosion. Perennial food crops such as berries and orchard crops could be successful on lands limited to perennial and pasture production. However, there are many other economic and cultural reasons why a complete conversion of these lands is unlikely. Beef cattle production is a dominant component of the agricultural economy of the foodshed and there is a strong market for these animal products. Converting these lands to perennial food crops would be more likely due to consumer dietary modification and reduced demand for animal products. However, this is the province of nutrition educators and policy makers. The MyPlate recommendations do not give suggestions for animal product-free diets, reflecting the marginalized position of completely animal product-free diets in terms of realistic dietary patterns held by the majority of Americans. However, this study sought to test the extremes as well as the typical and recommended diet types in terms of their overall impact on regional land requirements and agricultural carrying capacity. If land limited to perennial or pasture production is not fully converted from livestock agriculture, the productivity of these lands, though limited, would be wasted in terms of supporting human nutrition if not included in the food system.

This study concludes that diets exceeding recommended amounts of animal product intakes were found to support a population below current levels, whereas all other diets (MP, FR, FRV, and V) have an agricultural carrying capacity above that of the current foodshed population. A regionally-based food system could maximize community food security by fully utilizing all of the 1746781 ha of land limited to pasture and perennial forages for animal product production to support human nutrition and diets with moderate amounts of meat and animal products. While productive land is limited in the Appalachian Foodshed, it is not a complete enough picture to simply say that all diets with animal products decrease overall community food security, when these food items clearly make use of more marginal lands. Not all diet types tested are limited by annual cropland requirements and are rather limited by the availability of perennial cropland and pastureland. The potential for the south-central Appalachian foodshed to meet all food needs for balanced, healthy diets for a population that exceeds current totals is a hopeful insight for producers and consumers invested in building regional food economies, enhancing food security, and improving regional health.

One limitation of this complete-diet study is that it does not specifically consider the place-based differences in soil productivity throughout the region but instead relies on yield estimates based on average soil productivity. Chapter 3 uses the estimates of this complete-diet model to further observe the impacts of soil productivity on the production potential of the foodshed in a geographic information system (GIS). This helps to qualify the findings of this complete diet model with more spatial precision. This study gives suggested limits to relying on diets that far exceed federal dietary recommendations in terms of animal product intake. If the current population of the Appalachian Foodshed continues to mirror national and global trends of dietary patterns that exceed recommended animal product and fat intake, it cannot do so in an entirely regional manner. External sources of foods will be needed to support diets high in animal product intake. However, this research illuminates possible opportunities for increasing community food security through increased food system regionalization to support the given population if individuals take steps to reduce their animal product intake to levels that the regional lands can support.

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CHAPTER 3

MAPPING APPALACHIAN REGIONAL FOOD PRODUCTION POTENTIAL: A SPATIAL MODEL FOR FOODSHED ANALYSIS

Introduction

Local and regional food systems are currently promoted for a variety of economic, environmental, and cultural reasons that include improving health and nutrition, strengthening local economies and social justice, and increasing land preservation and ecosystem health (Martinez et al. 2010). In south-central Appalachia, communities are promoting regional agriculture as a way to enhance community food security, or as Hamm and Bellows (2003) describe, a system in which all people can adequately and healthfully meet their dietary needs. Food availability is limited by regional biocapacity, or the combination of abiotic and biotic factors that determine productivity and land use. In addition to addressing issues of food processing and distribution, areas investing in local and regional agriculture need information and tools to understand the local geography of agricultural production potential and how this aligns with the food needs of the population.

In the past decade, research at a variety of geographic scales has emerged that attempt to classify and quantify the capacity of localized systems to provide an alternative to the centralized global food system (Martinez et al. 2010). Local and regional planners, producers, and consumers employ a variety of metrics to describe the flows of food from farm to plate. These efforts are described as food system assessments or foodshed analyses and include broad assessments of cultural and environmental resources. The scope of these various assessments ranges from estimating the capacity of defined geographic areas to meet current, recommended, or future food demands (Peters et al. 2007; Herrin and Gussow 1989; Cowell and Parkinson 2003). In a previous study[6], non-spatially discrete data sources were used to conduct a Foodshed assessment in the southern Appalachian region. Developing and applying a geospatial database to a foodshed analysis allows for greater geographic precision (Peters et al. 2009).

Ostry and Morrison (2008) combine economic, population, land use, and agricultural statistics to construct a foodshed database for British Columbia. They argue that geospatial databases relating detailed soil productivity and yield data to land cover data are centrally important to determining the capacity of regional systems to feed their populations. In another approach, Peters et al. (2009) link geospatial data and an optimization model to estimate the capacity of New York State lands to meet food needs in the minimum distance possible. They use an aggregate unit of food that represents per capita dietary requirements and the land needed to support this demand along with

[6] See Chapter 2 of thesis document.

aggregated estimates of soil quality and yield potential to map how areas of production connect to zones of consumption that are primarily urban. Many other foodshed analyses adapt the methods of the New York study to estimate both the food need and production capacity, focusing primarily on meeting the needs of population centers (Hu et al. 2011; Giombolini et al. 2010; Desjardins et al. 2010).

Agriculture must meet the growing food needs of population centers, particularly in underserved areas known as food deserts. However, the issues of unequal access and poor nutrition that plague these areas are not a strictly urban phenomenon (Martinez et al. 2010; Ver Ploeg et al. 2009). Rural areas also struggle with issues of food access and availability and merit the attention of foodshed analyses techniques (Hu et al. 2011). In order to determine the regional capacity of agricultural lands to feed rural populations, producers, consumers, and regional planners need to know the distribution of soil productivity, the extent of agricultural land, what types of foods can be produced and at what quantity and how balanced diets based on these foods affect regional land requirements and population. Mapping regional agricultural lands along with expected yields helps to determine the current alignment and future potential for meeting the population's dietary needs from within the region. Linking spatially explicit soil mapping units with soil productivity and expected yield data helps to determine the capacity of regional agriculture to provide adequate, balanced nutrition to meet emerging public health challenges (Buzby et al. 2006; Martinez et al. 2010).

This study has two primary objectives:

1. To conduct a geospatial analysis to improve previous estimates of agricultural lands available to meet the complete diet food needs of south-central Appalachia, and
2. To consider the implications of a geospatial analysis on regional food security.

Study area

This paper describes the development of a geospatial database relating soil productivity, expected yields, and land cover used as a part of larger foodshed analysis in south-central Appalachia. A sub-region of the south-central Appalachian foodshed is used for this study and contains 61 counties of western North Carolina and Virginia designated by the Appalachian Regional Commission (ARC) as part of the overall Appalachian region[7](Fig. 7). It is a culturally, economically, and environmentally distinct region with a population of 2,465,209 (U.S. Census Bureau 2012). Forestry, mining, chemical industries and agriculture are dominant in the regional economy (Pollard and Jacobsen 2014). The region is markedly less urban than the study areas of many other foodshed

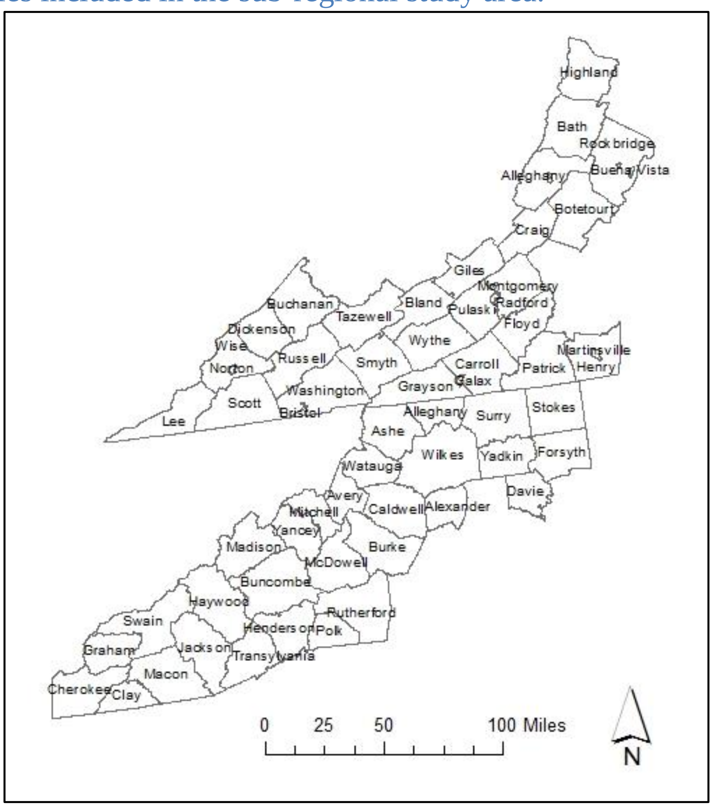
[7] All counties defined by the ARC in Virginia and North Carolina as Appalachia counties are included in this study except one, Caldwell County, North Carolina, which is excluded due to lack of spatial soils information. The West Virginia counties within this regional foodshed are excluded due to yield data constraints. See Appendix 1.

mapping studies, with 42% of the population classified as rural (ARC 2012). The study area encompasses 6.02 x 10^{6} ha (23,250 square miles) of land.

This study area was selected in order to inform the Appalachian Foodshed Project (AFP)[8], an ongoing community food security project research project. The AFP emerged in a context of a poor rural economy, decline in regional agriculture, and an alarming rise in diet-related disease such as obesity and diabetes (ARC 2012; USDA 2012). This joint effort between community stakeholders with academic researchers reflects the growing interest in community food systems and the need to measure the upper bounds of regional resources to meet the food needs of the contained population.

Along with other environmental determinants, the potential for regional agriculture to meet regional food needs is shaped by the topography and soils of south-central Appalachia. Topographic factors such as elevation, slope, and landscape position also greatly impact agriculture in this mountainous landscape. These parameters combine to shape the relatively high rates of erosion, shallow depths of soil, lower rates of water infiltration and the varying suitability for different types of vegetation in the Appalachian and Blue Ridge Mountains (Feldman et al., 1991; Simon et al., 2005).

Figure 7. Counties included in the sub-regional study area.



[8] The Appalachian Foodshed Project is funded through the USDA's Agriculture, Food and Research Initiative (AFRI) grants program. Award Number: 2011-68004-30079. See Web site http://appalachianfoodshedproject.org for more information.

The acidity of soils in the study area is generally high, which is to be expected in a region dominated by heavy forest. Most upland soils are strongly acidic with pH ranging from 4.5 to 5.5, though there are pockets of less-acidic soils where carbonate or mafic rock formations is present (Simon et al., 2005). Soils are predominantly Ultisols (Hapludults) and Inceptisols (Miller et al., 2004; Pittillo et al., 1998). The acidity of soils in most southern Appalachian soils influences fertility and nutrient availability. The subsoil acidity in particular limits root penetration and thus uptake of water from the subsoil.

The topography of the study area varies greatly, from the flat floodplains and alluvial terraces to nearly vertical rock faces and steep backslopes (Liebens and Schaetzl, 1997). This southern portion of the Appalachians contains the highest peaks and largest relief of the system, with elevation ranging from around 250 meters up to 2,038 meters at Mount Mitchell in North Carolina. Steep slopes and high relief of up to 450 meters are observed in the study area (Hack, 1982; Ryder, 1995). Slope varies across locations according to landscape position, with values around 5-7 degrees[9] common in the flatter plateau and valley areas, values of 7-15 degrees common in lower elevation mountains, and values over 15 degrees common on mountainsides and backslopes (Feldman et al., 1991). Agriculture is typically limited at 8 to 10 degrees (Simon et al., 2005; Wiser, 1998). The terrain of many local upland areas within the Appalachian Basin and Blue Ridge Mountains are more suited for grazing livestock agriculture than significant crop and vegetable production . While agricultural potential is limited by these factors, the degree to which regional production can contribute to the diet of the regional population with the aim of enhancing food security merits further investigation in this study area.

Methods

Previous foodshed analyses at various scales and locations have mapped food production potential in relation to population centers. In this study, food need of the population and the ability to supply this need are considered in the aggregate in order to provide information about the sub-region as a whole. The capacity for south-central Appalachia to internally supply regional food need as determined by the complete diet (CD) model[10] was tested by developing a geospatial foodshed (GF) model. The GF model calculates sub-regional food production potential in a geographic information system (GIS) by determining soil suitability for various types of agricultural production. Land cover data was then used to relate crop specific soil suitability to the current extent of agricultural land. With the aim of informing practitioners, policy makers and community stakeholders, the GF model integrates several data sources to determine the extent to which the region can enhance food security within its internal agricultural land resources. The model and procedure of data preparation and integration are outlined below.

Complete diet sub-model

[9] Slope degrees are equal to the tangent of degrees x 100.
[10, 5] See Chapter 2 of thesis document.

Data from a CD model of the annual per capita land requirements of the human diet were used as a sub-model within the GF model to determine the relationship between diet-based land demand, land use, and agricultural carrying capacity.[11] The GF model in this study makes use of a single diet designed for the CD model. The diet selected complies with USDA MyPlate standards for an average, moderately-active person consuming an entirely regionally grown diet. Results from the CD model can describe food need of the MyPlate diet in terms of annual per capita land requirements and quantities of specific food crops. These results were compared to GF model output of land suitability and availability as well as total production potential (Table 11). The methods for calculating this food need in the CD model are summarized here.

Along with all other diets tested in the CD model, the MyPlate diet tests the relationship between dietary intake of fat and animal products and land requirements. This particular diet was selected as the single representative diet in this study as it represents a balanced consumption pattern of all food groups, relies on a variety of animal and plant-based proteins, and meets caloric recommendations (2308 kcal/day) for the average person.

Table 11. Annual per capita land requirements and weight of food need to meet consumption needs of the diet used in the spatial model by crop category, as calculated in the sub-model.[12]

Crop category	Hectares (acres) cropland required	Annual per capita food need (Mg)	Percent of food demand	Percent of land demand
Annual	0.073 (0.18)	0.63	41%	18%
Perennial	0.342 (0.85)	0.90	59%	82%
Total	0.415 (1.02)	1.53	100%	100%

Land requirements and food needs were calculated by allocating servings of 54 food crops to meet food group serving and caloric recommendations. Food need for consumption was converted into agricultural commodities with conversion factors to account for the effects of food waste, spoilage, processing, and other transformations that affect the weight of the food product from the farm gate to the plate[13]. Animal products were further converted to supporting crops required for production (feed, forage, pasturage). Non-cropland areas used for animals were not considered.

The CD model uses highly aggregated soils and land availability data. Total agricultural land availability was estimated using county-based data from the Census of Agriculture (COA) land use data for census years 2007 and 2012 (USDA 2014). To account for the fact that not all soils are suited for all types of crop production, the CD model classifies the quality of all available agricultural land, estimating the current proportion of land used for high-value annual crops and perennial cropland and pastureland (Table 12). The

[12] Includes weight and land requirements for all food commodities included in diet including supplemental crops included in livestock rations.
[13] See Chapter 2 of thesis for details.

ratio of annual and perennial land use was assumed to represent land use limits in the CD model. Average soil productivity was assumed for all available productive land.[14] The amounts of each agricultural commodity (for both food commodities and supplemental crops supporting animal production) required to meet MyPlate dietary demand were divided by regional crop yields to determine food land requirements and the weight of each food crop. These were then aggregated by annual, perennial, and total crops, expressed in Mg.

According to the CD model, the average person in the study area following a regionally-grown MyPlate diet requires 1.53 Mg of total food annually. Perennial crops, including feed and forage requirements of livestock for the animal products included in the diet, represents 59% of per capita annual food weight need, but 82% of land demand.

Table 12. Agricultural land use limits used in the complete diet (CD) sub-model for Appalachian Virginia and North Carolina counties.[15]

Land use	Land area (ha)		
	2007	**2012**	**Average**
Productive land available	1,315,749	1,310,134	1,312,941
Usable for any crop	344,652	376,838	360,745
Limited to perennial crops or pasture	971,097	933,296	952,196

This study refines the results of the sub-model by accounting for the spatial variability of soil productivity within a GIS, adding a more spatially-precise level of analysis. The land use data from the Census of Agriculture are self-reported by producers and data are often suppressed in rural areas in order to maintain farmer confidentiality. Thus, this study improves upon the sub-model through the use of fine-resolution soil and land cover data.[16]

Outline of the geospatial foodshed model

To refine the analysis of the capacity of this foodshed to meet recommended dietary consumption, the GF model integrates a variety of soils and land cover data and makes use of the most recent and relevant data available for application to the study area (Fig. 8). First, crop-specific soil suitability for agricultural production and expected crop yields were calculated. Second, the extent of land in production was determined. This

[14] Average soil productivity values were taken from the Virginia Agricultural Land Use Evaluation System (VALUES). Class IIA soil productivity was assumed for all lands in the sub-model using corn silage as an annual indicator crop and tall fescue as a perennial indicator crop to estimate yield (VDCR 2005).

[15] Values and categories of actual land use from the USDA National Agricultural Statistics Service Census of Agriculture (2007 and 2012) for select Virginia and North Carolina counties included in the spatial model. Assumes that all harvested or pastured cropland and all permanent pasture are available for productive use. For soil management and economic reasons, it is assumed that some cropland is in perennial crop or pasture production at any given time. Proportion of land limited to production of perennial crops or pasture is based on the current ratio of pastured cropland, pastureland, and pastured woodland to the total of harvested cropland and all pastureland (73.1%).

[16] See Chapter 2 of thesis for details.

information was combined to estimate the production potential of the study area, which was then compared to recommended diet demand.

Both states included in this study have developed expected yield databases based on soil series. Only soil series deemed suitable for agriculture are recognized in these state-based yield databases. The Virginia Agricultural Land Use Evaluation System (VALUES) and the North Carolina Realistic Yield Expectations (NCRYE) database provided estimates of soil productivity under good management[17]. Both the VALUES and RYE databases list expected yields for select crops.

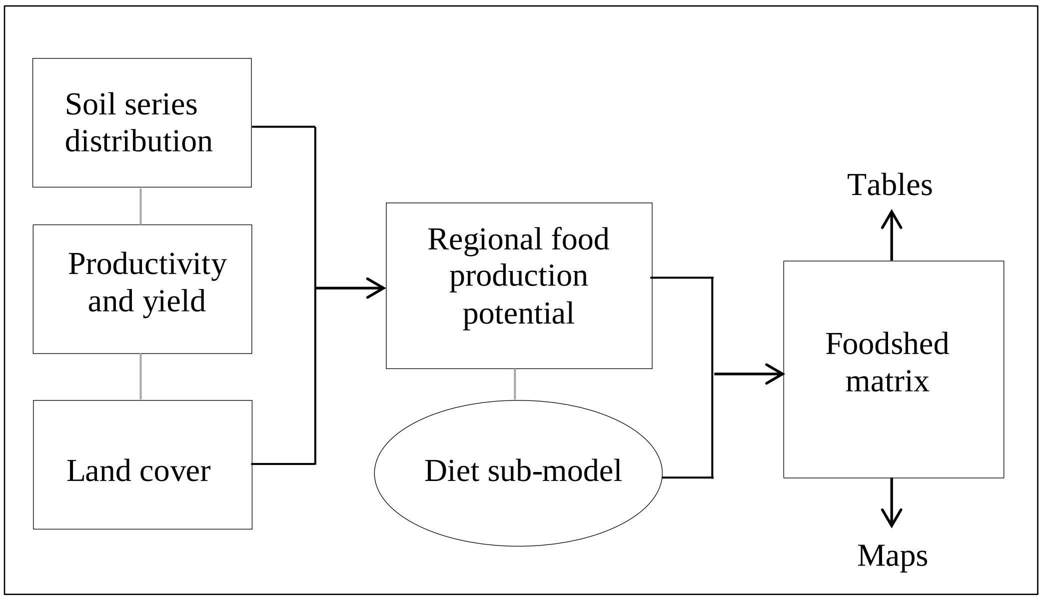


Figure 8. Simplified diagram of data flow for the geospatial sub-regional foodshed model.

To group soils for both states in the sub-region, productivity classes were used based on those found in the VALUES database. Soil series in the VALUES database were assigned by the Virginia Department of Conservation and Recreation into one of five crop-specific soil productivity groups ranging from most productive (I) to least productive (V). Each soil series in the productivity group is then assigned the same yield for each specific crop. Six agronomic crops, 2 silage crops, 4 hay crops, and pasture are assigned productivity groups with associated yields based on these management groups and if applicable, subgroup. In the NCRYE database, each North Carolina soil series was re-classified into a corresponding VALUES productivity group by expected yield value. Mapping these productivity groups provides more precise food crop yield estimates than the sub-model alone.

In order to map productivity and expected yield, the Gridded Soil Survey Geographic database (gSSURGO) provided spatial data on the distribution on specific soil series in the study area. This dataset is a file geodatabase format suited for national, regional, and

[17] See Appendix 2 for details.

statewide soil analyses. It contains detailed spatial and tabular data developed from detailed field testing and mapping conducted by the National Cooperative Soil Survey and maintained by the USDA National Resource Conservation Service (USDA 2013; Soil Survey Staff, 2014). Soil map units (mukey) are displayed at a 10-meter raster resolution. Within database and GIS software, the VALUES and NCRYE data were linked to SSURGO data based on soil series name. This required a text-based join and therefore minor actions were taken such as correcting the spelling and removing supplemental information from the soil series name field[18]. This allowed for the soil productivity and potential yield data to be mapped according to soil series using the map unit key (mukey) embedded in the gSSURGO data.

Slope is explicitly accounted for in the NCRYE database, but not in the VALUES database. Therefore, expected yield values for both annual and perennial crops were corrected for the soil map units for Virginia counties using an erosion/slope adjustment on the slope gradient attribute value[19], which was taken from the representative slope value from the gSSURGO component table (Table 13). In database software, a field was added classifying embedded slope values into one of six slope classes presented in the VALUES handbook (VDCR 2005). Each of these slope classes is assigned a percent yield reduction based on the severity of the erosion potential and slope. In this way, estimated yields for Virginia soils were adjusted based on slope and productivity group, with higher slopes assigned lower yield values and slopes over 25% assigned to no yield (Donohue et al. 1994). As the NCRYE database already accounts for differences in yield due to slope and erosion, the expected yield values for North Carolina soils were not altered.

Table 13. Accounting for slope in Virginia soils using the yield adjustment factors in the VALUES handbook assuming conservation tillage.[1]

Slope class	% Slope, Mountain region	% Yield reduction[2]
A	0-2	NA
B	2-7	NA
C	7-15	0
D	15-25	10
E	25-45	Too steep for production
F	45+	Too steep for production

1- VDCR 2005.
2- Assumes no till.

With each soil series connected to a spatially related mukey and assigned yields for both annual and perennial indicator crops, soils were mapped according to the productivity groups and expected yield. This spatial join of the soil productivity, soil mapping units, and detailed land cover data in a GIS allowed for potential productivity to be displayed for each 10m by 10m pixel. A classification scheme based on the resulting yield maps

[18] For more a more detailed explanation of data preparation, see Appendix 3.
[19] The Slope Gradient Representative Value is indicated as "slope_r" within the component table. See SSURGO Metadata for more information at Web site: http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_053631.

was developed to assign all agricultural pixels into either an annual or perennial production suitability class. This study reports on the results in aggregate for the entire study region but the findings can be adapted to even smaller areas of interest such as individual counties or communities.

Annual and perennial production suitability by soil mapping unit was determined using the VALUES productivity groups for two indicator crops, corn (*Zea mays*) silage and tall fescue hay (*Festuca*). Corn silage was used as an indicator crop for the productive potential of annual crop yield and the hay crops were used as an indicator for the productive potential of perennial crop yields, following the methods of Peters et al. (2009). Table 14 displays the ranges of expected yield of each indicator crop by soil productivity group. With the joined soil productivity and gSSURGO databases, the productivity group of each pixel was calculated in a GIS based on the expected yields of each indicator crop.

Table 14. Estimated yields in tons per hectare (T/Ha) of corn silage and hay for soil productivity groups.[1] Soil productivity conversion factors listed for each indicator crop by productivity group created from expected yield ratios.

Indicator crop	**Soil productivity group**								
	I		II		III		IV		V
	A	B	A	B	A	B	A	B	
Corn Silage (T/Ha)	18.75	17.86	16.96	16.07	15.18	14.29	13.39	11.61	8.93
Annual crop factor	1.11	1.05	1.00	0.95	0.89	0.84	0.79	0.68	0.53
Hay (T/Ha)[2]	4.46		3.35	2.90	2.23		NA	NA	NA
Perennial crop factor	1.33		1.00	0.87	0.67		0	0	0

1- Adapted from Virginia Nutrient Management Standards and Criteria, Department of Conservation and Recreation Division of Soil and Water Conservation, DCR; 1995
2- Multiple species (tallgrass hay and tall fescue).

Each agricultural pixel recognized as having agricultural potential was assigned to a crop-specific soil productivity group for annual crops (corn silage) and perennial (tall fescue hay) crops. Land allocation was determined by assigning each pixel to either annual or perennial production based its soil productivity group for each indicator crop. All map units at or above the productivity group of IIB for estimated corn silage yield were assigned as best-suited for annual crop production, with remaining map units assigned as suited for perennial cropland and pastureland. This procedure gave preference to annual crops so that the model would first meet all annual crop demand before turning to perennial crop production to use the remaining lands. However, this does not necessarily mean that all low productivity soils were allotted to perennial crop production. There are soil series which are estimated as having low productivity for corn silage but high productivity for hay production. This resulted in crop suitability maps with land allocated to either annual or perennial crop production.

