CONTRIBUTION OF RURAL LAND USE TO FLORISTIC DIVERSITY: A MULTI-SCALE STUDY OF ORGANIC FARMS AND SUBDIVISIONS IN THE SOUTHERN APPALACHIANS

A Thesis
By
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ABSTRACT

CONTRIBUTION OF RURAL LAND USE TO FLORISTIC DIVERSITY: A MULTI-SCALE STUDY OF ORGANIC FARMS AND SUBDIVISIONS IN THE SOUTHERN APPALACHIANS

(May 2010)

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In the rural countryside of the Southern Appalachians, a trend of land-use change from agriculture to exurban development continues to alter the landscape at multiple spatial scales. This research seeks to answer how such land-use trends alter species richness, habitat structure and landscape patterns of the Southern Appalachians. By combining GIS analysis with field data collection, this study specifically addresses the following questions: (1) What are the overall patterns of habitat composition and spatial structure of the landscapes surrounding farms and subdivisions? (2) What are the patterns of habitat composition and spatial structure of agricultural and subdivided sites? (3) How do farms and low-density residential development maintain or differ from the broader landscape in habitat composition and spatial structure. (4) How do farms and low-density residential development compare in terms of floristic biodiversity?

Using ArcGIS® and six-inch resolution aerial photography, I mapped and classified various habitat patches (forest, field, shrub, riparian, built and crop) within eight study sites (four farms and four subdivisions) and documented plant species composition, cover, and structure in two $100m^2$ plots within each habitat patch at all sites. I compared total cover of all plant species and relative cover of native and exotic species, as well as various measures of species richness (total, native, and exotic), between habitats and land use types.

Forested habitats dominated both landscape types, accounting for approximately 62 percent of the total landscape surrounding both farms and subdivisions. Results from this study revealed that as land-use changes from agriculture to exurban development, habitats become more fragmented and complex. I found an overall decrease in total species richness, lower total native species richness, and higher exotic species within forested habitats. Subdivisions also displayed a higher amount of habitat fragmentation than farms. Further, farm sites maintained an overall closer relationship to the surrounding landscape than subdivisions in area weighted mean patch fractal dimension and edge density as well as habitat composition. These results show the immense capability of rural land use such as organic agriculture and low-density residential development to influence a wide array of habitats by affecting patch structure, total species richness, and native and exotic species richness. Further, they also display a potential to affect broader biodiversity involving species assemblages of a wide variety of animal species, microorganisms, and invertebrates.

As population pressures continue to rise and natural areas experience greater ecological pressure due to human involvement, a tremendous need exists to understand how specific human activities may alter natural habitats. Such knowledge can inform

land management strategies including land conservation (e.g. land trusts) and sustainable development practices that may mitigate harmful environmental effects.

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INTRODUCTION

Across the United States, many rural areas are experiencing land-use conversions from agriculture to low-density exurban housing developments (Bock and Bock 2009). This increase in human alteration of landscapes creates questions as to the ecological ramifications of such land-use practices, both during and after conversion from one land use type to another (Hansen et al. 2005). While many studies establish the effects of agriculture on biotic diversity, few examine how exurban development affects ecological communities and species assemblages, especially effects resulting from land-use change (Hansen et al. 2005). This chapter will examine the role of rural human-dominated agricultural and exurban development systems in influencing biotic diversity. I will review the current body of literature that examines the rural landscape and its potential to contribute to biological diversity, the role of specific agricultural practices and exurban developments in maintaining and/or altering biodiversity and the current state of land-use change in the Southern Appalachian region.

Rural Land Use and Biodiversity

Biodiversity refers to the total of life (plants, animals, fungi and microorganisms) on Earth including phenotypic and genetic variation within each classification group (Dirzo and Raven 2003). This includes wild as well as domesticated species used in agricultural cultivation and ornamental gardens (Dirzo and Raven 2003). Biodiversity is essential for all species by providing fundamental needs for survival. For human populations, biodiversity provides a vast array of goods and services, from shelter to food and clothing to recreation (McNeely and Scherr 2003). Apart from the direct benefits of biodiversity to humans, ecosystem function also relies on the diversity of species for nutrient cycling, pollination, regeneration, purification, decomposition, rejuvenation and stabilization (Altieri 1999). However, continued debates question the extent to which ecosystems depend on biodiversity and individual species to maintain balance, especially at multiple spatial scales (Srivastava and Velland 2005; Tilman 2000).

In rural landscapes, local livelihoods often depend directly on the goods and services that biotic diversity provides, making research on the effects of rural land uses necessary for both conservation and community sustainability. For example, in agricultural systems, the intricate web of biodiversity is essential for maintaining productivity within the entire cropping system. A diversified matrix of wild plant and animal species directly affects the reproductive success of agricultural crops by influencing seed dispersal, pest management and soil nutrients (McNeely and Scherr 2003). Further, the diversity of habitats also contributes to rural economies. Many rural industries depend on the natural resources, aesthetic/recreational values and natural amenities of the countryside (Hansen et al. 2005). This presents a tremendous quandary as to how to support the needs of a growing population while sustaining ecosystem function.

Land transformations cause the destruction and fragmentation of habitats worldwide, making them the leading cause of biodiversity loss and species extinctions today (Lindenmayer and Fischer 2006; Olff and Ritchie 2002; Pimm and Raven 2000; Vitousek et al. 1997). The principal driving force behind fragmentation is the consumptive exploitation of ecological goods and services for food, clothing, shelter, raw materials and intrinsic values (Altieri 1999). Within rural exurban developments, the increased desire of many homeowners for amenities of forest areas such as increased privacy and recreational activities can create a habitat structure of small fragmented forest patches intervened by patches of built/disturbed habitats (Bock and Bock 2009; Brown et al. 2008; USDA 2007; Hansen et al. 2005). Thus increasing the overall amount of fragmentation around such types of land uses.

In recent years, researchers have begun to describe the extent of human induced habitat transformations in an attempt to characterize landscapes for conservation and land management purposes. Many studies focus on the land use/cover trends of various ecosystems and biomes around the world, documenting the rates of change through time and estimating the degree of human influence on the environment (Sanderson et al. 2002; Lambin et al. 2001). In a study conducted on the global human footprint, Sanderson et al. (2002) mapped and discussed the extent of human impact. Using patterns of human environmental involvement and ecological impact, they estimated human population density, land transformation and infrastructure to create a human influence index. They concluded that the majority of land use activities exist in a moderate to extreme state of environmental influence, and that increased suburban/urban development and agricultural activities contributed the greatest amount of impact (Sanderson et al. 2002). Similarly, Foley et al. (2005) discussed how activities such as agriculture and development changed the landscape to a remarkable degree with an estimated global loss of forest cover between 7 to 11 million km^2 over the past 300 years.

While few question that urbanized landscapes contribute to environmental degradation and habitat fragmentation (Pickett et al. 2008; McKinney 2002), many fail to recognize the role that rural land uses play in this equation. In actuality, land uses such as agriculture and low-density housing development (i.e., subdivisions and exurban development) may alter landscapes to considerable degrees and at unprecedented spatial scales (Pickett et al. 2008; Luck 2007; Hansen et al. 2005; Lambin et al. 2001; Paoletti 1999; Knight, Wallace, and Riebsame 1994). These alterations have direct impacts on biotic diversity, soil structures, hydrologic systems and atmospheric circulations (Alberti et al. 2003; Foley et al. 2005; Lambin et al. 2001). For example, anthropogenic land use practices such as industry and agriculture directly contributed 35 percent of carbon dioxide emissions to global concentrations since 1850 (Foley et al. 2005). Population strains on sensitive ecosystems such as coastal wetlands and tropical rainforests continue to threaten endemic species (Lindenmayer and Fischer 2006), while agricultural expansion threatens ecosystems worldwide (McNeely and Sherr 2003). However, the extent of alteration depends greatly on the type of rural land use employed and the degree of interaction (i.e., land clearing, forestry, grazing, hunting, fishing, trampling and cropping intensification) with the environment (Mayfield and Daily 2005; Sanderson et al. 2002; Vitousek et al. 1997). For example, in large-scale highly intensive agricultural settings, land use practices increased the amount of land transformation, water pollution and soil erosion (Foley et al. 2005). In contrast, alternative less intensive practices, such as small-scale productions, displayed less impact to surrounding areas and often increased rates of biodiversity (McNeely and Sherr 2003).

Countryside biogeography attempts to document and understand rural and human-dominated landscape effects on biotic diversity, species assemblages and environmental conservation (Daily 1997). In light of increased human population growth and its threat to species diversity (especially native species), Daily (1999) argued that rural countrysides display great potential for biodiversity conservation. According to Daily (1999), as populations continue to grow, the majority of undisturbed natural habitats and remnant native areas will reside within rural landscapes. Understanding the degree to which these areas support biodiversity is fundamental in protecting future species and ecosystem services (Daily 1999).

The study of countryside habitats is relatively new, and a comprehensive understanding of the potential conservation power of rural landscapes is currently being developed (Daily, Ehrlich, and Sánchez-Azofeifa 2001). However, studies of animal and insect populations in tropical habitats of Central and South America and temperate regions of Europe display the potential of fragmented countryside landscapes to influence biodiversity (Daily, Ehrlich, and Sánchez-Azofeifa 2001; Horner-Devine et al. 2003). For example, Daily, Ehrlich, and Sánchez-Azofeifa (2001) found a substantial number of native bird species among intermediate-intensity agricultural landscapes in southern Costa Rica, with the majority of species found in large forest fragments. Horner-Devine et al. (2003) further found that small forest patches in the tropical countryside of Costa Rica contributed to increased butterfly species richness. Similarly, in a study of bird species in the lowland countryside of Britain, Hinsley et al. (1995) established that small habitat patches may contain diverse avian populations. While these studies demonstrate the capacity of countryside habitats to support biotic diversity, some warn that these trends may not be sustainable in long-term scenarios or with intensification of land use practices (Daily, Ehrlich, and Sánchez-Azofeifa 2001). Further, spatial scale (i.e., local regional and global), habitat configuration and structure such as the size of habitats greatly contribute to the amount of conservation value of rural habitats (Hinsley et al. 1995).

Least studied within countryside biogeography is the diversity of flora within rural systems and the contributions of gardens and residential housing developments to biodiversity (Mayfield and Daily 2005; Daily, Ehrlich, and Sánchez-Azofeifa 2001). However, in a study of the herbaceous and shrubby plants in forested and deforested successional habitats, including cattle pastures, in the southern countryside of Costa Rica, Mayfield and Daily (2005) found significant evidence that countryside habitats can support native species assemblages. Of the 772 herbaceous and shrubby plant species surveyed, they found that deforested habitats supported 37 to 42 percent of all species (Mayfield and Daily 2005). Further, they found higher plant densities in deforested habitats than forested, likely due to environmental differences between open canopy deforested habitats and closed canopy tropical forests (Mayfield and Daily 2005). In additional study of the same sites, Mayfield et al. (2005) provided evidence that deforested and forested habitats differed in their ecological assembly processes among growth and fruit type traits, which subsequently influenced overall community function and species assemblages. This underscores the importance of studying and understanding the diversity patterns in different countryside habitats because each proves to have differing trait relationships among species and functional diversity patterns (Mayfield et al. 2005).

Historically, research on land-use change primarily focused on changes between natural ecosystems and human dominated systems such as agriculture and development (Mayfield, Ackerly, and Daily 2006; Maestas, Knight, and Gilgert 2003). Valued for their insight on the environmental changes to natural areas resulting from such land use practices and the potential conservation value of individual habitats within the human dominated systems, these studies hold high importance to ecology and conservation. However, understanding each land use type individually is not enough to fully grasp the scope of human environment interaction. As population pressures and industry push for space, a need exists to also understand the effects of land-use change between human dominated land use types.

Agriculture and Biodiversity

Agricultural biodiversity consists of all elements and levels of diversity among crops and both natural and semi-natural habitats within and surrounding the cropped areas. This includes the diversity among agricultural crops and livestock, wild plant and animal species, as well as the variety of pollinators, pests and predators (Thompson et al. 2007). As a dominant rural land use, agriculture displays great potential to influence biotic diversity at all levels. A growing body of research documents the effects of agriculture on biodiversity through a range of subjects from agricultural mosaics (Bennett, Radford, and Haslem 2006), farm size (Belfrage, Biörklund, and Salomonsson 2005), field boundary diversity (Harvey 2007; Cœur et al. 2002; McNeely and Scherr

2003), to habitat heterogeneity (Benton, Vickery, and Wilson 2003; Weibull, Östman, and Granqvist 2003).

Benton, Vickery, and Wilson (2003) argued that maintenance of habitat heterogeneity could be the key to sustaining biodiversity in agriculture. Landscapes associated with higher levels of biodiversity generally coincide with mosaics of various habitat patches of cropped and natural/semi-natural non-cropped areas, creating a heterogeneous setting (Harvey 2007; Benton, Vickery, and Wilson 2003; Weibull, Östman, and Granqvist 2003). According to Harvey (2007), these non-cropped intermediary areas of purposefully placed habitats such as hedgerows, windbreaks, live fences and boarder strips have immense capability to conserve biodiversity within the agricultural system. These areas create essential habitats for a variety of taxa including butterflies, spiders, plants, and birds that collectively play important roles in maintaining biodiversity at larger landscape scales (Benton, Vickery, and Wilson 2003). According to McNeely and Scherr (2003), these species use intermediary zones to move between differing patch types such as edge zones separating cropped and forested habitats, often increasing the amount of biotic diversity in the landscape overall. However, the degree of influence of habitat structure depends on the individual species present within the habitat and their specific needs for survival (Harvey 2007; NcNeely and Scherr 2003).

The shape and size of individual habitats affects both animal and plant species by influencing mobility and distribution from one habitat patch to another (Harvey 2007; McNeely and Scherr 2003). Often, larger vegetative patches tend to support a wider range of species than smaller habitats (Lafortezza and Brown 2004). However, small patches of remnant vegetation could be of great significance to conservation of a variety of organisms including plants (Angelstam and Pettersson 1997; Turner 1996), vertebrates (McCoy and Mushinsky 1999) and birds (Fischer and Lindenmayer 2002). Shape of vegetative patches also influences the spatial pattern and diversity of organisms (Lindenmayer and Fischer 2006; Lafortezza and Brown 2004).

The effects of farming practices are complex and occur at multiple spatial scales. At the field scale, direct impacts such as tillage and chemical applications directly affect wide ranges of individual organisms. At the landscape and regional scales, replacement of natural habitats with arable and grazing fields simplifies the landscape (Concepción, Díaz, and Baquero 2008; Benton, Vickery, and Wilson 2003). Further, the degree of impact to biodiversity often depends on the type of agricultural practices employed by the individual farms. For example, conventional agricultural practices involve high inputs of synthetic fertilizers, pesticides, herbicides and fungicides, which prove hazardous to natural vegetation, soil structure and water quality (Altieri 1999; Paoletti 1999). In addition, conventional farming methods often lead to intense monocultural cropping that limits the genetic diversity within crop fields and creates a trend of decreased farmland biodiversity and habitat heterogeneity (Benton, Vickery, and Wilson 2003). According to Green et al. (2005), these intensive farming practices greatly reduce the capability of the land to support wild species and maintain natural habitats.

In recent years, organic farming has received increased support and attention as an alternative to conventional agriculture. Organic methods require that farmers use natural inputs that readily breakdown when introduced in the system and encourage diversified intercropping practices (Benton, Vickery, and Wilson 2003; Altieri 1999; Paoletti 1999). In theory, these restrictions promote environmental sustainability and provide increased habitat for a variety of organisms such as birds, butterflies, and plants (Benton, Vickery, and Wilson 2003).

Most studies that compare biodiversity of conventional versus organic farms indicate organic agriculture supports higher levels of biodiversity (Belfrage, Biörklund, and Salomonsson 2005; Fuller et al. 2005; Hole et al. 2005; Asteraki et al. 2004; Benton, Vickery, and Wilson 2003; Weibull, Östman, and Granqvist 2003; Elsen 2000). Hole et al. (2005) reviewed literature comparing the effects of organic and conventional farming practices on biodiversity, and found that sixty-six out of seventy-six studies reported higher species abundance and richness on organic farms than on conventional farms (Hole et al. 2005). These positive effects occurred across a wide range of taxa including birds, mammals, butterflies, spiders, earthworms, beetles and plants (Hole et al. 2005). For example, Fuller et al. (2005) found that organic farms displayed higher measures of species diversity and abundance than conventional farms, especially for plant species. They reported organic farms had 68-105 percent more plant species, 74-153 percent more weedy plant species, 5-48 percent more spiders and 16-62 percent more birds than conventional farms (Fuller et al. 2005). In a similar study, Boutin, Baril, and Martin (2008) found that out of sixteen conventional and fourteen organic farms in Peterborough, Ontario, organic farms not only showed higher plant species richness in arable fields and habitat boundaries, but also a greater degree of overall habitat variability. Furthermore, they found that overall species composition varied between different farm types, with sixty-nine out of 193 species found exclusively on organic farms.

Studies of organic practices show that they are not exempt from negative impacts on biodiversity. In a study conducted in the southwest region of England on the diversity patterns of organic versus conventional agriculture, Gibson et al. (2007) found that organic farms did not have higher rates of biodiversity in semi-natural boundary habitats than paired conventional farms. They hypothesized that the spatial arrangement of the semi-natural habitats may play a key role in the rates of biodiversity at higher trophic levels (Gibson et al. 2007). Thus, landscape scale habitat diversity and habitat heterogeneity may provide a key to understanding the role of biodiversity on various landscapes (Benton, Vickery, and Wilson 2003).

Exurban Development and Biodiversity

As a fast growing trend of development across the United States, exurbia greatly influences American life by affecting economic advancement, infrastructure (Nelson 1992), as well as landscape ecological structure and function (Bock and Bock 2009; Hansen et al. 2005). Defining exurban landscapes proves difficult since definitions encompass both physical location and socio-economic (i.e., income classes) attributes and have been debated since the first appearance of the term in Auguste C. Spectorsky's 1955 book, *The Exurbanites* (Nelson 1992; Spectorsky 1955). However, exurban development generally consists of areas of low-density housing located beyond the urban or small town fringe (Bock and Bock 2009; USDA 2007; Hansen et al. 2005), including a rage of subdivision sizes from acreage tract to estates (Nelson 1992). Normally these areas consist of larger land parcels nestled among natural/semi-natural habitats in rural settings (Bock and Bock 2009; Hansen et al. 2005), but within close commuting distance to urban opportunities including employment, services, and social networks (Nelson 1992). The locations of such developments are far from indiscriminate and placement tends to coincide with scenic amenities such as streams, lakes, wetlands, national parks and forests (USDA 2007).

In the American West, exurban developments continue to replace land once used for cattle ranching. In recent years, scholars have begun to document biotic response to such changes. Results from these studies demonstrate the effect of exurban developments on biotic structures and landscape composition noting increased infrastructure, buildings, gardens, numbers of human-commensal avian, domesticated animals and exotic vegetation (Bock and Bock 2009; Huntsinger 2009; USDA 2007; Hansen et al. 2005; Maestas, Knight, and Gilgert 2003; Odell and Knight 2001). However, not all findings yield negative results. In a series of studies on the exurbanizing landscape of Arizona, Bock, Jones, and Bock (2008; 2006; 2006a) found positive responses to avian populations, grasshopper densities, and forb cover as well as unchanged richness in native rodent populations with increased rates of development. Further, in a study of the correlations between butterfly populations and vegetation on exurban developments versus cattle ranches, Bock et al. (2007) found higher species richness of vegetation on exurban lands. Many attribute such effects to differing past land use practices and housing densities (Bock and Bock 2009; Bock, Jones, and Bock 2006a; Lenth, Knight, and Gilgert 2006) as well as active management practices of current homeowners (Yandik 2009; Hansen et al. 2005).

Similar to patterns observed in diverse agricultural landscapes, fragmentation in exurban landscapes may produce positive effects to overall diversity. According to Bock and Bock (2009), the indirect effects of habitat fragmentation such as edge boundary interactions and homeowner land management practices may significantly contribute to biodiversity. Rather, fragmentation may provide a heterogeneous setting for a diversity of vegetation, birds (Yandik 2009; Bock, Jones, and Bock 2008), small mammals (Bock, Jones, and Bock 2006), and insects (Bock, Jones, and Bock 2006a). For example, Yandik (2009) documented an increase in edge-adapted avian populations within residential developments, which he attributed to increased amount of edge density of various habitat patches.

Despite the recent studies in the American Southwest, we lack a comprehensive understanding of exurban development effects on the landscape. This results in speculation as to how the natural environment responds. Often, authors hypothesize potential effects suggesting changes including increased habitat loss and number of exotic species (Huntsinger 2009; Maestas, Knight, and Gilgert 2003) as well as ecological alteration to adjacent natural habitats (Hansen et al. 2005). However, a need exists for continued research into exurban development in order to understand the effects on biodiversity in multiple settings.

Urban Ecology

Given the shortage of studies that document rural residential development effects to biodiversity (Hansen et al. 2005), recent findings in urban ecology may provide valuable insights into the diversity patterns of human-dominated rural environments. According to Pickett et al. (2008), ecological explanations of urban ecosystems emerged in the middle of the 20th century to explain the spread of disease and spatial layout of neighborhoods. Recently, urban ecology has expanded to incorporate biological, physical and social components of the urban landscape to explain the biodiversity, social structure, nutrient cycling and spatial heterogeneity (Pickett et al. 2008).

One key factor in urban ecology is the pattern of biodiversity changes across the rural to urban gradient (Maestas, Knight, and Gilgert 2003; McKinney 2002). In a recent literature review McKinney (2002), examined the negative impact of urban and suburban developments on biodiversity and biotic responses to human alterations across the rural-urban gradient, noting drastically reduced numbers of species with increased development throughout most studies. As areas become more urbanized, the level of biological activity tends to decrease leaving fragmented patches of developed land, managed vegetation, ruderal vegetation and/or remnant natural habitat. However, species response along the rural-urban gradient often varies among taxa (McKinney 2002) and with the scale of analysis (Pautasso 2007). In some cases, authors noted increased species richness in urban areas compared to lower intensity land uses often associated with high numbers of exotic and synanthropic species (Kühn, Brandl, and Klotz 2004; McKinney 2002).

In recent years, strong debates have continued on the impact of purposefully planted gardens and landscaping on species assemblages (Hansen et al. 2005; Yandik 2009). Some authors have argued that biodiversity has increased in urban/suburban developments due to purposeful plantings of many ornamental plant species (Smith et al. 2006; McKinney 2002; Wuerthner 1994). For example, recent comprehensive analyses of the biodiversity of gardens in Sheffield, UK, documented extremely high rates of floristic diversity in private urban gardens, which they attributed to active management by garden owners (Smith et al. 2006; Thompson et al. 2003). Though gardens supported an abundance of nonnative plants, they also contained noteworthy assemblages of native species uncommon to the surrounding rural landscapes (Smith et al. 2006) as well as lawn areas that closely resembled nearby semi-natural habitats (Thompson et al. 2003).

Certainly, these findings challenge the conventional wisdom, which suggests the decline of biodiversity along the rural-urban gradient (McKinney 2002). Based on this theory, we would infer that urban landscapes would have fewer species than rural lands. However, research on urban gardens reveal that not all developments adhere to the pattern of declining biodiversity along the gradient and demonstrate the potential for domestic urban gardens to exhibit high species richness (Smith et al. 2006; Thompson et al. 2003). Application of these findings to the rural landscape yields contrasting hypotheses regarding the overall diversity patterns expected within rural subdivisions. On one hand, since subdivisions increase the rate of development, we would expect the diversity within residential developments to decline due to habitat loss and fragmentation. On the other hand, rural domesticated gardens might increase rural diversity through purposeful plantings, maintenance and care of some natural species.

The Southern Appalachians and Land-Use Change

Across the United States, the demand for the rural lifestyle is on the rise (Milder, Lassoie, and Bedford 2008; Hansen et al. 2005). Population growth and increased demand for mountain land exemplify the current trend of exurban development (Hansen et al. 2005; Maestas, Knight, and Gilgert 2003). In areas such as the Rocky Mountains, Pacific Northwest, and the southeastern United States, the patterns of rural exurban development have had a long history dating back to the 1950s (Hansen et al. 2005). In Southern Appalachia, this pattern has caused tremendous increases in land and housing values in both the urban areas and the rural landscapes (Wear and Bolstad 1998; SAMAB 1996). The diverse climate and biological richness of the region attract a wide range of seasonal travelers and outdoor adventurers. Such tourists, seasonal residents, and recreationists enjoy the scenic beauty of the many streams, lakes, national parks and forests throughout the region (SAMAB 1996). The tourism industry within much of the region continues to grow (SAMAB 1996), amplifying the desire for accommodations for the growing number of people. As noted by many, the combination of natural amenities and the rural lifestyle can make a region ideal for exurban development (Bock and Bock 2009; Hansen et al. 2005). According to Harden (2004), urbanization and development continue to thrive in the Southern Appalachian region and often replace land formerly used for agricultural purposes. Subsequent to such trends, the landscape structure is changing throughout the region including further habitat fragmentation and increased road network densities (Harden 2004).