The crop suitability mapping includes any soils with productivity that could result in a reasonable, economical return in yield of agricultural crops. However, not all soils selected through this process are actually available to agriculture. This could be due to many factors such as development, idle land, or land set aside for parks or conservation. Following the explicit assumptions made by previous foodshed analyses, this study assumes that the current total extent of agriculture and the current proportion of land in annual and perennial production shown by the high-resolution land cover data represent a reasonable use of the limited available arable land in the study area (Peters et al. 2009; Hu et al. 2011).

The 2013 Cropland Data Layer (CDL) provided land cover data for estimating the location of agricultural land. This dataset is a geospatial raster dataset of land cover across the United States. It is released annually by the USDA National Agricultural Statistical Service (NASS) using information from both satellite imagery and ground validation methodologies (Johnson and Mueller 2010). The CDL has a 30-meter resolution of over 100 specific crops. Commodity, horticultural crops, pasture and grazing lands, as well as non-agricultural land cover are all classified by the CDL. This allows for users of the CDL to determine the extent of total agricultural land as well as the relative proportion of annual and perennial crop cover.

Within a GIS, the CDL land cover categories were reclassified into agricultural and non-agricultural classes. Non-agricultural cover such as forests and parkland, municipalities, roads and water bodies were used to create an exclusion mask to create a GIS layer containing only pixels currently under agricultural uses. The agricultural categories were then further reclassified into separate annual and perennial crop classes. This provided the location and sums of total, annual, and perennial agricultural land.

The crop suitability raster was then related to the reclassified land cover data. A raster calculator operation in the GIS allowed for the estimation of productivity for each $900m^2$ agricultural pixel across the entire study area. The resulting output from the model is in the form of a foodshed matrix, with each pixel assigned to an indicator crop and corresponding type of agricultural production based on productivity group. This provides a basis for adjusting the expected yield of specific food crops included in the recommended diet type relative to the original assumption of average yield used in the diet sub-model. To accomplish this, soil productivity conversion factors were created based on the expected yields presented in the VALUES database (Table 14).[20] The calculation of these yield factors is shown in Equation 1.

[Eqn. 1] $X_i = (E_i \text{ x } G_i) / E_i$

The soil productivity factor (*X*) used to determine yields for crops in a given food crop category (*i*)- being either annual or perennial- was calculated as the product of the average expected yield (*E*) assumed in the sub-model and the actual expected yield (*G*) by productivity group expressed in the VALUES database divided by the average expected yield. This allows the expected yield of all annual and perennial crops to be mapped and production potential calculated and compared to dietary demand which is discussed in subsequent sections.

[20] (See Appendix 2).

Calculating potential regional food production and self-sustainability

To measure the alignment of regional consumption and production in a generalized way, a regional self-sustainability index value is calculated as proposed in a foodshed analysis of Iowa by Hu et al. (2011). The researchers from that study offer it as a metric to normalize the capacity of a region to feed its population using internal agricultural lands. The regional self-sustainability index calculation is described in Equation 2.

[Eq. 2] $S = [(R_d \times N) / L] \times 100$

The regional self-sustainability index (*S*) is determined as the product of the per capita land requirement of a given diet type (*d*) for a region and its population (*N*) divided by the total productive cropland (*L*). This ratio is then converted into a percentage value. Values under 100% indicate the potential for regional self-sustainability, while values over 100% indicate that the region cannot supply all its food needs. This value has since been used by researchers and organizations in other regions metric for describing the overall capacity of regional agriculture the food need of its population (Mast 2013; Castillo et al. 2013; Griffin et al. 2014). It is included in this study as a means of comparing agricultural capacity across various regions.

To estimate the potential of land resources to meet food needs of specific crop types, a more exact metric is needed for the study area. Equation 3 shows how the potential regional food production was estimated following the calculation presented by Peters et al. (2009).

[Eq. 3] $P_i = (A_i \times E_i \times Y_i) / \bar{E}_i$

The potential production (*P*) of a given food crop category (*i*)- being either annual or perennial- was calculated as the product of the area in agricultural land cover for each given food crop type (*A*), the expected yield (*E*) of the indicator crop, and the calculated average yield (*Y*) of all specific food crops included in the diet sub-model by food crop category divided by the land area weighted average expected yield ($\bar{E}$) of the indicator crop. The terms *A*, *E*, and $\bar{E}$ were calculated within the GIS using the joined spatial data layers, while *Y* was calculated in prior research (Chapter 2). The term *A* was given as hectares of land for both annual and perennial cropland. The term *E* and *Y* were expressed as Mg per hectare.

The results from the soil and land cover analyses provided the input for a foodshed matrix. In the GIS, the two layers were overlaid to compare productive capacity and land use in the study area. This procedure of obtaining this kind of foodshed matrix was adapted from Peters et al. (2009) and Griffin et al. (2014) and estimates the degree to which agricultural lands are currently put to their best use in terms of contributing to balanced, complete diets.

Results

Describing the geography of food production

The model output reveals that the vast majority of land is unavailable for food production despite the fact that soil types on most land are suited for agricultural production and able to produce a slope-adjusted yield of one of the indicator crops tested. Mapping soil series by VALUES productivity group of annual and perennial indicator crops classified all soils that would be suitable to produce yield of either of these crop categories (annual, Fig. 9, perennial, Fig. 10). According to this soil suitability classification, 87% of soils in the sub-region are productive enough to produce a yield (Table 15). However, this result does not necessarily translate to lands that are actually able to produce an economically viable and environmentally sustainable return.

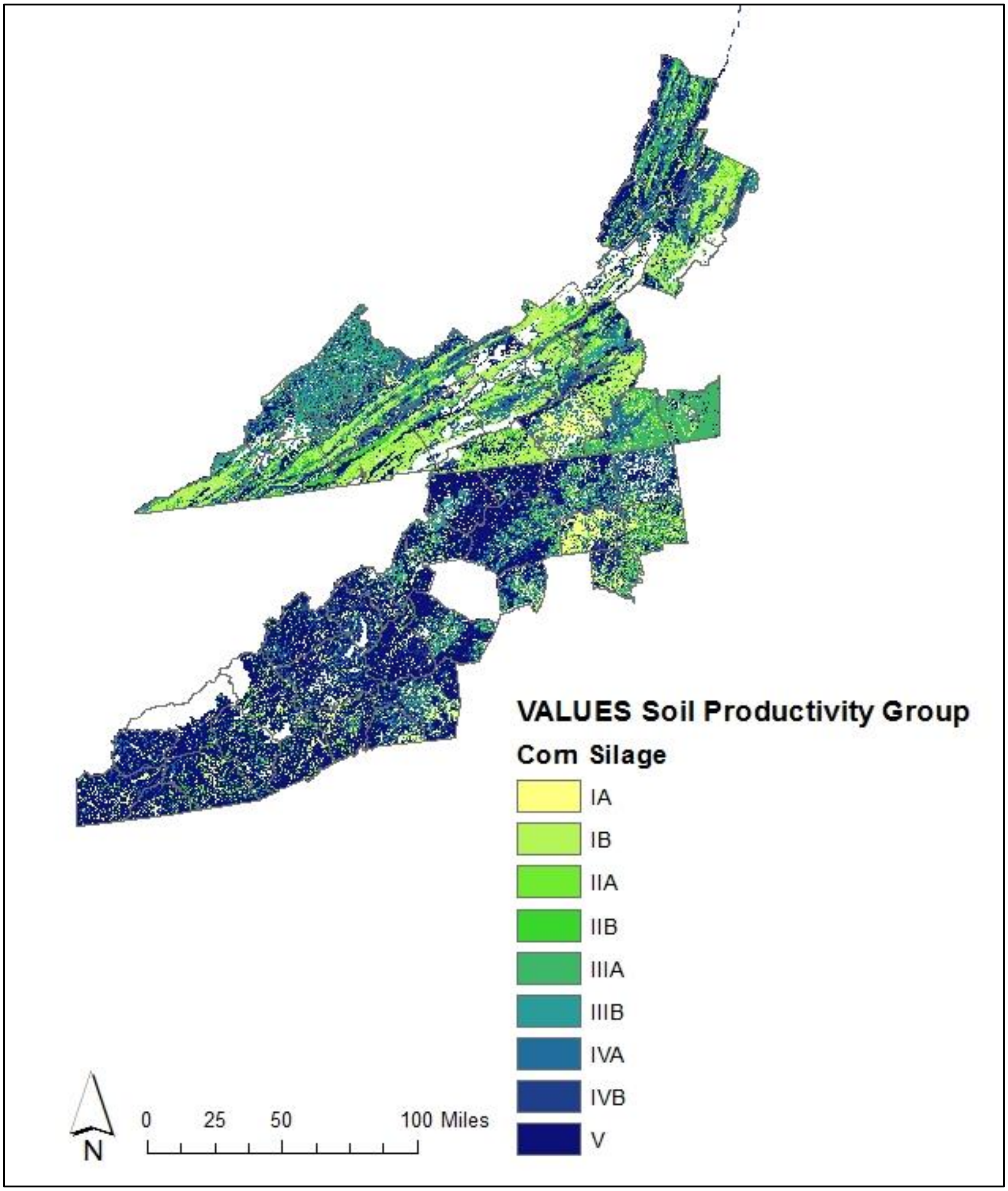
A soil suitability map for the sub-region was created in a GIS through a binary pixel assignment scheme in which all soils suitable for either type of agricultural production were reclassified into their "most suitable use" in terms of the type of agricultural production (Fig. 11). This land allocation process assigned land with high productivity values for annual crops as soils best-suited for annual production and all other agricultural lands as best-suited for perennial production. This land allocation assigned 73% of suitable agricultural soils to perennial crop production with the remaining 27% assigned to annual crop suitability. Some of the land area had no data and was therefore not included in either category for production, but 12% of land in the study area was assigned as unsuited for any type of production based on soil productivity group alone. These were pixels with zero values attached to the map unit keys, or else were so low that they did not qualify for agricultural production suitability. Often these are government lands lacking a modern soil survey.

Table 15. Soil suitability classification for agricultural production according to soil productivity in Appalachian Virginia and North Carolina.[1]

	Soil suitability type (ha)		
State	Suitable	Not suitable[2]	Total
Virginia	2,591,246	323,384	2,914,631
North Carolina	2,624,610	482,334	3,106,943
Sub-region total	5,215,856	805,718	6,021,574

1- Results from joined spatial soil productivity groups and SSURGO databases in a GIS.
2- Lands classified as "not suitable" were not identified as being capable of producing a crop yield of corn silage or tall fescue hay. Null values also included in this category.

Figure 9. Distribution of annual[21] crop-suited soils in Appalachian Virginia and North Carolina by productivity group[22]



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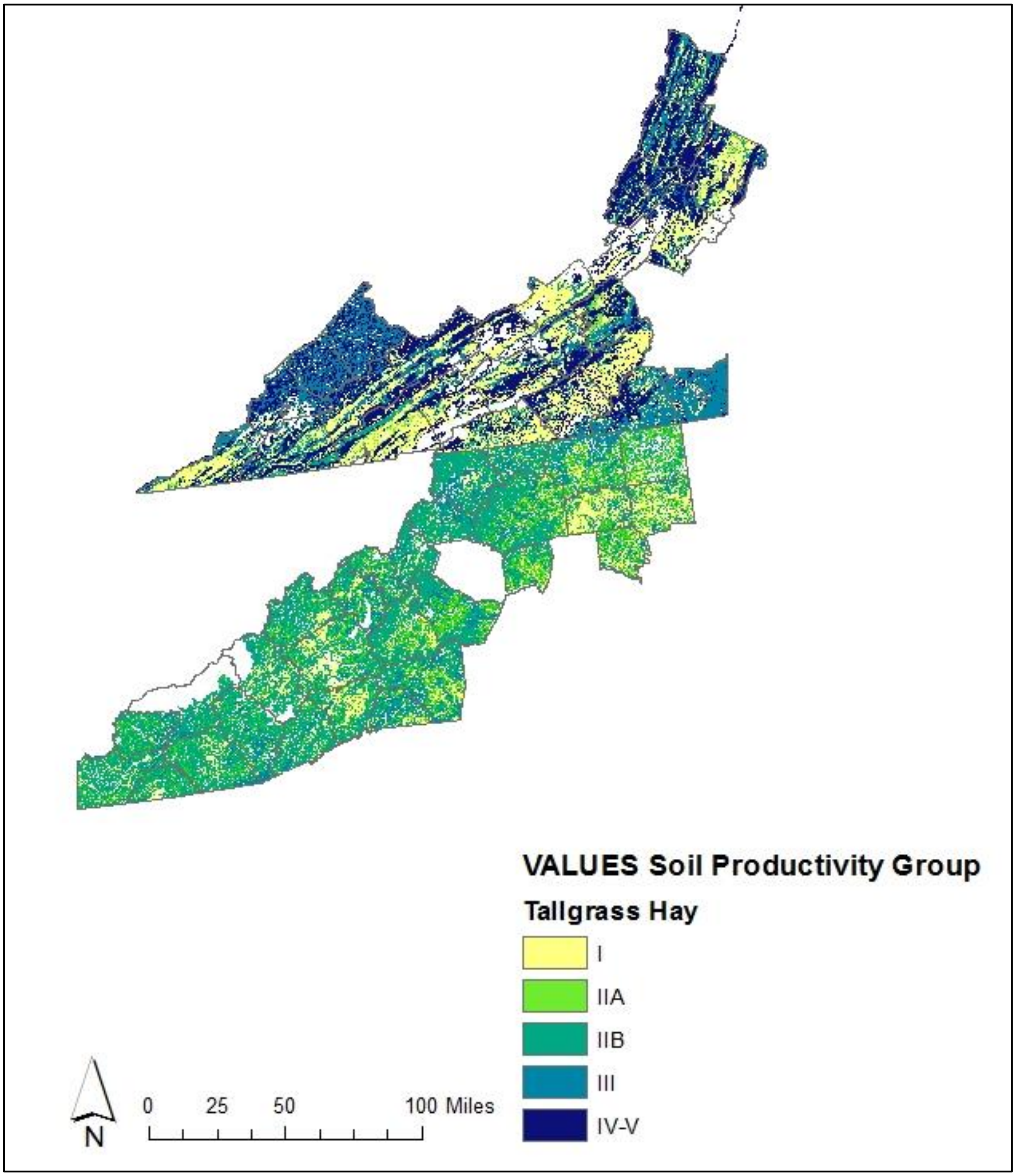
[21] Indicator crop of corn silage used to determine soil suitability for annual crop production (as per methods of Peters et al. 2009)

[22] Blank areas in white within the displayed boundaries of the sub-region contained no productivity data and were excluded from this analysis.

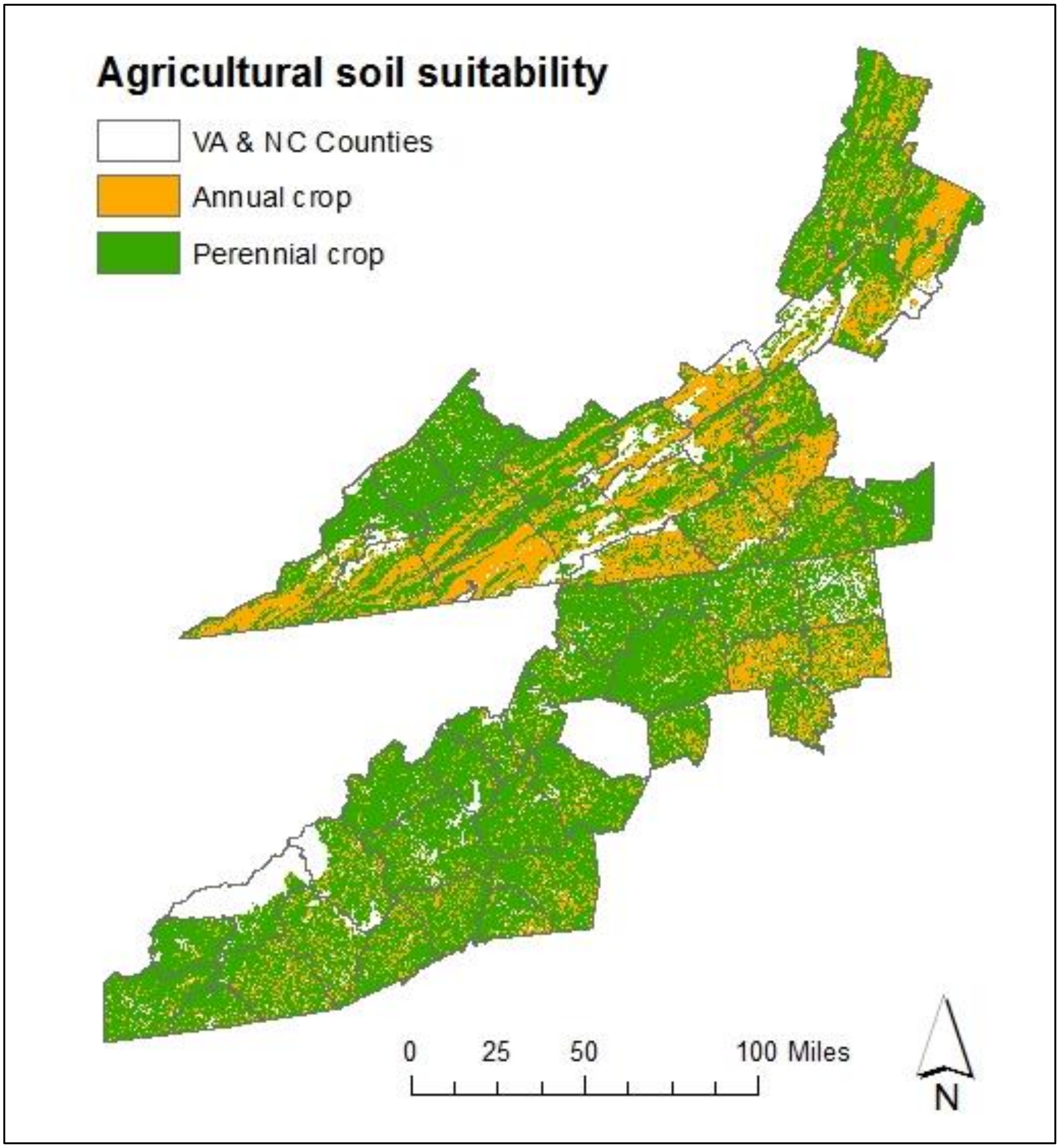
Figure 10. Distribution of perennial[23] crop-suited soils in Appalachian Virginia and North Carolina by productivity group.[24]



[23] Indicator crop of fescue hay used to determine soil suitability for perennial crop production (as per methods of Peters et al. 2009)

[24] Blank areas in white within the displayed boundaries of the sub-region contained no productivity data and were excluded from this analysis.

Figure 11. Annual and perennial crop designation by crop suitability.[25]



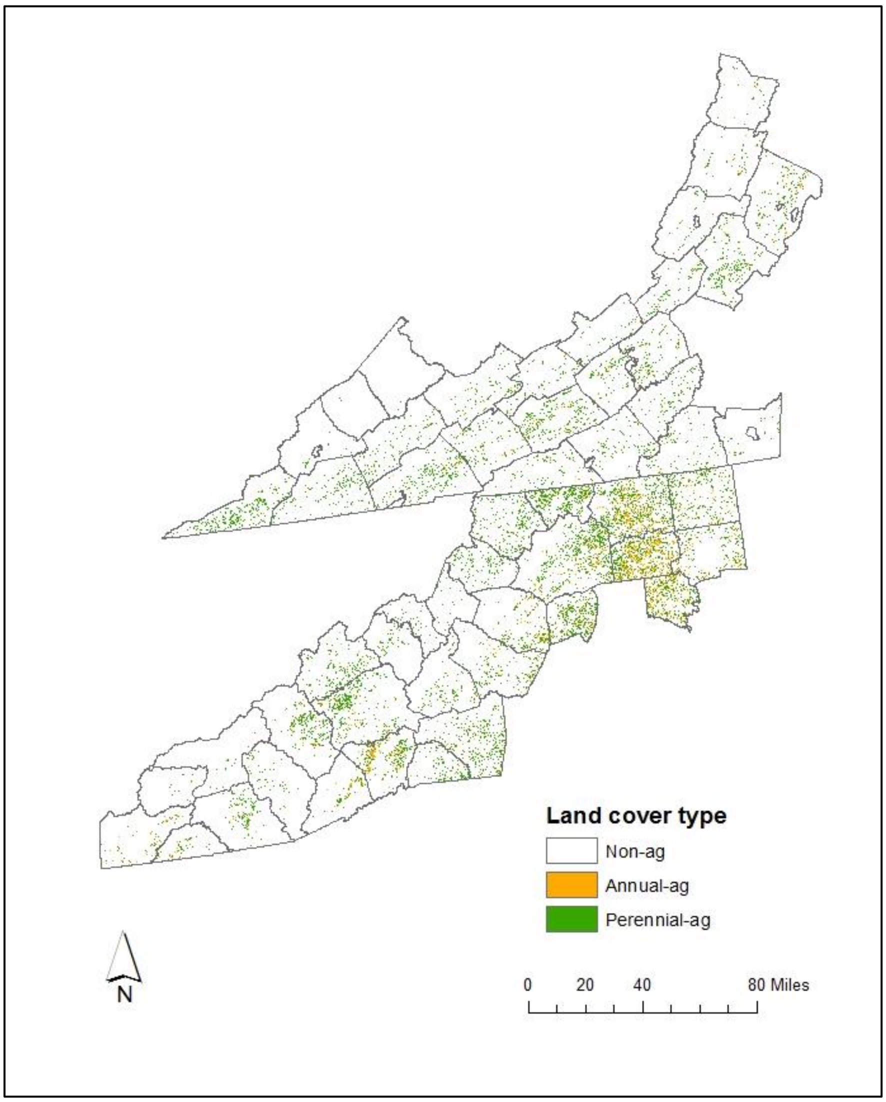
After classifying soil productivity and crop suitability, the model next dealt with the land cover data. The CDL was reclassified in order to characterize the current extent and distribution of agricultural lands in the sub-region (Fig. 12). First, land was reclassified as agricultural or non-agricultural cover. Second, agricultural land cover was broken into annual crop and perennial crop cover. This reclassification calculates that only 7% of the total sub-regional land base (432,851 ha) is currently in agriculture land cover (Table 16). According to the land use limits in the CD model (Table 12), 19% of the entire south-central Appalachian foodshed (including West Virginia) is in agriculture.

[25] Blank areas in white within the displayed boundaries of the sub-region contained no productivity data and were excluded from this analysis.

Table 16. Current land cover types reclassified from the 2013 Cropland Data Layer land categories in Appalachian Virginia and North Carolina.

	Land cover type (ha)				
State	Non-agricultural	Annual crop agriculture	Perennial crop agriculture	Total Agriculture	Total land
Virginia	2,786,244	12,382	115,776	128,158	2,914,401
North Carolina	2,802,389	76,524	228,169	304,693	3,107,082
Sub-region total	5,588,633	88,906	343,945	432,851	6,021,483

Figure 12. Distribution of annual crop and perennial crop land cover from 2013 Cropland Data Layer.



Potential regional food production and self-sustainability

The annual per capita land requirements and weight of food crop need by food type in the CD model were used to calculate both a regional self-sustainability index value (Eqn. 2) and the relative food productive potential (Eqn. 3) within Appalachian Virginia and North Carolina. This study region self-sustainability index was calculated as 236.4%, indicating that the region does not have the potential for self-sustainability based on total arable land cover as calculated in a GIS.

While offering a generalized metric for comparison across regions, the self-sustainability index does not account for the fact that not all regional arable soils are suited for all types of agricultural production. To account for spatial differences in expected yield, the GF model distinguishes between annual and perennial crop types due to different productivity and management factors and also assumes that soils suitable for annual crops can be planted in annuals each year and thus limit soil erosion without rotation into perennial crops. When the methods described by Peters et al. (2009) are applied to this region, the potential regional production was estimated at 957,994 Mg of total food crops included in the MyPlate diet (Table 17). Agricultural lands in the sub-region have approximately double the production potential for perennial crops than they do for annual crops.

Table 17. Current Agricultural land area, land area weighted average yields and total food production potential in the sub-region by food category (adapted from Peters 2009).

Food category	Land (ha)[1]	Yield (Mg/ha)[2]	Production potential (Mg)[3]
Annual crops	88,906	8.03	319,721
Perennial crops	343,945	1.19	638,273
Total crops	432,851	3.08	957,994

1- Area of land available based on 2013 land cover data from the Cropland Data Layer.
2- Land area weighted average expected yield by indicator crop (corn silage for annual crops and fescue hay for perennial pasture and forage crops) as calculated in a GIS.
3- Product of area in each category of agricultural land cover and average expected yield of indicator crop under good management (See Ch. 2) divided by the land area weighted average expected yield.

Table 18 compares these results of available cropland and production potential on a per capita basis. Though a higher proportion of annual cropland is available to meet per capita food requirements than perennial cropland, the production potential calculation shows that a higher proportion of perennial crop food need can be met than that of annual crop food need. Based on the current sub-regional population of approximately 2.5 million, the per capita food need of the representative diet exceeds that of the study area production potential by the weight of food and land requirements (Table 18). Production need is 1.53 diet equivalent Mg per person, while the current regional production potential on a per capita basis for the current population only supplies 0.39 Mg of food per capita. Therefore, according to the regional productivity of soils and limited arable land, the regional population of south-central Appalachia can acquire 25.4% of complete dietary food needs from within the region. Perennial crop food need can be met at a higher rate (29%) than that of annual crop food need (21%).