As the demand for rural land and mountain homes increases, many farmers across Southern Appalachia recognize the economic benefits of selling their land for development. This pattern repeatedly prevails throughout the High Country region of western North Carolina. Simultaneously, a growing trend has emerged for organic agriculture throughout much of the region. Some farmers realize the economic profitability of organic agriculture and have converted from conventional practices. Based on reports from the 2002 and 2007 agricultural census (USDA 2002; 2007a), this trend is expected to continue well into the future.

Many have established that organic agriculture can support high levels of biodiversity (Belfrage, Biörklund, and Salomonsson 2005; Fuller et al. 2005; Hole et al. 2005; Asteraki 2004; Benton, Vickery, and Wilson 2003; Weibull, Östman, and Granqvist 2003; Elsen 2000) and others speculate similar effects from exurban development (Bock and Bock 2009; Bock, Jones, and Bock 2008, 2006, 2006a). It is important to understand how both types of land use practices influence diversity in the Southern Appalachians. Further, since few have studied the impacts of land-use change from agriculture to low-density residential development, it is unclear how such trends are affecting biodiversity in this region. It is the goal of this research to help fill this need and provide a foundation to understanding how land use and land-use change affect biodiversity in the Southern Appalachians.

One way of understanding the influence of land use on the environment is through multi-scale analysis. Such studies examine the ecological complexities from a variety of spatial (and often temporal) scales in attempts to better document and understand the full scope of ecological processes. Multi-scale studies can incorporate large scale (regional to global range of study) and small-scale data (localized habitats to individual populations). As well as the intermediary range between large and small scales that incorporates surrounding landscapes and often matrixes of varying habitats (Lindenmayer and Fischer 2006; Farina 2006). Many argue that incorporating multi-scale analysis into ecological based studies improves the understanding of natural phenomena such as species habitat requirements, dispersal movements, community structure and function, and overall ecosystem and biome complexities (Lindenmayer and Fischer 2006; Farina 2006).

Often used in ecological studies to assess the spatial configuration of habitats and land cover within a variety of scales, geographic information systems (GIS) provides a birds-eye view of the landscape and helps identify potential patterns and habitat mosaics. Such analysis often includes the characterization of habitats through examination of aerial photography, satellite imagery, and various forms of land cover maps (Lindenmayer and Fischer 2006; Lafortezza and Brown 2004). Further, spatial metrics and indexes generated in GIS help characterize the size, shape, and arrangement of landscape elements in attempts to document spatial configuration effects on ecological functionality and biological diversity (Lafortezza and Brown 2004; Olff and Ritchie 2002).

This research examines the role of organic farms and low-density residential subdivisions in maintaining biodiversity at multiple scales across the rural landscape. The overall research question asks how land-use change from agriculture to exurban development alters species richness, habitat structure and landscape patterns of the Southern Appalachians. By combining GIS analysis with field data collection, this study specifically addresses the following questions: (1) What are the overall patterns of habitat composition and spatial structure of the landscapes surrounding farms and subdivisions? (2) What are the patterns of habitat composition and spatial structure of agricultural and subdivided sites? (3) How do farms and low-density residential developments maintain or differ from the broader landscape in habitat composition and spatial structure? (4) How do farms and low-density residential development compare in terms of floristic biodiversity?

Chapter 2

METHODS

Study Area

I conducted this study in the mountains of North Carolina, which is part of the larger Southern Appalachian mountain range that spans from western Tennessee to Roanoke, Virginia and includes the mountain areas of Virginia, North Carolina and Georgia. The Southern Appalachians are an ancient mountain range dominated by varying topographic and climatic patterns making them rich in ecological diversity. The topographic variance of the mountain range creates a myriad of habitats and microhabitats that support a wide variety of flora, fauna and microorganisms. Dominated by deciduous forests and complex assemblages of understory herbaceous plant species, the region displays great ecological complexity (Turner et al. 2003).

Aside from the natural beauty of the region, the area also displays a variety of land-use practices, including agriculture, residential development, recreation and industry. While the topography and geologic features attract many to the region, the steep slopes and rocky soils limit the degree of interaction of many of these land uses. In agriculture, these limitations constrain the establishment of many large-scale farming practices but do not completely limit agricultural activity (SAMAB 1996). According to the Southern Appalachian Man in the Biosphere (1996), most agriculture consists on a relatively small scale with many individual farm owners.

For most of the northwestern region of North Carolina, the majority of farms range in size from ten to forty acres of harvested land (USDA 2007). Within Ashe and Watauga counties in North Carolina, higher elevations (~500-1,800m) result in cooler climates and a shortened growing season, while the steep topography limits the availability of suitable agricultural land. However, the elevation and topography also create diverse climatic variations that provide circumstances for a myriad of agricultural practices including livestock, vegetable and fruit cultivation, to nursery and ornamental plant cultivation (USDA 2002).

I focused my study in northwestern North Carolina located within the Blue Ridge Mountain Range of the Southern Appalachian region. The Blue Ridge ecoregion extends from the mountain regions of southwestern Virginia, through western North Carolina, to northwestern Georgia (Wear 1998) and is characterized by mountainous terrain, steep topography and rural nature (NC NHP 2008). Specifically, I narrowed my study locations to Watauga and Ashe Counties in northwestern North Carolina due to recent trends of land-use change of increased exurban development as well as decreased agricultural activity. Further, these counties also display a growing trend toward organic agriculture (USDA 2007) and display landscape characteristics similar to much of the western mountains of North Carolina (Table 2.1).

Table 2.1 Terrain characteristics per county.

	Elevation (meters)		Slope (degrees)	
County	min	max	min	max
Watauga	408	1,805	0.00	82.66
Ashe	653	1,588	0.00	72.12

Source: Elevation and slope data was generated from Lidar elevation points within ArcGIS®.

Study Design

In order to examine site (farm and subdivision) context in the surrounding landscape, I designed a multi-scale study including landscape, site and patch analysis. At the landscape and site scale, I conducted a habitat patch analysis using ESRI ArcGIS® 9.3 to analyze the overall structure and habitat matrix. To examine species composition, and richness, I conducted patch scale analysis through field-based data collection at each site and subdivision.

I selected four pairs of organic farms and subdivisions within my study region. Because factors such as climate, topography, geographical positioning, history and natural environmental conditions play key roles in influencing ecological processes and species composition, it is important to consider these influences in any research addressing human environment interaction (Lindenmayer and Fischer 2006). As such, I based my site selection not only on land use but also on the overall topographic characteristics of each study site. All sites selected for the study had been operational/built for a minimum of five years with three pairs located in Watauga County and two pairs in Ashe County (Figure 2.1). Further, I paired organic farms and subdivisions according to similarity in size, topography, elevation and overall landscape characteristics (i.e., valley, ridge, and/or flood plain) to minimize differences in vegetative structure due to environmental conditions (Table 2.2).

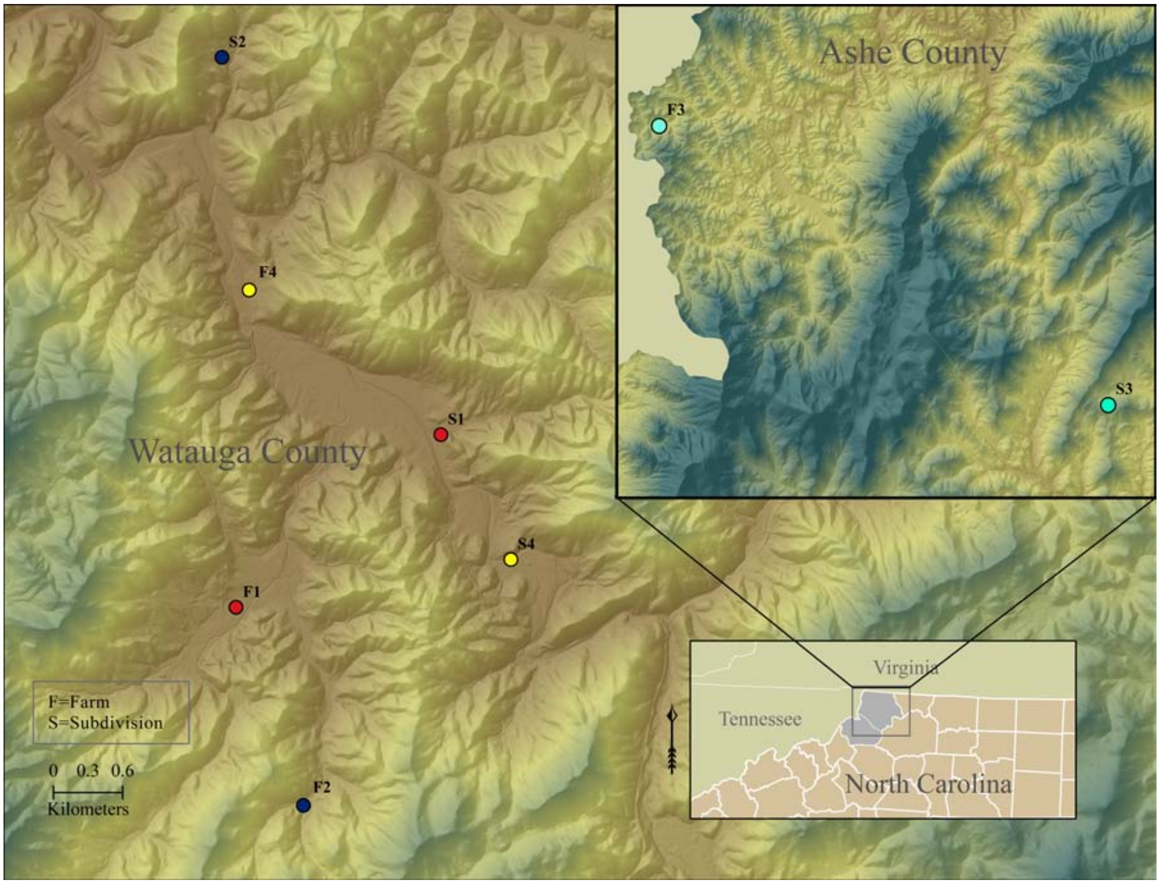


Figure 2.1. Map showing eight sites and the topography of the surrounding area.

Table 2.2. Landscape characteristics of each paired site.

Site	Size (ha)	Elevation (m)	Topographic Position	County Location
Farm 1	5.47	832	valley; flood plain	Watauga
Subdivision 1	6.45	824	valley; flood plain	
Farm 2	9.31	888	valley	Watauga
Subdivision 2	9.71	845	valley	
Farm 3	16.63	1019	ridge & valley	Ashe
Subdivision 3	15.56	1129	ridge & valley	
Farm 4	23.74	811	valley	Watauga
Subdivision 4	23.74	825	valley	

Note: Elevation data was taken from a center point within each site. Ridge and valley areas are characterized by both valley areas as well as areas of steeper slopes.

I analyzed each site in ArcGIS® using six-inch digital elevation models (DEMs) and aerial photography to obtain accurate estimates of site size and physical characteristics. I then calculated farm and subdivision sizes, and if any differences greater than one to two hectares occurred between the pairs, I removed land from the larger subdivision by randomly choosing a point at an edge location and removing land parcels until I achieved a matching size for analysis.

GIS Analysis

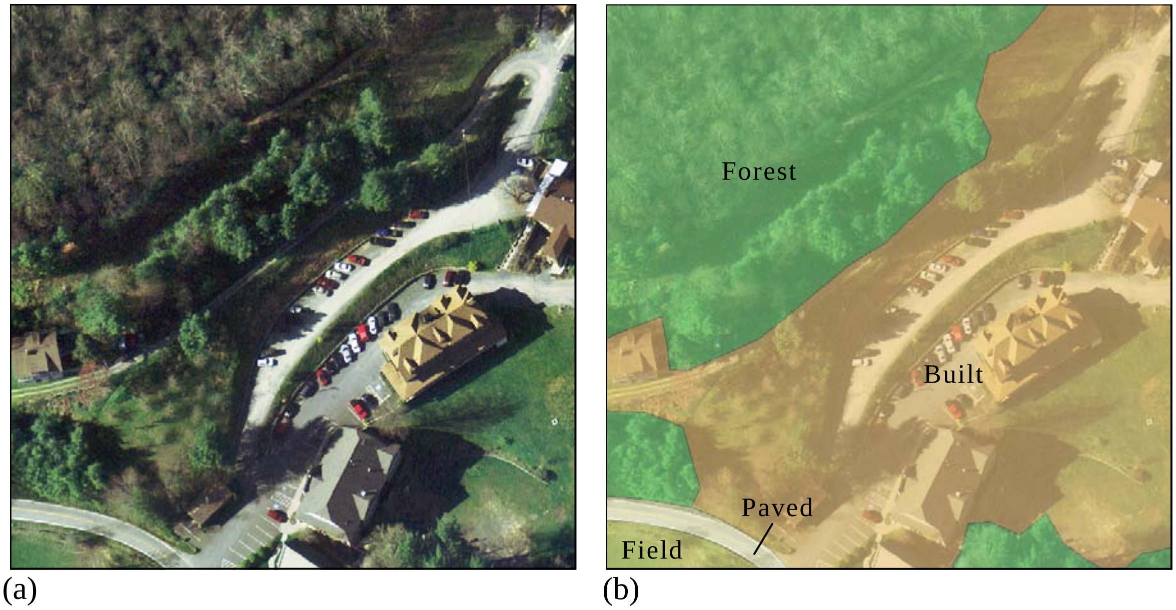
I conducted geographic information system analysis using ArcGIS® 9.3, coupled with the Patch Analyst 4 (Rempel 2008) extension to examine the spatial structure of each of the study sites (site-scale) and its surrounding landscape (landscape-scale). The landscape boundary consisted of a $2km^2$ area surrounding each of the four subdivisions and farms. Using six-inch spatial resolution digital orthophoto quarter-quadrangles (DOQQ) (NCFMP 2005) of both Watauga and Ashe counties, I categorized each patch as one of eight patch types; built, crop, field, forested, paved, riparian, shrub and water. Table 2.3 displays the qualifications and criteria for each patch type.

Table 2.3. Qualifications and criteria for each patch type.

Patch Type	Description
Forest	Areas characterized by continuous natural and/or semi-natural tree cover of deciduous, evergreen, and mixed forest land; tree canopy 25-100 percent of cover
Shrub	Areas characterized by natural to semi-natural woody vegetation of short aerial height
Field/woodlot	Areas of dominant grass or forb cover, low density herbaceous, and/or low density tree or shrub; areas may be subject to grazing and/or used for pasture or hay, but not intensively managed; this may also include areas cleared for utilities (i.e., power and telephone lines)
Crop/cultivated	Areas used for the production of crops, including herbaceous vegetation planted for specific purposes (e.g. food, feed, fiber, etc.), field margins of semi-natural habitats surrounding individual crop rows and/or crop field perimeters
Built	Highly managed areas with a large percentage of the land covered with structures of either commercial, industrial, and/or low to high density residential; area may also include linear driveways, lawns, and landscaped areas
Riparian	Distinctive natural to semi-natural habitats adjacent to linear water bodies that are structurally distinctive from the surround habitats
Water*	All areas of open water including linear water bodies such as streams, rivers, and canals and enclosed bodies of water such as ponds, lakes, or reservoirs
Paved	Areas of continuous impervious surfaces and/or gravel areas connected in linear patterns; primarily highways and roads, but does not include individual driveways

*Denotes areas excluded from the min. requirement of 500m^2 patch size

Using the ArcGIS® Editor tool at a scale of 1:1,500 (Figure 2.2), I manually digitized each habitat patch with a minimum size of 500m^2, creating individual vector layers and classes for each of the eight habitat patches within the 2km^2 area surrounding every site (Figure 2.3). Any class that did not meet the 500m^2 minimum patch allowance, I included with the adjacent patch type that most closely matched its habitat characteristics. To insure no overlaps or gaps existed between the layers, I snapped each vertex of the adjacent layers so that they coincided exactly. In addition, to avoid an exaggerated number of patches, I dissolved the boundary between any adjacent polygons within the same patch type (i.e., attribute class). I then combined each of the layers into one landscape shapefile by using the union function within ArcToolbox, allowing each patch, polygon, and contiguous shapes to be included in one theme for further analysis.



(a) (b)

Figure 2.2. Habitat detail (a) and digitized example (b) at the minimal zoom of 1:1,500.

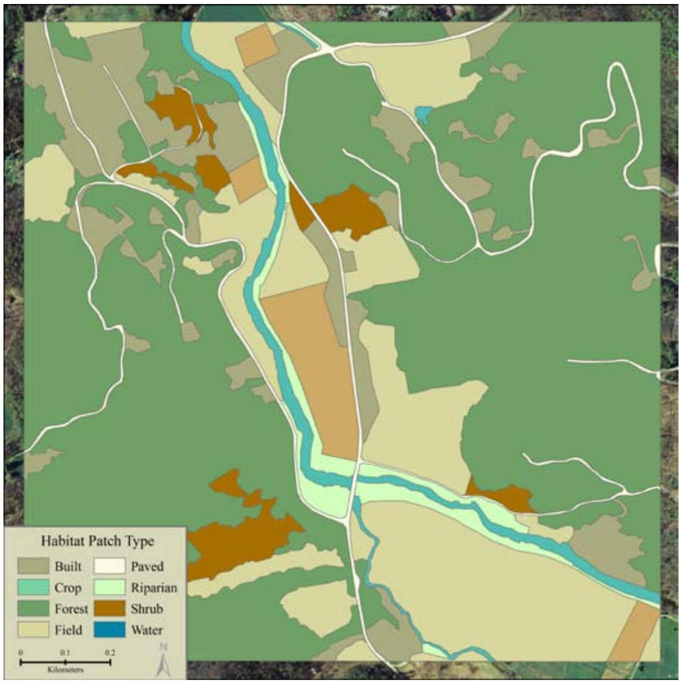


Figure 2.3. Fully digitized example of a 2km^2 landscape surrounding an agricultural site.

At the site spatial scale, I used the county parcel data for Watauga and Ashe counties to identify all land parcels within the selected farms and subdivisions. I dissolved the boundaries of the individual land parcels to create one shapefile of each site. Using the site scale shapefile, I then clipped the landscape shapefile to create a site scale theme of all patch types within each site.

To quantitatively characterize the spatial patterns at both the site and landscape scales, I used Patch Analyst 4 (Rempel 2008) extension within ArcGIS®. Patch Analyst extension calculates various spatial statistics and metrics that help describe the overall landscape structure of specific areas (Table 2.4). Using this extension, I calculated the area and perimeter of each habitat patch, as well as generated spatial metrics for area, patch density, size and shape at the landscape-scale (2km^2), site-scale and class (patch) level.

Table 2.4. Spatial analysis metric and statistic summary.

Spatial Metrics	Spatial Statistics
Area	Class Area (ha)
	Total Landscape Area (ha)
Patch Density and Size	Patch Number
	Mean Patch Size (ha)
	Median Patch Size (ha)
	Patch Size Standard Deviation (ha)
	Patch Size Coefficient of Variance (%)
Shape	Edge Density (m/ha)
	Area Weighted Mean Patch Fractal Dimension

Area, density and size metrics provide a general understanding of the layout of the landscape and the dominant habitat types. Class area indicates how much area each individual patch type comprises within each 2km^2 landscape and at each individual site. General spatial statistics, such as patch number, mean patch size and patch size standard deviation and coefficient of variation provide a framework with which to assess spatial patterns at all spatial scales. In order to compare site size of farms and subdivisions with patch number and size, I graphed size and number of habitat patches as a function of the land area and visually accessed any patterns for both farms and subdivisions at the site scale.

Statistics such as edge density and area weighted mean patch fractal dimension (AWMPFD) provide an understanding of the complexity and regularity/irregularity of the individual habitat patches by providing measures of the patch shape. Fractal dimensions quantifies the complexity of habitats by using principles of Euclidean geometry to provide a measurement of patch shape irregularity and habitat border convolution (Olff and Ritchie 2002; van Hees 1994). Based on Euclidean dimensions, shapes with fractal values of one, or close to one, represent habitats with smooth borders (Olff and Ritchie 2002; van Hees 1994). The greater the deviation from one, the more convoluted and irregular the shape becomes (van Hees 1994). Given the ambiguity of language used to describe fractal measures, others have sought to graphically depict the range of complexity (Bourke 2003; Olff and Ritchie 2002). Such graphics are helpful in understanding the degree of change from even a tenth of a point difference in fractal dimension (see Bourke 2003). To determine if any significant difference existed between patch shape and composition for farms and subdivisions, I tested the AWMPFD, edge density and all habitat patch proportions for farm and subdivision sites using the Mann-Whitney U test within SAS 9.1.3 within the 90 and 95 percent confidence intervals (SAS Institute 2004). I also tested the same metrics to see if any differences in habitat structure and composition occurred at the landscape spatial scale and site spatial scale for both farms and subdivisions.

Vegetation Analysis

At the patch scale, I conducted a field-based analysis to document the plant species composition of each site. Excluding paved and water patch types from vegetative analysis, I limited the data collection to six of the habitat patch types including forest, field, riparian, built, crop and shrub. At each site, I sampled a minimum of two study plots per patch, using a modified version of the Intensive plot design developed by Barnett and Stohlgren (2003). The plot design (Figure 2.4) consisted of four $1m^2$ subplots all contained within one $100m^2$ plot. The standard plot configuration was

10×10m; however, in some cases irregular shaped patches required a 5×20m modified design. Within each of the $1m^2$ subplots, I identified all vascular plant species and estimated cover to the nearest percent class (<1, 1-5, 5-10, 10-25, 25-50, 50-75, 75-95, >95 percent) for each species. In the $100m^2$ plots, I recorded species presence of all vascular plant species. I also collected referenced location data with a Garmin Global Positioning System (GPS) unit and recorded latitude, longitude and elevation.

Field Collection

I collected field data during July, August and early September 2008. At each farm and subdivision, I randomly placed a minimum of two plots in each patch. If the patch area was larger than 9.5 hectares, I placed an extra plot within that patch to give a more accurate account of the vegetative structure of the larger area. Within ArcGIS®, I used HawthsTools© extension (Beyer 2004) to randomly determine the placement of the plots within each patch without overlap. I then extracted the coordinates (latitude and longitude) of each of the plots and used a GPS unit to find the plot locations in the field. Each GPS location was used as the point-of-origin and west corner of the plot. The location of any point that fell within an area I could not sample, such as a rooftop, I adjusted until I reached a suitable sampling location.

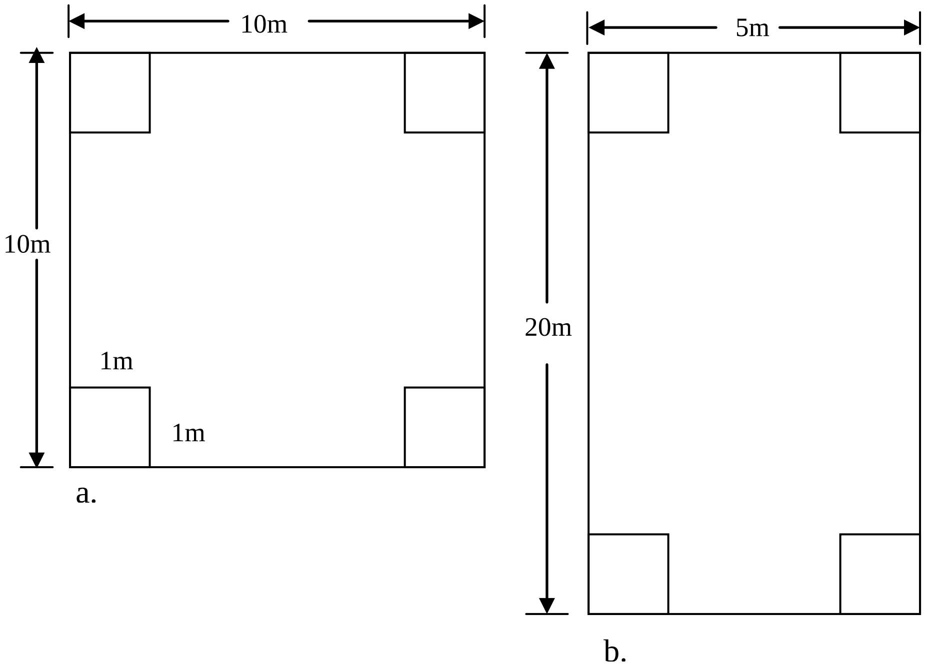


Figure 2.4. The layout of the plot design; (a) the standard design (b) modified design for irregular patch shapes.

Figure 2.5. Field data collection and plot layout design.

Plant Identification

I identified all plant species using Wofford's *Guide to the Vascular Plants of the Blue Ridge* (1989) and Weakley's *Flora of the Carolinas, Virginia, Georgia, and Surrounding Areas* (2007). I collected, pressed and cataloged any plants that I could not identify in the field and gave them a unique classification code for future identification. In the I.W. Carpenter, Jr. Herbarium with the help of several botany specialists, I identified the collected specimens to species. In some cases, it was not possible to identify the collections to species due to missing flowers, mowed or grazed specimens or lack of vegetative matter. However, I identified all specimens to the lowest possible level and recorded each with a unique number. Often, cultivated plant species proved to be very difficult to identify due to the high variability in species types and hybrids. Where possible, I did assign the genus along with the cultivar name according to horticultural encyclopedic guides (Brickell 2002; Taylor 2002). In accordance with the National Plants Database (USDA 2009), I also recorded growth form (tree, shrub, herbaceous and vine), origin (native or exotic) and lifespan (annual and perennial) data for each of the identified species. Based on species lists compiled by North Carolina Natural Heritage Program (2008), I identified all rare species encountered throughout the study. Further, I also identified all noxious weed species based on the Southeast Exotic Pest Plant Council (2004) online publication entitled, "Invasive Plants of the Thirteen Southern States." Based on federal noxious weed and state exotic pest council species lists, they complied a database for all invasive and noxious weeds for a thirteen state area. For this study, I sub-sampled this list and examined only the plant species categorized as noxious in North Carolina.

Statistical Analysis

I performed all statistical analysis in SAS 9.1.3 (SAS Institute 2004). To test for differences in cover and richness between farms and subdivisions, I used the Mann-Whitney U non-parametric test at the 95 percent confidence interval (p-value ≤ 0.05). I also set a marginal significance level at the 90 percent confidence interval (p-value ≤ 0.10). I chose Mann-Whitney U test for all analysis since no assumptions exist for normality and is acceptable for smaller sample sizes.

To calculate average cover for all $1m^2$ subplots, I assigned a mid-point in each cover class range for every species. I summed total cover (or cover of native and exotic species) of each subplot. I then averaged species cover for the four $1m^2$ subplots per plot, and calculated the mean cover by patch type at each site by averaging all plots per patch type. To see if any habitat type differed in vegetative cover, I compared the mean patch type cover between farms and subdivisions. Following the same method as above, I calculated relative cover of native and exotic species for each patch type between farms and subdivisions and compared the mean patch type values. To calculate the site level weighted total cover, relative native cover, and relative exotic cover for each site, I multiplied mean cover ($1m^2$) for each habitat patch type by the habitat percent area (calculated in the GIS analysis) at each site. The weighted calculation gives a higher weight to habitats that comprise a larger percentage of each site. I then summed these weighted values and compared them between each farm and subdivision.

At $1m^2$, $4m^2$ and $100m^2$ plot scales, I calculated total mean species richness, native richness and exotic richness for each patch type. I totaled all species per plot, used the NODUPKEY function in SAS to remove any duplicated species and calculated the mean plot level richness within each habitat patch at each site. I then compared total species richness, native species richness, and exotic species richness (at $1m^2$, $4m^2$ and $100m^2$) of patch types between farms and subdivisions. Similar to the cover calculation methods, I generated weighted species richness at $1m^2$, $4m^2$ and $100m^2$ plot scales for total, native and exotic species richness. I compared all richness values by testing for differences using Mann-Whitney U nonparametric alternative test.

Chapter 3

RESULTS

GIS Analysis

Landscape Spatial Structure

The overall landscape scale (~200 hectares) spatial structure surrounding both agricultural and developed sites displayed similarity in patch size, shape, richness (Table 3.1) and composition (Table 3.2). I found no significant difference in the amount of edge density or area weighted mean patch fractal dimension (AWMPFD) between farm or subdivision landscapes. Patch richness (i.e., forest, field, built, crop, shrub, riparian, water and paved) surrounding both farms and subdivisions varied among the individual landscapes (Table 3.1). For both farms and subdivisions, three dominant patch types (forest, field, and built) comprised greater than 80 percent of landscape area. Forested habitats dominated both landscape types (Table 3.2), accounting for ~62 percent of the total landscape surrounding both farms and subdivisions. Field comprised the second most prevalent patch type in both landscape types, followed by built. The only significant differences between landscapes surrounding farms and landscape surrounding subdivisions were in the proportion of built habitats (Table 3.2). Landscapes surrounding subdivisions had a higher percentage of built habitats than did landscapes surrounding farms. Built areas accounted for 12.49 percent of the landscape surrounding subdivisions but only 8.51 percent of the landscapes surrounding farms.

Table 3.1. Landscape scale (~200 hectares) spatial structure for areas surrounding the eight study sites.

Site	Land Area (ha)	Patch Richness	Number of Patches	Mean Patch Size (ha)	Edge Density (m/ha)	AWMP Fractal Dimension
Farm 1	200.59	8	151	1.33	493.47	1.37
Farm 2	202.94	7	69	2.94	322.49	1.37
Farm 3	202.45	7	96	2.11	415.02	1.41
Farm 4	201.80	8	95	2.12	449.37	1.39
Mean	201.95	7.50	102.75	2.13	420.09	1.39
Subdivision 1	202.93	8	109	1.86	447.86	1.38
Subdivision 2	201.24	8	84	2.40	341.79	1.38
Subdivision 3	202.45	6	110	1.84	446.04	1.40
Subdivision 4	205.48	7	92	2.23	402.23	1.38
Mean	203.02	7.25	98.75	2.08	409.48	1.38

Note: Measures were generated using Patch Analyst spatial statistical function, which runs analysis in conjunction with ArcGIS® FragStats. Appendix A, provides detailed results from the Patch Analyst analysis for each site. The number associated with each farm and subdivision indicates the corresponding paired sites (ex. Farm 1 paired with Subdivision 1).

Table 3.2. Percentage of habitat patch types in landscapes (~200 hectares) surrounding farms and subdivisions.

	Landscape Mean Percent (SE)		
Habitat Patch Type	Agricultural Landscape	Exurban Landscape	*P*
Forest	61.52 (0.08)	62.87 (0.05)	0.44
Field	20.70 (0.06)	14.34 (0.03)	0.24
Built	**8.51 (0.01)**	**12.49 (0.01)**	**0.07**
Crop	3.25 (0.01)	2.39 (0.02)	0.23
Shrub	2.00 (0.01)	3.20 (0.01)	0.33
Paved	1.79 (0.00)	1.86 (0.00)	0.50
Riparian	1.23 (0.01)	1.61 (0.01)	0.23
Water	1.00 (0.00)	1.24 (0.05)	0.44

Note: Values are averages for each habitat class by landscape type (n=4 farm landscapes, n=4 subdivision landscapes). Standard error values represented in parentheses (n=4 farms, n=4 subdivisions). *P*-values based on Mann-Whitney U test. Bold indicates significance at the 95 percent confidence interval ($p \leq 0.05$) or the 90 percent confidence interval ($p \leq 0.10$).

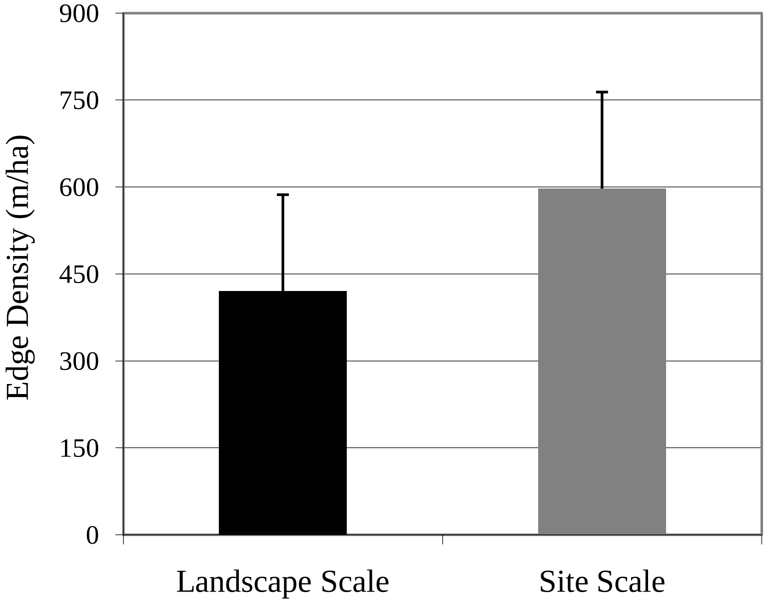
Site Scale Spatial Structure

Landscape and Site Scale Comparisons

Overall, habitat shape varied between subdivision sites and the surrounding landscapes. Subdivisions more than doubled the edge density (Figure 3.1) and had a significantly higher mean AWMPFD at the site scale compared to the landscape scale of analysis (Figure 3.2). In contrast, the patch shape on farms at the site-scale was similar to the overall landscape-scale measures in both edge density and AWMPFD.

Habitat patch proportions between landscape spatial scale and site spatial scale varied depending on the type of habitat under investigation (Figure 3.3). Farms significantly increased in the amount of crop habitats but decreased in the proportions of built and shrub habitat patches (Table 3.3). Overall, subdivisions demonstrated the greatest difference between landscape-scale and site-scale spatial structure than farms. Subdivisions significantly increased in the quantity of built habitats and paved areas. They also decreased in the amount of forest areas at the site-scale (Table 3.4). Results also indicated a marginally significant decrease in the proportion of crop areas on subdivision sites (Table 3.4).

(a) Farms



(b) Subdivisions

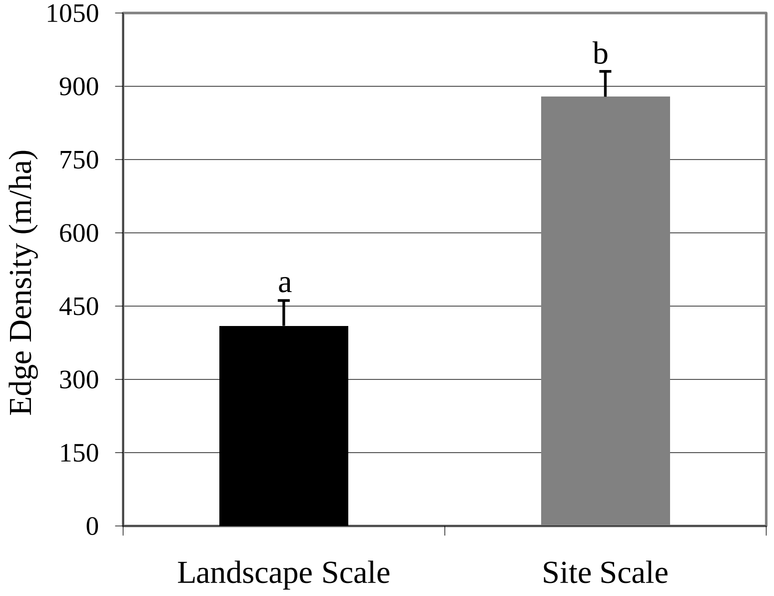
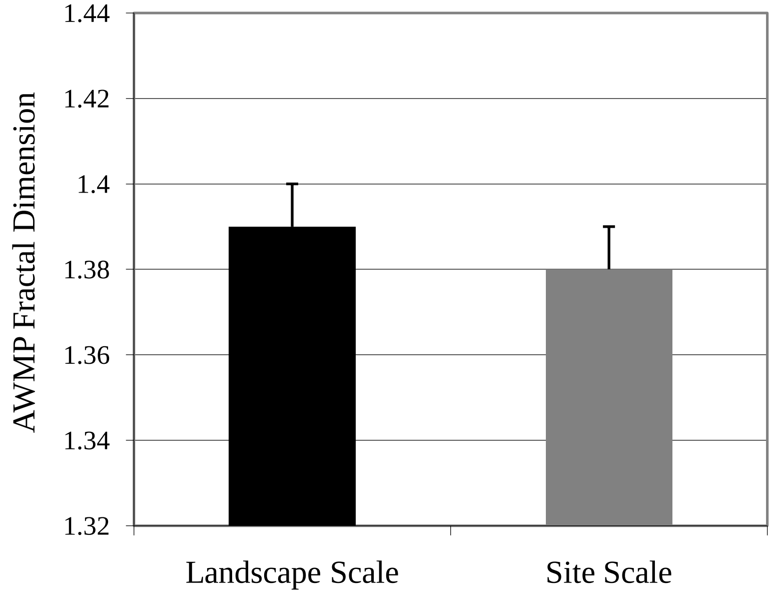


Figure 3.1. Landscape and site level edge density (ED) for each site type (n=4 farms, n=4 subdivisions). Different letters above error bars indicate a statistically significant difference (*p*-value = 0.02) at the 0.05 level according to Mann-Whitney U test.

(a) Farms



(b) Subdivisions

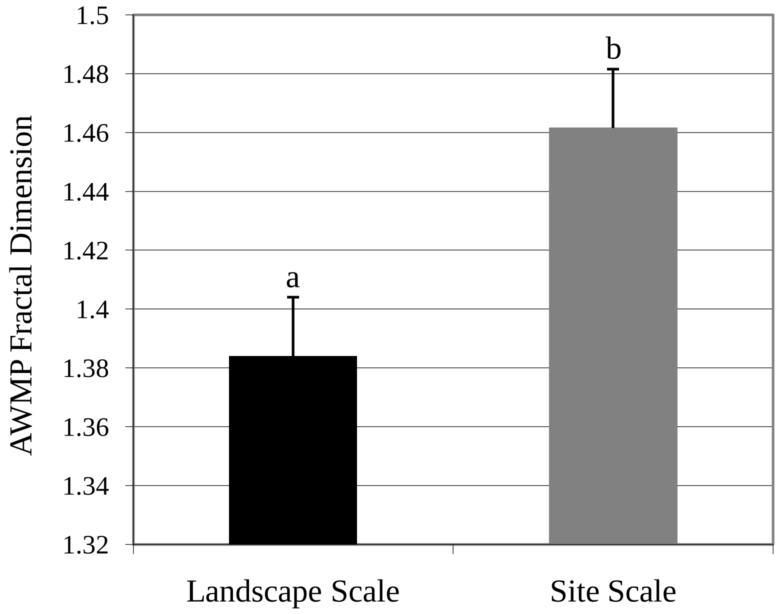
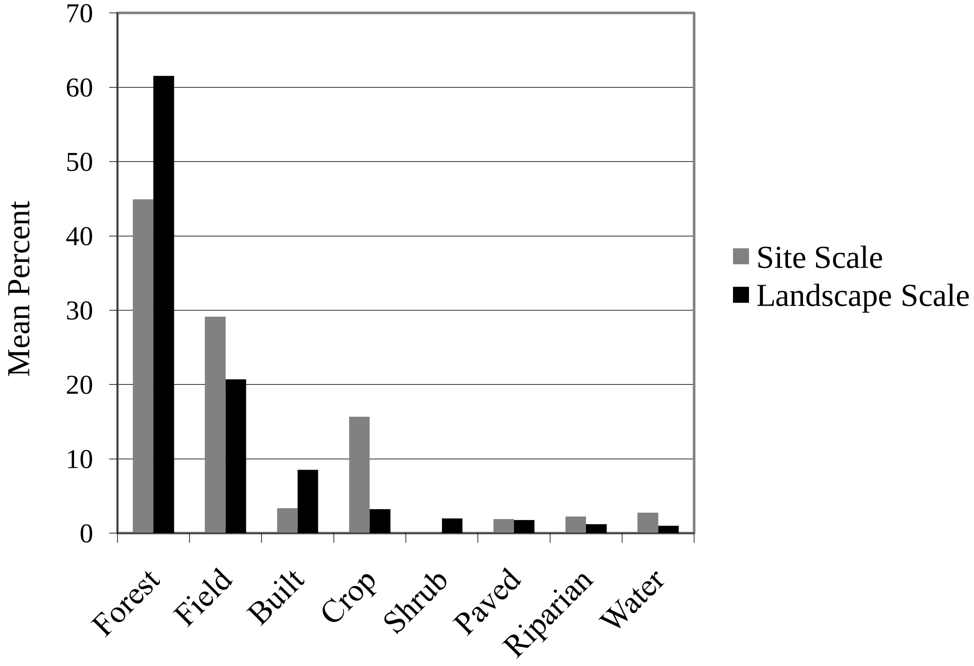


Figure 3.2. Landscape and site level area weighted mean patch fractal dimension (AWMPFD) for each site type (n=4 farms, n=4 subdivisions). Different letters above error bars indicate a statistically significant difference (*p*-value =0 .02) at the 0.05 level according to Mann-Whitney U test.

(a) Farms



(b) Subdivisions

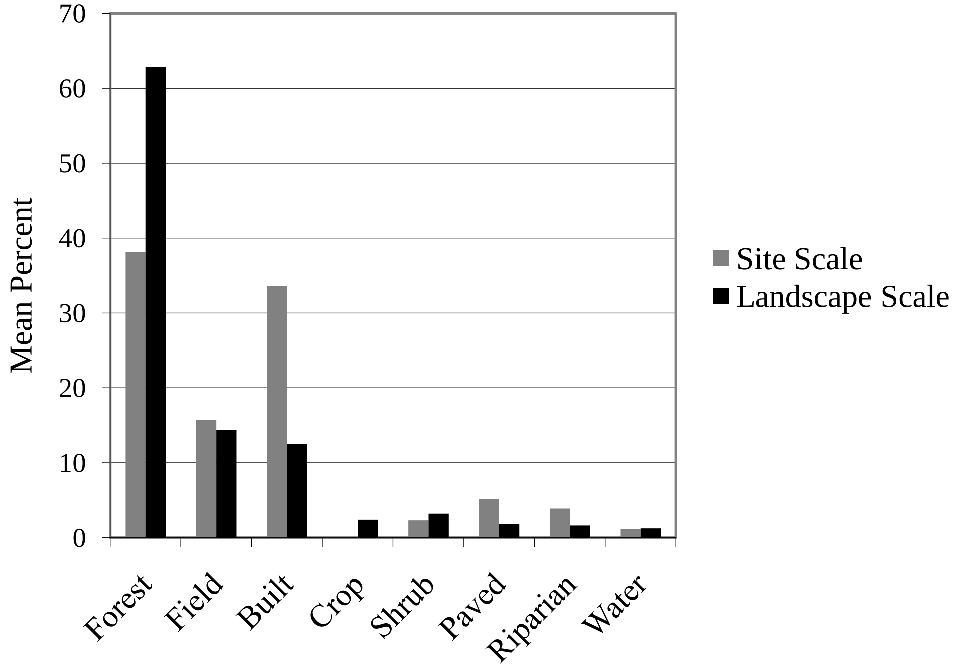


Figure 3.3. Site and landscape spatial scale comparisons of habitat patch structure, (a) farms n=4, and (b) subdivisions n=4.

Table 3.3. Comparisons of landscape and site scale habitat patch proportions for farms.

	Farm Mean Percent (SE)		
Habitat Patch Type	Landscape	Site	*P*
Forest	61.52 (0.08)	44.93 (0.18)	0.23
Field	20.70 (0.06)	29.12 (0.11)	0.23
Built	**8.51 (0.01)**	**3.37 (0.08)**	**0.03**
Crop	**3.25 (0.01)**	**15.69 (0.04)**	**0.02**
Shrub	**2.00 (0.01)**	**0.00**	**0.01**
Paved	1.79 (0.00)	1.90 (0.01)	0.44
Riparian	1.23 (0.01)	2.23 (0.01)	0.32
Water	1.00 (0.00)	2.75 (0.03)	0.33

Note: Values represent habitat percent averages across each land use type at the site scale of analysis. Standard error values represented in parentheses (n=4 farms, n=4 subdivisions). *P*-values based on Mann-Whitney U test. Bold indicates significance at the 95 percent confidence interval ($p \leq 0.05$) or the 90 percent confidence interval ($p \leq 0.10$).

Table 3.4. Comparisons of landscape and site scale habitat patch proportions for subdivisions.

	Subdivision Mean Percent (SE)		
Habitat Patch Type	Landscape	Site	*P*
Forest	**62.87 (0.05)**	**38.16 (0.12)**	**0.05**
Field	14.34 (0.03)	15.67 (0.06)	0.44
Built	**12.49 (0.01)**	**33.63 (0.01)**	**0.02**
Crop	**2.39 (0.02)**	**0.00**	**0.09**
Shrub	3.20 (0.01)	2.31 (0.01)	0.33
Paved	**1.86 (0.00)**	**5.17 (0.01)**	**0.02**
Riparian	1.61 (0.01)	3.90 (0.02)	0.44
Water	1.24 (0.05)	1.15 (0.01)	0.15

Note: Values represent habitat percent averages across each land use type at the site scale of analysis. Standard error values represented in parentheses (n=4 farms, n=4 subdivisions). *P*-values based on Mann-Whitney U test. Bold indicates significance at the 95 percent confidence interval ($p \leq 0.05$) or the 90 percent confidence interval ($p \leq 0.10$).

Farm and Subdivision Site Scale Comparisons

At the site scale (~6-23 hectares), farms and subdivisions displayed similar mean patch richness of 5.8 on farms and 5.3 on subdivisions (Table 3.5). Thus, every farm and subdivision did not contain all eight habitat patch types (Appendix B). Comparisons between farm and subdivision site-scale AWMPFD revealed that subdivisions had a marginally significantly greater shape complexity than farms, but no difference in edge density (Figure 3.4).

Table 3.5. Site scale spatial structure for the eight study sites.

Site	Land Area (ha)	Patch Richness	Number of Patches	Mean Patch Size (ha)	Edge Density (m/ha)	AWMP Fractal Dimension
Farm 1	5.47	6	10	0.55	1076.82	1.45
Farm 2	9.31	5	7	1.33	418.21	1.35
Farm 3	16.63	6	11	1.51	559.76	1.41
Farm 4	23.74	6	8	2.97	333.71	1.33
Mean	13.79	5.75	9	1.59	597.12	1.38
Subdivision 1	6.45	5	10	0.64	942.61	1.42
Subdivision 2	9.71	4	11	0.88	814.50	1.47
Subdivision 3	15.57	5	24	0.65	987.87	1.52
Subdivision 4	23.74	7	29	0.82	768.89	1.43
Mean	13.87	5.25	18.5	0.75	878.47	1.46

Note: Measures were generated using Patch Analyst spatial statistical function, which runs analysis in conjunction with ArcGIS® FragStats. The number associated with each farm and subdivision indicates the corresponding paired sites (ex. Farm 1 paired with Subdivision 1).

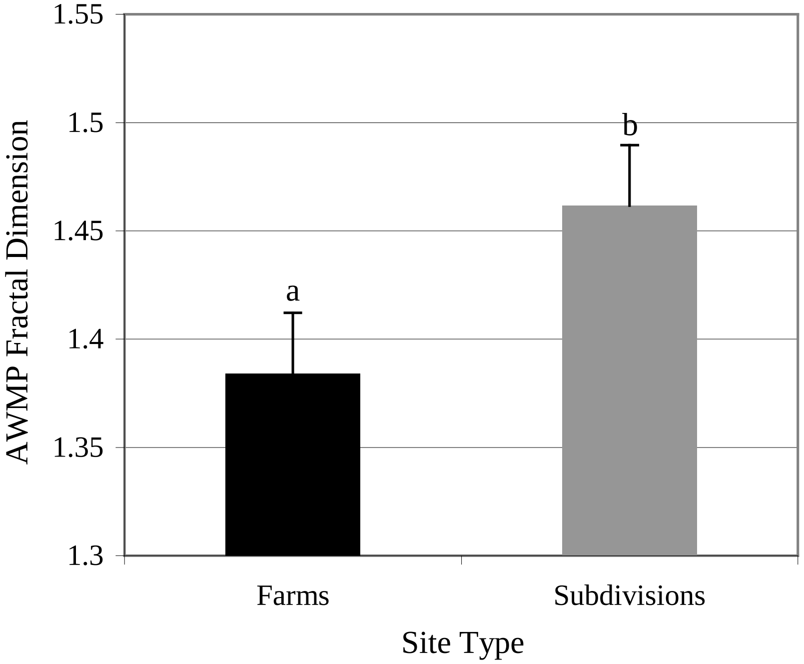


Figure 3.4. Site level area weighted mean patch fractal dimension (AWMPFD) for each site type (n=4 farms, n=4 subdivisions). Different letters above error bars indicate a statistically significant difference (*p*-value = 0.06) at the 0.10 level according to Mann-Whitney U test.

Habitat structure varied between farms and subdivisions (Table 3.6). Farm sites lacked shrub habitat, showed significantly low values for built and marginally significantly smaller proportion of paved areas than subdivision sites (Table 3.6). While subdivisions did display significantly higher amounts of shrub habitats, they were limited in number and percentage across all sites. Subdivisions lacked cropped areas, but displayed a notable percentage of field patches, although there were no differences between field habitats on subdivision and farm sites (Table 3.4).

Table 3.6. Percentage of habitat patch types at the site scale.

	Site Mean Percent (SE)		
Habitat Patch Type	Farms	Subdivisions	*P*
Forest	44.93 (0.18)	38.16 (0.12)	0.50
Field	29.12 (0.11)	15.67 (0.06)	0.16
Built	**3.37 (0.08)**	**33.63 (0.01)**	**0.02**
Crop	**15.69 (0.04)**	**0.00**	**0.01**
Shrub	**0.00**	**2.31 (0.01)**	**0.03**
Paved	**1.90 (0.01)**	**5.17 (0.01)**	**0.06**
Riparian	2.23 (0.01)	3.90 (0.02)	0.32
Water	2.75 (0.03)	1.15 (0.01)	0.31

Note: Values represent habitat percent averages across each land use type at the site scale of analysis. Standard error values represented in parentheses. (n=4 farms, n=4 subdivisions). *P*-values based on Mann-Whitney U test. Bold indicates significance at the 95 percent confidence interval ($p \leq 0.05$) or the 90 percent confidence interval ($p \leq 0.10$).

Patch number and patch size directly depended in the total land area of each farm and subdivision. Farm and subdivision sites displayed the greatest similarity in patch number (Figure 3.5) and patch size (Figure 3.6) when site size remained small. As site size increased, the similarity between the two site types diminished. On subdivisions, the number of patches increased as site size increased (Figure 3.5). However, farm sites did not display this relationship. Conversely, when comparing the mean patch size between the paired sites with the total site area, farms displayed larger patches as land area increased, while subdivisions did not exhibit the same relationship (Figure 3.6). For larger sites, patch size was five times greater for farms than for subdivisions.