Table 18. Annual per capita land and food requirements compared to annual per capita land availability and production potential in the sub-region by food category.

Food Category	Cropland required (ha) [1]	Current cropland available (ha)[2]	Food need (Mg)[1]	Production potential (Mg)[2]
Annual	0.073	0.036	0.63	0.13
Perennial	0.342	0.140	0.90	0.26
Total	0.415	0.176	1.53	0.39

1- Annual per capita cropland required and food need by food crop category were calculated in the sub-model. See Chapter 2 of this thesis for details.

2- Total cropland available and production potential were calculated using the 2013 CDL in the GF model in a GIS and divided by current sub-regional population to attain per capita values.

Excluding non-productive land or areas lacking data, the GF model estimates approximately 8% of all land capable of producing a yield of one of the indicator crops is currently in production (Fig. 13). Of the land both suited for production based on soil productivity and current land cover, 81% is in perennial crop production (Fig. 14). The foodshed matrix finds that the majority of available agricultural land is currently in agricultural land cover that matches its best-suited type of production based on soil productivity (Fig. 14).

Tabular output from the spatial model is given in Table 19, which lists the summarized results from the spatial overlay of soil productivity and crop suitability data and land cover data in the form of a spatial expected yield database, or foodshed matrix. The matrix summarizes the geospatial results of assigning each pixel to either annual or perennial crop production by soil productivity compared to current land cover. It estimates that 92% of land suited for agriculture by productivity type to be in non-agricultural land cover, as summarized in Figure 13. Through the spatial model, the matrix calculates that 88% of all suitable agricultural land is composed of the most productive soils by assigned indicator crop[26]. Therefore, the majority of current agricultural production in the sub-region aligns with its "best use" as determined by soil suitability for annual or perennial crop agriculture.

However, the foodshed matrix also estimates the amount of land currently in agriculture that does not follow the suitability assumptions used in the model. The foodshed matrix estimates that half of all perennial crop agriculture occurs on soils that the model deems best suited for annual crop production and 36% of all annual crop agriculture occurs on soils that the model deems best suited for perennial crop production. Figure 15 presents a map output of the spatial model, displaying the distribution of total agricultural land area by foodshed matrix result. Mapping the spatial distribution of the matrix reveals that there are increased pressures around populated areas, where mismatching between agricultural land cover type and crop suitability appears most evident.

[26] The most productive soil groups as defined by this study include soil productivity groups I and II and their included subgroups by indicator crop.

Figure 13. Interpreting the foodshed matrix: Percent land cover from the 2013 CDL on crop-suited soils.[27]

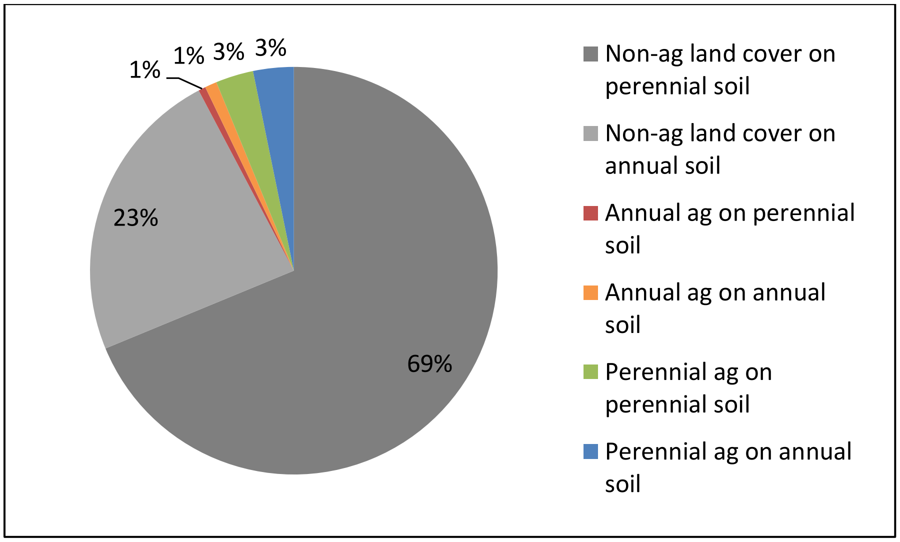
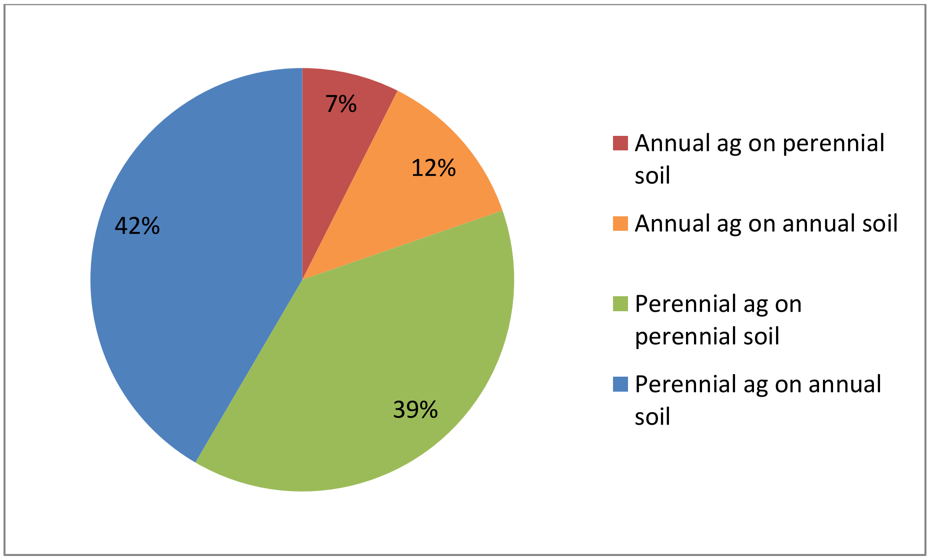


Figure 14. Interpreting the foodshed matrix: Distribution of agricultural land cover as defined by the 2013 Cropland Data Layer by crop suitability classification.[28]



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[27] Overlay of land cover on crop suitability raster, and therefore excluding land cover not located on soils productive for one of the selected indicator crops. Figure 13 does not represent total land in the sub-region, but lands identified by VALUES soil productivity groups. Annual soils were identified as highly productive for corn silage, the indicator crop used in this model for annual production. Perennial soils were identified as all other productive lands based on hay productivity. See text for details.

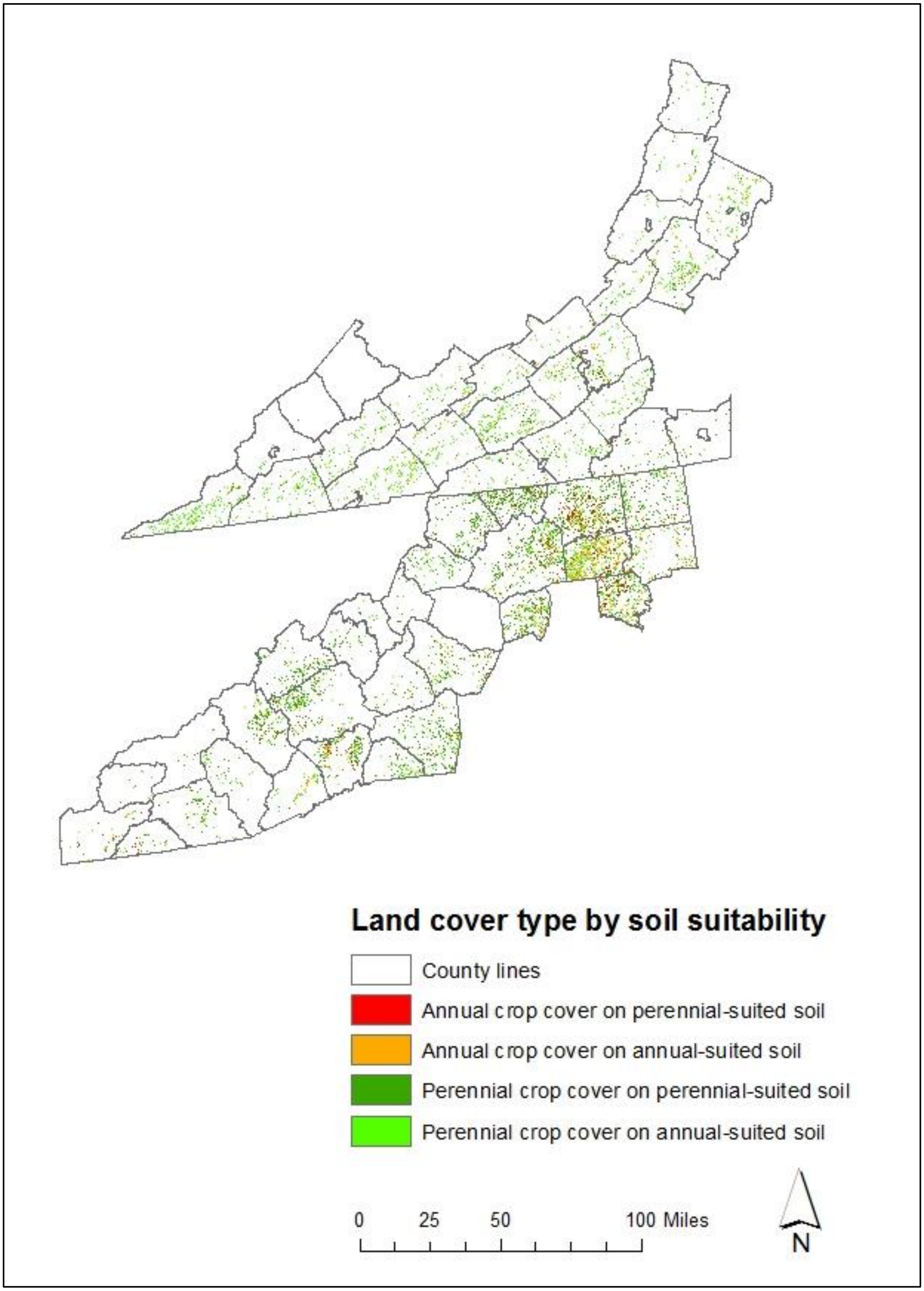
[28] Overlay of land cover on crop suitability raster, and therefore excluding land cover not located on soils productive for one of the selected indicator crops. Figure 13 does not represent total land in the sub-region, but lands identified by VALUES soil productivity groups. Annual soils were identified as highly productive for corn silage, the indicator crop used in this model for annual production. Perennial soils were identified as all other productive lands based on hay productivity. See text for details.

Table 19. Foodshed matrix tabular results comparing the soil productivity and crop suitability to land cover by crop production type for agricultural land as calculated in a GIS.[1]

Result	Observed Land cover type	Crop suitability	Productivity group	Indicator crop	Land (ha)
1	Non-agricultural	Perennial	V	Hay	1,055,053
2	Non-agricultural	Perennial	III	Hay	869,103
3	Non-agricultural	Perennial	IIB	Hay	1,303,286
4	Non-agricultural	Perennial	IIA	Hay	272,079
5	Non-agricultural	Perennial	I	Hay	86,223
6	Non-agricultural	Annual	IIB	Corn silage	232,698
7	Non-agricultural	Annual	IIA	Corn silage	116,712
8	Non-agricultural	Annual	IB	Corn silage	567,492
9	Non-agricultural	Annual	IA	Corn silage	308,549
11	Annual crops	Perennial	V	Hay	818
12	Annual crops	Perennial	III	Hay	4,785
13	Annual crops	Perennial	IIB	Hay	7,653
14	Annual crops	Perennial	IIA	Hay	12,529
15	Annual crops	Perennial	I	Hay	4,162
16	Annual crops	Annual	IIB	Corn silage	3,727
17	Annual crops	Annual	IIA	Corn silage	8,351
18	Annual crops	Annual	IB	Corn silage	7,469
19	Annual crops	Annual	IA	Corn silage	29,915
21	Perennial crops	Perennial	V	Hay	11,584
22	Perennial crops	Perennial	III	Hay	28,593
23	Perennial crops	Perennial	IIB	Hay	51,701
24	Perennial crops	Perennial	IIA	Hay	41,510
25	Perennial crops	Perennial	I	Hay	22,725
26	Perennial crops	Annual	IIB	Corn silage	11,540
27	Perennial crops	Annual	IIA	Corn silage	22,631
28	Perennial crops	Annual	IB	Corn silage	67,974
29	Perennial crops	Annual	IA	Corn silage	65,500
Total					5,214,362

1- Result and pixel counts calculated in a GIS. Land cover type reclassified from the 2013 Cropland Data Layer. Soil suitability reclassified from joined state-based soil productivity data and SSURGO soil map units. Productivity groups relate to those described in the VALUES database. Hay used as yield indicator crop for perennial cropland. Corn silage used as yield indicator crop for annual cropland. See text for details. Results of foodshed matrix consider only lands within the sub-region with current agricultural land cover and soil productivity groups for one of the indicator crops and therefore does not represent all sub-regional land.

Figure 15. Model output: foodshed matrix of crop suitability and land cover.



Discussion and Conclusions

The first objective of this study was to refine estimates of land availability to meet complete diet needs within the region. Including spatially explicit differences in soil productivity and expected yield, the geospatial component of this overall foodshed analysis improves upon the estimates given by the diet CD model and provides a sub-regional picture of the spatial distribution of production. The geospatial foodshed model calculated that the proportion of agricultural land in the selected sub-region was less than that estimated by the CD model of the entire south-central Appalachian foodshed[29]. Differences also arose in the estimates of annual and perennial crop production. The CD model estimated that 73% of regional agricultural land was limited to perennial crop production, whereas the spatial model found the proportion to be closer to 80% of all agricultural land in the sub-region. However, the differences in the findings of both approaches stem from the different nature of survey and remote-sensing datasets.

Comparing the findings of each model, the CDL land cover data used in the GF model estimates 33% of the total productive land reported by the USDA Census of Agriculture (COA) used in the CD model. The CDL reported only 24.6% of the total annual cropland reported by the COA and 36.1% of the total perennial cropland reported by the COA. This has important implications for data-users in the Appalachian sub-region and suggests the need for further analysis into the sources of difference and uncertainty when these datasets are used in tandem.

The CD model limits on land use were calculated from survey data representing a five-year timeframe published in the COA, whereas the calculation of the extent and type of agricultural production in the GF model occurred by linking spatial soil and remotely sensed annual land cover data. That the CD model land use area exceed those calculated in the spatial model is of particular interest for researchers and practitioners in the study area, as the COA routinely suppresses some county-level data for purposes of producer confidentiality. The COA land use areas are based on survey techniques including farmer-reported areas, and therefore may not adequately describe the total extent of agricultural lands. However, they do serve as useful estimates in the overall breakdown of agriculture by production or crop type- that is for annual and perennial crops and general ratios of the production of different food types by food group. These are details the spatial model used in isolation may not satisfactorily capture. A foodshed analysis benefits from the integration of both complete diet and geospatial approaches and as such, further analysis comparing and combining these datasets is warranted as they represent the best information available for regional-scale analysis of food systems.

There is a documented, inherent downward bias with the estimation of crop area associated with remote-sensing applications such as the CDL (GEOSS 2009). This bias is higher for minor (small-scale, horticultural crops) than for major crops (large-scale, commodity crops). Furthermore, the estimation of crop areas using pixel counting underestimates the full effect of slope on the total area estimated. Remote sensing is

[29] See Chapter 2 of thesis document.

unable to capture all crops and cannot distinguish between all crop types, but serves well to capture the spatial distribution of agriculture (Bellow et al. 1996). Therefore, the estimates provided in this study appear to underestimate the total extent of annual, perennial, and total agriculture, especially when compared to the land use data reported by the COA.

The central improvement contained within this spatial model is in the integration of state-based soil productivity information to calculate a more realistic expected yield than that found in the sub-model. The sub-model relied on regional yields based on average soil productivity from VALUES productivity class IIA soils for each indicator crop and was applied to all available lands determined from the COA. The spatial model reveals the highly variable, discontinuous nature of soil productivity throughout the sub-region. For both types of agricultural production, the GF model estimates a lower productivity ranking than that assumed by the CD model. The GF model calculated the average VALUES soil productivity group to be IIB for annual crops and III for perennial crops. The production potential calculated with data from the foodshed matrix provides a much more precise estimation of the capacity of regional agriculture to meet food needs.

The map results of the different soil productivity values seen at the Virginia and North Carolina state line speak to the difficulty of integrating two distinct productivity databases created by different agencies over different scales of sampling (Fig. 9 and Fig. 10). These differences observed in the mapping outputs of the GF model present state-based differences in the soil suitability classification which possibly arise from two sources of uncertainty: the adjusted slope values and different expected yields assigned in the two states.

While the RYE database explicitly assigns expected yields for sloping and non-sloping lands, the VALUES database had to be manipulated in order to associate each soil map unit with a yield adjustment according to slope. Different thresholds could exist in North Carolina, or the process for adjusting expected yield could be different. Though the slope adjustment process may have some effect on the results contained within this study, the state-based differences in expected yield assignment is a more likely overall cause of these major differences that are so apparent at the state line. The expected yields used in this study are products of two different assignment processes in two different states. By state, soil series in a state were assigned a single value, an average for that soil series across all locations within each state though yields within a soil series can vary from north to south due to subtle climactic gradients and other site-specific factors. Essentially, it might be expected that yields are more sensitive to climactic conditions than soil-forming processes and soil taxonomic classes. Other more broad-scale topographic realities result in yield changes across state lines, as witnessed in the Blue Ridge plateau area. A more detailed study of the yields of soil series extending across state lines is needed to resolve this issue for an even more precise regional analysis.

To better understand the discrepancy between soil suitability and current agricultural production, locations showing high areas of annual-suited soil yet very low agricultural land cover were viewed in the GIS. It appears that the issue involves the wide definition of suitability used in this study. Soils suited for agriculture are defined as any soil able to produce a yield expressed in the VALUES or NCRYE database productivity groups for the indicator crops included. Therefore, soils with extremely low yields are still considered suitable, though map units with erosion or slope factors too steep for tillage were excluded. The majority of areas with high amounts of suitable soils and low amounts of agricultural land cover contain large amounts of low-productivity soils. This is a limitation in using soil-based estimates of yield, but this study still offers a level of refinement not otherwise available. These differences across the sub-region merit the attention of future research.

Though the majority of agricultural land in the sub-region matches its suitability by production type, there are areas that could be reallocated in order to contribute to improved nutrition and health outcomes of the people of south-central Appalachia. Most significantly is that half of all perennial production occurs on lands described by the model as suited for annual crop production (Fig. 14). Perennial crop production on annual-suited soils could be occurring for a variety of economic and cultural reasons. This could reflect the high economic return and consumer demand of perennial food crops and animal-based agriculture or the fact that while full time farmers struggle make a living, animal-based agriculture can supplement income from off farm jobs. Shifts in dietary preference or better prices for annual horticultural products within the region could lead to changes in land cover and use such as dedicating more perennial-suited soils to perennial food crops and less to the production of perennial feed and forage for animal product production. The impacts of reallocating perennial land to annual production on agricultural carrying capacity in the sub-region would need to be better understood, especially as the CD model determines that it is perennial and not annual cropland which is the limiting factor to populations following a MyPlate diet.

Land reallocation could have effects on the environmental quality of agriculture in the sub-region as well. The foodshed matrix reveals that 8% of agricultural land is currently in annual crop production on soils that are best suited for perennial crop production. This means that marginal, lower productivity, and often more erodible soils are being used to produce agronomic and horticultural crops, resulting in lower yield returns overall. Even more interesting was that the foodshed matrix estimates that 40%, or half of all perennial crop production occurs on soils that are suited for annual crop production (Fig. 14).

The results of the GF model are generally transferable to the entire south-central Appalachian foodshed, finding that the region is unable to meet all complete diet food need for its entire population. The region is certainly limited by total agriculture land and by below-average soil productivity ratings, but despite these natural barriers, the region is poised to fulfill a quarter of total food need, meeting 21% of annual crop need and 29% of perennial crop need. To contextualize these findings, the seminal study conducted by Peters et al. (2009) found that New York State (NYS) could meet 34% of total food need, meeting 32% of annual crop need and 44% of perennial crop need. Appalachia is unable to meet as high of a proportion of food need from within the region as NYS, however, these findings offer a realistic regional target that can be used for further regional planning to optimize production of specific crops and general food groups in order to further align the fields of agriculture and nutrition. The GF model offers further justification for developing and improving regional food systems in Appalachia as a strategy to make measurable improvements in food security and health outcomes.

Current campaigns to increase local food consumption have found that local populations rarely spend more than 1% of their food budget on local foods. In regions with more developed local and regional food systems, that number might increase to closer to 2%, and a review of published reports on the topic find that a local food consumption rate of 5% in Vermont is on the higher end of what is currently seen in local food consumption (Martinez et al. 2010; Conner et al. 2013). Currently, there are multiple regional efforts attempting to raise this figure to the 10% mark (Curtis et al. 2010). These efforts highlight that the contribution of local and regional food crops in overall diet is a fraction of total consumption. The findings of this study reveal that Appalachian lands are insufficient to meet total dietary need, but also estimate a reasonable target or upper bound to regional food production if the goal is alignment with nutritional guidelines. There are other social, cultural, and economic reasons to support these regional food systems that go beyond the scope of this particular study including the fact that local and regional food production and consumption do act as economic multipliers and bring more money back into local economies than imported food crops, and therefore their economic impact is important to rural economies (Peters et al. 2012). The fact that 25% of complete diet food need by food weight could be met regionally is an important finding and indicates room for growth and supports the further development of regional food systems in south-central Appalachia.

With limited agricultural land resources, the spatial model estimates that the production potential of the study area is unable to fully meet the food need of its current population under the MyPlate recommendations. This study provides important information for producers and other community stakeholders invested in maximizing the potential of regional agriculture. Despite severe limits to land availability and highly productive soils, regional food systems in Appalachia offer significant potential if harnessed with the goal of meeting optimal nutritional needs of the population. The spatial model reveals a complex picture of the alignment between land use, soil suitability, and production potential. The Appalachian foodshed may turn to regional agriculture systems to enhance food security, but with the understanding that annual cropland is limited and that current recommendations for a complete diet including animal products cannot be fully met for the entire population. This means that the Appalachian foodshed does not have the biocapacity to be entirely self-sufficient in terms of the production of balanced diets and must coordinate with other regional or global systems to jointly make the most of its limited agricultural resources and improve nutrition outcomes. Stakeholders, researchers and producers can take the information contained herein and use it to consider strategies for prioritizing regional production of specific foods and food groups of these complete diet needs based on regional production potential.

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CHAPTER 4

CONCLUSIONS

This thesis uses multiple approaches to measuring regional capacity to enhance food security through regional agriculture. From the perspective of a data user, tools and methods developed for use in regions throughout the U.S. were applied to the south-central Appalachian foodshed. These tools and methods- including the complete diet approach and foodshed mapping techniques- quantify the impacts of both consumption and production at a regional scale in a region struggling to healthfully meet the food needs of its population. This research was driven by the direct data needs of community stakeholders, producers and researchers in the study area interested in the potential of local and regional food systems in hopes of reaping an array of social and environmental benefits ranging from the nutritional, supporting local economies, preserving agricultural traditions, and improving environmental health.

The complete diet study (Chapter 2) and the geospatial foodshed mapping study (Chapter 3) allow for some conclusions to be drawn and opens the door for many questions about the regional capacity to produce complete diet needs for its population. The complete diet approach serves as a useful framework for realizing the relationship between consumer dietary choice and land requirements. These findings can serve as a justification for community nutrition educators to link diets that reduce the typical intake of fat and animal products with environmental impacts. Others who may benefit from this approach and the results presented in this thesis include regional planners and those modeling the effects of population change in the region as they relate to regional food systems.

The complete diet study estimates that diets exceeding recommended amounts of animal product intake could not be fully supplied from within the region for all people. It also estimates that the federally recommended MyPlate diet could be met for all people given yields estimated based on an assumed average soil productivity rating and survey-reported land use figures from the Census of Agriculture. However, the geospatial foodshed model reveals that there is substantially less land available for agricultural production based on current land cover and furthermore, that the lands available are affected by highly variable soil productivity. The CD model assumed an average soil productivity throughout the study region, which would result in expected yields of 17 tons per hectare of the annual indicator crop (corn silage) and 3.4 tons per hectare of the perennial indicator crop (hay). The GF model calculated lower than average soil productivity in the sub-region, estimating yields of 16.4 tons per hectare for annual crops and 2.3 tons per hectare of perennial crops.

Again, the study areas used for both studies are different, with the entire regional foodshed included in the CD model and the Virginia-North Carolina sub-region used for the GF model. According to the geospatial model, most high productivity land is currently in agricultural production, supporting the assumption that the current land cover represents a reasonable estimate of agricultural potential. The refinement of the geospatial model concludes that the south-central Appalachian region could not meet the complete diet needs of the current population given the current extent of agricultural lands and expected yield values, but estimates that approximately 25% of total food needs could be met from within the region.