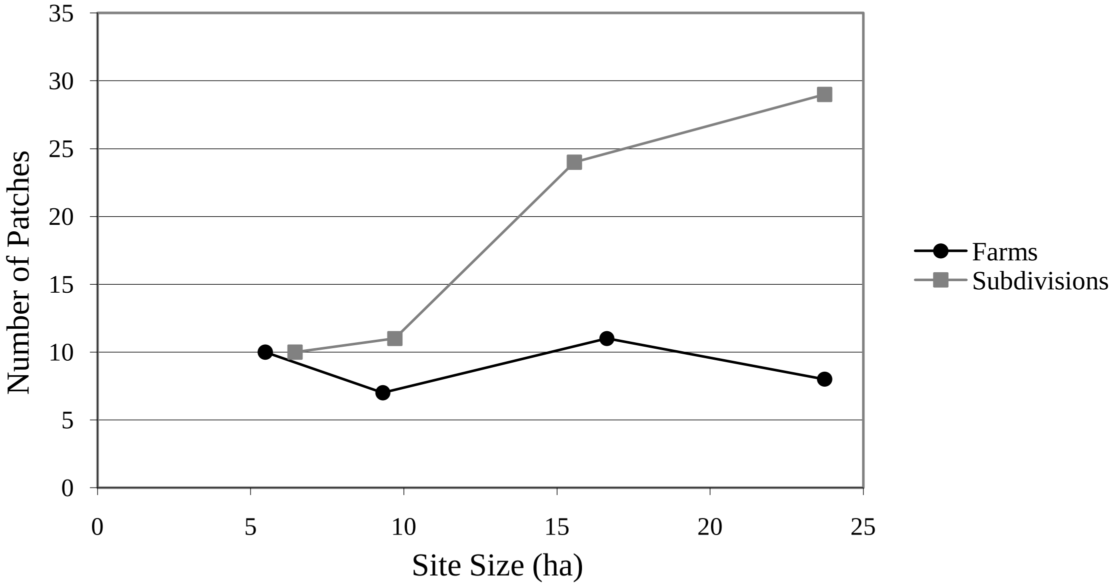


Figure 3.5. Site scale habitat patch number as a function of site size (n=4 farms, n=4 subdivisions).

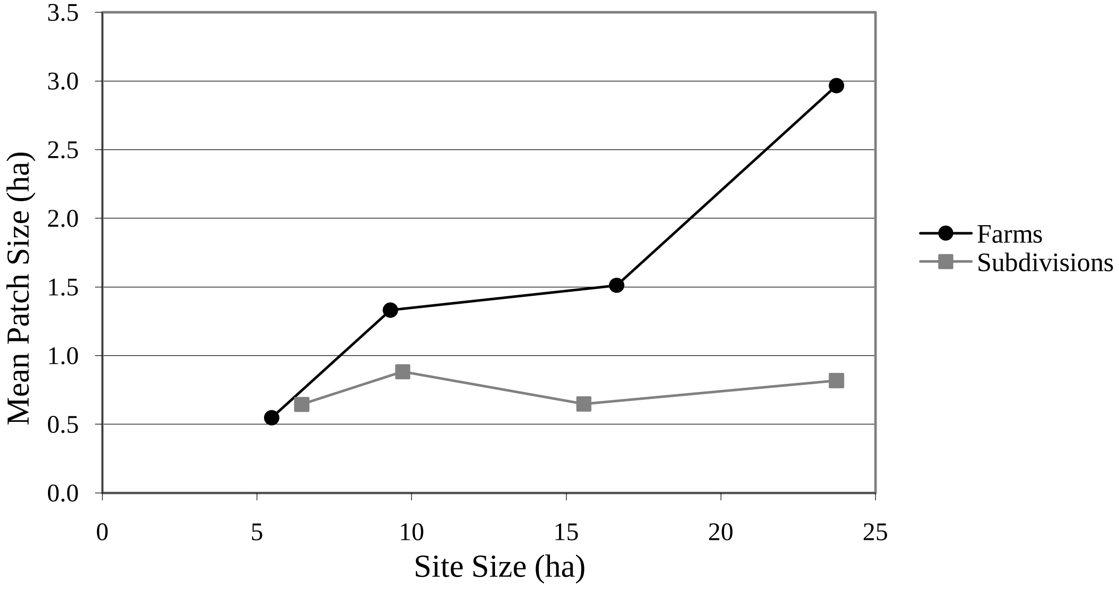


Figure 3.6. Site scale mean patch size as a function of site size (n=4 farms, n=4 subdivisions).

Vegetation Analysis

Flora

The complete data set from 138 100m^2 plots contained 681 species (Appendix C) across all eight sites. Overall, I sampled forty-six plots on farms and ninety-two on subdivisions. In total, the forty-six plots on farms contained 329 species while the ninety-two plots on subdivisions contained 538 species (Table 3.7). For both land use types, perennial herbaceous plants characterized the majority of species (Table 3.8).

Table 3.7. Number of sampled 100m^2 plots and total number of species encountered for each patch type at farms and subdivisions.

	Farms	Subdivisions
Number of Plots		
Forest	8	13
Field	14	14
Riparian	4	8
Built	6	45
Crop	14	0
Shrub	0	12
Total	46	92
Number of Species		
Forest	84	94
Field	107	46
Riparian	29	65
Built	38	291
Crop	118	0
Shrub	0	42
Total	329	538

Note: Data are total number of plots sampled in each patch type at each site type (all sites combined), and total number of species encountered in these plots.

Table 3.8. Percentage of species encountered in all sampled 100m^2 plots on farms and subdivisions by growth form and lifespan.

	Farms							Subdivisions						
	Total	G	H	S	T	V	U	Total	G	H	S	T	V	U
Annual	20.2	2.7	15.9	0	0	1.6	0	14.1	1.5	11.9	0	0	0.7	0
Perennial	62.5	10.9	33.0	6.4	8.0	4.2	0	65.6	9.3	32.9	9.9	10.2	3.4	0
Biennial	2.7	0	2.7	0	0	0	0	2.9	0	2.9	0	0	0	0
Unknown*	14.6	6.4	7.1	0.5	0	0.3	0.3	17.3	6.0	10	1.1	.4	0	0.4
Total	100	20.0	59	7.0	8.0	6.1	0.3	100	16.5	57.4	11.0	10.6	4.1	0.4

Note: G = grasses; H = herbaceous; S = shrub; T = tree; V = vine; U = unknowns
All values presented are percentages of the total number of species encountered on farms and subdivisions.
* indicates plants without reproductive parts and could not be identified to species

Of the total 681 species collected, twenty were known noxious weed species (SE-CPPT 2004) and nine were considered rare in North Carolina (NC NHP 2008). Table 3.9 presents the rare species and extinction risk ranking according to the North Carolina Natural Heritage Program (2008), including one endangered species, *Houstonia montana* (Table 3.10). Among noxious weed species, seven were found on both site types with *Rosa multiflora* being the most prevalent of any species (NC NHP 2008).

Table 3.9. Total rare species identified.

Species	Common Name	Current Status	Projected Status	F	S
Berberis canadensis	American Barberry	SR-T	SC-V	x	
Carya laciniosa	Big Shellbark Hickory	SR-P	T		x
Cardamine rotundifolia	Mountain Watercress	SR-P	T	x	x
Euphorbia commutata	Cliff Spurge	SR-P	T		x
Houstonia montana	Roan Mountain Bluet	E	E		x
Juniperus communis	Dwarf Juniper	SR-D	SC-V		x
Kalmia angustifolia	Sheep-laurel	SR-P	T		x
Rubus idaeus	Red Raspberry	SR-P	T	x	x
Trillium simile	Sweet White Trillium	SR-L	T		x

Source: N.C. Natural Heritage Program
Note: F (farm)s; S (subdivisions); E (endangered), T (threatened), SR-T (species rare throughout range), SC-V (special concern), SR-L (species limited to North Carolina and adjunct states), SR-D (species disjunct in North Carolina), SR-P (species only found in periphery locations of range).

Table 3.10. Federal and state listed noxious weed species for North Carolina encountered throughout the study.

Species	Common Name	F	S	Cultivated
Alliaria petiolata	Garlic Mustard		x	
Berberis thunbergii	Japanese Barberry		x	
Buddleja davidii	Butterflybush	x	x	x
Celastrus orbiculatus	Oriental Bittersweet	x	x	
Cirsium vulgare	Bull thistle		x	
Euonymus alatus	Winged Burning Bush		x	x
Euonymus fortunei	Winter Creeper		x	x
Hedera helix	English Ivy		x	x
Hemerocallis fulva	Orange Daylily		x	x
Lespedeza cuneata	Chinese Lespedeza		x	
Lonicera japonica	Japanese Honeysuckle	x	x	
Microstegium vimineum	Nepalese Browntop	x	x	
Polygonum cuspidatum	Japanese Knotweed		x	
Pyrus calleryana	Bradford Pear	x		x
Rosa multiflora	Multiflora Rose	x	x	
Rubus phoenicolasius	Wine Raspberry	x		
Sorghum halepense	Johnsongrass	x	x	x
Spiraea japonica	Japanese Spiraea	x	x	x
Vinca major	Bigleaf Periwinkle		x	x
Vinca minor	Common Periwinkle		x	

Source: Southeastern Exotic Pest Plant Council, “Invasive Plants of the Thirteen Southern States”
Note: Species only represent noxious weed species for North Carolina in accordance with federal noxious weed lists and state exotic pest council reports.

Vegetative Cover

Agricultural and exurban areas were similar in vegetative cover at the 1m^2 scale. I found no significant difference between farms and subdivisions in any measure of cover including the total cover of each of the six-patch types (Table 3.11), total weighted cover, and relative native and exotic cover (Table 3.12). I also found no significant differences in native and exotic relative cover within the six habitat patch types between site types

(Table 3.13). Due to the lack of shrub habitat on farms and the lack of crop habitat on subdivisions, I could not test for differences of in native and exotic relative cover between the site types.

Table 3.11. Comparisons of mean percent cover ($1m^2$ subplots) for each habitat patch type between farms and subdivisions.

	Farms		Subdivisions		P
Habitat Type	Mean (SE)	n	Mean (SE)	n	(Mann-Whitney U)
Cover ($1m^2$)					
Forest	88.9 (8.5)	3	100.6 (6.0)	4	0.30
Field	212.9 (24.7)	4	232.7 (47.2)	3	0.50
Riparian	145.3 (21.7)	2	145.5 (21.9)	2	0.35
Built	166.7 (32.2)	3	129.8 (12.5)	4	0.30
Crop	169.1 (9.9)	4	n/a	0	n/a
Shrub	n/a	0	205.3 (23.9)	3	n/a

Note: *P*-values based on Mann-Whitney U test. Standard error values represented in parentheses.

Table 3.12. Weighted total cover and relative native and exotic cover at $1m^2$ for each site.

	Farms	Subdivisions	P
	Mean (SE)	Mean (SE)	(Mann-Whitney U)
Weighted Cover (%)			
Total	132.4 (13.1)	132.4 (16.3)	0.50
Relative Cover (proportion of total cover)			
Native	.57 (6.8)	.50 (9.7)	0.33
Exotic	.30 (3.9)	.30 (5.0)	0.44

Note: *P*-values based on Mann-Whitney U test (n=4 farms, n=4 subdivisions). Standard error values represented in parentheses. Relative cover does not equal one due to unknown species that could not be identified as either native nor exotic.

Table 3.13. Mean relative cover of native and exotic species (proportion of total cover) in study plots at farms and subdivisions, by habitat type.

	Native					Exotic				
	Farms		Subdivisions			Farms		Subdivisions		
Habitat Type	Mean (SE)	n	Mean (SE)	n	*P*	Mean (SE)	n	Mean (SE)	n	*P*
Cover ($1m^2$)										
Forest	0.80 (6.0)	3	0.70 (12.1)	4	0.43	0.11 (4.4)	3	0.20 (10.7)	4	0.43
Field	0.48 (0.6)	4	0.49 (9.4)	3	0.30	0.48 (1.8)	4	0.47 (9.7)	3	0.30
Riparian	0.53 (12.4)	2	0.52 (12.8)	2	0.35	0.37 (13.9)	2	0.41 (11.1)	2	0.35
Built	0.26 (4.3)	3	0.30 (3.0)	4	0.30	0.58 (5.4)	3	0.46 (4.4)	4	0.11
Crop	0.40 (5.9)	4	n/a	0	n/a	0.54 (4.8)	4	n/a	0	n/a
Shrub	n/a	0	0.62 (1.5)	3	n/a	n/a	0	0.28 (4.4)	3	n/a

Note: *P*-values based on Mann-Whitney U test. Standard error values represented in parentheses. Relative cover does not equal one due to unknown species that could not be identified as either native nor exotic.

Species Richness

Species richness within the six habitat patch types varied depending on the type of habitat and the scale of analysis. At $1m^2$ and $4m^2$ subplot levels, I found no significant differences in species richness of any patch type between farms and subdivisions within any of the six patch types (Table 3.14). However, at the whole plot level ($100m^2$), farms displayed a higher richness than subdivisions within forested and field habitats (Table 3.14).

Table 3.14. Total species richness at three plot scales at farms and subdivisions for each patch type.

	Farms		Subdivisions		
Habitat Type	Mean (SE)	n	Mean (SE)	n	*P*
Richness ($1m^2$)					
Forest	8.0 (0.9)	3	8.6 (1.4)	4	0.50
Field	10.4 (1.0)	4	10.7 (0.6)	3	0.50
Riparian	8.2 (2.2)	2	9.8 (1.2)	2	0.35
Built	8.5 (1.9)	3	6.3 (0.8)	4	0.24
Crop	8.7 (0.3)	4	n/a	0	n/a
Shrub	n/a	0	9.5 (1.2)	3	n/a
Richness ($4m^2$)					
Forest	20.8 (1.2)	3	21.1 (1.8)	4	0.50
Field	24.3 (1.4)	4	22.5 (0.9)	3	0.19
Riparian	22.3 (3.8)	2	26.1 (4.1)	2	0.35
Built	19.5 (4.0)	3	15.6 (1.8)	4	0.30
Crop	22.1 (0.9)	4	n/a	0	n/a
Shrub	n/a	0	23.5 (3.0)	3	n/a
Richness ($100m^2$)					
Forest	**41.8 (2.4)**	3	**34.4 (1.7)**	4	**0.03**
Field	**40.7 (2.2)**	4	**30.4 (0.7)**	3	**0.03**
Riparian	49.3 (4.8)	2	47.9 (3.9)	2	0.35
Built	36.3 (7.7)	3	27.9 (3.0)	4	0.12
Crop	34.1 (2.7)	4	n/a	0	n/a
Shrub	n/a	0	37.0 (4.2)	3	n/a

Note: *P*-values based on Mann-Whitney U test. Bold indicates significance at the 95 percent confidence interval ($p \leq 0.05$) or the 90 percent confidence interval ($p \leq 0.10$). Standard error values represented in parentheses.

Site level weighted total species richness did not differ between farms and subdivisions at the $1m^2$ and $4m^2$ sample scales (Table 3.15). The most notable difference existed between total richness at the plot scale of analysis. Agricultural sites had higher total richness than the developed sites (Table 3.15). Native and exotic species richness also varied depending on the scale of analysis and the habitat type. At $1m^2$ and $4m^2$, I found no significant difference in native or exotic richness within any of the six patch types (Table 3.16). At the plot scale ($100m^2$), weighted site level native and exotic richness values were more different. Farms had marginally higher native species at this scale (Table 3.15).

Table 3.15. Weighted site level richness for total, native and exotic species at three plot scales for farms and subdivisions.

	Farms	Subdivisions	
	Mean	Mean	*P*
Richness ($1m^2$)			
Total	8.3 (0.9)	7.3 (0.6)	0.24
Native	5.0 (0.7)	4.3 (0.9)	0.33
Exotic	2.7 (0.5)	2.5 (0.5)	0.44
Richness ($4m^2$)			
Total	20.7 (1.4)	17.8 (0.9)	0.16
Native	12.8 (1.1)	10.5 (1.6)	0.24
Exotic	6.1 (1.1)	5.7 (0.9)	0.44
Richness ($100m^2$)			
Total	**39.2 (2.0)**	**29.8 (2.1)**	**0.02**
Native	**26.0 (3.1)**	**18.1 (2.2)**	**0.06**
Exotic	10.1 (1.7)	8.9 (1.1)	0.33

Note: *P*-values based on Mann-Whitney U test. Bold indicated significance at the 95 percent confidence interval ($p \leq 0.05$) or the 90 percent confidence interval ($p \leq 0.10$). Standard error values represented in parentheses (n=4 farms, and n=4 subdivisions).

When broken down into individual habitat types, forested areas on farms also displayed significantly greater native species than subdivisions, while subdivisions displayed a significantly higher amount of exotic species within these same forested habitats (Table 3.16; Figure 3.7). Field habitats on farms had marginally higher exotic richness than fields on subdivisions (Table 3.16).

Table 3.16. Native and exotic richness at three plot scales at farms and subdivisions for each patch type.

	Native					Exotic				
	Farms		Subdivisions			Farms		Subdivisions		
Habitat Type	Mean (SE)	n	Mean (SE)	n	*P*	Mean (SE)	n	Mean (SE)	n	*P*
Richness ($1m^2$)										
Forested	6.2 (1.1)	3	6.0 (0.9)	4	0.43	0.8 (0.1)	3	1.8 (1.0)	4	0.24
Field	5.4 (0.5)	4	5.5 (1.0)	3	0.50	4.8 (0.8)	4	4.8 (1.0)	3	0.30
Riparian	4.8 (1.1)	2	5.8 (1.5)	2	0.35	2.6 (1.0)	2	3.1 (0.3)	2	0.50
Built	2.9 (1.1)	3	2.4 (0.4)	4	0.43	4.8 (0.7)	3	3.3 (0.5)	4	0.11
Crop	4.2 (0.4)	4	n/a	0	n/a	4.0 (0.1)	4	n/a	0	n/a
Shrub	n/a	0	6.0 (0.5)	3	n/a	n/a	0	2.8 (0.6)	3	n/a
Richness ($4m^2$)										
Forested	16.4 (0.3)	3	14.3 (1.7)	4	0.19	2.1 (0.3)	3	4.6 (1.7)	4	0.11
Field	12.2 (0.4)	4	11.8 (2.2)	3	0.30	10.3 (1.1)	4	9.4 (1.4)	3	0.43
Riparian	13.5 (2.5)	2	15.3 (4.3)	2	0.50	6.5 (2.0)	2	8.1 (0.1)	2	0.50
Built	7.0 (2.0)	3	6.5 (0.8)	4	0.50	10.7 (1.9)	3	7.4 (1.2)	4	0.19
Crop	10.3 (0.6)	4	n/a	0	n/a	10.1 (0.3)	4	n/a	0	n/a
Shrub	n/a	0	14.3 (0.7)	3	n/a	n/a	0	7.6 (2.2)	3	n/a
Richness ($100m^2$)										
Forested	**34.5 (1.3)**	3	**24.2 (2.9)**	4	**0.03**	**3.5 (0.9)**	3	**7.0 (1.5)**	4	**0.05**
Field	21.8 (1.8)	4	17.3 (1.7)	3	0.11	**15.8 (1.3)**	4	**11.5 (1.7)**	3	**0.06**
Riparian	31.8 (1.8)	2	27.9 (3.6)	2	0.35	13.8 (2.3)	2	16.3 (0.5)	2	0.35
Built	14.6 (3.7)	3	12.6 (1.6)	4	0.43	17.8 (3.6)	3	12.2 (1.5)	4	0.11
Crop	15.8 (1.0)	4	n/a	0	n/a	15.6 (1.1)	4	n/a	0	n/a
Shrub	n/a	0	22.6 (1.7)	3	n/a	n/a	0	12.0 (3.4)	3	n/a

Note: *P*-values based on Mann-Whitney U test at the 95 percent confidence interval ($p \leq 0.05$) and the 90 percent confidence interval ($p \leq 0.10$). Standard error values represented in parentheses.

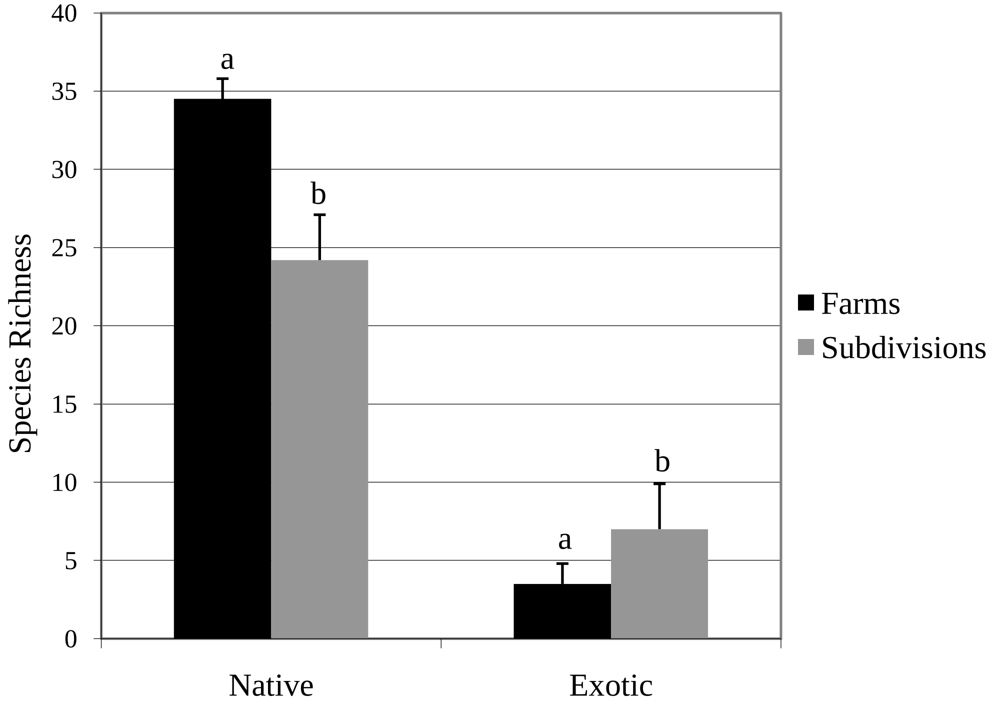


Figure 3.7. Native and exotic species richness at the plot level ($100m^2$) within forested habitats (n=3 farms, and n=4 subdivisions). Standard error represented by error bars. Different letters above error bars indicate a statistically significant difference (native *p*-value = 0.03 and exotic *p*-value = 0.05) at the 0.05 level according to Mann-Whitney U test.

Chapter 4

DISCUSSION

GIS Analysis

Landscape and Site Scale Spatial Structure

Landscape Structure

The landscape composition surrounding both farms and low-density residential subdivisions demonstrates the rural nature of the of the study locale and resembles the habitat composition and structure of the larger region. Within both landscape types, the dominant habitats included forest, field and built with the largest percentage of habitat occupied by forested patches (~62 percent). These findings coincide with other documented land use/cover patterns for the region. According to the N.C. Natural Heritage Program (2000, 1999), forested habitats make up around 67 percent of the land use for Watauga and Ashe Counties, and 80 percent of the larger Blue Ridge Mountain ecosystem. The low percentage of cropped habitat (~3 percent) in both landscapes is also consistent with recent reports for the region. NC NHP (2000, 1999) estimated that agricultural practices (i.e., pastures and agricultural fields) comprise 28 percent of land area, but cropped land area only accounted for 3 percent.

Landscape and Site Scale Comparisons

Comparisons of site scale spatial data to the landscape scale spatial measures help provide a framework for understanding how farms and subdivisions change and/or maintain habitat composition and structure of the larger landscape or region (Lindenmayer and Fischer 2006). When comparing the site scale spatial structure of farms and subdivisions to the surrounding landscape spatial structure, two patterns arose.

The first pattern was the similarity of site-scale patch composition of both farms and subdivisions to patch composition at the landscape scale. Similar to the landscape-scale, at the site scale for both farms and subdivisions, forest and field habitats accounted for over 50 percent of the habitat patch matrix. High forest cover on agricultural lands may seem surprising given reports directly attributing forest cover loss to agricultural activities (Foley et al. 2005). However, according to McNeely and Scherr (2003), many farming practices maintain tree cover in and around the farm for forest resources such as timber, fruits, nuts and shade. Gibson et al. (2007) found similar results for organic farms in the southwest region of England where they noted a high number of woodland areas that seemed to be attributed to the direct planting efforts of the farm operators/owners. The amount of open field areas on farms was also likely due to active management of farm owners for resources such as pasture and hayfields.

The second pattern that emerged was the variation in measures of habitat shape between site scale spatial structure and landscape scale spatial structure. Habitat shape on farms maintained a closer relationship to the larger landscape than did habitat shape on subdivisions (Table 3.1; Table 3.3). Subdivisions displayed higher AWMPFD values and more than doubled the measure of edge density when compared to the corresponding landscape values. These results suggest that habitat patch structure may become more complex with increased exurban development. Such increases in shape complexity may have broader implications for the patterns of species assemblages of a variety of taxa (Harvey 2007; McNeely and Scherr 2003) including increased susceptibility to invading species (Cumming 2002).

Farm and Subdivision Site Scale Comparisons

The most obvious differences between farm site-scale patch composition and subdivision site-scale patch composition were in the lack of crop habitats on subdivisions and the lack of shrub habitats on farms. According to Bock and Bock (2009), the first observable change to habitat structure upon conversion of agricultural land to exurban development is the replacement of agricultural habitats by buildings, landscaping, and roads. My findings directly display this relationship revealing no crop habitats on subdivisions but higher percentages of built and paved areas. There are several possible reasons for the occurrence of shrub habitats on subdivisions and the lack on farms. On farms, it may be due to active management by farm owners to maximize all cultivatable land. In contrast, on subdivisions former field and crop areas may be purposely left un-tended and allowed to mature. Through succession, these areas would develop into shrub habitats and ultimately forest over time. Additionally, shrub habitats on subdivisions may represent areas of forest that were cleared during development but are no longer actively cleared or managed by homeowners.

While subdivisions maintained a high percentage of forested areas at the site-scale (~45 percent). According to Bock and Bock (2009), since most exurbanites locate in rural areas for the natural amenities, it is common to find that most exurban land parcels consist of upwards of 94 percent of some type of natural vegetation. Valued for the recreational activities and intrinsic value of natural settings, exurban homeowners often prefer living in areas with some intact forest (Brown et al. 2008). The amount of field habitat on subdivisions seems surprising based on a survey of exurban homeowners conducted by Brown et al. (2008). He reported that most homeowners in Southeastern Michigan preferred land parcels that consisted of higher percentage of forested habitats rather than field or open-space. However, several homeowners within my four subdivision sites noted that the entire community maintained field areas for valued activities such as nature watching (i.e., deer, birds and other wildlife), horseback riding and other recreational activities. These differing viewpoints influence the variability in land management from place to place, and demonstrate how landscape structure in human dominated areas can be directly dependent on the values of the individual homeowners and/or community.

Overall, subdivisions displayed a higher amount of habitat fragmentation than farms. This was especially true within larger subdivisions. The degree of fragmentation on each subdivision was directly dependent on land area. The size of the habitat patches remained small (~1.5 acres), regardless of subdivision area, but the number of patches increased as land area increased. This reveals that spatial structure of subdivisions consists of greater numbers of small habitats. For farms, I did not find this same relationship. Farms maintained a consistent number of patches, regardless of farm size, and as land area increased, the size of the habitat patches also increased. These findings provide clues as to how patch structure may change as land use changes from farms to subdivisions. Based on these results, we can expect habitat change from large continuous patches to small and fragmented patches with land conversion. However, when subdivisions remained small (~5-10 hectares), patch number and size more closely corresponded with patterns on similar sized farms.

Increased fragmentation of forests, open-space and agricultural lands by land-use change to exurban development is a common trend around the United States and in countries such as Japan (Sorenson 1999) and The Netherlands (van der Valk 2002). For example, Robinson, Newell, and Marzluffa (2005) described single-family exurban developments in Kings County, Washington, as highly fragmented with dispersed remnant patches of vegetation. Some attribute the increased fragmentation in subdivisions to the extensive road networks throughout developments, especially within larger sized subdivisions (Bock and Bock 2009; Harden 2004; Odell, Theobald, and Knight 2003). As one of the major contributors to biodiversity loss (Lindenmayer and Fischer 2006; Olff and Ritchie 2002; Pimm and Raven 2000; Vitousek et al. 1997), habitat fragmentation proves highly important to conservation (Fischer and Lindenmayer 2007; Fazey, Fischer, and Lindenmayer 2005; Haila 2002). According to Fischer and Lindenmayer (2007), effects of fragmentation to biodiversity range from the reduction of native species richness to declines in avian populations, amphibians and invertebrates. Fragmentation can also lead to other indirect impacts such as disruption of animal movements (Dale et al. 2005), alteration of breeding patterns, and species interactions involving competition, predation, parasitism and mutualism of plants, animals, and invertebrates (Fischer and Lindenmayer 2007).

Subdivisions also showed a significantly higher degree of shape complexity than farms in AWMPFD. This indicates that patches on subdivisions had more complex perimeters than similarly sized patches on farms and the surrounding landscape. In an analysis of land cover transformations in Washington State's Puget Sound region, Robinson, Newell, and Marzluffa (2005) recorded similar vegetative patch shape patterns for exurban single-family developments. They recorded increased amounts of edge density combined with decreased size of forested wildlands, which they linked directly to the expansion of exurban developments around the area. The edge density and patch shape can affect vegetation by altering reproduction, seed dispersal and growth (Hobbs and Yates 2003). There can be both positive and negative effects to species composition with increased amounts of edge. Some noted increased species diversity and richness along edges (Yandik 2009; Bock, Jones, and Bock 2006a), but most also report that many species were non-native (Honnay, Verheyen, and Hermy 2002) and weedy (Beer and Fox 1997). Further, Lindenmayer and Fischer (2006), noted that linear shaped patches, such as those around power lines or road networks, may be more prone to abiotic and biotic edge effects due to small core area.

Vegetation Analysis

Species Composition

On average, farms displayed a higher number of species per plot ($100m^2$) than subdivisions. Further, results demonstrated that for both agricultural and developed areas in the western region of North Carolina, there exists great potential for the establishment of perennial species. The majority of the species for both farms and subdivisions consisted of herbaceous perennial plants accounting for over 60 percent of the species identified. Other studies on urban domestic gardens, found similar percentages of perennial species in Sheffield, UK (Smith et al. 2006). According to this study, over 60 percent of species identified were perennial/biennials, and similar to my findings on subdivisions, they found that 16 percent of species were trees and 8 percent were shrubs (Smith et al. 2006).

Of the total species collected, nine were rare species for North Carolina, including one endangered species, *Houstonia montana*. This species was found twice on one subdivision, once in a forest habitat and once in a field habitat. The most common rare species was *Cardamine rotundifolia* (mountain watercress) and *Rubus idaeus* (red raspberry). As a semi-aquatic species (NC NHP 2008), the location of *Cardamine rotundifolia* generally corresponded with areas along seeps, streams or river channels on both farms and subdivisions. *Rubus idaeus* generally corresponded with built areas on subdivisions and field and crop patches on farms, with the majority of occurrence related to purposeful plantings by home and farm owners. The few individuals that were located in forested locations likely escaped cultivation.

Across all sites, I identified twenty invasive species classified as noxious weeds according to state or federal criteria (SE-CPPT 2004). Of the twenty, almost half were cultivated or planted by the farm and homeowner or subdivision developer including species such as *Buddleja davidii* (butterflybush), *Euonumus alatus* (winged burning bush), *Euonymus fortunei* (winter creeper), *Hedra helix* (english ivy), *Hemerocallis fulva* (orange daylily), *Pyrus calleryana* (bradford pear), *Sorghum halepense* (Japanese spriaea), and *Vinca major* (bigleaf periwinkle). Other species such as *Rosa multiflora*

(multiflora rose), *Polygonum cuspidatum* (Japanese knotweed), and *Cirsium vulgare* (bull thistle) are highly aggressive weedy species that tend to correspond to areas of high soil disruption.

Vegetative Cover

Farms and subdivisions showed striking similarity for total weighted cover and for cover in specific habitat patch types. I found the same similarity in relative native and exotic species cover. These results demonstrate the potential for both organic agriculture and exurban development to maintain a thick vertical vegetative structure leaving few areas of bare ground. However, differences in compositional structure still warrants further examination to fully understand the full degree of similarity between farms and subdivisions. Maestas, Knight, and Gilgert (2003) found contrasting results reporting higher nonnative cover in exurban areas than on ranches, which they attributed to human plantings and introduction of alien species as well as disturbance from houses, roads and trails.

Species Richness

Overall, farms demonstrated higher (100m^2 scale) total weighted species richness than subdivisions, suggesting that as land-use changes from agriculture to exurban development there is great potential for a decrease in overall species richness. These findings correspond with documented trends of decreased species richness along the rural-urban gradient (McKinney 2002). Maestas, Knight, and Gilgert (2003) reported such trends noting higher plant species richness on ranches in Larimer County, Colorado than in exurban developments. Conversely, Bock et al. (2007) found higher plant species richness on cattle ranches when compared to exurban developments in southwestern Arizona. Other agricultural land uses have also been found to support high species richness, especially small organic operations like those examined in this study (Boutin, Baril, and Martin 2008; Gibson et al. 2007; Mayfield, Ackerly, and Daily 2006). Further, these results also contrast findings regarding increased species richness due to urban domestic gardens (Smith et al. 2006; Thompson et al. 2007). Within this study landscaping and purposeful plantings did not seem to play that large of a role in the overall weighted species numbers. However, since this study was not a total inventory, there were areas left unsampled.

Farms also displayed significantly higher numbers of native species than subdivisions. Others have found similar results in studies that compared exurban development to ranchlands and/or undeveloped areas. Maestas, Knight, and Gilgert (2003) reported higher numbers of native species on ranchlands than on exurban developments, which they attributed to human activities that either accidentally or deliberately increased the numbers of introduced non-native competitive species. In a study comparing exurban development to natural (i.e., undeveloped) areas, Lenth, Knight, and Gilgert (2006) also documented decreased numbers of native plant species within exurban developments. While both of these studies documented decreases in native species with development, they also reported a significant increase in exotic species richness (Lenth, Knight, and Gilgert 2006; Maestas, Knight, and Gilgert 2003). In other studies on domestic gardens, Thompson et al. (2003) reported similar results noting that most plant species identified were typically alien to the area. This trend of increased exotic species with development is perhaps the most commonly documented trend in studies in exurban developments (Huntsinger 2009; Hansen et al. 2005; Maestas, Knight, and Gilgert 2003). In this study, exotic richness was generally low in all patch types and at all sites. Further, I did not find any significant difference in the total number of exotic species between farms and subdivisions.

Analysis of species richness yielded contrasting results for the different habitat patches. At the plot level ($100m^2$), farms showed a tendency for higher richness values than subdivisions for all comparable patch types, but only had significantly higher richness in field and forest habitats. While field habitats on farms displayed a significantly higher number of total species than subdivision fields, a large number were exotic. This may be attributed to escaped exotics from nearby habitats such as crop fields or sown exotic species planted for purposes such as hay or grazing of livestock. Applications such as fertilizers may also contribute to degraded soil structures that may increase the number of exotic species (Altieri 1999; Paoletti 1999).

My results further support the claim that low-density/exurban development may increase the number of exotic species in surrounding natural/semi-natural habitats (Huntsinger 2009; Hansen et al. 2005; Maestas, Knight, and Gilgert 2003). Forest areas in farms had significantly higher total species richness and native species richness forests in than subdivisions. Within these same forested habitats, farms also had significantly lower numbers of exotic species than subdivisions. Thus, forests in subdivisions had significantly lower numbers of native species but also significantly higher richness of exotic species than farms. Several possible explanations for these differences include increased habitat fragmentation and higher irregularity of patch shape on subdivisions. Other possibilities include increased direct human and domesticated animal interactions and/or direct homeowner management of the natural/semi-natural areas in subdivisions as compared to farms. Thus, as land-use changes from agriculture to low-density subdivisions, we can expect a decline in native species richness within the forested habitats. Further, since many exurban developments are located near forest areas (Bock and Bock 2009; Brown et al. 2008; Hansen et al. 2005), these findings raise questions as to future health of these natural habitats and their potential for biodiversity conservation.

Implications for Biodiversity

Results from this study demonstrate that both agriculture and exurban development have tremendous effects on habitat composition and structure as well as species assemblages. Further, they also display a potential to affect broader biodiversity patterns involving species assemblages of a wide variety of animal species, microorganisms, and invertebrates. According to Benton, Vickery, and Wilson (2003), heterogeneous settings such as those in this study may potentially provide habitat for a high diversity of organisms. However, since increased amounts of fragmentation and smaller habitats have been linked to losses of species, subdivisions may be affecting broader diversity patterns of avian and mammalian (especially large species) populations (Fischer and Lindenmayer 2007) to a greater degree than the agricultural areas presented in this study. Pidgeon et al. (2007) found negative correlations between housing density and populations of forest and woodland avian species including short-distance migrants, ground-nesting species and cavity-nesting species. However, they did find some positive species richness relationships in synanthropic species within specific areas (Pidgeon et al. 2007). The lower plant species richness on subdivision sites in this study may potentially decrease a variety of species that have mutualistic relationships with plant species. Further, decreases in native species in forest habitats on subdivisions may have broader influences on specialist species that depend on specific vegetative matter for survival. However, since the broader biodiversity patterns are beyond the scope of this study, these are only speculations and merit further examination.

Chapter 5

CONCLUSION

Results from this study show the potential capability of rural land use to influence a wide array of habitats by affecting patch structure, total species richness, and native and exotic species richness. The degree of impact of rural land uses such as organic agriculture and low-density residential development depends on the scale of analysis and the habitat type under investigation. The greatest differences in floristic biodiversity between farms and subdivisions existed at the $100m^2$ scale and within natural/semi-natural habitats. At the $100m^2$ scale, farms had higher total species richness and native species richness than subdivisions. If these trends continue at higher spatial scales such as site or landscape, there could be tremendous concern over the loss of floristic diversity on and surrounding rural residential developments.

Forested habitats comprised the highest proportions of any patch type within both farm and subdivision sites. These results shed some positive light that both organic agriculture and low-density residential development may maintain some forest habitats as opposed to clear cutting entire areas (at least within the observed spatial scales). However, at the patch-scale of analysis, forested habitats displayed the greatest difference in species richness between the two land use types, which may be of greatest conservation concern and further amplify the need for multi-scale analysis. Forests on farms maintained higher total and native species richness than forests on subdivisions.

These results indicate that as land-use changes from agriculture to low-density residential development, we can expect an overall decrease in floristic diversity within forest areas. Further, subdivisions not only had significantly lower numbers of native species within forested habitats but also had higher numbers of exotic species. These findings are of great concern because most residential developments, like those in this study, tend to coincide with locations of high forest area and many pose great threat to surrounding natural areas.

As low-density residential developments continue to replace agricultural areas in this region, we may begin to see greater changes to our forest ecosystems. Reasons explaining the greater degree of impact to species richness within forested habitats on subdivisions warrant additional examination. As population pressures continue to rise and natural areas experience greater ecological pressure due to human involvement, a tremendous need exists to understand how specific human activities may alter natural habitats. Such knowledge can inform land management strategies including land conservation (e.g. land trusts) and sustainable development practices that may mitigate harmful environmental effects.

Overall, low-density residential subdivisions showed the greatest impact to habitat structure revealing increased amount of habitat fragmentation, especially at larger subdivision sizes. Many note that habitat fragmentation can drastically alter species numbers (Lindenmayer and Fischer 2006; Olff and Ritchie 2002; Pimm and Raven 2000; Vitousek et al. 1999) and could be a contributing factor to overall loss of species on subdivisions as well as increased number of exotic species in forest habitats. Since fragmentation is often linked to increased housing density and road networks (Bock and

Bock 2009; Harden 2004; Odell, Theobald, and Knight 2003) some claim that clustered developments would alleviate some of the environmental stress (Hansen et al. 2005). However, there are two conflicting views in this area. Bock and Bock (2009), claim that low density dispersed housing may decrease the effects to the natural areas. Certainly the effects of both types of residential subdivisions needs further evaluation before making a suggestion towards either development pattern, for patterns may be region specific and vary between vegetative composition and structure.

As land-use changes, further concerns exist as to how increased fragmentation and floristic species loss may affect higher levels of biodiversity. Lower vegetative richness and increased exotic species may contribute to decreased numbers of native higher order species such as birds, mammals and invertebrates, but may increase the number of human commensal species. Concerns also exists when considering the effects of land-use conversion from more intensive agricultural practices such as conventional agriculture to exurban development. Since this study presents the best case scenario for agriculture by examining organic practices, we may find greater impacts to species within different agricultural landscapes. However, results from this study may inform land use and farm land preservation decisions that promote alternative agriculture practices which reduce environmental impacts.

Obviously, this study reveals the potential negative environmental effects of uncontrolled rural development in both agriculture and exurban development and magnify the need for increased communication between scientific researchers, policy makers and landowners. We do not know how changes such as habitat fragmentation, decreased species richness and native species loss will affect the surrounding natural areas such as national forests or less disturbed areas of privately owned land. However, further research might yield answers to these questions, and aid in the development of conservation measures to help protect the biodiversity of the Southern Appalachian region.

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APPENDIX A

Landscape Spatial Scale Habitat Patch Maps and Complete Patch Analyst Measures

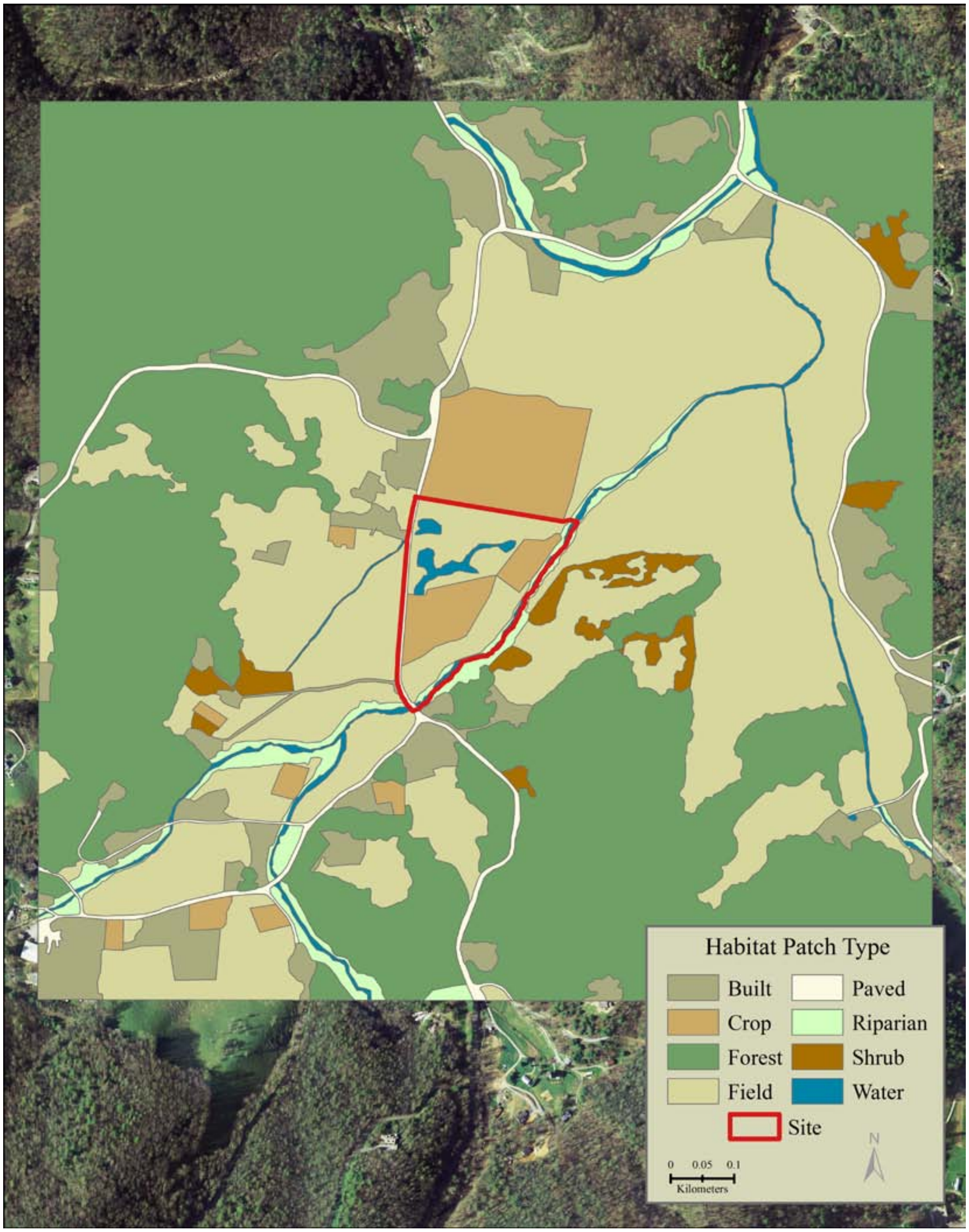

Figure 1. ASU Sustainable Farm (farm 1) landscape spatial scale habitat patch structure.

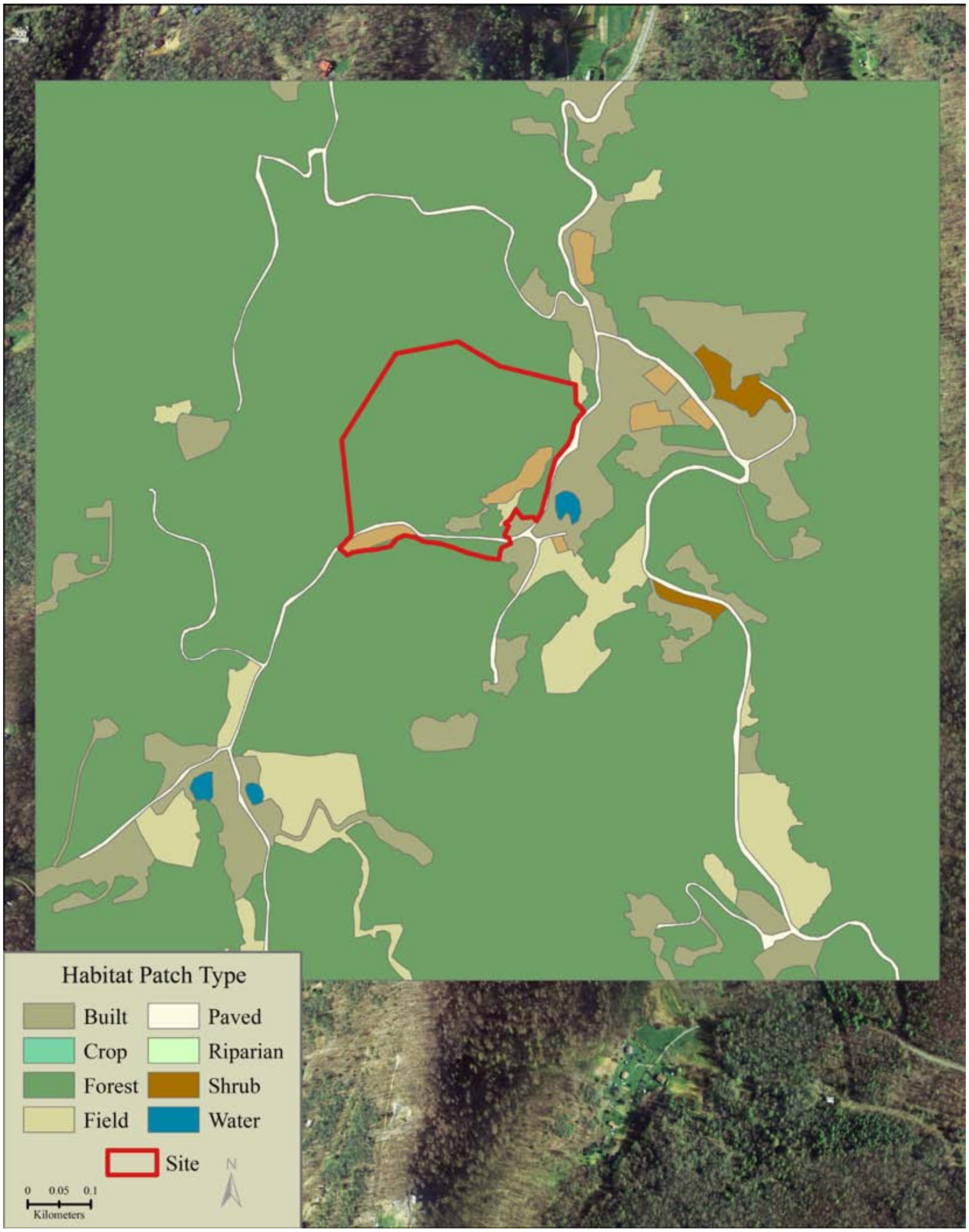

Figure 2. Maverick Farm (farm 2) landscape spatial scale habitat patch structure.