Regional foodshed models are data intensive, involve inherently complex systems, and require detailed, place-based knowledge of diets and production in order to be relevant. Future foodshed analyses based in south-central Appalachia or other regions would benefit enormously from more detailed data on actual dietary intakes of a given population in order to more precisely measure land and food requirements. This thesis does not consider the contributions of home gardening or hunting to human diets, potentially important sources of nutrition in Appalachia. Data on areas gardened and pounds of meat obtained from hunting would add another layer of place-based information to this study. Moreover, specific data on production types and yields would benefit the study region, though this is constrained by the fact that this type of information is frequently considered proprietary information and growers are not required to report yields. This thesis relies on expert knowledge of expected yields as neither Virginia or North Carolina report yields of individual food crops on an annual basis for each county as is done in other states but rather report them in the form of expected yield by soil series. A database linking annual reported yields by soil series and adjusted for slope would create a vastly improved, precise foodshed analysis.

While this thesis measures the relationship between diet, agricultural land availability, and soil productivity, many other environmental, agronomic, social, cultural, and political factors contribute to overall food security. Interdisciplinary approaches integrating data from multiple sectors are needed in order to make concrete improvements in an area as complex as food security. The contained foodshed analysis continues the work of regional-scale assessments that will be necessary as agriculture faces the concurrent challenges of population change, increased demand for animal products, and diminishing numbers of farmers and farms. It is necessary to note that this thesis experiments with generalized forms of data and models regional production potential and diets based on numerous stated assumptions. The results and conclusions contained herein are useful in that they can inform current regional discussions on strategies for enhanced food security.

APPENDIX A

INPUT AND OUTPUT DATA USED IN THE COMPLETE-DIET MODEL

Datasets used in the complete diet model

USDA Census of Agriculture data for years 2007 and 2012 were used to determine categories of land use (Fig. A1; USDA 2014). This gave the total land in farms, cropland, pastureland, woodland, and other land. Cropland was further broken down into harvested cropland, pastured cropland, and other cropland. Pastureland was classified as permanent or non-permanent pasture or grazing lands. Woodlands were classified as pastured or non-pastured. The category of "other lands" included land in farms that were not part of one of these categories and include things like house lots, on-farm vending and processing sites, bodies of water, roads, waste land, or other non-production uses.

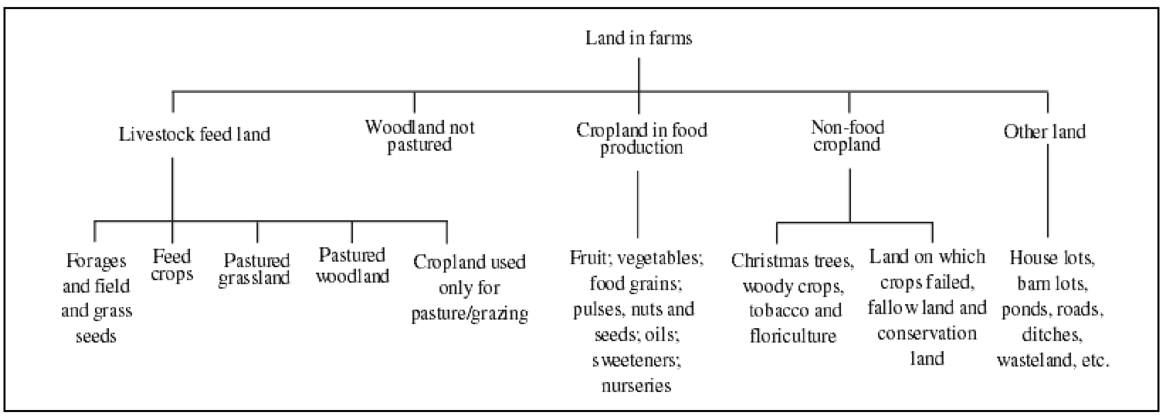

Figure 16. Land use classification with Census of Agriculture (Griffin et al. 2014).

Nutritional information for each specific food crop included in the six regional diet types were taken from the USDA National Nutrient Database for Standard Reference, which was last updated in 2011. This database allows users to determine standard nutritional content of all foods included in the diets, including total energy (calories), energy density, fat content, and the unique identifier called an NDB number. Preparation method was also noted by NDB number, as different methods of cooking, preserving and processing influence nutritional content.

The Food Availability Per Capita Data System was used to calculate relative preferences for each food item in the diets. These preference percentages were based on a five-year average of annual food disappearance from 2008-2012. There was no data that was more detailed or specific about the exact dietary intake patterns of the population of the study area. Therefore, this national data was used, following the methods of Peters et al. (2007).

County or regional-level yield data was unavailable for all regional crops selected for use in this model. Therefore, annual state yield and output data was used when possible (mainly for commodity crops like corn, soybeans, small grains). Horticultural crop yields for the study area were derived from personal communication with regional experts in the field. These yields represent above-average expected yield for producers using good management practices over the course of several years of production.

The USDA MyPlate dietary recommendations were used to create a baseline diet for the average, moderately active adult person within the study area. Information consulted in the creation of the diets contained in this thesis are presented subsequently.

Serving size specifications by food group for the MyPlate federal dietary recommendations used to design diets.

Table A. 1. Grain food group servings.

What counts as an ounce equivalent of grains?

In general, 1 slice of bread, 1 cup of ready-to-eat cereal, or ½ cup of cooked rice, cooked pasta, or cooked cereal can be considered as 1 ounce equivalent from the Grains Group.

The chart lists specific amounts that count as 1 ounce equivalent of grains towards your daily recommended intake. In some cases the number of ounce-equivalents for common portions are also shown.

		Amount that counts as 1 ounce equivalent of grains	Common portions and ounce equivalents
Bagels	WG*: whole wheat RG*: plain, egg	1 "mini" bagel	1 large bagel = 4 ounce equivalents
Biscuits	(baking powder/ buttermilk—RG*)	1 small (2" diameter)	1 large (3" diameter) = 2 ounce equivalents
Breads	WG*: 100% Whole wheat RG*: white, wheat, French, sourdough	1 regular slice 1 small slice French 4 snack-size slices rye bread	2 regular slices = 2 ounce equivalents
Bulgur	cracked wheat (WG*)	½ cup cooked	
Cornbread	(RG*)	1 small piece (2 ½" x 1 ¼" x 1 ¼")	1 medium piece (2 ½" x 2 ½" x 1 ¼") = 2 ounce equivalents
Crackers	WG*: 100% whole wheat, rye	5 whole wheat crackers 2 rye crispbreads	
	RG*: saltines, snack crackers	7 square or round crackers	
English muffins	WG*: whole wheat RG*: plain, raisin	½ muffin	1 muffin = 2 ounce equivalents
Muffins	WG*: whole wheat RG*: bran, corn, plain	1 small (2 ½" diameter)	1 large (3 ½" diameter) = 3 ounce equivalents
Oatmeal	(WG)	½ cup cooked 1 packet instant 1 ounce (1/3 cup) dry (regular or quick)	
Pancakes	WG*: Whole wheat, buckwheat RG*: buttermilk, plain	1 pancake (4 ½" diameter) 2 small pancakes (3" diameter)	3 pancakes (4 ½" diameter) = 3 ounce equivalents
Popcorn	(WG*)	3 cups, popped	1 mini microwave bag or 100-calorie bag, popped = 2 ounce equivalents
Ready-to-eat breakfast cereal	WG*: toasted oat, whole wheat flakes RG*: corn flakes, puffed rice	1 cup flakes or rounds 1 ¼ cup puffed	
Rice	WG*: brown, wild RG*: enriched, white, polished	½ cup cooked 1 ounce dry	1 cup cooked = 2 ounce equivalents
Pasta--spaghetti, macaroni, noodles	WG*: whole wheat RG*: enriched, durum	½ cup cooked 1 ounce dry	1 cup cooked = 2 ounce equivalents
Tortillas	WG*: whole wheat, whole grain corn RG*: Flour, corn	1 small flour tortilla (6" diameter) 1 corn tortilla (6" diameter)	1 large tortilla (12" diameter) = 4 ounce equivalents

*WG = whole grains, RG = refined grains. This is shown when products are available both in whole grain and refined grain forms.

Table A. 2. Vegetable food group serving sizes.

What Counts as a Cup of Vegetables?

In general, 1 cup of raw or cooked vegetables or vegetable juice, or 2 cups of raw leafy greens can be considered as 1 cup from the Vegetable Group.

The chart lists specific amounts that count as 1 cup of vegetables (in some cases equivalents for ½ cup are also shown) towards your recommended intake.

	Amount that counts as 1 cup of vegetables	Amount that counts as ½ cup of vegetables
Dark Green Vegetables		
Broccoli	1 cup chopped or florets 3 spears 5" long raw or cooked	
Greens (collards, mustard greens, turnip greens, kale)	1 cup cooked	
Spinach	1 cup, cooked 2 cups raw is equivalent to 1 cup of vegetables	1 cup raw is equivalent to ½ cup of vegetables
Raw leafy greens: Spinach, romaine, watercress, dark green leafy lettuce, endive, escarole	2 cups raw is equivalent to 1 cup of vegetables	1 cup raw is equivalent to ½ cup of vegetables
Red and Orange Vegetables		
Carrots	1 cup, strips, slices, or chopped, raw or cooked	
	2 medium	1 medium carrot
	1 cup baby carrots (about 12)	About 6 baby carrots
Pumpkin	1 cup mashed, cooked	
Red peppers	1 cup chopped, raw, or cooked 1 large pepper (3" diameter, 3¾" long)	1 small pepper
Tomatoes	1 large raw whole (3")	1 small raw whole (2¼" diameter)
	1 cup chopped or sliced, raw, canned, or cooked	1 medium canned
Tomato juice	1 cup	½ cup
Sweet potato	1 large baked (2¼" or more diameter)	
	1 cup sliced or mashed, cooked	
Winter squash (acorn, butternut, hubbard)	1 cup cubed, cooked	½ acorn squash, baked = ¾ cup
Beans and Peas		
Dry beans and peas (such as black, garbanzo, kidney, pinto, or soy beans, or black eyed peas or split peas)	1 cup whole or mashed, cooked	

Table A. 2 continued.

Starchy Vegetables		
Corn, yellow or white	1 cup 1 large ear (8" to 9" long)	1 small ear (about 6" long)
Green peas	1 cup	
White potatoes	1 cup diced, mashed 1 medium boiled or baked potato (2½" to 3" diameter) French fried: 20 medium to long strips (2½" to 4" long) (Contains added calories from solid fats.)	
	Amount that counts as 1 cup of vegetables	**Amount that counts as ½ cup of vegetables**
Other Vegetables		
Bean sprouts	1 cup cooked	
Cabbage, green	1 cup, chopped or shredded raw or cooked	
Cauliflower	1 cup pieces or florets raw or cooked	
Celery	1 cup, diced or sliced, raw or cooked 2 large stalks (11" to 12" long)	1 large stalk (11" to 12" long)
Cucumbers	1 cup raw, sliced or chopped	
Green or wax beans	1 cup cooked	
Green peppers	1 cup chopped, raw or cooked 1 large pepper (3" diameter, 3¾" long)	1 small pepper
Lettuce, iceberg or head	2 cups raw, shredded or chopped = equivalent to 1 cup of vegetables	1 cup raw, shredded or chopped = equivalent to ½ cup of vegetables
Mushrooms	1 cup raw or cooked	
Onions	1 cup chopped, raw or cooked	
Summer squash or zucchini	1 cup cooked, sliced or diced	

Table A3. Fruit food group serving sizes.

What Counts as a Cup of Fruit?

In general, 1 cup of fruit or 100% fruit juice, or ½ cup of dried fruit can be considered as 1 cup from the Fruit Group. The following specific amounts count as 1 cup of fruit (in some cases, other equivalent amounts are also shown) towards your daily recommended intake:

	Amount that counts as 1 cup of fruit	Other amounts (count as ½ cup of fruit unless noted)
Apple	½ large (3.25" diameter) 1 small (2.5" diameter) 1 cup sliced or chopped, raw or cooked	½ cup sliced or chopped, raw or cooked
Applesauce	1 cup	1 snack container (4 oz)
Banana	1 cup sliced 1 large (8" to 9" long)	1 small (less than 6" long)
Cantaloupe	1 cup diced or melon balls	1 medium wedge (1/8 of a med. melon)
Grapes	1 cup whole or cut-up 32 seedless grapes	16 seedless grapes
Grapefruit	1 medium (4" diameter) 1 cup sections	½ medium (4" diameter)
Mixed fruit (fruit cocktail)	1 cup diced or sliced, raw or canned, drained	1 snack container (4 oz) drained = 3/8 cup
Orange	1 large (3-1/16" diameter) 1 cup sections	1 small (2-3/8" diameter)
Orange, mandarin	1 cup canned, drained	
Peach	1 large (2 ¾" diameter) 1 cup sliced or diced, raw, cooked, or canned, drained 2 halves, canned	1 small (2" diameter) 1 snack container (4 oz) drained = 3/8 cup

Table A. 3 continued.

Pear	1 medium pear (2.5 per lb) 1 cup sliced or diced, raw, cooked, or canned, drained	1 snack container (4 oz) drained = 3/8 cup
Pineapple	1 cup chunks, sliced or crushed, raw, cooked or canned, drained	1 snack container (4 oz) drained = 3/8 cup
Plum	1 cup sliced raw or cooked 3 medium or 2 large plums	 1 large plum
Strawberries	About 8 large berries 1 cup whole, halved, or sliced, fresh or frozen	 ½ cup whole, halved, or sliced
Watermelon	1 small wedge (1" thick) 1 cup diced or balls	6 melon balls
Dried fruit (raisins, prunes, apricots, etc.)	½ cup dried fruit is equivalent to 1 cup fruit: ½ cup raisins ½ cup prunes ½ cup dried apricots	¼ cup dried fruit is equivalent to ½ cup fruit 1 small box raisins (1.5 oz)
100% fruit juice (orange, apple, grape, grapefruit, etc.)	1 cup	½ cup

Table A. 4. Dairy food group servings.

What Counts as a Cup in the Dairy Group?

In general, 1 cup of milk, yogurt, or soymilk (soy beverage), 1 ½ ounces of natural cheese, or 2 ounces of processed cheese can be considered as 1 cup from the Dairy Group.

The chart lists specific amounts that count as 1 cup in the Dairy Group towards your daily recommended intake:

	Amount That Counts as a Cup in the Dairy Group	Common Portions and Cup Equivalents
Milk (choose fat-free or low-fat milk)	1 cup milk	
	1 half-pint container milk	
	½ cup evaporated milk	
Yogurt (choose fat-free or low-fat yogurt)	1 regular container (8 fluid ounces)	1 small container (6 ounces) = ¾ cup
	1 cup yogurt	1 snack size container (4 ounces) = ½ cup
Cheese (choose reduced-fat or low-fat cheeses)	1 ½ ounces hard cheese (cheddar, mozzarella, Swiss, Parmesan)	1 slice of hard cheese is equivalent to ½ cup milk
	⅓ cup shredded cheese	
	2 ounces processed cheese (American)	1 slice of processed cheese is equivalent to ⅓ cup milk
	½ cup ricotta cheese	
	2 cups cottage cheese	½ cup cottage cheese is equivalent to ¼ cup milk
Milk-based desserts (choose fat-free or low-fat types)	1 cup pudding made with milk	
	1 cup frozen yogurt	
	1 ½ cups ice cream	1 scoop ice cream is equivalent to ⅓ cup milk
Soymilk (soy beverage)	1 cup calcium-fortified soymilk	
	1 half-pint container calcium-fortified soymilk	

Table A. 5. Protein-rich foods (meat, eggs, pulses, nuts and seeds food groups) servings.

What Counts as an Ounce Equivalent in the Protein Foods Group?

In general, 1 ounce of meat, poultry or fish, ¼ cup cooked beans, 1 egg, 1 tablespoon of peanut butter, or ½ ounce of nuts or seeds can be considered as 1 ounce equivalent from the Protein Foods Group.

The chart lists specific amounts that count as 1 ounce equivalent in the Protein Foods Group towards your daily recommended intake:

	Amount that counts as 1 ounce equivalent in the Protein Foods Group	Common portions and ounce equivalents
Meats	1 ounce cooked lean beef	1 small steak (eye of round, filet) = 3½ to 4 ounce equivalents
	1 ounce cooked lean pork or ham	1 small lean hamburger = 2 to 3 ounce equivalents
Poultry	1 ounce cooked chicken or turkey, without skin	1 small chicken breast half = 3 ounce equivalents
	1 sandwich slice of turkey (4 ½ x 2 ½ x 1/8")	½ Cornish game hen = 4 ounce equivalents
Seafood	1 ounce cooked fish or shell fish	1 can of tuna, drained = 3 to 4 ounce equivalents 1 salmon steak = 4 to 6 ounce equivalents 1 small trout = 3 ounce equivalents
Eggs	1 egg	3 egg whites = 2 ounce equivalents 3 egg yolks = 1 ounce equivalent
Nuts and seeds	½ ounce of nuts (12 almonds, 24 pistachios, 7 walnut halves) ½ ounce of seeds (pumpkin, sunflower or squash seeds, hulled, roasted) 1 Tablespoon of peanut butter or almond butter	1 ounce of nuts or seeds = 2 ounce equivalents
Beans and peas	¼ cup of cooked beans (such as black, kidney, pinto, or white beans) ¼ cup of cooked peas (such as chickpeas, cowpeas, lentils, or split peas) ¼ cup of baked beans, refried beans	1 cup split pea soup = 2 ounce equivalents 1 cup lentil soup = 2 ounce equivalents 1 cup bean soup = 2 ounce equivalents
	¼ cup (about 2 ounces) of tofu 1 oz. tempeh, cooked ¼ cup roasted soybeans 1 falafel patty (2 ¼", 4 oz) 2 Tablespoons hummus	1 soy or bean burger patty = 2 ounce equivalents

Table A. 6. Added fats food group servings.

How Much Is My Allowance for Oils?

Some Americans consume enough oil in the foods they eat, such as:

- nuts
- fish
- cooking oil
- salad dressings

Others could easily consume the recommended allowance by substituting oils for some solid fats they eat. A person's allowance for oils depends on age, sex, and level of physical activity. Daily allowances are shown in the chart.

Daily allowance*		
Children	2-3 years old	3 teaspoons
	4-8 years old	4 teaspoons
Girls	9-13 years old	5 teaspoons
	14-18 years old	5 teaspoons
Boys	9-13 years old	5 teaspoons
	14-18 years old	6 teaspoons
Women	19-30 years old	6 teaspoons
	31-50 years old	5 teaspoons
	51+ years old	5 teaspoons
Men	19-30 years old	7 teaspoons
	31-50 years old	6 teaspoons
	51+ years old	6 teaspoons

*These amounts are appropriate for individuals who get less than 30 minutes per day of moderate physical activity, beyond normal daily activities. Those who are more physically active may be able to consume more while staying within calorie needs.

All serving size recommendations can be found at Web site http://www.choosemyplate.gov/food-groups/ (Verified 15 May 2014).

Table A. 7. Consumer relative preferences by food group and subgroup used to design diets.

Food items by food group and subgroup.	Relative preference[1]	2008	2009	2010	2011	2012	5-year average
	(%)	g/day	g/day	g/day	g/day	g/day	g/day
GRAINS							
WHEAT, flour	**84.73**	119.5	117.8	118.0	115.9	117.6	117.8
RYE, flour	**0.30**	0.43	0.42	0.42	0.42	0.43	0.42
CORN, meal	**12.29**	16.9	16.9	16.9	17.4	17.3	17.1
OATS, cereal	**2.68**	3.47	3.79	3.73	3.81	3.78	3.72
All grains	100.00						139.0
VEGETABLES, SUMMER							
dark green vegetables:							
BROCCOLI, FRESH	**28.76**	2.98	3.06	2.77	2.93	3.11	2.97
GREENS, COLLARDS, FRESH	**1.10**	0.09	0.10	0.13	0.12	0.12	0.11
GREENS, KALE, FRESH	**0.54**	0.05	0.05	0.06	0.06	0.06	0.06
LETTUCE, ROMAINE, FRESH	**59.39**	5.73	5.50	6.61	6.46	6.35	6.13
SPINACH, FRESH	**10.21**	1.05	1.22	1.02	1.08	0.91	1.05
Dark green vegetables	100.00						10.32
beans & peas:							
LIMA BEANS	**8.98**	0.25	0.21	0.32	0.24	0.31	0.27
PEAS, GREEN, FROZEN	**45.51**	1.46	1.37	1.23	1.18	1.48	1.35
PEAS, GREEN, CANNED	**45.51**	1.46	1.37	1.23	1.18	1.48	1.35
Beans & peas	100.00						2.96
starchy vegetables:							
POTATOES, FRESH	**98.77**	35.4	34.3	34.5	31.9	33.3	33.9
SWEET CORN, FRESH	**1.23**	0.42	0.42	0.42	0.41	0.44	0.42
Starchy vegetables	100.00						34.3
red & orange vegetables:							
CARROTS, FRESH	**22.22**	5.07	4.65	4.88	4.72	4.92	4.85
SWEET POTATOES, FRESH	**7.55**	1.36	1.41	1.70	1.91	1.85	1.65
TOMATOES, FRESH	**70.23**	14.26	15.09	15.83	15.69	15.72	15.32
Red & orange vegetables	100.00						21.81
other vegetables:							
ASPARAGUS, FRESH	**1.81**	0.42	0.46	0.49	0.50	0.52	0.48
CABBAGE, FRESH	**15.27**	4.48	4.03	4.15	3.83	3.74	4.05
CAULIFLOWER, FRESH	**1.57**	0.46	0.51	0.39	0.37	0.35	0.42
CUCUMBERS, FRESH	**11.32**	2.81	2.99	2.97	2.84	3.39	3.00
EGGPLANT	**1.49**	0.38	0.40	0.38	0.38	0.42	0.39
GREEN BEANS, FRESH	**4.39**	1.20	1.07	1.14	1.20	1.20	1.16

Table A. 7 continued.

Food items by food group and subgroup.	Relative preference[1]	2008	2009	2010	2011	2012	5-year average
	(%)	g/day	g/day	g/day	g/day	g/day	g/day
ONIONS	**36.76**	10.00	9.70	9.70	9.47	9.82	9.74
PEPPERS, FRESH	**17.74**	4.30	4.44	4.68	4.79	5.29	4.70
SUMMER SQUASH, FRESH	**9.49**	2.37	2.51	2.46	2.55	2.69	2.51
WINTER SQUASH & PUMPKIN, FRESH	**0.17**	0.05	0.04	0.04	0.04	0.05	0.05
OTHER VEGETABLES	100.00						26.50
VEGETABLES, WINTER							
dark green vegetables:							
BROCCOLI, FROZEN	**75.08**	2.08	1.93	1.89	2.05	1.98	1.99
SPINACH, FROZEN	**18.51**	0.41	0.39	0.60	0.57	0.49	0.49
GREENS, COLLARDS, FRESH	**4.30**	0.09	0.10	0.13	0.12	0.12	0.11
GREENS, KALE, FRESH	**2.12**	0.05	0.05	0.06	0.06	0.06	0.06
Dark green vegetables	100.00						2.65
beans & peas:							
PEAS, GREEN, FROZEN	**45.51**	1.46	1.37	1.23	1.18	1.48	1.35
PEAS, GREEN, CANNED	**45.51**	1.46	1.37	1.23	1.18	1.48	1.35
LIMA BEANS, CANNED	**8.98**	0.25	0.21	0.32	0.24	0.31	0.27
Beans & Peas	100.00						2.96
starchy vegetables :							
POTATOES, FRESH	**82.73**	35.4	34.3	34.5	31.9	33.3	33.9
SWEET CORN, CANNED	**12.72**	5.35	6.03	5.44	4.61	4.64	5.21
SWEET CORN, FROZEN	**4.55**	1.87	1.83	1.73	1.92	1.96	1.86
Starchy vegetables	100.00						41.0
red & orange vegetables:							
CARROTS, FROZEN	**2.35**	0.65	0.63	0.61	0.64	0.49	0.60
SWEET POTATOES, FRESH	**6.40**	1.36	1.41	1.70	1.91	1.85	1.65
TOMATOES, CANNED	**91.25**	23.14	24.23	24.51	22.75	22.89	23.51
Red & orange vegetables	100.00						25.76
other vegetables:							
CABBAGE, FRESH	**23.42**	4.48	4.03	4.15	3.83	3.74	4.05
CAULIFLOWER, FROZEN	**1.35**	0.26	0.21	0.22	0.26	0.20	0.23
GREEN BEANS, CANNED	**10.36**	1.78	1.93	1.96	1.70	1.59	1.79
GREEN BEANS, FROZEN	**8.22**	1.58	1.41	1.50	1.19	1.42	1.42
ONIONS	**56.38**	10.00	9.70	9.70	9.47	9.82	9.74

Table A. 7 continued.

Food items by food group and subgroup.	Relative preference[1]	2008	2009	2010	2011	2012	5-year average
WINTER SQUASH & PUMPKIN, FRESH	**0.27**	0.05	0.04	0.04	0.04	0.05	0.05
Other vegetables	100.00						17.28
FRUIT, SUMMER							
whole fruit:							
APPLES, FRESH	**36.40**	12.245	12.510	11.771	11.855	12.287	12.134
BLACKBERRIES, FRESH	**3.12**	0.757	0.903	1.056	1.214	1.262	1.038
BLUEBERRIES, FRESH	**3.12**	0.757	0.903	1.056	1.214	1.262	1.038
CHERRIES, FRESH	**1.76**	0.440	0.687	0.574	0.573	0.661	0.587
MELONS, CANTALOUPES, FRESH	**2.06**	0.712	0.732	0.686	0.700	0.610	0.688
MELONS, HONEYDEW FRESH	**0.13**	0.045	0.042	0.043	0.042	0.041	0.043
MELONS, WATERMELONS, FRESH	**16.38**	5.658	5.415	5.704	5.146	5.374	5.459
NECTARINES, FRESH	**7.21**	2.695	2.340	2.510	2.386	2.081	2.402
PEACHES, FRESH	**7.21**	2.695	2.340	2.510	2.386	2.081	2.402
PEARS, FRESH	**6.27**	2.136	2.190	1.993	2.204	1.924	2.089
RASPBERRIES, FRESH	**3.12**	0.757	0.903	1.056	1.214	1.262	1.038
STRAWBERRIES, FRESH	**13.24**	3.964	4.397	4.437	4.497	4.771	4.413
All whole fruit	100.00						33.332
fruit juice:							
APPLE JUICE	83.47	19.482	19.379	20.462	16.183	17.278	18.557
GRAPE JUICE	16.53	4.242	3.545	3.483	3.965	3.139	3.675
All fruit juice	100.00						22.232
FRUIT, WINTER							
whole fruit:							
APPLES, FRESH	**66.55**	12.245	12.510	11.771	11.855	12.287	12.134
PEARS, FRESH	**11.46**	2.136	2.190	1.993	2.204	1.924	2.089
BLACKBERRIES, FROZEN	**0.34**	0.072	0.064	0.063	0.048	0.061	0.061
BLUEBERRIES, FROZEN	**2.16**	0.316	0.438	0.477	0.376	0.366	0.395
CHERRIES, FROZEN[2]	**1.51**	0.266	0.296	0.280	0.272	0.261	0.275
PEACHES, CANNED	**14.23**	2.662	2.933	2.698	2.338	2.339	2.594
STRAWBERRIES, FROZEN	**2.03**	0.358	0.333	0.383	0.374	0.403	0.370
RASPBERRIES, FROZEN	**1.72**	0.304	0.282	0.325	0.317	0.341	0.314
All whole fruit	100.00						18.232

Table A. 7 continued.

Food items by food group and subgroup.	Relative preference[1]	2008	2009	2010	2011	2012	5-year average
fruit juice:							
APPLE JUICE	**83.47**	19.482	19.379	20.462	16.183	17.278	18.557
GRAPE JUICE	**16.53**	4.242	3.545	3.483	3.965	3.139	3.675
All fruit juice	100.00						22.232
DAIRY							
MILK, WHOLE	N/A	44.3	43.0	40.8	39.6	39.3	41.4
MILK, SKIM	N/A	23.7	23.4	23.0	22.1	22.0	22.8

Table 2 continued.

Food items by food group and subgroup.	Relative preference[1]	2008	2009	2010	2011	2012	5-year average
PULSES, NUTS, SEEDS							
pulses							
BLACK BEANS, dry	**77.30**	0.56	0.57	0.39	0.93	0.75	0.64
SOYBEANS, tofu[3]	**22.70**	N/A	N/A	N/A	N/A	N/A	N/A
All pulses	100.00						
nuts and seeds							
SUNFLOWER SEEDS	**100.00**	N/A	N/A	N/A	N/A	N/A	N/A
MEAT AND EGGS[4]							
BEEF, REGULAR	**35.98**	56.5	55.3	53.9	51.8	51.9	53.9
PORK, REGULAR	**25.01**	38.8	39.3	37.4	35.8	35.9	37.4
CHICKEN, REGULAR	**39.01**	59.6	56.9	58.9	59.2	57.5	58.4
All meat, regular	100.00						149.7
BEEF, LEAN	**35.98**	56.5	55.3	53.9	51.8	51.9	53.9
PORK, LEAN	**25.01**	38.8	39.3	37.4	35.8	35.9	37.4
CHICKEN, LEAN	**39.01**	59.6	56.9	58.9	59.2	57.5	58.4
All meat, lean	100.00						149.7
EGGS	**100.00**	72.0	72.0	72.0	72.0	72.0	72.0
OILS & ADDED FATS							
BUTTER	**7.88**	3.8	3.7	3.7	4.1	4.2	3.9
LARD	**1.20**	0.7	0.7	0.4	0.6	0.6	0.6
BEEF TALLOW	**2.24**	1.57	1.19	1.19	0.28	1.33	1.11
CHICKEN FAT[5]	**3.16**	1.9	1.5	1.5	1.5	1.5	1.6
SOYBEAN, oil[6]	**85.51**	37.2	41.9	45.1	42.6	44.7	42.3
All oils and added fats	100.00						49.5
ADDED SUGARS							
CORN SYRUP	**88.32**	50.1	47.7	46.6	45.1	44.8	46.9
HONEY	**11.68**	6.1	5.6	6.3	6.5	6.5	6.2
All added sugars	100.00						53.1

1- All relative preferences were calculated using per capita availability of each food item within each food group using 2012 ERS Food Availability (Per Capita) Data System, Loss Adjusted Food Availability Data (FADS).

2- value is average of sweet & sour cherries

3- relative preference values based on ratio provided in Peters et al 2005; soybeans for tofu availability per capita unavailable

4- preferences for both regular and lean cuts of meat based on FADS data for total per capita availability of all beef, pork and chicken respectively

5- value for "other edible fats" in FADS

6- value for "salad and cooking oils" in FADS

Table A. 8. Food commodities included in the diets and their average caloric value per serving1, by food group and food subgroup[2].

Commodity	Specifications	Serving description	Counts as…	NDB #[3]	Serving size	Energy per serving	Fat	Relative preference[4]
	(preparation)	(cups)	(MyPlate)		(g)	(kcal)	(g)	(%)
GRAINS								
WHEAT, flour	average value of white and wheat	1/6 cup	1 ounce equiv	20481, 20081	20.3	72	0.35	84.73
RYE, flour	rye flour, medium	1/6 cup	1 ounce equiv	20064	16.93	59	0.26	0.30
CORN, meal	whole-grain, yellow	1/6 cup	1 ounce equiv	20020	20.25	73	0.73	12.29
OATS, cereal	regular and quick, not fortified, dry	1/2 cup	1 ounce equiv	8120	40.54	154	2.64	2.68
All grains	Average value, weighted					**74.27735**	**0.4577**	100
VEGETABLES, SUMMER								
dark green vegetables:								
BROCCOLI, FRESH	raw	1/2 cup	counts as ½ cup dark green vegetables	11090	44	15	0.16	28.76

Table A. 8 continued.

Commodity	Specifications	Serving description	Counts as…	NDB #[3]	Serving size	Energy per serving	Fat	Relative preference[4]
	(preparation)	(cups)	(MyPlate)		(g)	(kcal)	(g)	(%)
GREENS, COLLARDS, FRESH	cooked, boiled, drained, without salt	1 cup	counts as ½ cup dark green vegetables	11162	190	63	1.37	1.10
GREENS, KALE, FRESH	cooked, boiled, drained, without salt	1 cup	counts as ½ cup dark green vegetables	11234	130	36	0.52	0.54
LETTUCE, ROMAINE, FRESH	raw	1 cup	counts as ½ cup dark green vegetables	11251	47	8	0.14	59.39
SPINACH, FRESH	raw	1 cup	counts as ½ cup dark green vegetables	11457	30	7	0.12	10.21
All dark green vegetables	Average value, weighted					10.6690791	0.15933	100
beans & peas:								
LIMA BEANS	large mature seeds, cooked, boiled, drained, without salt	1/2 cup	1/2 cup dry beans and peas	16072	94	108	0.36	8.98
PEAS, GREEN, FROZEN	cooked, boiled, drained, without salt	1/2 cup	1/2 cup dry beans and peas	11313	80	62.4	0.22	45.51

Table A. 8 continued.

Commodity	Specifications (preparation)	Serving description (cups)	Counts as… (MyPlate)	NDB #[3]	Serving size (g)	Energy per serving (kcal)	Fat (g)	Relative preference[4] (%)
PEAS, GREEN, CANNED	drained	1/2 cup	1/2 cup dry beans and peas	11308	85	60	0.7	45.51
All beans & peas	Average value, weighted					65.4029202	0.45102	100
starchy vegetables:								
POTATOES, FRESH	boiled, cooked in skin, flesh, without salt	1 cup	counts as 1 cup starchy vegetables	11365	156	136	0.16	98.77
SWEET CORN, FRESH	cooked, boiled, drained, without salt	1/2 cup	counts as ½ cup starchy vegetables	11168	74.5	72	1.12	1.23
All starchy vegetables	Average value, weighted					135.215569	0.17177	100
red & orange vegetables:								
CARROTS, FRESH	raw	1/2 cup	counts as 1/2 cup orange vegetables	11124	64	26	0.15	22.22
SWEET POTATOES, FRESH	cooked, baked in skin, without salt	1 cup	counts as 1 cup orange vegetables	11508	200	180	0.3	7.55
TOMATOES, FRESH	raw	1/2 cup	counts as ½ cup other vegetables	11529	90	16	0.18	70.23
All red & orange vegetables	Average value, weighted					30.6106387	0.1824	100

Table A. 8 continued.

Commodity	Specifications (preparation)	Serving description (cups)	Counts as… (MyPlate)	NDB #[3]	Serving size (g)	Energy per serving (kcal)	Fat (g)	Relative preference[4] (%)
other vegetables:								
ASPARAGUS, FRESH	cooked, boiled, drained	1/2 cup	counts as ½ cup other vegetables	11012	90	20	0.2	1.81
CABBAGE, FRESH	raw	1/2 cup	counts as ½ cup other vegetables	11109	44.5	11	0.04	15.27
CAULIFLOWER, FRESH	raw	1/2 cup	counts as ½ cup other vegetables	11135	53.5	13	0.15	1.57
CUCUMBERS, FRESH	raw, with peel	1/2 cup	counts as ½ cup other vegetables	11205	52	8	0.06	11.32
EGGPLANT	boiled, drained, without salt	1/2 cup	counts as ½ cup other vegetables	11210	49.5	17	0.11	1.49
GREEN BEANS, FRESH	cooked, boiled, drained, without salt	1/2 cup	counts as ½ cup other vegetables	11053	62.5	22	0.18	4.39
ONIONS	cooked, boiled, drained, without salt	1/2 cup	counts as ½ cup other vegetables	11283	105	46	0.2	36.76
PEPPERS, FRESH	sweet, green, raw	1/2 cup	counts as ½ cup other vegetables	11333	74.5	15	0.13	17.74
SUMMER SQUASH, FRESH	summer, all varieties, raw	1/2 cup	counts as ½ cup other vegetables	11641	56.5	9	0.1	9.49
WINTER SQUASH & PUMPKIN, FRESH	winter, all varieties, raw	1/2 cup	counts as ½ cup other vegetables	11643	58	20	0.08	0.17

Table A. 8 continued.

Commodity	Specifications (preparation)	Serving description (cups)	Counts as… (MyPlate)	NDB #[3]	Serving size (g)	Energy per serving (kcal)	Fat (g)	Relative preference[4] (%)
All other vegetables	Average value, weighted					24.8269723	0.13461	100
ALL SUMMER VEGETABLES	Average value, weighted[5]					53.3450359	0.21982	
VEGETABLES, WINTER								
dark green vegetables:								
BROCCOLI, FROZEN	frozen, chopped, cooked, boiled, drained, without salt	1/2 cup	counts as ½ cup dark green vegetables	11093	92	26	0.11	75.08
SPINACH, FROZEN	chopped or leaf, cooked, boiled, drained, without salt	1 cup	counts as ½ cup dark green vegetables	11464	190	65	1.65	18.51
GREENS, COLLARDS, FRESH	cooked, boiled, drained, without salt	1 cup	counts as ½ cup dark green vegetables	11162	190	63	1.37	4.30
GREENS, KALE, FRESH	cooked, boiled, drained, without salt	1 cup	counts as ½ cup dark green vegetables	11234	130	36	0.52	2.12
All dark green vegetables	Average value, weighted					35.0211353	0.4579	100

Table A. 8 continued.

Commodity	Specifications	Serving description	Counts as…	NDB #[3]	Serving size	Energy per serving	Fat	Relative preference[4]
	(preparation)	(cups)	(MyPlate)		(g)	(kcal)	(g)	(%)
beans & peas:								
PEAS, GREEN, FROZEN	cooked, boiled, drained, without salt	1/2 cup	1/2 cup dry beans and peas	11313	80	62.4	0.22	45.51
PEAS, GREEN, CANNED	drained	1/2 cup	1/2 cup dry beans and peas	11308	85	60	0.7	45.51
LIMA BEANS, CANNED	large, mature seeds, drained	1/2 cup	1/2 cup dry beans and peas	16073	120.5	95	0.2	8.98
All beans & Peas	Average value, weighted					64.2354424	0.43665	100
starchy vegetables :								
POTATOES, FRESH	boiled, cooked in skin, flesh, without salt	1 cup	counts as 1 cup starchy vegetables	11365	156	136	0.16	82.73
SWEET CORN, CANNED	yellow, canned, whole kernel, drained solids	1/2 cup	counts as 1/2 cup starchy vegetables	11172	82	65	0.91	12.72
SWEET CORN, FROZEN	yellow, frozen, kernels cut off cob, boiled, drained, without salt	1/2 cup	counts as 1/2 cup starchy vegetables	11179	82.5	67	0.55	4.55
All starchy vegetables	Average value, weighted					123.830803	0.27314	100
red & orange vegetables:								
CARROTS, FROZEN	cooked, boiled, drained, without salt	1/2 cup	counts as ½ cup other vegetables	11131	73	27	0.5	2.35

Table A. 8 continued.

Commodity	Specifications (preparation)	Serving description (cups)	Counts as… (MyPlate)	NDB #[3]	Serving size (g)	Energy per serving (kcal)	Fat (g)	Relative preference[4] (%)
SWEET POTATOES, FRESH	cooked, baked in skin, without salt	1 cup	counts as 1 cup orange vegetables	11508	200	180	0.3	6.40
TOMATOES, CANNED	red, ripe, canned, packed in tomato juice	1/2 cup	counts as ½ cup other vegetables	11531	120	20	0.16	91.25
All red & orange vegetables	Average value, weighted					30.3997732	0.17694	100
other vegetables:								
CABBAGE, FRESH	raw	1/2 cup	counts as ½ cup other vegetables	11109	44.5	11	0.04	23.42
CAULIFLOWER, FROZEN	cooked, boiled, drained, without salt	1/2 cup	counts as ½ cup other vegetables	11135	53.5	13	0.15	1.35
GREEN BEANS, CANNED	snap, green, canned, regular pack, drained solids	1/2 cup	counts as ½ cup other vegetables	11056	76.5	19	0.28	10.36
GREEN BEANS, FROZEN	snap, green, frozen, cooked, boiled, drained without salt	1/2 cup	counts as ½ cup other vegetables	11061	67.5	19	0.11	8.22
ONIONS	cooked, boiled, drained, without salt	1/2 cup	counts as ½ cup other vegetables	11283	105	46	0.2	56.38
WINTER SQUASH & PUMPKIN, FRESH	winter, all varieties, raw	1/2 cup	counts as ½ cup other vegetables	11643	58	20	0.08	0.27
All other vegetables	Average value, weighted					32.2711987	0.16242	100

Table A. 8 continued.

Commodity	Specifications (preparation)	Serving description (cups)	Counts as… (MyPlate)	NDB #[3]	Serving size (g)	Energy per serving (kcal)	Fat (g)	Relative preference[4] (%)
ALL WINTER VEGETABLES	Average value, weighted[5]					57.1516705	0.30141	
ALL VEGETABLES (SUMMER AND WINTER)	Average value, weighted[6]					**54.93113**	**0.2538**	
<u>FRUIT, SUMMER</u>								
whole fruit								
APPLES, FRESH	raw, with skin	1/2 cup	counts as ½ cup fruit	9003	62.5	32	0.11	36.40
BLACKBERRIES, FRESH	raw	1/2 cup	counts as ½ cup fruit	9042	72	31	0.35	3.12
BLUEBERRIES, FRESH	raw	1/2 cup	counts as ½ cup fruit	9050	74	42	0.24	3.12
CHERRIES, FRESH	sweet, raw, pitted	1/2 cup	counts as ½ cup fruit	9070	77	49	0.15	1.76
MELONS, CANTALOUPES, FRESH	raw, diced	1/2 cup	counts as ½ cup fruit	9181	80	27	0.3	2.06

Table A .8 continued.

Commodity	Specifications (preparation)	Serving description (cups)	Counts as… (MyPlate)	NDB #[3]	Serving size (g)	Energy per serving (kcal)	Fat (g)	Relative preference (%)
MELONS, HONEYDEW FRESH	raw, diced	1/2 cup	counts as ½ cup fruit	9184	85	31	0.12	0.13
MELONS, WATERMELONS, FRESH	raw, diced	1/2 cup	counts as ½ cup fruit	9326	76	23	0.11	16.38
NECTARINES, FRESH	raw, sliced	1/2 cup	counts as ½ cup fruit	9191	71.5	31	0.23	7.21
PEACHES, FRESH	raw, sliced	1/2 cup	counts as ½ cup fruit	9236	77	30	0.19	7.21
PEARS, FRESH	raw, sliced	1/2 cup	counts as ½ cup fruit	9252	70	40	0.1	6.27
RASPBERRIES, FRESH	raw	1/2 cup	counts as ½ cup fruit	9302	61.5	32	0.4	3.12
STRAWBERRIES, FRESH	raw, sliced	1/2 cup	counts as ½ cup fruit	9316	83	27	0.25	13.24
All whole fruit	Average value, weighted					30.6244149	0.16752	100.00
fruit juice								
APPLE JUICE	canned or bottled, unsweetened, without added ascorbic acid	1 cup	counts as ½ cup fruit	9016	248	114	0.32	83.47
GRAPE JUICE	canned or bottled, unsweetened, without added ascorbic acid	1 cup	counts as ½ cup fruit	9135	253	152	0.33	16.53

Table A. 8 continued.

Commodity	Specifications (preparation)	Serving description (cups)	Counts as… (MyPlate)	NDB #[3]	Serving size (g)	Energy per serving (kcal)	Fat (g)	Relative preference (%)
All fruit juice	Average value, weighted					120.281516	0.32165	100.00
ALL SUMMER FRUIT	Average value, weighted					60.5101152	0.2189	
FRUIT, WINTER								
whole fruit								
APPLES, FRESH	raw, with skin	1/2 cup	counts as ½ cup fruit	9003	62.5	32	0.11	66.55
PEARS, FRESH	raw, sliced	1/2 cup	counts as ½ cup fruit	9252	70	40	0.19	11.46
BLACKBERRIES, FROZEN	frozen, unsweetened, unthawed	1/2 cup	counts as ½ cup fruit	9048	75.5	48	0.32	0.34
BLUEBERRIES, FROZEN	frozen, unsweetened, unthawed	1/2 cup	counts as ½ cup fruit	9054	77.5	40	0.5	2.16
CHERRIES, FROZEN	frozen, unsweetened, unthawed, average of sweet & sour	1/2 cup	counts as ½ cup fruit	09068, 09076	77.5	52.3	0.35	1.51
PEACHES, CANNED	canned, heavy syrup, drained	1/2 cup	counts as ½ cup fruit	9370	111	80	0.2	14.23

Table A .8 continued.

Commodity	Specifications (preparation)	Serving description (cups)	Counts as… (MyPlate)	NDB #[3]	Serving size (g)	Energy per serving (kcal)	Fat (g)	Relative preference (%)
STRAWBERRIES, FROZEN	frozen, unsweetened, unthawed	1/2 cup	counts as ½ cup fruit	9318	74.5	26	0.08	2.03
RASPBERRIES, FROZEN	frozen, red, sweetened, unthawed	1/2 cup	counts as ½ cup fruit	9306	125	129	0.2	1.72
All whole fruit	Average value, weighted					41.8270818	0.14568	100
fruit juice								
APPLE JUICE	canned or bottled, unsweetened, without added ascorbic acid	1 cup	counts as ½ cup fruit	9016	248	114	0.32	83.47
GRAPE JUICE	canned or bottled, unsweetened, without added ascorbic acid	1 cup	counts as ½ cup fruit	9135	253	152	0.33	16.53
All fruit juice	Average value, weighted					120.281516	0.32165	100.00
ALL WINTER FRUIT	Average value, weighted					67.9785597	0.20434	
ALL FRUIT (SUMMER AND WINTER)	Average value, weighted[7]					**63.62197**	**0.2128**	

Table A. 8 continued.

Commodity	Specifications (preparation)	Serving description (cups)	Counts as… (MyPlate)	NDB #[3]	Serving size (g)	Energy per serving (kcal)	Fat (g)	Relative preference (%)
DAIRY								
MILK, WHOLE	3.25% milkfat, without added vitamin A and vitamin D	1 cup	counts as 1 cup dairy	1211	244	**149**	**7.98**	N/A
MILK, SKIM	nonfat, fluid, without added vitamin A and vitamin D (fat free or skim)	1 cup	counts as 1 cup dairy	1151	245	**83**	**0.2**	N/A
PULSES, NUTS, SEEDS								
pulses								
BLACK BEANS	mature seeds, cooked, boiled, without salt	1/2 cup	½ cup dry beans and peas and 2 oz equiv. protein foods	16015	86	114	0.46	77.30
SOYBEANS, tofu	raw, regular, prepared with calcium sulfate	1/2 cup	1/2 cup dry beans and peas and 2 z equiv protein	16427	124	94	5.93	22.70
All pulses	Average value, weighted					109.460993	1.70142	100
nuts and seeds								

Table A .8 continued.

Commodity	Specifications (preparation)	Serving description (cups)	Counts as… (MyPlate)	NDB #[3]	Serving size (g)	Energy per serving (kcal)	Fat (g)	Relative preference (%)
SUNFLOWER SEEDS	kernels, dry roasted, without salt	1/2 oz	1 oz equiv protein	12037	14.18	82	7.06	100
All pulses, nuts, seeds	Average value, weighted[8]					**104.8842**	**2.5945**	
MEAT AND EGGS								
BEEF, REGULAR	cooked, average of all retail cuts (trimmed to 1/4" fat) and ground beef (75% lean, broiled)	1 oz	1 oz equiv protein	13004, 23578	28.4	84.4	5.3	35.98
PORK, REGULAR	cooked, average of all retail cuts, sausage, and bacon	1 oz	1 oz equiv protein	10188, 07064, 10124	28.4	95	5.82	25.01
CHICKEN, REGULAR	roasted, meat and skin	1 oz	1 oz equiv protein	5112	28.4	63.3	3.79	39.01
All meat, regular	Average value, weighted					**78.81895**	**4.8409**	100
BEEF, LEAN	average of all retail cuts (trimmed to 0" fat) and ground beef (95% lean, broiled)	1 oz	1 oz equiv protein	13364, 23558	28.4	56.6	2.245	35.98
PORK, LEAN	composite of ham, shoulder and loin cuts	1 oz	1 oz equiv protein	10093	28.4	60.2	2.61	25.01
CHICKEN, LEAN	roasted, meat only	1 oz	1 oz equiv protein	5114	28.4	47.4	1.87	39.01

Table A .8 continued.

Commodity	Specifications (preparation)	Serving description (cups)	Counts as… (MyPlate)	NDB #[3]	Serving size (g)	Energy per serving (kcal)	Fat (g)	Relative preference (%)
All meat, lean	Average value, weighted					**53.91104**	**2.19**	100
EGGS	large, whole, raw, fresh	1 egg	1 oz equiv protein	1123	50	**72**	**4.76**	100
OILS & ADDED FATS								
BUTTER	unsalted	1 tbsp	N/A	1145	14.2	102	11.52	7.88
LARD		1 tbsp	N/A	4002	12.8	115	12.8	1.20
BEEF TALLOW		1 tbsp	N/A	4001	12.8	115	12.8	2.24
CHICKEN FAT		1 tbsp	N/A	4542	12.8	115	12.77	3.16
SOYBEAN, oil		1 tbsp	N/A	4044	13.6	120	13.6	85.51
All oils and added fats	Average value, weighted					**118.2507**	**13.382**	100
ADDED SUGARS								
CORN SYRUP	average of light and dark syrups	1 tsp	N/A	19349, 19350	7	21	0	88.32
HONEY		1 tsp	N/A	19296	7	21	0	11.68

Table A .8 continued.

Commodity	Specifications	Serving description	Counts as…	NDB #[3]	Serving size	Energy per serving	Fat	Relative preference
	(preparation)	(cups)	(MyPlate)		(g)	(kcal)	(g)	(%)
All added sugars	Average value, weighted					**21**	**0**	100

1- Nutritional data on food commodities obtained from the Nutrient Database for Standard Reference (NDB), release 26 (USDA Agricultural Research Service, 2011). Diets contain only foods which are or can be grown in the South-Central Appalachian Region.
2- In accordance with the USDA MyPlate dietary recommendations, food is divided into seven food groups: grains; vegetables; fruits; dairy; meat, eggs, nuts and pulses; added fats, and added sweeteners. Vegetables are further subdivided into three categories: dark green, starchy, red and orange, beans and peas, and other vegetables. Distinctions are also drawn between whole fruit and juice. For more information see the 2010 Dietary Guidelines for Americans (USDA and US Department of Health and Human Services, 2010.
3- Reference number used by the Nutrient Database for Standard Reference (NDB).
4- All relative preferences were calculated using per capita availability of each food item within each food group using ERS Food Availability (Per Capita) Data System, Loss Adjusted Food Availability Data (2012), see table X.
5- One-fifth of total vegetable servings is assumed to come from each subgroup.
6- Assumes 7/12 servings from summer vegetables and 5/12 servings from winter vegetables

7- Assumes 7/12 servings from summer fruits and 5/12 servings from winter fruits
8- Assumes that 5 out of 6 servings come from pulses and 1 out of 6 from nuts and seeds

Table A. 9. Weighted average caloric and fat content per serving of food groups in diets[1].

	avg k/cal per serving	avg fat per serving
grains	74.27734854	0.457689478
vegetables	54.93113364	0.253819146
fruit	63.62196709	0.212831475
skim	83	0.2
whole	149	7.98
pulses nuts seeds	104.8841608	2.594515366
lean	53.91104147	2.189974629
regular	72	4.840938228
eggs	118.2507258	4.76
fats	21	13.38224109
sugars	21	0

1- Weighted averages calculated from all food commodities listed in Table 3.