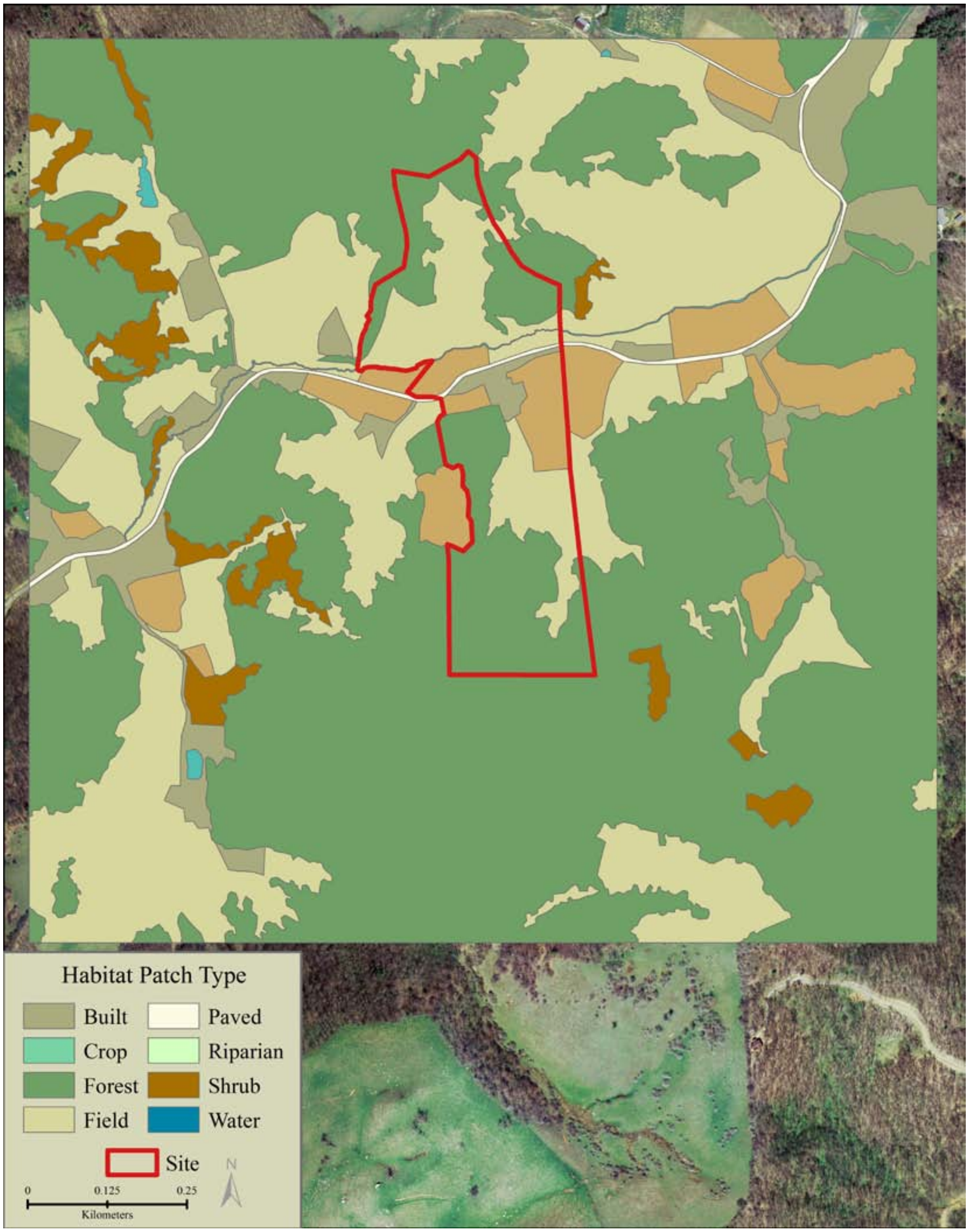

Figure 3. Creeksong Farm (farm 3) landscape spatial scale habitat patch structure.

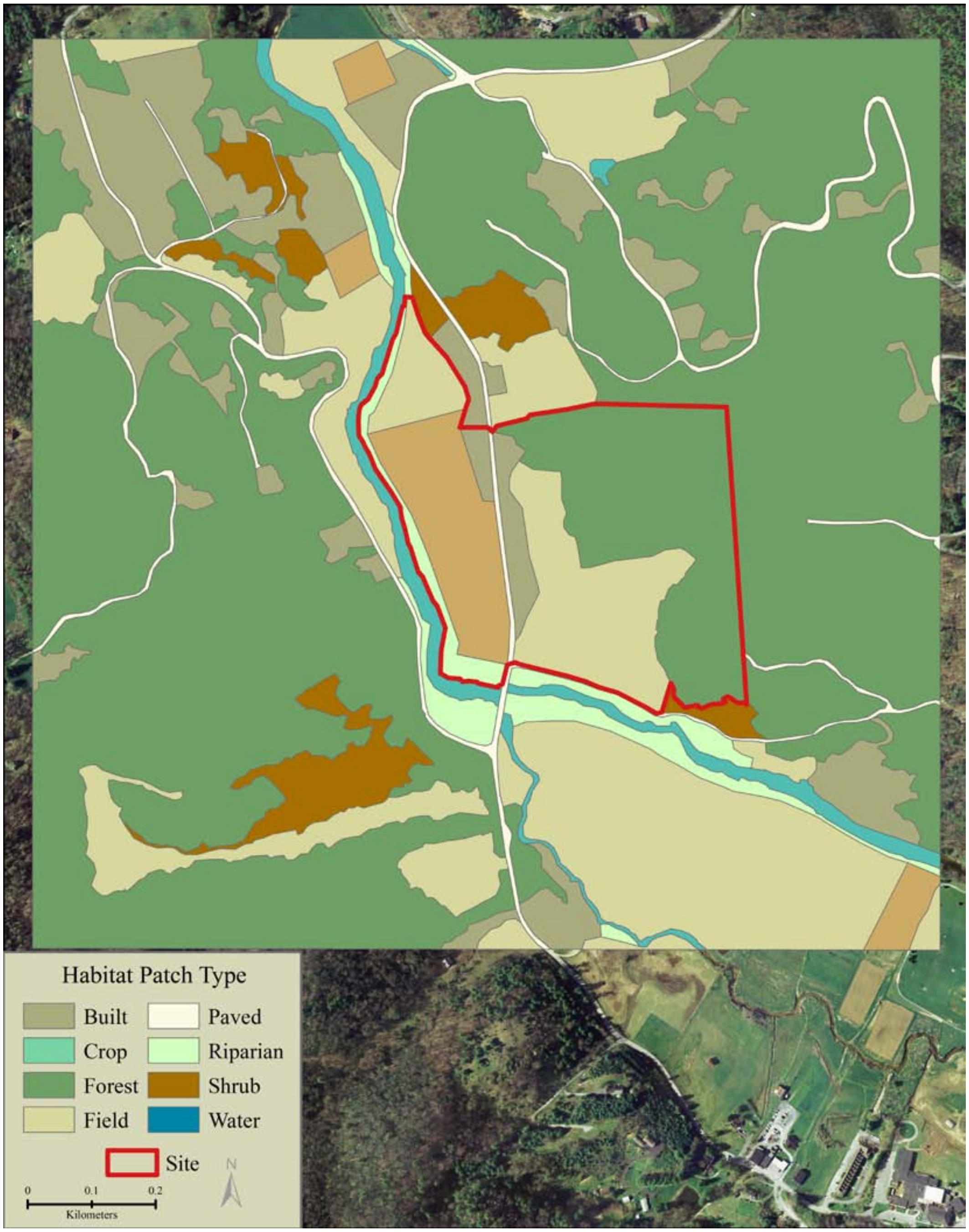

Figure 4. Watauga River Farms (farm 4) landscape spatial scale habitat patch structure.

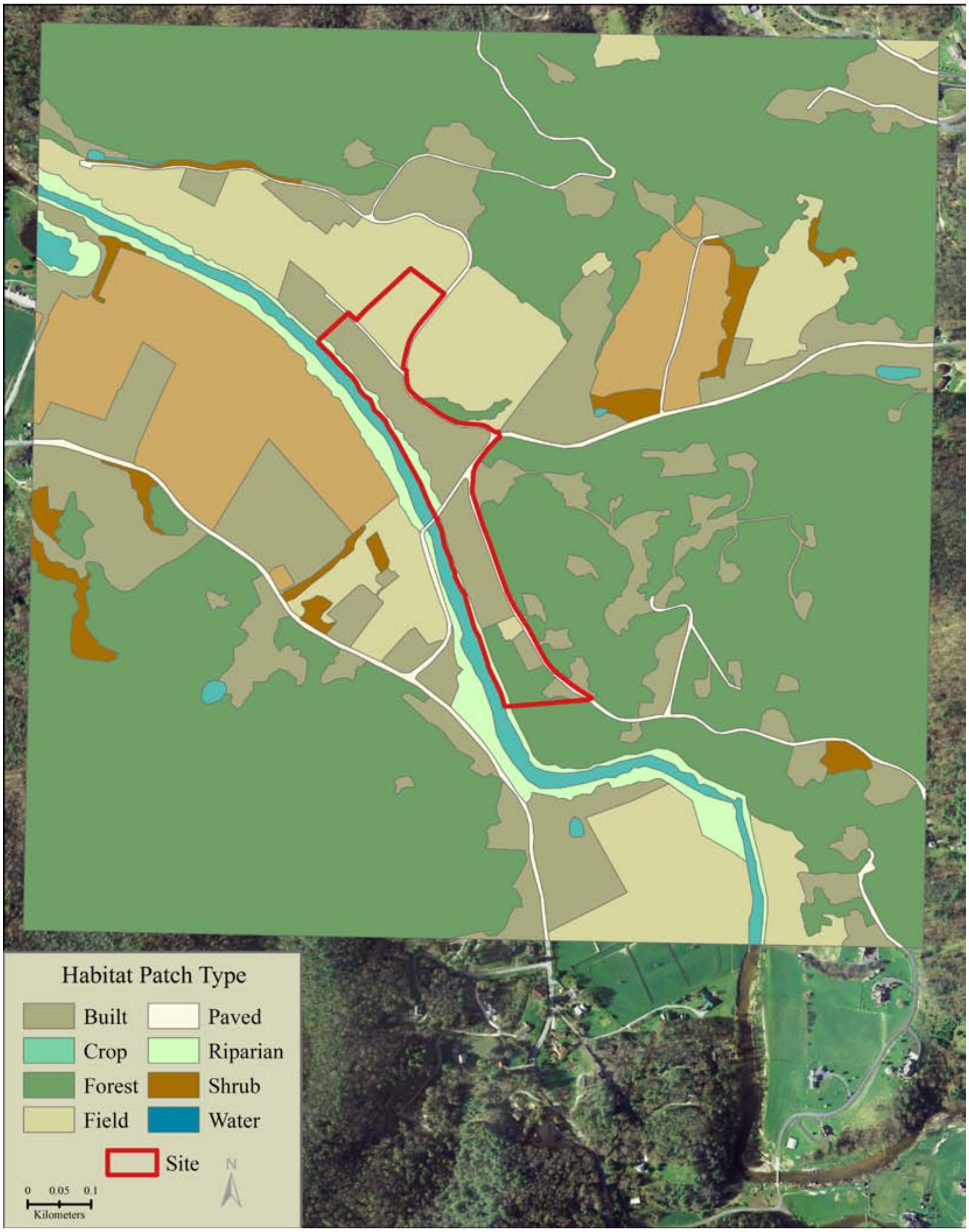

Figure 5. Riverside Homes (subdivision 1) landscape spatial scale habitat patch structure.

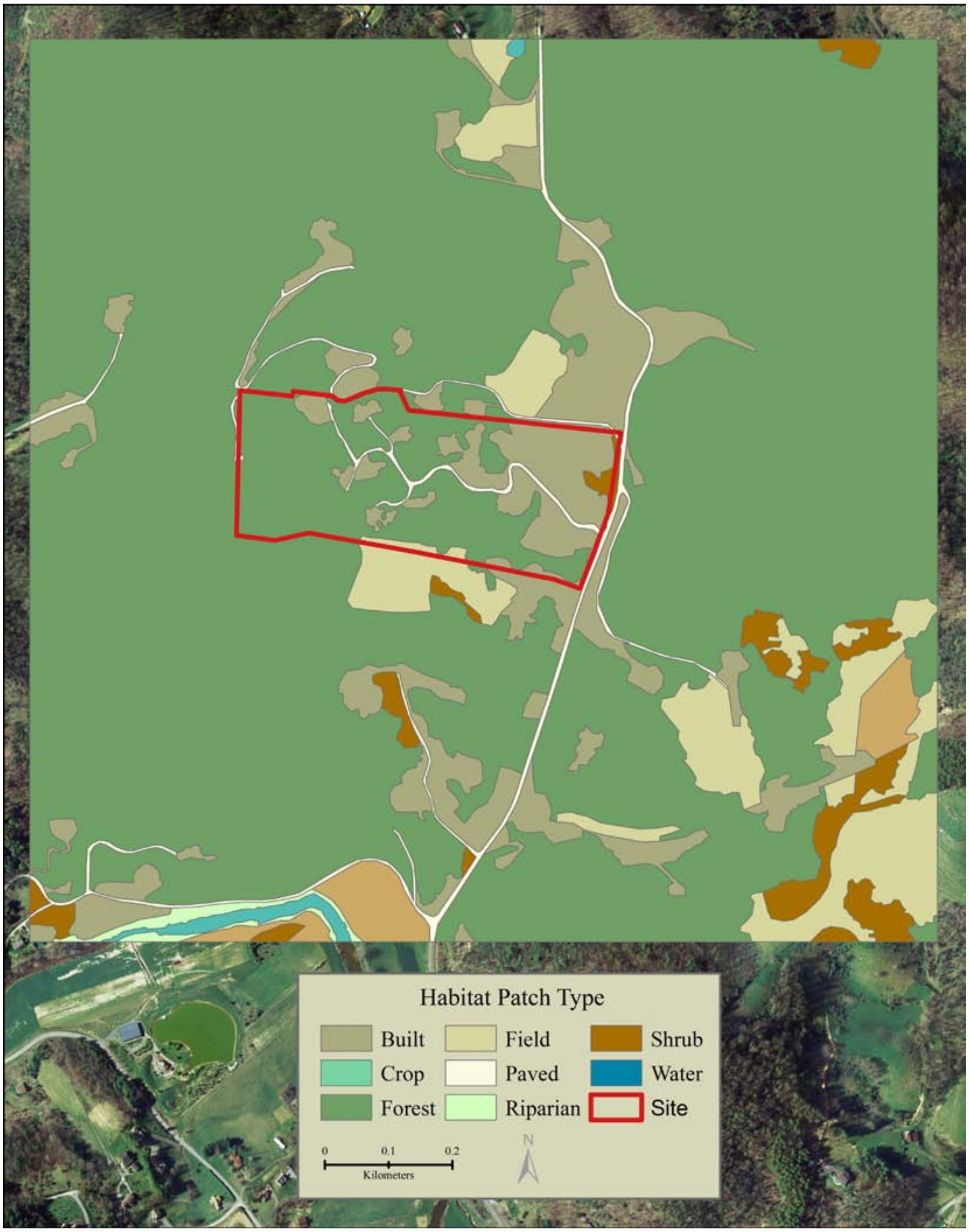

Figure 6. The Glen at Mast Gap (subdivision 2) landscape spatial scale habitat patch structure.

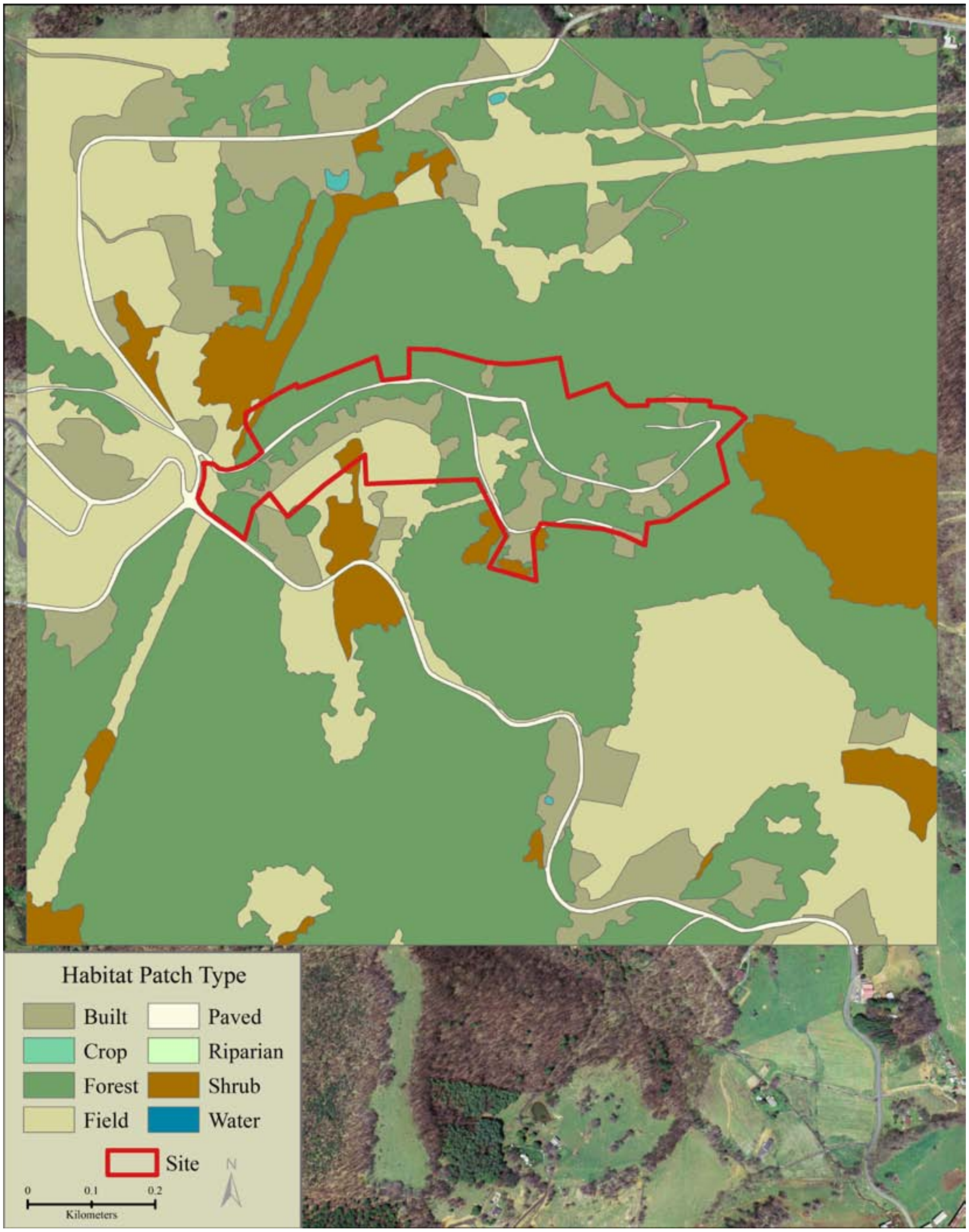

Figure 7. Laurel Mountain (subdivision 3) landscape spatial scale habitat patch structure.

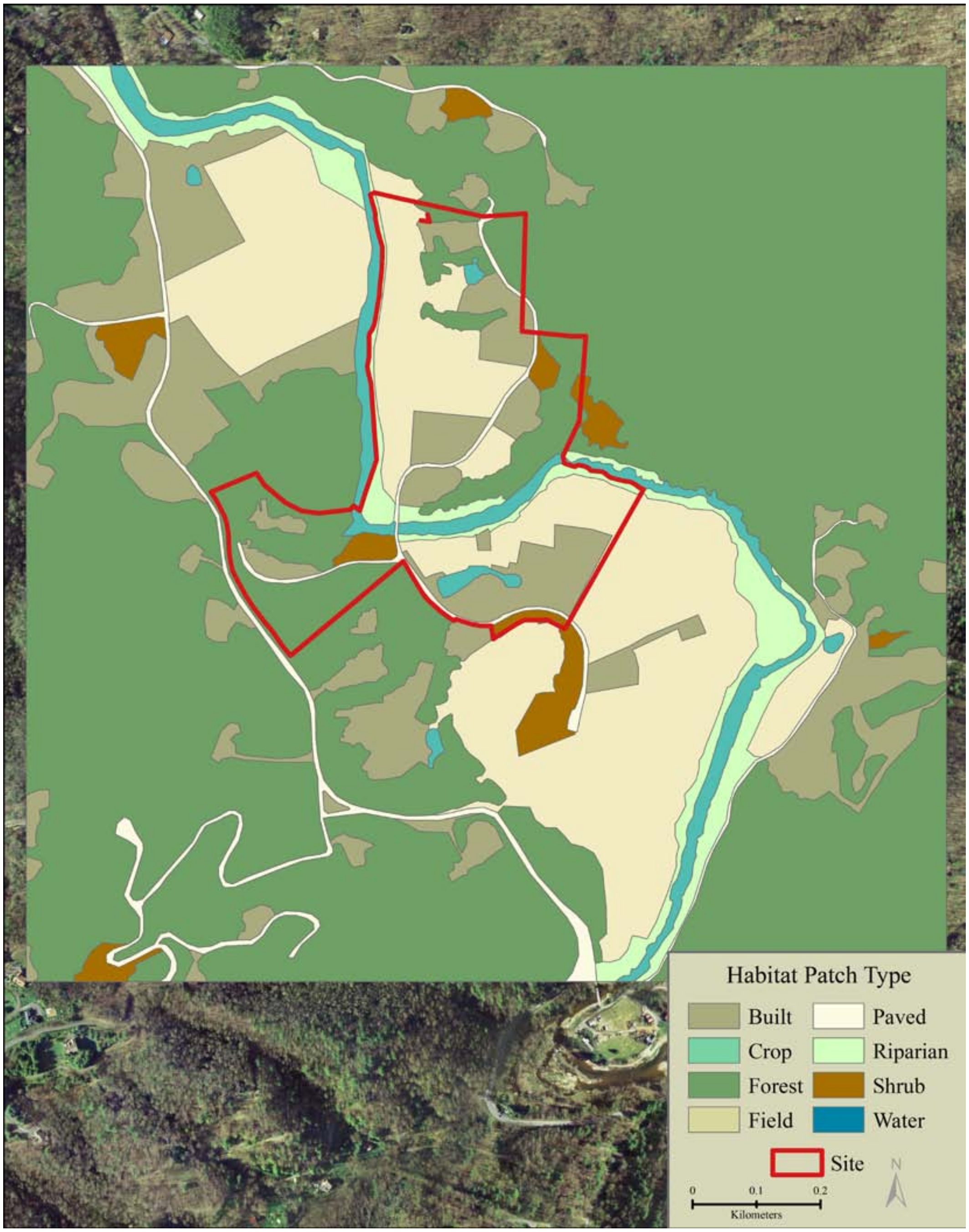

Figure 8. Shull's Farm (subdivision 4) landscape spatial scale habitat patch structure.

Table 1. All generated patch analyst measures for landscape spatial scale surrounding farms.

	F1	F2	F3	F4
Total Land Area (ha)	200.59	202.94	202.45	201.80
Patch Number	151.00	69.00	96.00	95.00
Mean Patch Size (ha)	1.33	2.94	2.11	2.12
Median Patch Size (ha)	0.27	0.41	0.43	0.51
Patch Richness	8.00	7.00	7.00	8.00
Patch Size Coefficient of Variation (%)	285.95	347.59	409.01	266.94
Patch Size Standard Deviation (ha)	3.80	10.22	8.63	5.67
Mean Shape Index	2.15	2.04	2.16	2.11
Area Weighted Mean Shape Index (%)	2.38	2.89	3.53	2.97
Mean Perimeter-Area Ratio	1580.07	1035.79	1168.27	1002.08
Mean Patch Fractal Dimension	1.48	1.43	1.45	1.43
Area Weighted Mean Patch Fractal Dimension	1.37	1.37	1.41	1.39
Edge Density (m/ha)	493.47	322.49	415.02	449.37
Total Edge (m)	98986.73	65446.34	84019.58	90682.67
Mean Patch Edge (m/ha)	655.54	948.50	875.20	954.55
Shannon's Diversity Index	1.34	0.65	1.13	1.38
Shannon's Evenness Index	0.64	0.33	0.58	0.66
Patch Type Percents				
Forest	48.00	83.40	58.46	56.24
Shrub	1.52	0.39	2.78	3.31
Field	32.42	4.36	26.83	19.18
Crop	3.52	0.69	5.68	3.12
Riparian	2.43	0.00	0.00	2.49
Crop	1.27	0.17	0.26	2.28
Built	8.84	9.18	5.34	10.69
Paved	2.01	1.81	0.65	2.70

Note: All measures were generated using Patch Analyst spatial statistical function, which runs analysis in conjunction with ArcGIS® FragStats.

Table 2. All generated patch analyst measures for landscape spatial scale surrounding subdivisions.

	S1	S2	S3	S4
Total Land Area (ha)	202.92	201.24	202.45	205.48
Patch Number	109.00	84.00	110.00	92.00
Mean Patch Size (ha)	1.86	2.40	1.84	2.23
Median Patch Size (ha)	0.37	0.27	0.50	0.37
Patch Richness	8.00	8.00	6.00	7.00
Patch Size Coefficient of Variation (%)	258.11	470.91	336.46	298.10
Patch Size Standard Deviation (ha)	4.81	11.28	6.19	6.66
Mean Shape Index	2.10	2.07	1.99	2.17
Area Weighted Mean Shape Index (%)	2.61	3.31	2.98	2.71
Mean Perimeter-Area Ratio	2318.87	1284.71	1109.48	5923.01
Mean Patch Fractal Dimension	1.43	1.46	1.44	1.41
Area Weighted Mean Patch Fractal Dimension	1.38	1.38	1.40	1.38
Edge Density (m/ha)	447.86	341.79	446.04	402.23
Total Edge (m)	90880.72	68782.67	90302.74	82651.16
Mean Patch Edge (m/ha)	833.77	818.84	820.93	898.38
Shannon's Diversity Index	1.41	0.81	1.15	1.21
Shannon's Evenness Index	0.68	0.40	0.64	0.62
Patch Type Percents				
Forest	54.04	78.27	57.47	61.72
Shrub	1.65	2.26	7.14	1.73
Field	11.65	6.00	23.90	15.81
Crop	8.10	1.46	0.00	0.00
Riparian	2.67	0.41	0.00	3.35
Crop	2.00	0.38	0.09	2.51
Built	17.92	9.75	9.56	12.72
Paved	1.97	1.47	1.84	2.17

Note: All measures were generated using Patch Analyst spatial statistical function, which runs analysis in conjunction with ArcGIS® FragStats.

APPENDIX B

Site Spatial Scale Habitat Patch Maps and Complete Patch Analyst Measures

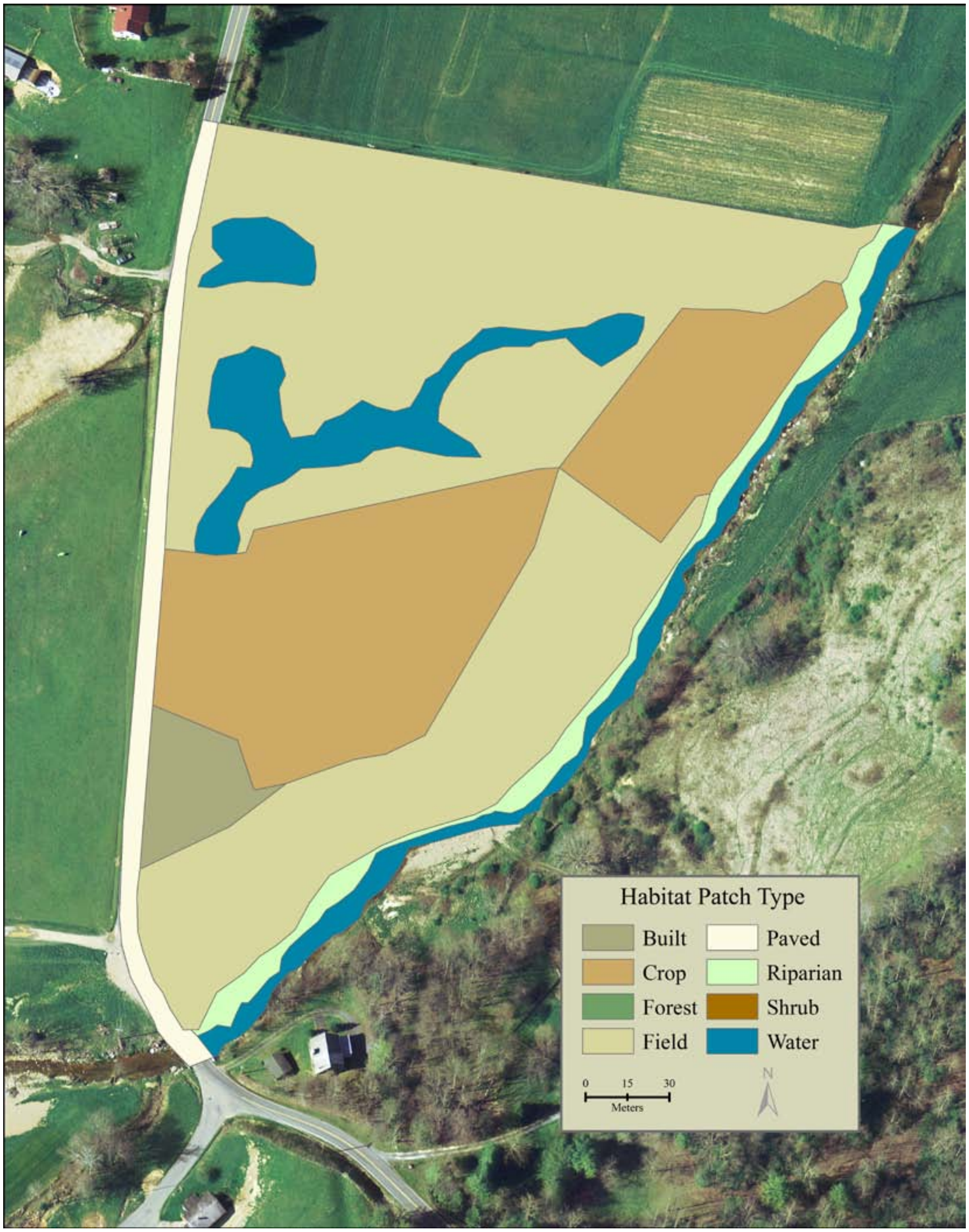

Figure 9. ASU Sustainable Farm (farm 1) site spatial scale habitat patch structure.

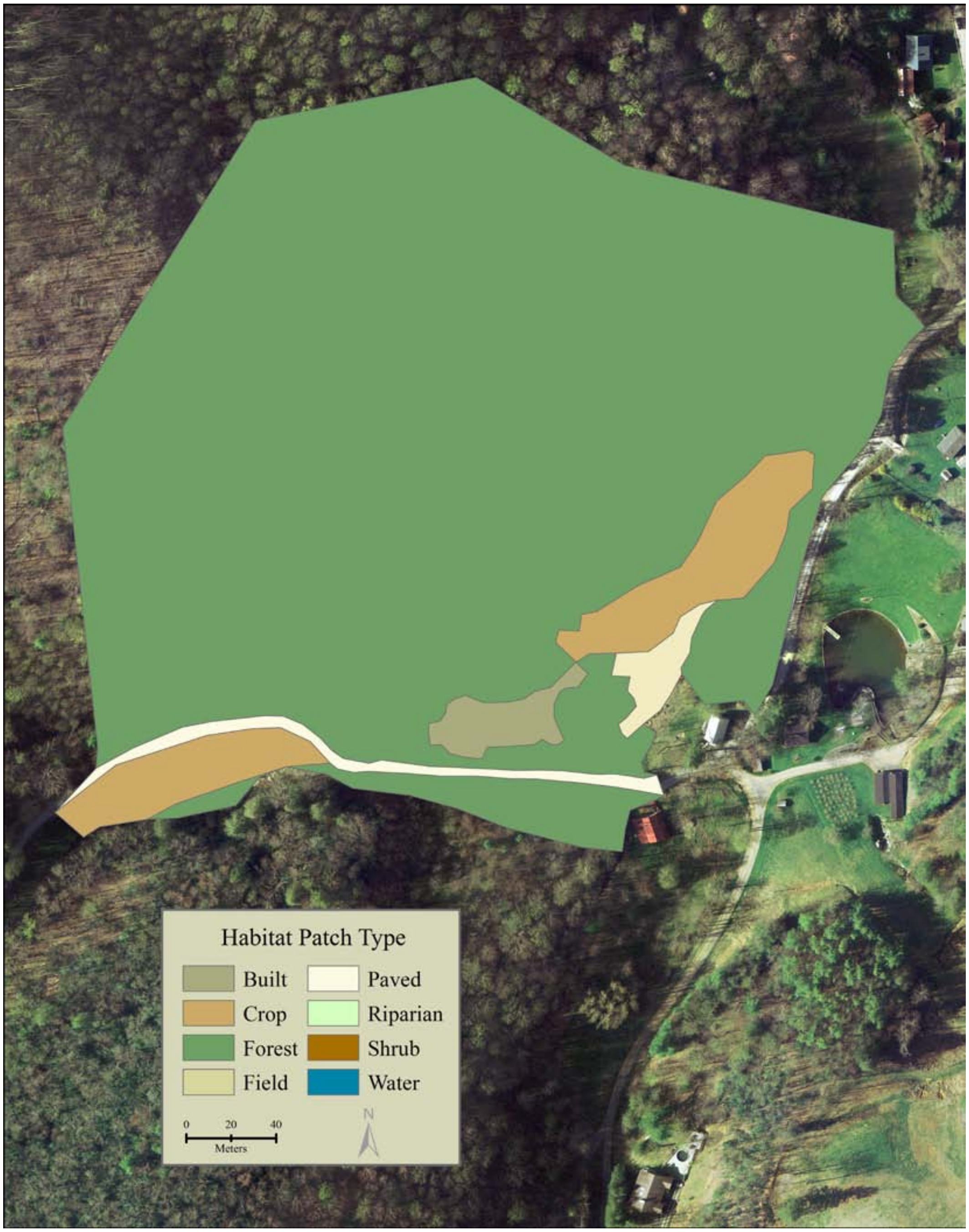

Figure 10. Maverick Farms (farm 2) site spatial scale habitat patch structure.

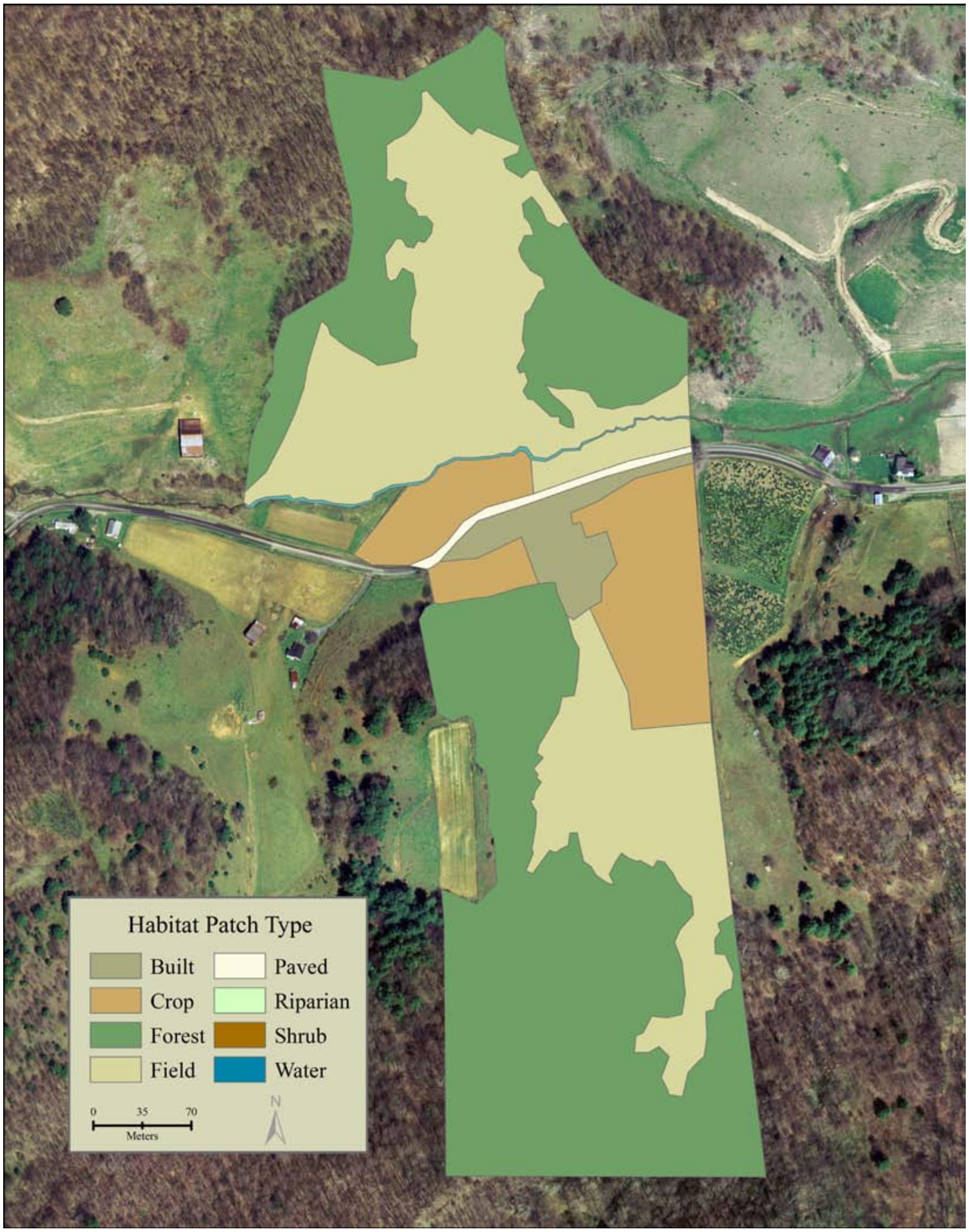

Figure 11. Creeksong Farm (farm 3) site spatial scale habitat patch structure.

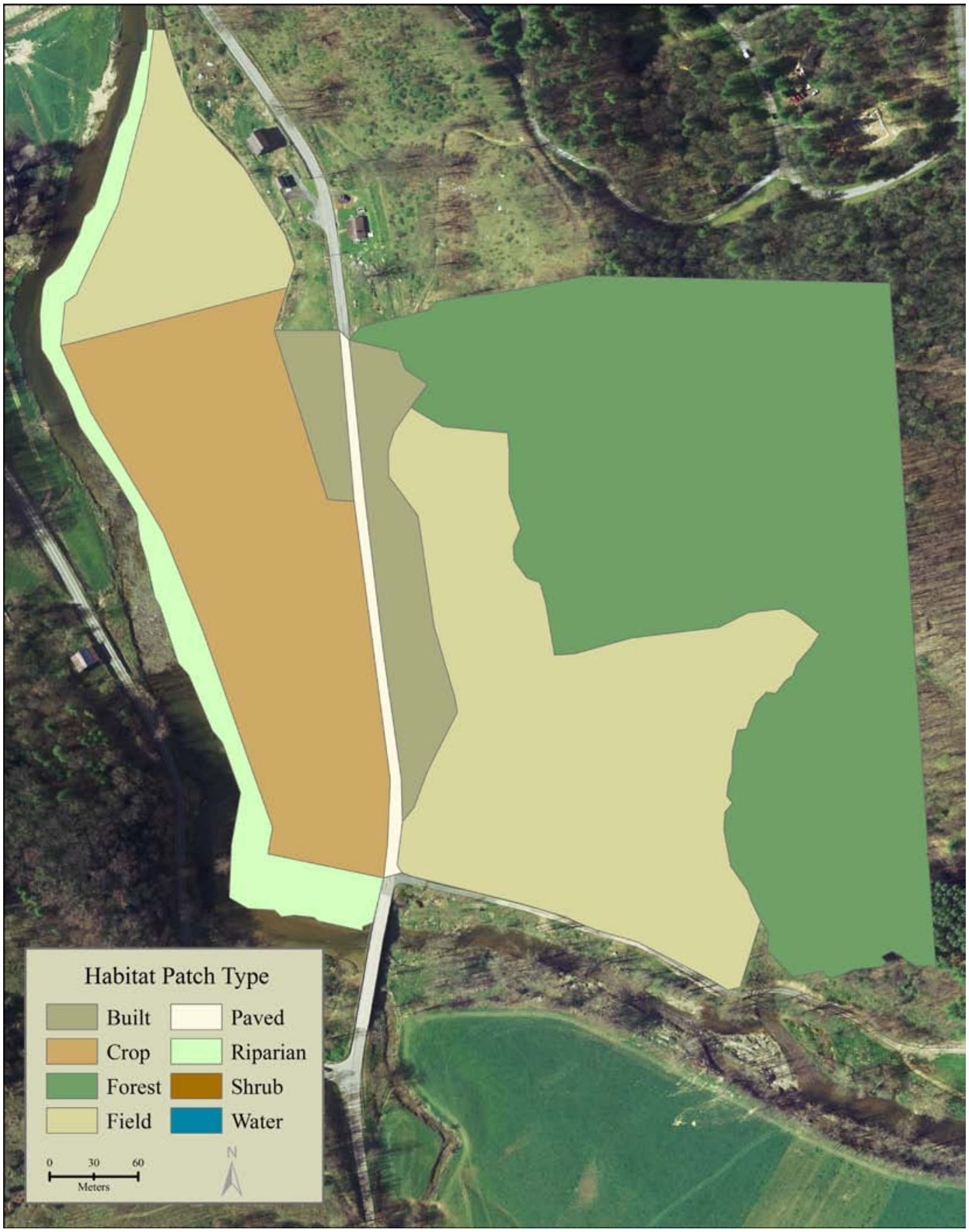

Figure 12. Watauga River Farms (farm 4) site spatial scale habitat patch structure.

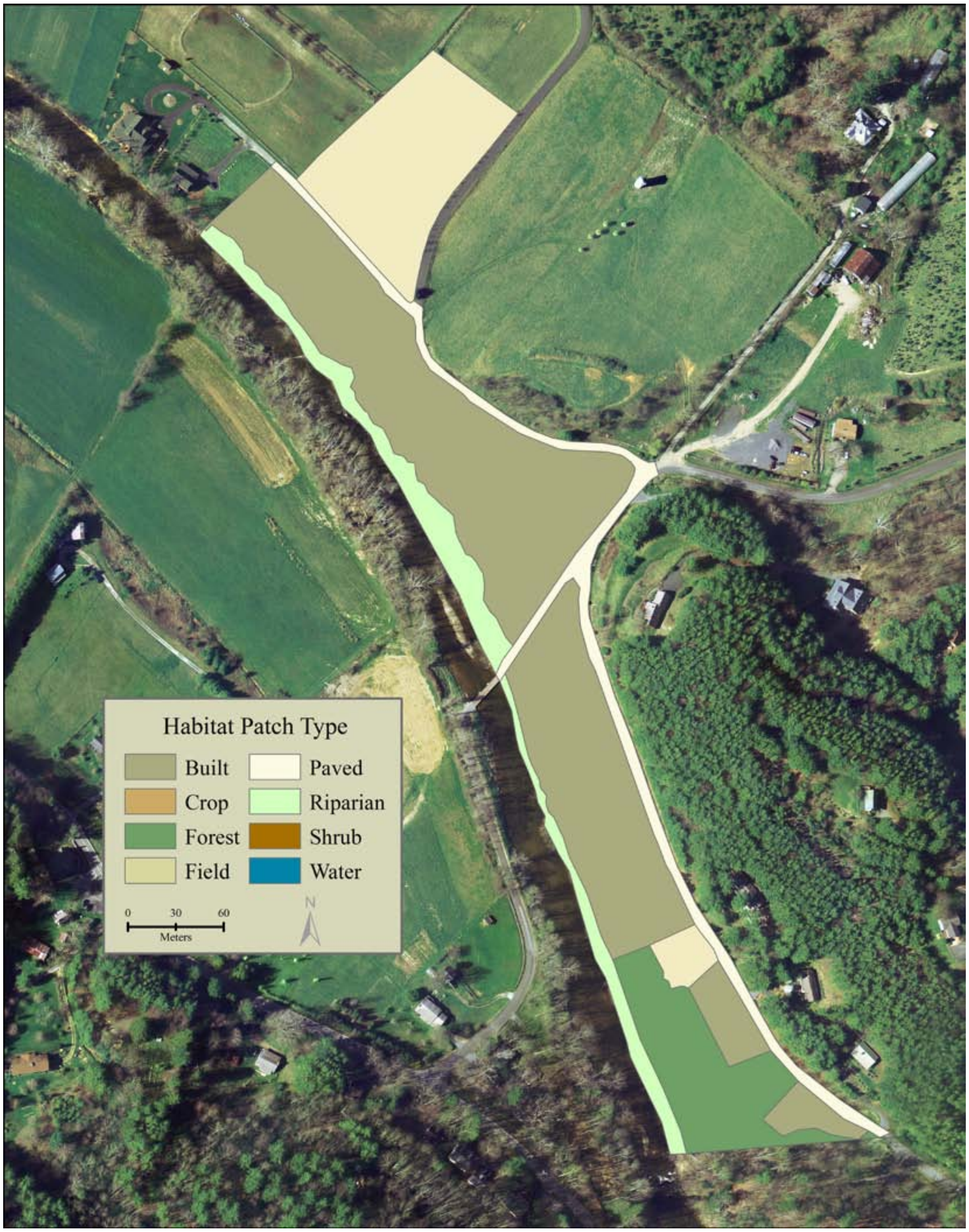

Figure 13. Riverside Homes (subdivision 1) site spatial scale habitat patch structure.

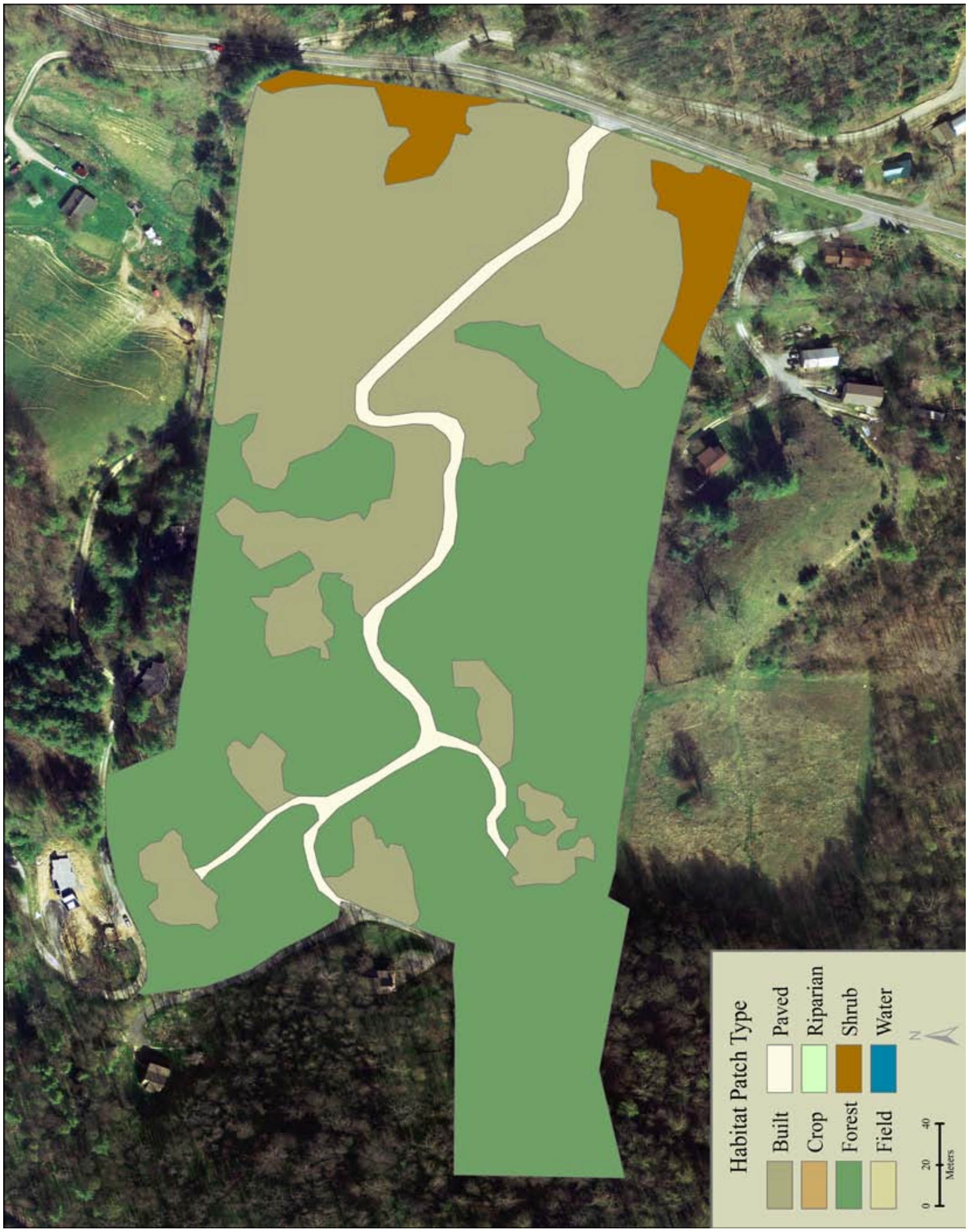

Figure 14. The Glen at Mast Gap (subdivision 2) site spatial scale habitat patch structure.

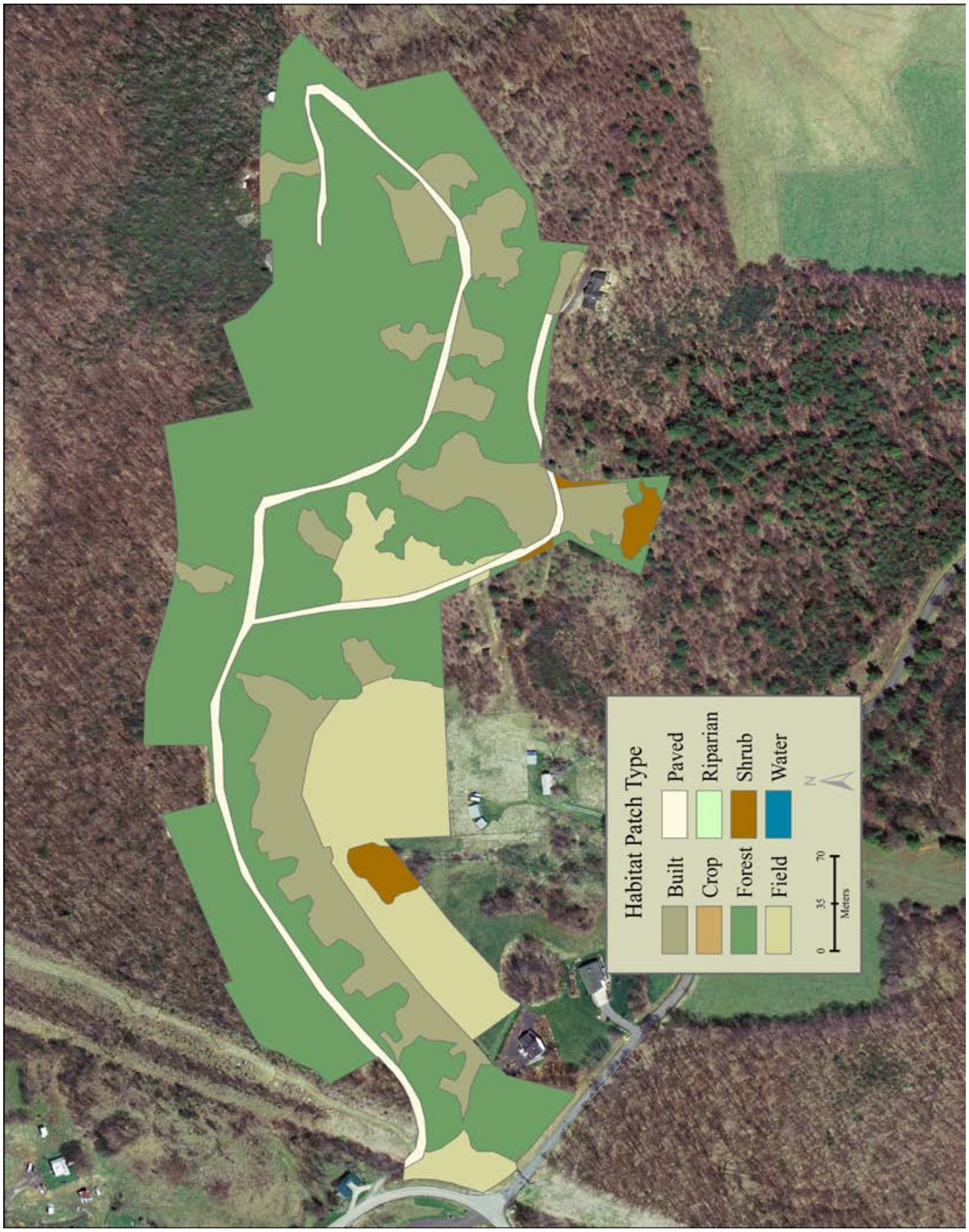

Figure 15. Laurel Mountain Homes (subdivision 3) site spatial scale habitat patch structure.