Table A. 10. Daily servings of food from major food groups and selected food subgroups, by diet.

Diet type	Meat	Fat	Grains	Vegetables	Fruit	Dairy: skim	Dairy: whole	Protein: pulses & seeds	Protein: lean meat	Protein: regular meat	Protein: eggs	Added oils & fats	Added sugars
	--g (oz)/day--	*servings/day*											
AR	227 (8)	65	8.7	3	2	3	2	0	5	3	2	0.6	4.2
AFR	227 (8)	104	8.7	3	2	1	3	0	3	5	2	2.6	1.29
MP	88 (3)	65	9	5	4	1.5	1.5	2	2	1.1	1.5	1.8	7.17
FR	88 (3)	104	8	3	2.5	0	3	1.5	0	3.1	2	3.5	12.02
V	0 (0)	65	9.5	6.1	5	0	0	6.6	0	0	0	3.06	9.18
FRV	0 (0)	104	9.4	6.1	5	0	0	6.6	0	0	0	6	6.6

Table A. 11. Annual servings of food from major food groups and selected food subgroups, by diet.

Diet type	Meat	Fat	Grains	Vegetables	Fruit	Dairy: skim	Dairy: whole	Protein: pulses & seeds	Protein: lean meat	Protein: regular meat	Protein: eggs	Added oils & fats	Added sugars
	----g/year----		*---servings/year---*										
"Animal product-rich"	82855	23725	3175.5	1095	730	1095	730	0	1825	1095	730	219	1533
"Typical"	82855	37960	3175.5	1095	730	365	1095	0	1095	1825	730	949	470.9
"Recommended"	32120	23725	3285	1825	1460	547.5	547.5	730	730	401.5	547.5	657	2617
"Fat-rich"	32120	37960	2920	1095	913	0	1095	547.5	0	1131.5	730	1278	4387
"Animal product-free"	0	23725	3467.5	2226.5	1825	0	0	2409	0	0	0	1117	3351
"Fat-rich, animal product-free"	0	37960	3431	2226.5	1825	0	0	2409	0	0	0	2190	2409

1- Serving sizes as outlined in Table 1. Note that serving sizes are not consistent across food groups (see Table 1).

Table A. 12. Estimates of food system losses, inedible portions, and yields of processed product per unit input used to calculate the farm weight of commodities needed to provide the consumption outlined in the diets.

Food item	% Food-service & consumer loss[1]	% Inedible share[1]	% Cooking loss[1]	% Retail loss[1]	% Loss from primary to retail weight[1]	% Yield per unit weight of farm commodity[2]
APPLE JUICE	15%	0%	0%	1%	0%	73%
APPLES, FRESH	30%	8%	0%	2%	4%	100%
ASPARAGUS, FRESH	30%	47%	7%	2%	9%	85%
BEEF TALLOW	50%	0%	0%	1%	0%	19%
BEEF, LEAN	15%	9%	22%	2%	0%	41%
BEEF, REGULAR	15%	0%	22%	2%	0%	44%
BLACK BEANS	15%	0%	0%	1%	0%	100%
BLACKBERRIES, FRESH	15%	0%	0%	1%	0%	100%
BLACKBERRIES, FROZEN	15%	0%	0%	1%	0%	95%
BLUEBERRIES, FRESH	30%	2%	0%	2%	5%	100%
BLUEBERRIES, FROZEN	15%	0%	0%	1%	0%	97%
BROCCOLI, FRESH	30%	39%	0%	2%	8%	100%
BROCCOLI, FROZEN	15%	0%	6%	1%	25%	75%
BUTTER	30%	0%	0%	2%	0%	3%
CABBAGE, FRESH	30%	20%	0%	2%	7%	100%
CARROTS, FRESH	30%	11%	0%	2%	3%	100%
CARROTS, FROZEN	15%	0%	2%	1%	45%	55%
CAULIFLOWER, FRESH	30%	61%	0%	2%	8%	100%
CAULIFLOWER, FROZEN	15%	0%	7%	1%	0%	70%
CHERRIES, FRESH	30%	10%	0%	2%	8%	100%
CHERRIES, FROZEN[3]	15%	0%	0%	1%	0%	88%
CHICKEN FAT	20%	0%	0%	1%	0%	13%
CHICKEN, LEAN	15%	19%	30%	2%	0%	44%
CHICKEN, REGULAR	15%	0%	30%	2%	0%	44%
CORN, meal	20%	0%	0%	2%	0%	89%
CUCUMBERS, FRESH	30%	27%	0%	2%	8%	100%
EGGPLANT	30%	19%	7%	2%	10%	100%
EGGS	30%	11%	0%	2%	0%	100%

Table A. 13 continued.

Food item	% Food-service & consumer loss[1]	% Inedible share[1]	% Cooking loss[1]	% Retail loss[1]	% Loss from primary to retail weight[1]	% Yield per unit weight of farm commodity[2]
GRAPE JUICE	15%	0%	0%	1%	0%	81%
GRAPES	30%	4%	0%	2%	9%	100%
GREEN BEANS, CANNED	15%	0%	0%	1%	0%	140%
GREEN BEANS, FRESH	30%	12%	2%	2%	6%	100%
GREEN BEANS, FROZEN	15%	0%	10%	1%	0%	85%
GREENS, COLLARDS, FRESH	15%	0%	13%	1%	30%	100%
GREENS, KALE, FRESH	15%	0%	13%	1%	30%	100%
HONEY	30%	0%	0%	1%	0%	100%
LARD	50%	0%	0%	1%	0%	20%
LETTUCE, ICEBURG, FRESH	30%	16%	0%	2%	7%	100%
LETTUCE, ROMAINE, FRESH	30%	16%	0%	2%	7%	100%
MELONS, CANTALOUPES, FRESH	30%	49%	0%	2%	8%	100%
MELONS, HONEYDEW FRESH	30%	54%	0%	2%	8%	100%
MELONS, WATERMELONS, FRESH	30%	48%	0%	2%	10%	100%
MILK, SKIM	30%	0%	0%	2%	0%	97%
MILK, WHOLE	30%	0%	0%	2%	0%	100%
NECTARINES, FRESH	30%	11%	0%	2%	5%	100%
OATS, cereal	20%	0%	0%	2%	0%	58%
ONIONS	30%	10%	15%	2%	6%	100%
PEACHES, CANNED	15%	0%	0%	1%	0%	109%
PEACHES, FRESH	30%	11%	0%	2%	5%	100%
PEARS, FRESH	30%	8%	0%	2%	5%	100%
PEAS, GREEN, CANNED	15%	0%	0%	1%	0%	135%
PEAS, GREEN, FROZEN	15%	0%	7%	1%	0%	92%

Table A. 13 continued.

Food item	% Food-service & consumer loss[1]	% Inedible share[1]	% Cooking loss[1]	% Retail loss[1]	% Loss from primary to retail weight[1]	% Yield per unit weight of farm commodity[2]
PEPPERS, FRESH	30%	18%	0%	2%	8%	100%
PORK, LEAN	15%	0%	39%	2%	0%	35%
PORK, REGULAR	15%	0%	39%	2%	0%	54%
POTATOES, FRESH	30%	23%	10%	2%	4%	100%
RASPBERRIES, FRESH	15%	0%	0%	1%	0%	100%
RASPBERRIES, FROZEN	15%	0%	0%	1%	0%	95%
RYE, FLOUR	20%	0%	0%	2%	0%	86%
SOYBEANS, oil type	20%	0%	0%	1%	0%	18%
SOYBEANS, tofu	30%	0%	0%	2%	0%	592%
SPINACH, FRESH	30%	28%	0%	2%	15%	100%
SPINACH, FROZEN	15%	0%	33%	2%	0%	70%
STRAWBERRIES, FRESH	30%	6%	0%	2%	8%	100%
STRAWBERRIES, FROZEN	15%	0%	0%	1%	0%	112%
SUMMER SQUASH, FRESH	15%	0%	13%	1%	30%	100%
SUNFLOWER SEEDS	15%	0%	0%	1%	0%	100%
SWEET CORN, CANNED	15%	0%	0%	1%	0%	39%
SWEET CORN, FRESH	30%	64%	12%	2%	8%	100%
SWEET CORN, FROZEN	15%	0%	4%	1%	0%	27%
SWEET POTATOES, FRESH	30%	25%	11%	2%	4%	100%
TOMATOES, CANNED	15%	0%	0%	1%	0%	64%
TOMATOES, FRESH	30%	9%	0%	2%	15%	100%
WHEAT[4]	20%	0%	0%	2%	0%	86%
WINTER SQUASH & PUMPKIN, FRESH	30%	26%	15%	2%	8%	100%

Estimates of loss are from Kantor, 1998.
Estimates of loss in processing (yield product per unit weight of farm commodity) are from USDA-ERS 1992.
Average of sweet and sour frozen cherries.
Average of white and wheat flours.

Table A. 14. Feed requirements for hogs, broilers, and laying hens[1].

Livestock class	Corn grain required	Soybean meal required	Mineral supplements	Total feed
	-------------------------------*lbs per marketable animal*			---------------------------------
Hogs				
Feeder pigs	598.5	196.7	59.9	855
Sows	81.4	26.7	8.1	116.3
Boars	2.4	0.8	0.2	3.5
Total, hogs	682.3	224.2	68.2	974.8
Broilers				
Pullets	6.62	3.86	0.55	11.03
Hens	0.5	0.29	0.04	0.83
Roosters	0.05	0.03	0	0.08
Total, broilers	7.16	4.18	0.6	11.93
Layers	--------------------------------------*lbs per 300 eggs*			--------------------------------------
Layers, mature	51.07	25.54	8.51	85.12
Layers, immature	8.96	4.48	1.49	14.93
Hens	0.47	0.24	0.08	0.79
Roosters	0.05	0.02	0.01	0.08
Total, layers	60.55	30.27	10.08	100.91

1- Feed requirements are from Peters et al., 2005 Input Output Data and verified via personal communication with Dr. Cindy Wood, Dept of Animal and Poultry Science, Virginia Polytechnic Institute (8 November 2013). For more information see also: USDA/NRCS Publications on Feed Management http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/plantsanimals/livestock/afo/pub/

Table A. 15. Feed requirements for beef cattle[1].

Type of cattle	End weight *lbs*	Sell weight *lbs*	Time *days*	*months*	Corn grain *bushels*	Corn silage *tons*	Soy (SBOM 48%) *tons*	Grass hay *tons*	Pasture *acres*
Cow and calf[2]	600	600	242	Feb-Sep	22.2545	-	-	4.87823	2.5
Stocker steers[3]	714	700	89	Oct-Dec	12.4241	-	0.02802	1.02232	1.35
Finishing steers[4]	1227	1202	189	Jan - Jul	35.0545	3.37145	0.12433	0.03465	-
Total, beef cattle			520	1.5 years	**69.733**	**3.3714**	**0.1524**	**5.9352**	**3.85**

1- Per marketable animal. Feed requirements compiled as Enterprise Budgets by G. Groover, Dept of Agricultural and Applied Economics, Virginia Polytechnic Institute. Obtained via personal communication with G. Groover (4 April 2014).
2- Assuming hay ration and spring calving with a 90% conception rate, 85% weaned calves per cow exposed, 40 cows per bull, 30% of heifers weaned kept as replacements, 14% annual culling rate, and 1% annual cow death loss. Amounts of feed include steers, heifers, cull cows, cull heifers and cull bulls required to produce one 600lb stocker steer to move to stocker phase.
3- Assuming hay ration and fall to fall stocker period with 30 days on feed with an 0.85 lbs average daily gain and 59 days on pasture with 1.5 lbs average daily gain. Death loss of 2% assumed. Calves purchased at 600 lbs and fed on this ration until reaching end weight of 714 lbs for a selling weight of 700 lbs assuming 2% shrinkage.
4- Assuming two-phase ration system with 14 days on hay/corn silage with 1 lbs average daily gain, 100 days on 1st phase with 2.5 lbs average daily gain and 75 days on 2nd phase with 3.5 lbs average daily gain. Death loss of 2% assumed. Stockers purchased at 700lbs and fed on this ration until reaching end weight of 1227 lbs for a selling weight of 1202 lbs assuming 2% shrinkage.

Table A. 16. Feed and forage requirements for 21000 production dairy cattle fed on a corn silage-alfalfa haylage ration[1].

Unit of cattle	Corn Silage, KP	Alfalfa Haylage	Orchard-grass Hay	SBOM 48%	Corn Grain	Corn Distillers w/ SOL.	Roasted Soybeans	Pasture
	Ton	*Ton*	*Ton*	*Ton*	*Bushel*	*Ton*	*Ton*	*Acre*
per 100 cattle	1510.4	296.46	142.64	79.67	5555.36	62.22	46.67	125
per cow	15.104	*2.9646*	*1.4264*	*0.797*	*55.554*	0.6622	0.4667	1.25
	-----------------------------Lbs feed per lb milk-------------------------							*-ac/lb milk-*
Feed per unit fluid milk	**143.84**	**28.2343**	**13.5848**	**7.5876**	**14.81429**	**5.92571**	**4.44476**	**0.00595238**

Feed requirements compiled as Enterprise Budgets by G. Groover, Dept of Agricultural and Applied Economics, Virginia Polytechnic Institute. Obtained via personal communication with G. Groover (4 April 2014). Assuming 21000 lbs milk production per cow per year in an operation of 100 cows. Assuming 35% cows leaving herd annually with 57.534 lbs production per cow per day, a 94% conception rate, 4% annual cow death loss rate (31 cull cows and heifers at 13 Cwt, 47 bull calves and 5 dairy heifers and cows).

Table A. 17. Regional crop yields (lbs/ac) used to estimate per capita land requirements of diet for identified soil productivity groups[9].

Crop	Soil Productivity Groups[9] I A	I B	II A	II B	III A	III B	IV A	IV B	V
	lbs/ac								
ALFALFA HAY[1]	12000	12000	10000	8000	6000	4000	NA	NA	NA
APPLES[2]	20000	19000	18000	17000	16000	15000	14000	13000	12000
ASPARAGUS[2]	2000	1900	1800	1700	1600	1500	1400	1300	1200
BLACK BEANS[2]	10000	9500	9000	8500	8000	7500	7000	6500	6000
BLACKBERRIES[2]	10000	9500	8500	8500	8000	7500	7000	6500	6000
BLUEBERRIES[2]	10000	9500	9000	8500	8000	7500	7000	6500	6000
BROCCOLI[2]	10000	9500	9000	8500	8000	7500	7000	6500	6000
CABBAGE[2]	40000	38000	36000	34000	32000	30000	28000	26000	24000
CARROTS[3]	30,000	28500	27,000	25,500	24,000	22,500	21,000	19,500	18,000
CAULIFLOWER[2]	12000	11400	10800	10200	9600	9000	8400	7800	7200
CHERRIES[2]	5000	4750	4500	4250	4000	3750	3500	3250	3000
CORN, GRAIN[3]	8960	8400	7840	7280	6720	6160	5600	4760	3640
CORN, SILAGE[1]	42000	40000	38000	36000	34000	32000	30000	26000	20000
CUCUMBERS[2]	40000	38000	36000	34000	32000	30000	28000	26000	24000
EGGPLANT[2]	20000	19000	18000	17000	16000	15000	14000	13000	12000
GRAPES[2]	10000	9500	9000	8500	8000	7500	7000	6500	6000
GRASS HAY/TALLGRASS HAY[1]	9000	8000	7000	6000	5000	4000	NA	NA	NA
GREEN BEANS[2]	4500	4275	4050	3825	3600	3375	3150	2925	2700
GREENS, COLLARDS[2]	40000	38000	36000	34000	32000	30000	28000	26000	24000
GREENS, KALE[2]	40000	38000	36000	34000	32000	30000	28000	26000	24000
HONEY[4]	140	133	126	119	112	105	98	91	84
LETTUCE, ROMAINE[2]	20000	19000	18000	17000	16000	15000	14000	13000	12000
LIMA BEANS[2]	4500	4275	3847.5	3825	3600	3375	3150	2925	2700
MELONS, CANTALOUPES[2]	40000	38000	36000	34000	32000	30000	28000	26000	24000
MELONS, HONEYDEW[2]	30000	28500	27000	25500	24000	22500	21000	19500	18000

Table A. 17 continued.

Crop	Soil Productivity Groups[9] I A	I B	II A	II B	III A	III B	IV A	IV B	V
	lbs/ac								
MELONS, WATERMELONS[2]	40000	38000	36000	34000	32000	30000	28000	26000	24000
NECTARINES[2]	5000	4750	4500	4250	4000	3750	3500	3250	3000
OATS[1]	2560	2432	2304	2176	2048	1920	1792	1664	1536
ONIONS[2]	30000	28500	27000	25500	24000	22500	21000	19500	18000
ORCHARDGRASS HAY/TALLGRASS HAY[1]	9000	8000	7000	6000	5000	4000	NA	NA	NA
PEACHES[2]	7500	7125	6750	6375	6000	5625	5250	4875	4500
PEARS[2]	10000	9500	9000	8500	8000	7500	7000	6500	6000
PEAS, GREEN[2]	4000	3800	3600	3400	3200	3000	2800	2600	2400
PEPPERS[2]	50000	47500	45000	42500	40000	37500	35000	32500	30000
POTATOES[2]	20000	19000	18000	17000	16000	15000	14000	13000	12000
RASPBERRIES[2]	7500	7125	6750	6375	6000	5625	5250	4875	4500
RYE[2]	10000	9500	9000	8500	8000	7500	7000	6500	6000
SOYBEAN, FEED AND OIL[5]	3000	2700	2400	2400	2100	2100	1500	1500	1200
SOYBEANS, TOFU[6]	1300	1235	1170	1105	1040	975	910	845	780
SPINACH[2]	6000	5700	5400	5100	4800	4500	4200	3900	3600
STRAWBERRIES[2]	10000	9500	9000	8500	8000	7500	7000	6500	6000
SUMMER SQUASH[2]	20000	19000	18000	17000	16000	15000	14000	13000	12000
SUNFLOWER[3]	1,117	1,062	1,006	950	894	838	782	726	670
SWEET CORN[2]	10000	9500	9000	8500	8000	7500	7000	6500	6000
SWEET POTATOES[2]	20000	19000	18000	17000	16000	15000	14000	13000	12000
TOMATOES[2]	50000	47500	45000	42500	40000	37500	35000	32500	30000
WHEAT[8]	3840	3840	3360	3360	2880	2880	2400	2400	1440
WINTER SQUASH & PUMPKIN[2]	40000	38000	36000	34000	32000	30000	28000	26000	24000

1- Yields from Virginia Nutrient Management Standards and Criteria, Department of Conservation and Recreation Division of Soil and Water Conservation, DCR; 1995

2- Yields from estimates based on personal communication with Alan Straw, Area Specialist Horticulture, Small Fruit & Specialty Crops, Virginia Cooperative Extension

3- Yields from Peters et al 2005 Input Output data…
3- Corn grain yields used to represent corn grain for livestock and corn meal and syrup included in human diets taken from Virginia Nutrient Management Standards and Criteria, Department of Conservation and Recreation Division of Soil and Water Conservation, DCR; 1995
4- Yield from estimates based on personal communication with Dr. Richard Fell, Virginia Polytechnic Institute Department of Entamology 9 April 2014
5- Soybean feed figure includes those for soybean meal (SBOM 48%, roasted soybeans and oil-type soybeans); values for Early Season soybeans used from Virginia Nutrient Management Standards and Criteria, Department of Conservation and Recreation Division of Soil and Water Conservation, DCR; 1995
6- Rao, M.S.S., A.S.Bhagsari, and A.I. Mohamed. 1998. Yield, protein, and oil quality of soybean genotypes selected for tofu production. Plant Foods Human Nutr. 52:241–251.

7- Yields from USDA Weights and Measures, 1992.
8- Value for Standard Wheat estimate from Virginia Nutrient Management Standards and Criteria, Department of Conservation and Recreation Division of Soil and Water Conservation, DCR; 1995
9- Values for yields by soil productivity groups taken from source material if available. If unavailable, Yields were assumed to be 100% Group IA, 95% Group IB, 90% Group IIA, 85% Group IIB, 80% Group IIIA, 75% Group IIIB, 70% Group IVA, 65% Group IVB, 60% Group V.

Table A. 18. Annual per capita production need of food commodities by diet[1].

Commodity	AFR	AR	FR	MP	FRV	V
	---Yield (Kg)--					
ALFALFA HAY	162.49	190.50	130.71	121.99	0.00	0.00
APPLES	106.58	106.58	133.22	213.16	266.45	266.45
ASPARAGUS	0.79	0.79	0.79	1.32	1.62	1.62
BEEF[2]	114.29	116.74	44.57	47.13	0.00	0.00
BLACK BEANS	0.00	0.00	36.05	48.06	158.60	158.60
BLACKBERRIES	0.82	0.82	1.03	1.64	2.05	2.05
BLUEBERRIES	1.44	1.44	1.80	2.88	3.60	3.60
BROCCOLI	18.36	18.36	18.36	30.61	37.34	37.34
CABBAGE	3.56	3.56	3.56	5.94	7.25	7.25
CARROTS	3.69	3.69	3.69	6.16	7.51	7.51
CAULIFLOWER	0.56	0.56	0.56	0.93	1.13	1.13
CHERRIES	1.00	1.00	1.25	2.00	2.49	2.49
CHICKEN[3]	140.92	145.45	54.17	58.84	0.00	0.00
CORN, GRAIN[4]	983.11	1060.62	559.35	542.07	56.54	73.99
CORN, SILAGE	1311.72	1464.84	854.62	821.04	0.00	0.00
CUCUMBERS	1.63	1.63	1.63	2.72	3.32	3.32
EGGPLANT	0.20	0.20	0.20	0.34	0.41	0.41
EGGS	59.78	59.78	44.84	44.84	0.00	0.00
GRAPES	14.93	14.93	18.66	29.86	37.33	37.33
GRASS HAY	851.89	870.14	332.21	351.30	0.00	0.00
GREEN BEANS	2.03	2.03	2.03	3.38	4.13	4.13
GREENS, COLLARDS	1.98	1.98	1.98	3.29	4.02	4.02
GREENS, KALE	0.67	0.67	0.67	1.11	1.35	1.35
HOG[5]	92.43	101.56	31.37	40.56	0.00	0.00
HONEY	0.56	1.81	6.31	3.09	2.84	3.95

LETTUCE, ROMAINE	6.65	6.65	6.65	11.09	13.53	13.53
LIMA BEANS	2.69	2.69	2.69	4.49	5.47	5.47
MELONS, CANTALOUPES	1.46	1.46	1.82	2.91	3.64	3.64
MELONS, HONEYDEW FRESH	0.11	0.11	0.13	0.21	0.27	0.27
MELONS, WATERMELONS	11.01	11.01	13.76	22.01	27.52	27.52
MILK[6]	575.49	674.73	462.94	432.06	0.00	0.00
NECTARINES	2.52	2.52	3.15	5.04	6.31	6.31
OATS	7.57	7.57	6.97	7.84	8.18	8.27
ONIONS	20.95	20.95	20.95	34.91	42.59	42.59
ORCHARDGRASS HAY	78.18	91.66	62.89	58.69	0.00	0.00
PASTURE	0.31	0.32	0.14	0.14	0.00	0.00
PEACHES	6.21	6.21	7.76	12.41	15.52	15.52
PEARS	2.08	2.08	2.60	4.16	5.19	5.19
PEAS, GREEN	7.72	7.72	7.72	12.87	15.70	15.70
PEPPERS	3.26	3.26	3.26	5.44	6.63	6.63
POTATOES	68.94	68.94	68.94	114.89	140.17	140.17
RASPBERRIES	1.19	1.19	1.49	2.38	2.98	2.98
RYE	0.24	0.24	0.22	0.25	0.26	0.26
SOYBEAN, FEED AND OIL[7]	565.77	473.87	376.80	272.41	208.92	106.55
SOYBEAN, TOFU	0.00	0.00	3.16	4.22	13.91	13.91
SPINACH	9.15	9.15	9.15	15.25	18.60	18.60
STRAWBERRIES	5.58	5.58	6.98	11.17	13.96	13.96
SUMMER SQUASH	1.34	1.34	1.34	2.23	2.72	2.72
SUNFLOWER	0.00	0.00	1.54	2.05	6.77	6.77
SWEET CORN	5.05	5.05	5.05	8.42	10.27	10.27
SWEET POTATOES	7.05	7.05	7.05	11.74	14.33	14.33
TOMATOES	33.77	33.77	33.77	56.28	68.67	68.67
WHEAT	81.01	81.01	74.49	83.80	87.53	88.46
WINTER SQUASH & PUMPKIN	0.07	0.07	0.07	0.11	0.14	0.14

1- Includes commodities to support all human and livestock nutrition for each diet type based on annual serving need considering relative preferences of individual commodities within each food group and subgroup and accounting for food loss throughout the supply chain. "AFR," Animal product- and fat-rich diet type; "AR," Animal product-rich diet type; "FR," Fat-rich diet type; "MP," MyPlate recommended diet type; "FRV," Fat-rich animal product-free diet type; "V," Animal product-free diet type. See text for details.
2- Beef figure includes sum of lbs needed of all beef products (regular and lean cuts, tallow)
3- Chicken figure includes sum of lbs needed of regular and lean cuts, chicken fat
4- Corn, grain figure includes sum of lbs needed of feed grains (corn grain and corn distillers w/SOL), corn meal and corn syrup
5- Hog figure includes sum of lbs needed of all pork products (regular and lean cuts, lard)
6- Milk figure includes sum of lbs needed of all milk products (whole, skim, butter)
7- Soybean, feed and oil figure includes sum of lbs need of soybean meal (SBOM 48%) and roasted soybeans for livestock consumption and soybean oil for human consumption

Table A. 19. Counties included in the Appalachian Foodshed Region and their population[1].

STATE	COUNTY	POPULATION
NC	Alexander	37014
NC	Alleghany	11069
NC	Ashe	27099
NC	Avery	17815
NC	Buncombe	239000
NC	Burke	90821
NC	Caldwell	82493
NC	Cherokee	27304
NC	Clay	10575
NC	Davie	41183
NC	Forsyth	351368
NC	Graham	8766
NC	Haywood	58915
NC	Henderson	106577
NC	Jackson	39985
NC	McDowell	44926
NC	Macon	33815
NC	Madison	20727
NC	Mitchell	15539
NC	Polk	20386
NC	Rutherford	67446
NC	Stokes	47224
NC	Surry	73551
NC	Swain	13995
NC	Transylvania	32825
NC	Watauga	51103
NC	Wilkes	69265
NC	Yadkin	38254
NC	Yancey	17814
VA	Alleghany	16297
VA	Bath	4713
VA	Bland	6827
VA	Botetourt	33074
VA	Buchanan	24071
VA	Carroll	29989
VA	Craig	5186
VA	Dickenson	15877
VA	Floyd	15268

STATE	COUNTY	POPULATION
VA	Giles	17149
VA	Grayson	15535
VA	Henry	53971
VA	Highland	2317
VA	Lee	25528
VA	Montgomery	94179
VA	Patrick	18513
VA	Pulaski	34869
VA	Rockbridge	22357
VA	Russell	28773
VA	Scott	23061
VA	Smyth	32103
VA	Tazewell	44846
VA	Washington	54691
VA	Wise	41361
VA	Wythe	29203
VA	Bristol city	17747
VA	Buena Vista city	6679
VA	Covington city	5903
VA	Galax city	6942
VA	Lexington city	6990
VA	Martinsville city	13854
VA	Norton city	3971
VA	Radford city	16511
WV	Barbour	16472
WV	Berkeley	104410
WV	Boone	24617
WV	Braxton	14531
WV	Brooke	24021
WV	Cabell	96240
WV	Calhoun	7613
WV	Clay	9432
WV	Doddridge	8147
WV	Fayette	46000
WV	Gilmer	8623
WV	Grant	11929
WV	Greenbrier	35572

Table A. 19 continued.

STATE	COUNTY	POPULATION[1]
WV	Hampshire	23791
WV	Hancock	30594
WV	Hardy	13912
WV	Harrison	68959
WV	Jackson	29206
WV	Jefferson	53545
WV	Kanawha	192572
WV	Lewis	16389
WV	Lincoln	21714
WV	Logan	36508
WV	McDowell	21966
WV	Marion	56460
WV	Marshall	32993
WV	Mason	27242
WV	Mercer	62251
WV	Mineral	28049
WV	Mingo	26660
WV	Monongalia	96417
WV	Monroe	13528
WV	Morgan	17507
WV	Nicholas	26201
WV	Ohio	44307

STATE	COUNTY	POPULATION[1]
WV	Pendleton	7666
WV	Pleasants	7630
WV	Pocahontas	8750
WV	Preston	33471
WV	Putnam	55660
WV	Raleigh	78852
WV	Randolph	29361
WV	Ritchie	10391
WV	Roane	14884
WV	Summers	13813
WV	Taylor	16889
WV	Tucker	7109
WV	Tyler	9188
WV	Upshur	24210
WV	Wayne	42273
WV	Webster	9158
WV	Wetzel	16526
WV	Wirt	5769
WV	Wood	86835
WV	Wyoming	23668
TOTAL	117	4315690

1- Population figures from US Census Bureau American Community Survey 5-year estimates (2008-2012). Population used to calculate per capita complete diet food needs for the all counties listed (Chapter 2). Counties from Virginia and North Carolina used to calculate production potential of the foodshed, while West Virginia counties were excluded due to data limitations (Chapter 3). All counties listed are included in the complete diet model (Chapter 2). All Virginia and North Carolina counties listed are included in the spatial model with the single exception of Caldwell County, North Carolina. Caldwell County was excluded due to the lack of gSSURGO soils data. Land cover validation found that this county was mostly covered with the wooded land of Pisgah National Forest, and thus would not have had a significant contribution to the spatial model. West Virginia counties were excluded due to a lack of a soil productivity and yield data similar to that used in both Virginia and North Carolina.

APPENDIX B

Datasets used in the spatial model

A variety of soils and land cover and use data were processed in GIS and database software for application in the spatial model (Chapter 3). The Gridded Soil Survey Geographical Database (gSSURGO) is a file geodatabase dataset available for national, regional, and statewide soil analyses. It contains detailed spatial and tabular data developed from detailed field testing and mapping conducted by the National Cooperative Soil Survey and maintained by the USDA National Resource Conservation Service (USDA NRCS 2013; Soil Survey Staff, 2014). Soil map units are displayed at a 10-meter raster resolution available for entire states, which can then be clipped to any study area of interest. These soil map units represent multiple soil series and their associated components. The gSSURGO database has several associated tables that are possible to use in conjunction with the raster format data, including the National Value Added Look Up (valu) table database that can be useful for thematic mapping. The 54 Appalachian counties of western North Carolina and Virginia included in the spatial model were all included in the gSSURGO files.

Soil map units are unique to each county surveyed and can contain multiple types of soils, called components. These components have different properties associated with them affecting yield potential. Each soil map unit has a unique identifier, called a "mukey" that is spatially oriented. The breakdown of each mukey by the percentage of each soil component is included in the database. For the spatial model, these component percentages were used to map production potential by linking them to soil productivity data.

The Virginia Agricultural Land Use Evaluation System (VALUES) are a set of agricultural management recommendations most recently updated in 2005. It characterizes soil map units (soil series) into management groups based on physical and chemical properties and accounts for factors such as erosion and slope (Donohue et al. 1994). The production of the VALUES database was a collaborative effort between Virginia Cooperative Extension and Virginia Tech and provides a resource for land use managers to determine nutrient application limits based on typical crop yields by soil series in Virginia, though states with similar growing conditions can also use this tool. Estimated yields for various non-irrigated crops were determined using the management groups of each soil series. Poorly drained soil series are noted in the database and two sets of yield information given: drained and undrained. This was accounted for in the data preparation for the spatial model (See Appendix F). The VALUES database breaks down the productivity of these select crops into five management groups ranging from most productive (I) to least productive (V). Six agronomic crops, 2 silage crops, 4 hay crops, and pasture are assigned productivity values in yield per area units based on these management groups and if applicable, subgroup. The spatial model uses these estimated yields to determine production potential for of annual, perennial, and total agricultural crops in the study area. These yields are based on statistical information from farm trials across the state. This information is not spatially related, and therefore a database created to link spatial mukeys by soil series name was used in the spatial model.

Table B. 1. Estimated Yields in Tons (T) per Acre (A) of Various Non-Irrigated Crops for Identified Soil Productivity Groups.[1]

	I		II		III		IV		V
Crop	A	B	A	B	A	B	A	B	
Corn Silage (T/A)	21	20	19	18	17	16	15	13	10
Tallgrass Hay (T/A)	>4.0		3.5-4.0	3.0-3.5	<3.0		NA	NA	NA

Adapted from Virginia Nutrient Management Standards and Criteria, Department of Conservation and Recreation Division of Soil and Water Conservation, DCR; 1995

The RYE is a database developed by the USDA Natural Resources Conservation Service (NCRS), the North Carolina Department of Agriculture and Consumer Services, the North Carolina Division of Soil and Water Conservation, and North Carolina State University. It was most recently updated in 2003. Yields were determined from farm trials and surveying and represent weight per area achieved under good management. The developers of the RYE system define “good management” as that achieved by the top 20% of growers (North Carolina Nutrient Management Workgroup 2003). Therefore, the yield value for these soils reflect this assumption. Ten agronomic crops, four silage crops, 13 hay crops, and pasture are assigned yields in this resource. Poorly drained soil series are assumed to be drained in this database. Information in the RYE database is ready for spatial application as it includes mukeys for each soil series map unit.

The spatial model characterizes agricultural production potential by calculating the suitability for annual and perennial crop production based on soil productivity. For annual crop production, corn silage was used as an indicator crop. Corn silage yields from Virginia and North Carolina were available in both the VALUES and RYE datasets. For perennial crop production, hay was used as an indicator crop. There was not an exact match for hay between the VALUES and RYE datasets and therefore tallgrass hay yields were used for Virginia soils and fescue hay were used for North Carolina soils.

The Cropland Data Layer (CDL) is a geospatial raster dataset of agricultural land cover across the United States. It is released annually by the USDA National Agricultural Statistical Service (NASS) using information from both satellite imagery and ground validation methodologies (Johnson and Mueller 2010). The most recent version available from 2013 was used in the spatial model presented in Chapter 3. The CDL has a 30-meter resolution of over 100 specific crops. Commodity, horticultural crops, pasture and grazing lands, as well as non-agricultural land cover are all classified by the CDL. This allows for users to determine the extent of total agricultural land as well as the relative proportion of annual and perennial crop cover.

Table B. 2. Soil productivity group for annual and perennial indicator crops by soil series.

Soil Series	Corn Silage (Annual crops)	Hay (Pasture and perennial crops)
Abell	IIa	I
Abell variant	IIa	I
Ackwater	IIb	I
Acredale (drained)	Ib	I
Acredale (undrained)	V	NS*
Aden (drained)	Ib	I
Aden (undrained)	V	NS*
Airmont	IVb	III
Alaga	V	NS*
Alamance	IVb	III
Alanthus	Ib	I
Albano	V	IV
Albemarle	V	IV
Alderflats	V	NS*
Aldino	IVa	IV
Aldio	IVa	III
Allegheny	IIb	II
Alluvial Land, wet	V	IV
Alonemill	Ia	I
Alonemill, Fluvaquentic	IIa	I
Alonzville	IIb	II
Altavista	Ia	I
Altavista, variant	Ia	I
Alticrest	IIa	II
Angie	IVa	IV
Angie variant	IVa	IV
Appling	IVa	III
Appling gritty	IVa	III
Appomattox	IIb	II
Arapahoe	IVb	NS*
Arcola	IIIb	II
Ardilla	IVa	IV
Argent	V	NS*
Arkaqua	IIa	I
Ashburn	IVb	III
Ashe	V	IV
Ashlar	IVb	III
Assateague	V	NS*
Athol	IIb	II

Atkins	V	NS*
Atlee	IIIa	III
Augusta (drained)	IIb	III
Augusta (undrained)	IVa	NS*
Augusta variant (drained)	IIb	III
Augusta variant (undrained)	IVa	NS*
Aura	IIIb	III
Austinville	IIb	II
Axis	V	NS*
Aycock	IIIa	II
Ayersville	IVb	III
Backbay	V	NS*
Badin	IVa	II
Baile	IVb	IV
Bailegap	IVb	III
Balsam	IVb	III
Bama	IIIa	II
Banister	IIb	I
Barclay	IIa	II
Batteau	IIa	I
Bayboro (drained)	Ib	I
Bayboro (undrained)	V	NS*
Beckham	IIb	II
Bedington	IVb	III
Beech	IIb	II
Beech Grove	V	IV
Belhaven	V	NS*
Bellspur	IIa	IV
Beltsville	IVb	III
Belvoir	IVb	III
Benthole	IVb	III
Bentley	IIIa	II
Berks	V	IV
Berks variant	V	IV
Bermudian	Ia	I
Bertie	IIb	I
Bertie (variant)	IIb	I
Bethera (drained)	Ib	I
Bethera (undrained)	V	NS*
Bethesda	V	IV
Bethlehem	IVa	III
Bibb	IVb	NS*
Biltmore	V	NS*

Birdsboro	IIb	II
Blackthorn	IVb	III
Bladen (drained)	Ib	I
Bladen (undrained)	V	NS
Blago	IVb	IV
Blairton	IVb	III
Bland	IVa	III
Bleakhill	IIb	I
Blocktown	V	IV
Bloodyhorse	V	IV
Bluemount	V	IV
Bohicket	V	NS*
Bojac (ES, VA Beach, Ches.)	IIIb	III
Bojac (Mainland excl. VA Beach & Ches.)	IVb	III
Bolling	IIb	I
Bolling (variant)	IIb	I
Bolton	IIb	II
Bonneau	IVb	III
Bookwood	IIIb	II
Botetourt	IIa	I
Bourne	IVb	III
Bourne (variant)	IVb	III
Bowmansville	IIa	I
Braddock	IIb	II
Brandywine	IVb	III
Brecknock	IIIb	II
Bremo	V	IV
Brentsville	IVb	III
Brevard	Ia	I
Brickhaven	IVa	III
Brinkerton	V	IV
Brinklow	IVb	III
Broadway	Ia	I
Brockroad	IVa	III
Brownsville	V	IV
Brownwood	V	IV
Brumbaugh	IIb	II
Brushy	V	IV
Buchanan	IVb	III
Buchanan cobbly	V	IV
Buckhall	IVa	III
Buckingham	V	IV

Bucks	IIIb	II
Buckton	Ia	I
Buffstat	IVa	III
Bugley	V	IV
Buncombe	V	NS*
Burketown	IVb	III
Burrowsville	IVb	III
Burton	IVb	III
Buzzrock	V	IV
Cahaba	IIIa	II
Calverton	IVb	III
Calvin	V	IV
Calvin cobbly	V	IV
Camocca	V	NS*
Caneyville	IVa	III
Cape Fear (drained)	Ib	I
Cape Fear (undrained)	V	NS*
Captina	IVb	III
Carbo	IVa	III
Carbonton	IVa	III
Cardiff	IVb	III
Cardova	V	IV
Caroline	IVa	IV
Cartecay	IIa	I
Carteret	V	NS*
Cataska	V	IV
Catharpin	IVa	II
Catlett	V	IV
Catlett variant	V	IV
Catoctin	V	IV
Catoctin variant	V	IV
Catpoint	V	NS*
Caverns	IIa	I
Cecil	IVa	II
Cedarcreek	IVb	III
Chagrin	Ia	I
Chagrin variant	Ia	I
Chandler	IVb	III
Chapanoke (drained)	Ib	I
Chapanoke (undrained)	V	NS*
Charity	IIb	II
Chastain	V	IV
Chatuge (drained)	Ib	I

Chatuge (undrained)	V	NS*
Chavies	IIIb	II
Chavies variant	IIIb	II
Chenneby	IIa	I
Chesapeake	Ia	I
Chester	Ib	I
Chester Loam	Ib	I
Chesterfield	IVa	III
Chestnut	IVb	III
Chewacla	IIa	I
Chickahominy	V	IV
Chilhowie	V	IV
Chincoteague	V	NS*
Chipley	IVb	NS*
Chiswell	V	IV
Christian	IVa	IV
Christiana	IVa	IV
Cid	V	IV
Claiborne	IIIb	II
Clapham	IVb	III
Clarksburg	IVa	IV
Clarksville	IVb	III
Clearbrook	V	IV
Cliffield	V	IV
Clifford	IVa	II
Clifton	IIb	II
Clover	IVa	III
Cloverlick	V	IV
Clubcaf	V	IV
Clymer	IIIb	II
Codorus	Ia	I
Codorus variant	Ia	I
Codorus stony	Ia	I
Codorus variant	Ia	I
Colescreek	IIb	II
Colfax	IVb	III
Colfax variant	IVb	III
Colleen	V	IV
Colvard	V	NS*
Colvard fine	V	NS*
Colvard stony	V	NS*
Combs	Ia	I
Comus	Ia	I

Conetoe	IVb	III
Congaree	Ia	I
Coosaw	IVb	III
Corolla	IVb	NS*
Corydon	V	IV
Cotaco	IIa	I
Cotaco cobbly	IIa	I
Cotaco variant	IIa	I
Cottonbend	IIb	II
Coursey	IIa	I
Cowee	IIb	II
Coxville	V	IV
Craggey	V	IV
Craigsville	IVb	III
Craven	IVb	IV
Creedmoor	V	IV
Creedmoor variant	V	IV
Croton	V	IV
Cullasaja	IVb	III
Cullen	IIb	II
Culleoka	IIIb	II
Culpeper	IVa	II
Culpeper variant	IVa	II
Daleville (drained)	Ib	I
Daleville (undrained)	V	NS*
Dan River	IIa	I
Dandridge	V	IV
Danripple	IIb	II
Davidson	IIb	II
Dawhoo	V	NS*
Dawhoo variant	V	NS*
Decatur	IIb	II
Dekalb	IVb	III
Dekalb variant	IVb	III
Delanco	Ia	I
Delila	IVb	IV
Dellwood	IVb	III
Deloss (drained)	Ib	I
Deloss (undrained)	V	NS*
Derroc	IVb	III
Devotion	IVb	III
Diana Mills	IVa	III
Dillard	IIa	I

Dogue	IIb	I
Dogue variant	IIb	I
Dorovan	V	NS*
Dothan	IIIa	III
Downer	IIb	III
Dragston	IIa	II
Drall	IVb	III
Drapermill	IIIb	II
Drypond	V	IV
Duckston	V	NS*
Duffield	IIa	I
Dulles	IVa	III
Dumfries	IIIb	III
Dunbar (drained)	IIb	III
Dunbar (undrained)	IVa	NS*
Dunning (drained)	IIa	IV
Dunning (undrained)	V	NS*
Duplin	IIb	I
Durham	IVb	III
Dyke	IIb	II
Easthamlet	V	IV
Ebbing	IIa	I
Edgehill	IVb	III
Edgehill variant	IVb	III
Edgemont	IIIb	II
Edneytown	IIb	II
Edneyville	IIIb	III
Edom	IIb	II
Elbert	V	IV
Elbert variant	V	IV
Elioak	IVa	II
Elk	Ia	I
Elkton (drained)	Ib	I
Elkton (undrained)	V	NS*
Elliber	IIb	II
Elsinboro	IIb	II
Emory	IIa	I
Emporia	IIIa	II
Endcav	IVa	III
Enon	IVa	III
Enott	IVa	III
Ernest	IVa	IV
Escatawba	IIb	II

Eubanks	IIb	II
Eulonia	IIb	I
Eunola	IIIb	III
Evansham	V	IV
Evard	IIb	II
Evesboro	V	NS*
Exum	IIb	I
Faceville	IIIa	II
Fairfax	Ib	I
Fairpoint	V	IV
Fairview	IVa	II
Fairystone	IVa	II
Fallsington	IIa	II
Fauquier	IIb	II
Fauquier, deep phase	IIb	II
Faywood	IIIb	II
Featherstone	V	NS*
Fedscreek	IVb	III
Feedstone	IIa	I
Fisherman	V	NS*
Fiveblock	V	IV
Flatwoods	IIb	II
Fletcher	IIIb	II
Flume	IIIa	II
Fluvanna	IVa	III
Fluvaquents	IVb	IV
Forestdale	V	IV
Fork (drained)	IIb	III
Fork (undrained)	IVa	NS*
Fork variant (drained)	IIb	III
Fork variant (undrained)	IVa	NS*
Frankstown	IIIb	II
Frederick	IIb	II
Frederick/Christian	IIb	II
Frederick/Lodi	IIb	II
Freemanville	IIIa	III
French	Ia	I
Fripp	V	NS*
Funkstown	Ia	I
Gaila	IVb	III
Gainesboro	IVb	III
Galestown	V	NS*
Galtsmill	V	NS*

Georgeville	IVa	II
Germanna	IIb	II
Gertie	V	NS*
Gilpin	IIIb	II
Gilpin variant	IIIb	II
Gladehill	Ia	I
Glenelg(BRH)	IIb	II
Glenelg(NV)	IIIb	II
Glenville	IVa	IV
Glynwood	IVb	III
Glynwood variant	IVb	III
Goblintown	IVa	III
Goldsboro	IIb	I
Goldston	V	IV
Goldvein	IVb	III
Goldvein gritty	IVb	III
Goresville	IIb	II
Granville	IIIa	II
Grassland	IIb	II
Greendale	Ia	I
Greenlee	IVb	III
Grigsby	Ia	I
Grimsley	IVb	III
Gritney	IIIb	III
Groseclose	IIb	II
Grover	IVa	II
Guernsey	IIb	II
Gullion	Ia	I
Gundy	IVa	III
Gunstock	IVa	III
Guyen	IVa	NS*
Gwinnett variant	IVa	II
Hagerstown	IIb	II
Halewood	IIIb	II
Halifax	V	IV
Hanceville	IVa	III
Happyland	IIIb	II
Hartleton	IVb	III
Hartsells	IVb	III
Hatboro	IVb	IV
Hawksbill	IVb	III
Hawksbill cobbly	IVb	III
Hayesville	IVa	II

Haymarket	V	IV
Hayter	IIb	II
Haywood	V	IV
Hazel	V	IV
Hazel channery	V	IV
Hazel Run	IIIb	II
Hazleton	V	IV
Helena	V	IV
Helena taxadjunct	V	IV
Herndon	IVa	III
Hibler	IIb	II
Hickoryknob	IIb	II
Highsplint	IVb	III
Hiwassee	IIb	II
Hiwassee variant	IIb	II
Hoadley	IVb	III
Hobucken	V	NS*
Holly	V	NS*
Hollywood	V	IV
Hublersburg	IIb	II
Huntington	Ia	I
Hyde (drained)	Ib	I
Hyde (undrained)	V	NS*
Ingledove	Ia	I
Iotla	Ia	I
Iredell	V	IV
Iredell variant	V	IV
Irongate	IVb	III
Itmann	V	IV
Iuka	IIa	II
Izagora	IIb	I
Jackland	V	IV
Jedburg	IVa	NS*
Jefferson	IIIb	II
Jefferson variant	IIIb	II
Johns (drained)	Ib	I
Johns (undrained)	V	NS*
Johns variant (drained)	Ib	I
Johns variant (undrained)	V	NS*
Johnston	V	NS*
Junaluska	IIIb	II
Kalmia	IIIa	III
Kaymine	V	IV

Keener	IIb	II
Kelly	V	IV
Kempsville	IIIa	III
Kenansville	IVb	III
Kenansville variant	IVb	III
Keyport	IIb	I
Kinkora (drained)	Ib	I
Kinkora (undrained)	V	NS*
Kinston (drained)	Ib	I
Kinston (undrained)	V	NS*
Klej	IVb	NS*
Klinesville	V	IV
Konnarock	V	IV
Lackstown	IIb	I
Laidig	IVa	IV
Laidig cobbly	IVa	IV
Lakehurst	IVb	NS*
Lakeland	V	NS
Lakin	V	NS
Landisburg	IVa	IV
Lanexa	V	NS*
Lansdale	IVb	III
Laroque	IVb	III
Lawnes	V	NS*
Leadvale	IVb	III
Leaf (drained)	Ib	I
Leaf (undrained)	V	NS*
Leaksville	V	IV
Leatherwood	V	NS*
Leck Kill	IIIb	II
Leedsville	IIb	II
Leetonia	V	NS*
Legore	IVa	III
Lehew	V	IV
Lenoir	V	IV
Leon	V	NS*
Levy	V	NS*
Lew	IVb	III
Lewisberry	V	NS*
Lewisburg	IVb	III
Library	V	IV
Lickdale (drained)	IIa	IV
Lickdale (undrained)	V	NS*

Lignum	V	IV
Lily	IVb	III
Linden	IIa	II
Lindside	Ia	I
Littlejoe	IVa	III
Litz	V	IV
Lloyd	IIb	II
Lloyd variant	IIb	II
Lobdell	Ia	I
Lodi	IIb	II
Lostcove	IVb	III
Louisa	V	IV
Louisa variant	V	IV
Louisburg	IVb	III
Lowell	IIb	II
Lucketts	IVa	III
Lucy	IVb	III
Lumbee (drained)	Ib	I
Lumbee (undrained)	V	NS*
Lumbee variant (drained)	Ib	I
Lumbee variant (undrained)	V	NS*
Lunt	IVa	IV
Lynchburg	IIa	II
Macove	IVb	III
Madison	IVa	II
Madsheep	V	IV
Maggodee	Ia	I
Magotha	V	NS*
Malbis	IVa	IV
Manassas	Ib	I
Mandy	V	IV
Manor	IVb	III
Mantachie	IIa	I
Manteo	V	IV
Marbie	IVa	IV
Marbleyard	IVb	III
Margo	Ia	I
Markes	V	NS*
Marlboro	IIIa	II
Marr	IIIb	III
Marrowbone	V	NS*
Marumsco	IIb	I
Masada	IIb	II

Massanetta	Ia	I
Massanutten	V	IV
Matapeake	IIIa	II
Matewan	IVb	III
Matewan	IVb	III
Matneflat	IVb	III
Mattamuskeet	V	NS*
Mattan	V	NS*
Mattapex	IIb	I
Mattaponi	IIIa	II
Maurertown	V	NS*
Maury	IIb	II
Mayodan	IVa	III
McCamy	IVb	III
McClung	IIb	II
McGary (drained)	IIb	III
McGary (undrained)	IVa	NS*
McLaurin	IVb	III
McQueen	Ia	I
Meadowfield	V	IV
Meadows	V	IV
Meadowville	IIa	I
Meadowville variant	IIa	I
Meckesville	IVa	IV
Mecklenburg	IVa	III
Mecklenburg variant	IVa	III
Meggett (drained)	Ib	I
Meggett (undrained)	V	NS*
Melfa	V	NS*
Melvin (drained)	IIa	IV
Melvin (undrained)	V	NS*
Middleburg	IIa	I
Millrock	V	NS*
Mine Run	V	NS*
Minnieville	IIb	II
Mirerock	V	IV
Misenheimer	V	IV
Molena	V	NS*
Monacan	IIa	I
Mongle	IIa	IV
Monongahela	IVa	IV
Montalto	IIb	II
Montonia	IVa	II

Montresso	Ib	I
Montross	IIIa	III
Moomaw	IVa	IV
Morasonville	Ib	I
Morven	IIa	I
Mount Lucas	IIb	I
Mt. Rogers	IVb	III
Muckalee	V	IV
Munden	IIa	II
Murrill	IIb	II
Muskingum	V	IV
Myatt (drained)	Ib	I
Myatt (undrained)	V	NS*
Myatt variant (drained)	Ib	I
Myatt variant (undrained)	V	NS*
Myersville	Ib	I
Nahunta	IIa	II
Nanford	IVa	III
Nansemond	IIa	II
Nason	IVa	III
Nawney	V	NS*
Neabsco	IVb	III
Needmore	IVb	III
Nestoria	V	IV
Nevarc	IVb	IV
Newark (drained)	IIa	IV
Newark (undrained)	V	NS*
Newark variant (drained)	IIa	IV
Newark variant (undrained)	V	NS*
Newbern	V	IV
Newflat	V	IV
Newhan	V	NS*
Newmarc	Ia	I
Nicelytown	Ia	I
Nicholson	IVb	III
Nikwasi	V	NS*
Nimmo	IIa	II
Nixa	IVb	III
Nolichucky	IIb	II
Nolin	Ia	I
Nollville	IIa	I
Nomberville	Ia	I
Norfolk	IIIa	II

Oak Level	IVa	III
Oakhill	IVb	III
Oaklet	IVa	III
Oatlands	IVb	III
Occoquan	IVb	III
Ochlockonee	V	NS*
Ochlockonee variant	V	NS*
Ocilla	IIa	II
Ogles	IVb	III
Okeetee	V	IV
Opequon	V	IV
Orange	V	IV
Orange variant	V	IV
Orangeburg	IIIa	II
Orenda	V	IV
Oriskany	IVb	III
Orrville (drained)	Ib	I
Orrville (undrained)	V	NS*
Orrville variant (drained)	Ib	I
Orrville variant (undrained)	V	NS*
Orthents	V	IV
Osier	IIa	II
Ostin	V	NS*
Othello (drained)	Ib	I
Othello (undrained)	V	NS*
Ott	V	NS*
Pacolet	IVa	II
Pactolus	IVb	NS*
Paddyknob	V	IV
Pagebrook	IVa	III
Pamlico	V	NS*
Pamunkey	Ia	I
Pamunkey variant	Ia	I
Panorama	IIIb	II
Pantego (drained)	Ib	I
Pantego (undrained)	V	NS*
Parker	IVb	III
Partlow	IVb	IV
Pasquotank (drained)	Ib	I
Pasquotank (undrained)	V	NS*
Peaks	V	IV
Peawick	IVb	IV
Pecktonville	IIb	II

Penhook	IVa	II
Penn	IVb	III
Philo (drained)	IIa	IV
Philo (undrained)	V	NS*
Philomont	Ib	I
Pigeonroost	IIb	II
Pilot Mountain	V	IV
Pineola	IIb	II
Pineville	IIIb	II
Pineywoods	V	NS*
Pinkston	V	IV
Pinoka	V	IV
Pisgah	IIb	II
Plummer	IVb	NS*
Pocalla	IVb	III
Pocaty	V	NS*
Pocomoke	IIa	II
Poindexter	IVb	III
Poindexter variant	IVb	III
Polawana	V	NS*
Pooler variant (drained)	Ib	I
Pooler variant (undrained)	V	NS*
Pope	Ia	I
Poplimento	IIb	II
Porters	IVb	III
Portsmouth (drained)	Ib	I
Portsmouth (undrained)	V	NS*
Post	IVa	III
Pouncey	V	IV
Poynor	IVb	III
Psamments	V	NS*
Pungo	V	NS*
Purcellville	Ib	I
Purdy (drained)	IIa	IV
Purdy (undrained)	V	NS*
Quantico	IIIa	II
Rabun	IIb	II
Rains (drained)	Ib	I
Rains (undrained)	V	NS*
Ramsey	V	IV
Rapidan	IIb	II
Rappahannock	V	NS*
Raritan	IVa	IV

Rasalo	IVa	III
Rayne	IIIb	II
Readington	IVa	IV
Reaville	V	IV
Redbrush	IVa	III
Remlik	IVb	III
Rhodhiss	IVa	II
Rigley	IVb	III
Rion	IVa	II
Riverview	IIa	I
Rixeyville	V	NS*
Roanoke (drained)	IIa	IV
Roanoke (undrained)	V	NS*
Robertsville	V	IV
Rockbam	IVa	II
Rohrersville	IVb	III
Ross	Ia	I
Rough	V	IV
Rowland	Ia	I
Rumford	IVb	III
Rushtown	IVb	III
Ruston	IIIa	III
Saffell	IVb	III
Santuc	IIa	I
Sassafras	IIIb	III
Saunook	IIb	II
Sauratown	IVb	III
Savannah	IVb	III
Scattersville	IVb	III
Schaffenaker	V	NS*
Seabrook	IVb	NS*
Seagate	IVb	NS*
Sedgefield	V	IV
Sekil	IVb	III
Seneca	IIa	I
Sequatchie	Ia	I
Sequoia	IIIb	II
Sewell	V	IV
Shelocta	IIb	II
Shelocta variant	IIb	II
Shenval	IIb	II
Sherando	IVb	III
Sheva	V	IV

Shottower	IIb	II
Shouns	IIa	I
Sindion	Ia	I
Sketerville	V	IV
Slabtown	IIa	I
Slagle	IIb	I
Snicksville	Ib	I
Snowdog	IVb	III
Spears Mountain	IVa	III
Speedwell	Ia	I
Spessard	IVb	III
Spivey	IVb	III
Spotsylvania	IVa	III
Spray	V	IV
Spriggs	V	IV
Springwood	Ib	I
Stanton	V	IV
Starr	IIa	I
Starr-Dyke	IIb	II
Staser	Ia	I
State (ES)	IIIb	III
State (Mainland)	Ia	I
Steinsburg	V	IV
Stonecoal	V	IV
Stoneville	IVa	II
Stott Knob	IIb	II
Stough	IIa	II
Straightstone	IVa	III
Strawfield	IVa	II
Stumptown	IVb	III
Suches	Ia	I
Sudley	Ib	I
Suffolk	IIIb	III
Sugarhol	IIb	II
Sulfaquents	V	NS*
Summers	IVb	III
Susquehanna	V	IV
Swamp	V	NS*
Swampoodle	Ib	I
Sweetapple	IVb	III
Swimley	IIb	II
Sycoline	V	IV
Sylco	V	IV

Sylvatus	V	IV
Talladega	V	IV
Tallapoosa	V	IV
Tallapoosa variant	V	IV
Tanasee	V	IV
Tankerville	IIb	II
Tankerville taxadjunct	IIb	II
Tarboro	V	NS*
Tarrus	IVa	II
Tate	IIb	II
Tate variant	IIb	II
Tatum	IVa	II
Terric Medisarapists	V	NS*
Tetotum	IIb	I
Tetotum variant	IIb	I
Thunder	IVb	III
Thurmont	IIb	II
Tidal Marsh	V	NS*
Tidal Marsh, high	V	NS*
Tidal Marsh, low	V	NS*
Tidal Mudflats	V	NS*
Tidal Pool	V	NS*
Tifton	IIIa	III
Timberville	IIa	I
Timberville variant	IIa	I
Tioga	Ia	I
Toccoa	V	NS*
Toddstav	IVb	IV
Tomotley (drained)	Ib	I
Tomotley (undrained)	V	NS*
Toms	Ib	I
Toqast	IVa	III
Torhunta	IIa	II
Totier	IIIb	II
Toxaway	IVb	III
Toxaway (drained)	Ib	I
Toxaway (undrained)	V	NS*
Trappist	IIIb	II
Trego	IVa	IV
Trenholm	V	IV
Trimont	IVb	III
Trussel	IVb	NS*
Tuckahoe	Ia	I

Tuckasegee	IIa	I
Tugglesgap	IVb	III
Tumbling	IIb	II
Turbeville	IIb	II
Tusquitee	IIa	I
Tygart (drained)	IIb	III
Tygart (undrained)	IVa	NS*
Uchee	IVb	III
Udults	IVa	III
Unison	IIb	II
Unison variant	IIb	II
Vance	IVa	III
Vandalia	IIb	II
Varina	IIIa	III
Vaucluse	IIIa	III
Vertrees	IIb	II
Virgilina	V	IV
Wadesboro	IVa	II
Wagram	IVb	III
Wahee (drained)	Ib	I
Wahee (undrained)	V	NS*
Wakulla	V	NS*
Wallen	V	IV
Walnut	IVb	III
Wando	V	III
Warminster	IVa	II
Watahala	IIb	II
Watauga	IVa	III
Wateree	IVb	III
Watt	V	IV
Watt variant	V	IV
Waxpool	V	IV
Waynesboro	IIb	II
Weaver	Ia	I
Webbtown	V	IV
Wedowee	IVa	III
Weeksville (drained)	Ib	I
Weeksville (undrained)	V	NS*
Wehadkee	V	IV
Weikert	V	IV
Westfield	IVa	III
Westmoreland	IIIb	II
Weston	IIa	II

Westphalia	V	NS*
Weverton	IVb	III
Wharton	IIb	II
Wheeling	Ia	I
White Store	V	IV
White Store variant	V	IV
Whiteford	IIIb	II
Wickham	Ia	I
Wickham variant	Ia	I
Widgett	IVb	III
Wilkes	V	IV
Wingina	Ia	I
Winnsboro	V	IV
Wintergreen	IIb	II
Winton	Ia	I
Wolfgap	Ia	I
Wolftrap	IIb	I
Woodington	IVb	NS*
Woodstown	IIb	I
Woolwine	IVa	III
Worsham	IVb	IV
Worsham variant	IVb	IV
Wrightsboro	IIb	I
Wurno	V	IV
Wyrick	IIa	I
Yadkin	IVa	II
Yellowbottom	IVa	III
Yemassee (drained)	Ib	I
Yemassee (undrained)	V	NS*
Yeopim	IIb	I
Yogaville	V	IV
York	IVb	III
Zepp	V	IV
Zion	IVa	III
Zion variant	IVa	III
Zoar	IIb	I

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APPENDIX C

Data preparation for joining SSURGO soils data to VALUES soil productivity tables

I) In order to perform a text-based join in ArcGIS, the following soil series names were corrected for spelling differences between statewide SSURGO component table and VALUES table.

1. Batteau
2. Bellspur
3. Blumount
4. Itmann
5. Meggett
6. Nikwasi
7. Philomount
8. Rappahannock
9. Scattersville
10. Sketerville
11. Trussel
12. Widgett
13. Woolwine
14. Yemassee

II) In the VALUES table for Virginia soils productivity, 56 records have a drained or undrained designation in the name field. This designation was removed in order to perform the text-based join. After doing land cover analysis of specific mukeys affected by this issue, undrained soils are always undrained, while the drained designation reveals some lands that are forested, forested wetlands, agriculture, or urban. To isolate unique soil series names for each mukey, the drained designation and their associated potential yields were used and undrained designation disregarded. This approach was selected due to the fact that later steps taken mask out forested lands, wetland, and developed/urban lands. The soil series affected by this process are listed below.

1. Argent
2. Arapahoe
3. Acredale
4. Bladen
5. Belhaven
6. Bethera
7. Chatuge
8. Chickahominy
9. Clubcaf
10. Coxville
11. Daleville
12. Deloss
13. Fallsington
14. Hyde
15. Johnston
16. Kinston
17. Leaf
18. Lumbee
19. Meggett
20. Melvin
21. Myatt
22. Myatt variant
23. Nimmo
24. Osier
25. Polawana
26. Pooler variant
27. Portsmouth
28. Pungo
29. Rains
30. Roanoke
31. Tomotley
32. Torhunta
33. Wehadkee
34. Wet Spots
35. Yogaville
36. Aquults
37. Augusta
38. Chapanoke

39. Chewacla
40. Dragston
41. Dunbar
42. Fluvaquents
43. Fork
44. Gunston
45. Kinkora
46. Lenoir
47. Monacan
48. Nahunta
49. Newark
50. Newmarc
51. Okeetee
52. Pamlico
53. Pooler
54. Wahee
55. Woodington
56. Yemassee

Commonly there was more than one major component identified per mukey, resulting in duplicate mukeys in the soil productivity tables. These different components have different potential yield values assigned to them, and therefore it was necessary to separate mukeys with a single major component from those with multiple major components. For both states, 5987 mukeys were identified as having a single major component. There were 3281 mukeys with more than one major component. For these duplicate mukeys, a database query was conducted to identify all records affected by this issue and a weighted average function applied. The sum of these weighted averages of component potential yields was then assigned back to one unique mukey. Finally, the two sets of records were joined into a single file for use within a geospatial framework.

APPENDIX D

Crop classification for land allocation and estimating yield

Several food crops are horticultural crops grown on perennial-suited soils. For land allocation purposes, these crops were assigned to perennial lands in the spatial model. For determining yield, however, these crops were assigned to the annual indicator crop of corn silage. Crops affected by this include: asparagus, berry crops, orchard crops, and nuts. The classification of crops for yield estimates is given in Table AB. The classification of crops for land allocation is given in Table AC. Regional yield estimates were used based on average soil productivity. This thesis assumes that the VALUES soil productivity class IIA represents average yields for all crops. Table AD displays the yield conversion factors used for all productivity classes.

Table D. 1. Crop assignment to indicator crop used for determining yield in the spatial model.[1]

Commodity	Assignment	Commodity	Assignment
ALFALFA HAY	1	MELONS, WATERMELONS	0
APPLES	1	NECTARINES	1
ASPARAGUS	0	OATS	0
BLACK BEANS	0	ONIONS	0
BLACKBERRIES	1	ORCHARDGRASS HAY	1
BLUEBERRIES	1	PASTURE	1
BROCCOLI	0	PEACHES	1
CABBAGE	0	PEARS	1
CARROTS	0	PEAS, GREEN	0
CAULIFLOWER	0	PEPPERS	0
CHERRIES	1	POTATOES	0
CORN, GRAIN	0	RASPBERRIES	1
CORN, SILAGE	0	RYE	0
CUCUMBERS	0	SOYBEAN, FEED AND OIL	0
EGGPLANT	0	SOYBEAN, TOFU	0
GRAPES	1	SPINACH	0
GRASS HAY	1	STRAWBERRIES	0
GREEN BEANS	0	SUMMER SQUASH	0
GREENS, COLLARDS	0	SUNFLOWER	0
GREENS, KALE	0	SWEET CORN	0
HONEY	1	SWEET POTATOES	0
LETTUCE, ROMAINE	0	TOMATOES	0
LIMA BEANS	0	WHEAT	0
MELONS, CANTALOUPES	0	WINTER SQUASH & PUMPKIN	0
MELONS, HONEYDEW FRESH	0		

1- Horticultural and annual crops (0) were assigned to corn silage. Perennial crops (1) were assigned to hay.

Table D. 2. Cropland Data Layer (CDL) reclassification of non-agricultural (0), annual crops (1), and perennial crops (2) used to identify land allocation in the spatial model.

CDL Codes	Class Names	New Code	CDL Codes	Class Names	New Code
0	Background	0	46	Sweet Potatoes	1
1	Corn	1	47	Misc Vegs & Fruits	1
2	Cotton	1	48	Watermelons	1
3	Rice	1	49	Onions	1
4	Sorghum	1	50	Cucumbers	1
5	Soybeans	1	51	Chick Peas	1
6	Sunflower	1	52	Lentils	1
10	Peanuts	1	53	Peas	1
11	Tobacco	1	54	Tomatoes	1
12	Sweet Corn	1	55	Caneberries	2
13	Pop or Orn Corn	1	56	Hops	1
14	Mint	1	57	Herbs	1
21	Barley	1	58	Clover/Wildflowers	2
22	Durum Wheat	1	59	Sod/Grass Seed	2
23	Spring Wheat	1	60	Switchgrass	2
24	Winter Wheat	1	61	Fallow/Idle Cropland	2
25	Other Small Grains	1	62	Pasture/Grass	2
26	Dbl Crop WinWht/Soybeans	1	63	Forest	0
27	Rye	1	64	Shrubland	0
28	Oats	1	65	Barren	0
29	Millet	1	66	Cherries	2
30	Speltz	1	67	Peaches	2
31	Canola	1	68	Apples	2
32	Flaxseed	1	69	Grapes	2
33	Safflower	1	70	Christmas Trees	2
34	Rape Seed	1	71	Other Tree Crops	2
35	Mustard	1	72	Citrus	2
36	Alfalfa	2	74	Pecans	2
37	Other Hay/Non Alfalfa	2	75	Almonds	2
38	Camelina	1	76	Walnuts	2
39	Buckwheat	1	77	Pears	2
41	Sugarbeets	1	81	Clouds/No Data	0
42	Dry Beans	1	82	Developed	0
43	Potatoes	1	83	Water	0
44	Other Crops	1	87	Wetlands	0
45	Sugarcane	1	88	Nonag/Undefined	0
			92	Aquaculture	0

Table D. 2. Continued.

CDL Codes	Class Names	New Code	CDL Codes	Class Names	New Code
112	Perennial Ice/Snow	0	230	Dbl Crop Lettuce/Durum	1
121	Developed/Open Space	0	231	Lettuce/Cantaloupe Dbl Crop	1
122	Developed/Low Intensity	0	232	Dbl Crop Lettuce/Cotton	1
123	Developed/Med Intensity	0	233	Dbl Crop Lettuce/Barley	1
124	Developed/High Intensity	0	234	Dbl Crop Durum Wht/Sorghum	1
131	Barren	0	235	Dbl Crop Barley/Sorghum	1
141	Deciduous Forest	0	236	Dbl Crop WinWht/Sorghum	1
142	Evergreen Forest	0	237	Dbl Crop Barley/Corn	1
143	Mixed Forest	0	238	Dbl Crop WinWht/Cotton	1
152	Shrubland	0	239	Dbl Crop Soybeans/Cotton	1
171	Grassland Herbaceous	2	240	Dbl Crop Soybeans/Oats	1
181	Pasture/Hay	2	241	Dbl Crop Corn/Soybeans	1
190	Woody Wetlands	0	242	Blueberries	2
195	Herbaceous Wetlands	0	243	Cabbage	1
204	Pistachios	2	244	Cauliflower	1
205	Triticale	1	245	Celery	1
206	Carrots	1	246	Radishes	1
207	Asparagus	2	247	Turnips	1
208	Garlic	1	248	Eggplants	1
209	Cantaloupes	1	249	Gourds	1
210	Prunes	2	250	Cranberries	1
211	Olives	2	254	Dbl Crop Barley/Soybeans	1
212	Oranges	1			
213	Honeydew Melons	1			
214	Broccoli	1			
216	Peppers	1			
217	Pomegranates	1			
218	Nectarines	2			
219	Greens	1			
220	Plums	2			
221	Strawberries	2			
222	Squash	1			
223	Apricots	1			
224	Vetch	2			
225	Dbl Crop WinWht/Corn	1			
226	Dbl Crop Oats/Corn	1			
227	Lettuce	1			
229	Pumpkins	1			

Table D. 3. Crop yields by soil productivity groups.

Crop	Soil productivity group I A	I B	II A	II B	III A	III B	IV A	IV B	V
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ALFALFA HAY	16000	16000	12000	10400	8000	0	0	0	0
APPLES	26667	26667	20000	17333	13333	0	0	0	0
ASPARAGUS	2211	2105	2000	1895	1789	1684	1579	1368	1053
BLACK BEANS	11053	10526	10000	9474	8947	8421	7895	6842	5263
BLACKBERRIES	13333	13333	10000	8667	6667	0	0	0	0
BLUEBERRIES	13333	13333	10000	8667	6667	0	0	0	0
BROCCOLI	11053	10526	10000	9474	8947	8421	7895	6842	5263
CABBAGE	44211	42105	40000	37895	35789	33684	31579	27368	21053
CARROTS	33158	31579	30000	28421	26842	25263	23684	20526	15789
CAULIFLOWER	13263	12632	12000	11368	10737	10105	9474	8211	6316
CHERRIES	6667	6667	5000	4333	3333	0	0	0	0
CORN, GRAIN	9903	9432	8960	8488	8017	7545	7074	6131	4716
CORN, SILAGE	46421	44211	42000	39789	37579	35368	33158	28737	22105
CUCUMBERS	44211	42105	40000	37895	35789	33684	31579	27368	21053
EGGPLANT	22105	21053	20000	18947	17895	16842	15789	13684	10526
GRAPES	13333	13333	10000	8667	6667	0	0	0	0
GRASS HAY	12000	12000	9000	7800	6000	0	0	0	0
GREEN BEANS	4974	4737	4500	4263	4026	3789	3553	3079	2368
GREENS, COLLARDS	44211	42105	40000	37895	35789	33684	31579	27368	21053
GREENS, KALE	44211	42105	40000	37895	35789	33684	31579	27368	21053
HONEY	187	187	140	121	93	0	0	0	0
LETTUCE, ROMAINE	22105	21053	20000	18947	17895	16842	15789	13684	10526
LIMA BEANS	4974	4737	4500	4263	4026	3789	3553	3079	2368
MELONS, CANTALOUPES	44211	42105	40000	37895	35789	33684	31579	27368	21053
MELONS, HONEYDEW	33158	31579	30000	28421	26842	25263	23684	20526	15789

MELONS, WATERMELONS	44211	42105	40000	37895	35789	33684	31579	27368	21053
NECTARINES	6667	6667	5000	4333	3333	0	0	0	0
OATS	2829	2695	2560	2425	2291	2156	2021	1752	1347
ONIONS	33158	31579	30000	28421	26842	25263	23684	20526	15789
PASTURE (AC/AU)	1	1	1	1	1	0	0	0	0
PEACHES	10000	10000	7500	6500	5000	0	0	0	0
PEARS	13333	13333	10000	8667	6667	0	0	0	0
PEAS, GREEN	4421	4211	4000	3789	3579	3368	3158	2737	2105
PEPPERS	55263	52632	50000	47368	44737	42105	39474	34211	26316
POTATOES	22105	21053	20000	18947	17895	16842	15789	13684	10526
RASPBERRIES	10000	10000	7500	6500	5000	0	0	0	0
RYE	11053	10526	10000	9474	8947	8421	7895	6842	5263
SOYBEAN, FEED AND OIL	3316	3158	3000	2842	2684	2526	2368	2053	1579
SOYBEANS, TOFU	1437	1368	1300	1232	1163	1095	1026	889	684
SPINACH	6632	6316	6000	5684	5368	5053	4737	4105	3158
STRAWBERRIES	11053	10526	10000	9474	8947	8421	7895	6842	5263
SUMMER SQUASH	22105	21053	20000	18947	17895	16842	15789	13684	10526
SUNFLOWER	1235	1176	1117	1059	1000	941	882	765	588
SWEET CORN	11053	10526	10000	9474	8947	8421	7895	6842	5263
SWEET POTATOES	22105	21053	20000	18947	17895	16842	15789	13684	10526
TOMATOES	55263	52632	50000	47368	44737	42105	39474	34211	26316
WHEAT	4244	4042	3840	3638	3436	3234	3032	2627	2021
WINTER SQUASH & PUMPKIN	44211	42105	40000	37895	35789	33684	31579	27368	21053

APPENDIX E

Land cover data preparation

Land cover data from the 2013 Cropland Data Layer was used to determine the spatial extent of agricultural land cover in the study area. This geo-referenced raster dataset The 2013 CDL layer was reclassified to distinguish between agricultural and non-agricultural land categories. All non-agricultural land classes were removed and all agricultural classes were combined to include commodity and horticultural crops as well as pasture and grazing lands. Further analysis allowed these agricultural categories to be parsed apart to determine different types of agricultural land cover. As annual and high-value crops have different productivity requirements than perennial forage crops, these agricultural categories were reclassified into two new classes to represent these two components of agricultural land cover in the region.