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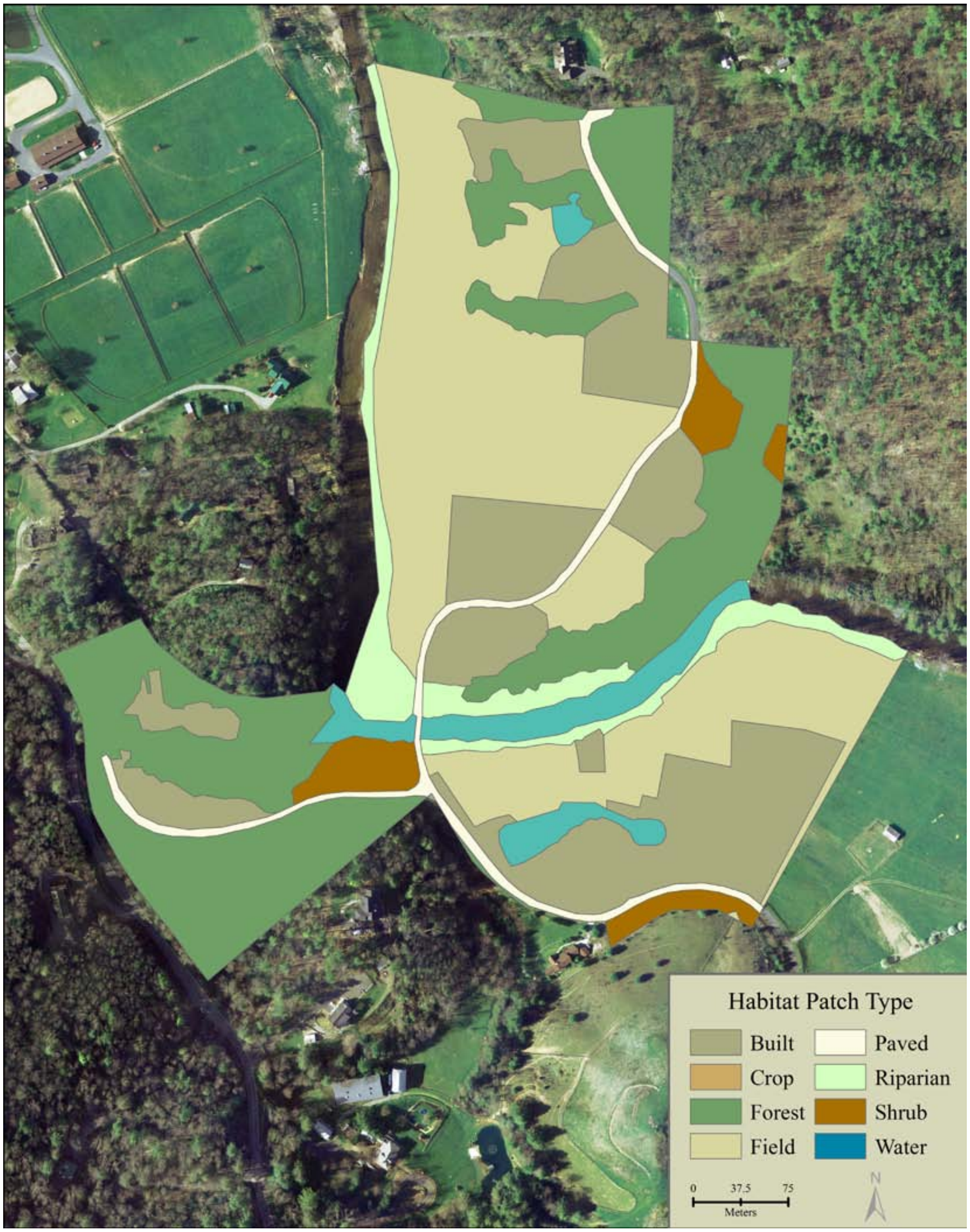

Figure 16. Subdivision four (Shull's Farm) one site spatial scale habitat patch structure.

Table 3. All generated patch analyst measures for farms sites.

	F1	F2	F3	F4
Total Land Area (ha)	5.47	16.63	6.45	15.57
Patch Number	10	11	10	24
Mean Patch Size (ha)	0.55	1.51	0.64	0.65
Median Patch Size (ha)	0.27	0.57	0.48	0.11
Patch Richness	6	6	5	5
Patch Size Coefficient of Variation (%)	98.59	110.23	90.32	273.69
Patch Size Standard Deviation (ha)	0.54	1.67	0.58	1.78
Mean Shape Index	1076.82	559.76	942.61	987.87
Area Weighted Mean Shape Index (%)	1.45	1.41	1.42	1.52
Mean Perimeter-Area Ratio	2.68	2.65	2.40	2.10
Mean Patch Fractal Dimension	2.35	2.27	2.20	4.79
Area Weighted Mean Patch Fractal Dimension	1820.54	1956.06	1393.53	1855.88
Edge Density (m/ha)	1.52	1.49	1.47	1.50
Total Edge (m)	5893.60	9308.90	6077.82	15379.53
Mean Patch Edge (m/ha)	589.360	846.26	607.78	640.81
Shannon's Diversity Index	1.285	1.138	1.313	1.10
Shannon's Evenness Index	0.72	0.64	0.82	0.69
Patch Type Proportions (%)				
Forest	0.00	50.08	10.76	61.18
Shrub	0.00	0.00	0.00	1.57
Field	52.40	33.59	16.94	14.17
Crop	26.17	11.76	0.00	0.00
Riparian	3.63	0.00	9.80	0.00
Crop	10.65	0.36	0.00	0.00
Built	2.87	3.44	53.86	18.05
Paved	4.26	0.77	8.64	5.03

Note: All measures were generated using Patch Analyst spatial statistical function, which runs analysis in conjunction with ArcGIS® FragStats.

Table 4. All generated patch analyst measures for subdivision sites.

	S1	S2	S3	S4
Total Land Area (ha)	9.31	23.74	9.71	23.74
Patch Number	7	8	11	29
Mean Patch Size (ha)	1.33	2.97	0.88	0.82
Median Patch Size (ha)	0.25	1.41	0.17	0.39
Patch Richness	5	6	4	7
Patch Size Coefficient of Variation (%)	206.99	102.10	170.09	133.56
Patch Size Standard Deviation (ha)	2.75	3.03	1.50	1.09
Mean Shape Index	418.21	333.71	814.50	768.89
Area Weighted Mean Shape Index (%)	1.35	1.33	1.47	1.43
Mean Perimeter-Area Ratio	2.25	2.15	2.33	2.10
Mean Patch Fractal Dimension	1.81	1.69	3.26	2.45
Area Weighted Mean Patch Fractal Dimension	1769.81	826.99	1540.86	1705.63
Edge Density (m/ha)	1.51	1.41	1.50	1.49
Total Edge (m)	3895.62	7921.19	7908.91	18254.05
Mean Patch Edge (m/ha)	556.52	990.15	718.99	629.45
Shannon's Diversity Index	0.44	1.41	0.96	1.59
Shannon's Evenness Index	0.28	0.79	0.69	0.82
Patch Type Proportions (%)				
Forest	89.68	39.96	53.45	27.27
Shrub	0.00	0.00	4.23	3.46
Field	1.00	29.48	0.00	31.57
Crop	6.47	18.37	0.00	0.00
Riparian	0.00	5.30	0.00	5.81
Crop	0.00	0.00	0.00	4.60
Built	1.42	5.77	38.50	24.12
Paved	1.43	1.12	3.83	3.18

Note: All measures were generated using Patch Analyst spatial statistical function, which runs analysis in conjunction with ArcGIS® FragStats.

APPENDIX C

Identified Species Lists

Table 5. Total encountered species for all eight sites.

Species Name	Origin	Life	Growth
Abies concolor	I	P	T
Abies fraseri	N	P	T
Acalypha rhomboidea	N	A	H
Acer rubrum	N	P	T
Acer saccharinum	N	P	T
Achillea ‘Appleblossom’	I	P	H
Achillea millefolium	N	P	H
Actaea podocarpa	N	P	H
Aegopodium podagraria	I	P	H
Aesculus flava	N	P	T
Aesculus pavia	N	P	S
Aesculus sylvatica	N	P	T
Agalinis sp. 1	I	P	H
Ageratina altissima	N	P	H
Agrostis gigantea	I	P	G
Agrimonia parviflora	N	P	G
Agrostis perennans	N	P	G
Ajuga reptans	I	P	H
Alchemilla mollis	I	P	H
Allium canadense	N	P	H
Alliaria petiolata	I	A	H
Allium sativum	I	P	H
Allium vineale	I	P	H
Alnus serrulata	N	P	T
Amaranthus retroflexus	N	A	H
Ambrosia artemisiifolia	N	A	H
Ambrosia trifida	N	A	H
Amphicarpaea bracteata	N	A	V
Andropogon virginicus	N	P	G
Anemone acutiloba	N	P	H
Anemone virginiana	N	P	H
Anthemis cotula	I	A	H
Antirrhinum majus	I	A	H
Anthoxanthum odoratum	I	P	G
Antennaria plantaginifolia	N	P	H
Apios americana	N	P	V
Aquilegia canadensis	N	P	H
Aquilegia vulgaris	I	P	H
Arabis laevigata	N	B	H

Note: N (native); I (exotic/introduced); A (annual); P (perennial); B (biennial); H (herbaceous); T (tree); S (shrub); G (grass); V (vine); (n=4 farms, n=4 subdivisions)

Table 5. Extended.

Species Name	Origin	Life	Growth
Arctium minus	I	B	H
Aristolochia macrophylla	N	P	V
Arisaema triphyllum	N	P	H
Arnoglossum atriplicifolium	N	P	H
Arrhenatherum elatius	I	P	G
Artemisia vulgaris	I	P	H
Asclepias incarnata	N	P	H
Asclepias syriaca	N	P	H
Asimina triloba	N	P	T
Astilbe x crispa	I	P	H
Asteraceae 1	U	U	H
Asteraceae 2	U	U	H
Asteraceae 3	U	U	H
Asteraceae 4	U	U	H
Asteraceae 5	U	U	H
Athyrium filix-femina	N	P	H
Aureolaria virginica	N	P	H
Barbarea verna	I	B	H
Barbarea vulgaris	I	B	H
Berberis canadensis	N	P	S
Berberis thunbergii	I	P	S
Betula alleghaniensis	N	P	T
Betula lenta	N	P	T
Beta vulgaris	I	A	H
Bidens bipinnata	I	A	H
Bignonia capreolata	N	P	V
Boehmeria cylindrica	N	P	H
Boechera laevigata	N	B	H
Brassica juncea	I	A	H
Brassica napus	I	A	H
Brassica oleracea	I	P	H
Brassica rapa	I	A	H
Bromus commutatus	I	A	G
Buddleja davidii	I	P	S
Buxus sempervirens	I	P	S
Calystegia sepium	N	P	V
Campanulastrum americanum	N	A	H
Campanula divaricata	N	P	G
Campsis radicans	N	P	V

Note: N (native); I (exotic/introduced); A (annual); P (perennial); B (biennial); H (herbaceous); T (tree); S (shrub); G (grass); V (vine); (n=4 farms, n=4 subdivisions)

Table 5. Extended.

Species Name	Origin	Life	Growth
Carya alba	N	P	T
Carex atlantica	N	P	G
Carex amphibola	N	P	G
Carex appalachica	N	P	G
Carya carolinae-septentrionalis	N	P	T
Carya cordiformis	N	P	T
Carex sp. 10	U	U	G
Carex sp. 11	U	U	G
Carex sp. 12	U	U	G
Carex sp. 13	U	U	G
Carex sp. 14	U	U	G
Carex sp. 5	U	U	G
Carex sp. 1	U	U	G
Carex sp. 2	U	U	G
Carex sp. 3	U	U	G
Carex sp. 4	U	U	G
Carex sp. 6	U	U	G
Carex sp. 7	U	U	G
Carex sp. 8	U	U	G
Carex sp. 9	U	U	G
Carya glabra	N	P	T
Carex gynandra	N	P	G
Cardamine hirsuta	I	A	H
Carya laciniosa	N	P	T
Carex lurida	N	P	G
Carex muehlenbergii	N	P	G
Carya ovata	N	P	T
Carya pallida	N	P	T
Carex pensylvanica	N	P	G
Carpinus sp. 1	U	P	T
Cardamine rotundifolia	N	P	H
Carex scoparia	N	P	G
Carya sp. 1	U	P	T
Castanea pumila	N	P	T
Caulophyllum thalictroides	N	P	H
Celastrus orbiculatus	I	P	V
Centaurea cyanus	I	A	H
Centaurea stoebe	I	B	H
Cerastium sp. 1	U	U	H

Note: N (native); I (exotic/introduced); A (annual); P (perennial); B (biennial); H (herbaceous); T (tree); S (shrub); G (grass); V (vine); (n=4 farms, n=4 subdivisions)

Table 5. Extended.

Species Name	Origin	Life	Growth
Cerastium fontanum	I	B	H
Cerastium semidecandrum	I	A	H
Chamaesyce maculata	N	A	H
Chenopodium album	N	A	H
Chimaphila maculata	N	P	H
Cichorium intybus	I	P	H
Cicuta maculata	N	P	H
Cirsium discolor	N	B	H
Cirsium vulgare	I	B	H
Cleome hassleriana	I	A	H
Clematis terniflora	I	P	V
Clematis viorna	N	P	V
Clematis virginiana	N	P	V
Clinopodium vulgare	N	P	H
Collinsonia canadensis	N	P	H
Commelina communis	I	A	H
Commelina virginica	N	P	H
Conyza canadensis	N	A	H
Convallaria majuscula	N	P	H
Corylus americana	N	P	S
Cornus amomum	N	P	S
Coreopsis sp. 1 (cultivated)	I	P	H
Cornus florida	N	P	T
Coreopsis pubescens	N	P	H
Coriandrum sativum	I	A	H
Cosmos sp. 1 (cultivated)	I	A	H
Cotoneaster horizontalis	I	P	S
Crambe cordifolia	I	P	H
Crataegus iracunda	N	P	T
Crataegus macrosperma	N	P	T
Crataegus punctata	N	P	T
Crataegus sp. 1	U	P	T
Crataegus sp. 2	U	U	T
Crepis capillaris	I	A	H
Crocosmia ‘Lucifer’	I	P	H
Cruciata pedemontana	I	A	H
Cryptotaenia canadensis	N	P	H
Cyperaceae sp. 1	U	U	G
Cyperus sp. 1 (seedling)	U	U	G

Note: N (native); I (exotic/introduced); A (annual); P (perennial); B (biennial); H (herbaceous); T (tree); S (shrub); G (grass); V (vine); (n=4 farms, n=4 subdivisions)

Table 5. Extended.

Species Name	Origin	Life	Growth
Cyperus strigosus	N	P	G
Dactylis glomerata	I	P	G
Danthonia compressa	N	P	G
Daucus carota	I	P	H
Dennstaedtia punctilobula	N	P	H
Deparia acrostichoides	N	P	H
Desmodium sp. 1	U	U	H
Desmodium paniculatum	N	P	H
Deutzia scabra	I	P	S
Dianthus armeria	I	A	H
Dianthus barbatus	I	P	H
Dianthus deltoides	I	P	H
Dichanthelium acuminatum	N	P	G
Dichanthelium clandestinum	N	P	G
Dichanthelium dichotomum	N	P	G
Dichanthelium meridionale	N	P	G
Digitaria ischaemum	I	A	G
Digitaria sanguinalis	N	A	G
Diodia virginiana	N	A	H
Dioscorea quaternata	N	P	V
Diospyros virginiana	N	P	T
Dorotheanthus sp. 1 (cultivated)	I	A	H
Dorotheanthus sp. 2 (cultivated)	I	A	H
Dryopteris intermedia	N	P	H
Duchesnea indica	I	P	H
Echinochloa crus-galli	I	A	G
Echium vulgare	I	B	H
Eleusine indica	I	A	G
Eleocharis obtusa	N	A	G
Elymus hystrix	N	P	G
Elymus repens	I	P	G
Elymus villosus	N	P	G
Epilobium coloratum	N	P	H
Equisetum arvense	N	P	H
Eragrostis capillari	N	A	G
Erechtites hieraciifolia	N	A	H
Erigeron annuus	N	A	H
Ericaceae 1	U	U	S
Erigeron pulchellus	N	P	H

Note: N (native); I (exotic/introduced); A (annual); P (perennial); B (biennial); H (herbaceous); T (tree); S (shrub); G (grass); V (vine); (n=4 farms, n=4 subdivisions)

Table 5. Extended.

Species Name	Origin	Life	Growth
Erigeron strigosus	N	B	H
Eruca vesicaria	I	A	H
Euonymus alatus	I	P	S
Euonymus fortunei	I	P	S
Euphorbia corollata	N	P	H
Euphorbia marginata	N	A	H
Eupatorium perfoliatum	N	P	H
Eupatorium purpureum	N	P	H
Euphorbia commutata	N	A	H
Eurybia divaricata	N	P	H
Eutrochium dubium	N	P	H
Eutrochium fistulosum	N	P	H
Fagus grandifolia	N	P	T
Fallopia sp. 1	U	U	V
Fallopia scandens	N	P	V
Festuca rubra	N	P	G
Festuca subverticillata	N	P	G
Festuca trachyphylla	I	P	G
Festuca sp. 1	N	P	G
Festuca sp. 2	N	P	G
Festuca sp. 3	N	P	G
Forsythia viridissima	I	P	S
Fraxinus americana	N	P	T
Fragaria vesca	N	P	H
Fragaria virginiana	N	P	H
Galium aparine	N	A	V
Galeopsis bifida	I	A	H
Galium latifolium	N	P	H
Galium pilosum	N	P	H
Galinsoga quadriradiata	I	A	H
Gentiana austromontana	N	P	H
Gentiana sp 1	U	U	H
Geranium columbinum	I	A	H
Geranium dissectum	I	A	H
Geranium maculatum	N	P	H
Geranium molle	I	A	H
Geranium pusillum	I	A	H
Geum canadense	N	P	H
Geum sp. 1	U	U	H

Note: N (native); I (exotic/introduced); A (annual); P (perennial); B (biennial); H (herbaceous); T (tree); S (shrub); G (grass); V (vine); (n=4 farms, n=4 subdivisions)

Table 5. Extended.

Species Name	Origin	Life	Growth
Geum virginianum	N	P	H
Glebionis coronarium	I	A	H
Glechoma hederacea	I	P	H
Glebionis segetum	I	A	H
Glyceria striata	N	P	G
Goodyera pubescens	N	P	H
Hamamelis virginiana	N	P	T
Hedera helix	I	P	V
Helenium amarum	N	A	H
Helianthus annuus	N	A	H
Helenium autumnale	N	P	H
Helianthus sp. 1	U	U	H
Helianthus microcephalus	N	P	H
Helictotrichon sempervirens	I	P	G
Hemerocallis sp. 2	U	U	H
Hemerocallis sp. 3	U	U	H
Hemerocallis sp. 4	I	P	H
Hemerocallis fulva	I	P	H
Hemerocallis 'Great Expression'	U	P	H
Hemerocallis 'Orange Show'	I	P	H
Hemerocallis 'Piano Man'	I	P	H
Hesperis matronalis	I	B	H
Heuchera sp. 1	U	U	H
Heuchera hispida	N	P	H
Hibiscus sp. 1	I	P	S
Hieracium caespitosum	I	P	H
Hieracium sp. 1	U	U	H
Hieracium sp. 2	U	U	H
Holcus lanatus	I	P	H
Hosta fortunei	I	P	H
Hosta 'Ground Master'	I	P	H
Hosta 'Patriot'	I	P	H
Hosta 'Regal Splendor'	I	P	H
Hosta sieboldiana 'Francee'	I	P	H
Hosta undulata	I	P	H
Houstonia montana	N	P	H
Houstonia purpurea	N	P	H
Hydrangea arborescens	N	P	S
Hydrophyllum canadense	N	P	H

Note: N (native); I (exotic/introduced); A (annual); P (perennial); B (biennial); H (herbaceous); T (tree); S (shrub); G (grass); V (vine); (n=4 farms, n=4 subdivisions)

Table 5. Extended.

Species Name	Origin	Life	Growth
Hydrangea paniculata	I	P	S
Hydrangea quercifolia	N	P	S
Hydrangea serrata	I	P	S
Hypericum densiflorum	N	P	S
Hypericum mutilum	N	A	H
Hypericum perforatum	I	P	H
Hypericum punctatum	N	P	H
Ilex ambigua	N	P	T
Ilex decidua	N	P	T
Ilex verticillata	N	P	S
Ilex sp. 1 (cultivated)	I	P	S
Impatiens capensis	N	P	H
Impatiens pallida	N	A	H
Impatiens walleriana	I	A	H
Iris cristata	N	P	H
Iris pseudacorus	I	P	H
Iris sp. 1	U	U	H
Iris sp. 2	U	U	H
Iris sp. 3	U	U	H
Iris sp. 4	U	U	H
Iris sp. 5	U	U	H
Iris sp. 6	U	U	H
Iris sp. 7	U	U	H
Iris sp. 8	U	U	H
Iris sp. 9 (cultivated)	I	P	H
Iris sp. 10	U	U	H
Isotrema tomentosa	N	P	V
Itea virginica	N	P	S
Juglans nigra	N	P	T
Juncus acuminatus	N	P	G
Juniperus communis	N	P	H
Juncus effusus	N	P	G
Juniperus horizontalis	N	P	S
Juniperus sp. 1	U	U	S
Juncus marginatus	N	P	G
Juglans nigra	N	P	T
Juniperus scopulorum	I	P	T
Juncus tenuis	N	P	G
Kalmia angustifolia	N	P	S

Note: N (native); I (exotic/introduced); A (annual); P (perennial); B (biennial); H (herbaceous); T (tree); S (shrub); G (grass); V (vine); (n=4 farms, n=4 subdivisions)

Table 5. Extended.

Species Name	Origin	Life	Growth
Kalmia carolina	N	P	S
Kalmia latifolia	N	P	S
Krigia sp. 1	U	P	H
Krigia virginica	N	A	H
Kyllinga pumila	N	P	G
Lactuca canadensis	N	A	H
Lactuca saligna	I	A	H
Lactuca sativa	I	A	H
Lamiaceae 1	U	U	G
Lamium purpureum	I	A	H
Lamprocapnos spectabilis	I	P	H
Laportea canadensis	N	P	H
Leersia oryzoides	N	P	G
Leonurus cardiaca	I	P	H
Lepidium campestre	I	A	H
Lepidium virginicum	N	A	H
Lespedeza cuneata	I	P	S
Lespedeza thunbergii	I	P	S
Leucanthemum maximum	I	A	H
Leucanthemum vulgare	I	P	H
Lilium bulbiferum	I	P	H
Lilium sp. 1 (cultivated)	I	P	H
Lilium sp. 3 (cultivated)	I	P	H
Lilium sp. 2 (cultivated)	I	P	H
Lilium michauxii	N	P	H
Lilium ‘Olina’	I	P	H
Lilium superbum	N	P	H
Lindera benzoin	N	P	T
Linaria vulgaris	I	P	H
Liriodendron tulipifera	N	P	T
Lobelia cardinalis	N	P	H
Lobelia inflata	N	A	H
Lobularia maritima	I	A	H
Lobelia siphilitica	N	P	H
Lolium perenne	I	P	G
Lonicera japonica	I	P	V
Lunaria annua	I	B	H
Lupinus polyphyllus	N	P	H
Luzula acuminata	N	P	G

Note: N (native); I (exotic/introduced); A (annual); P (perennial); B (biennial); H (herbaceous); T (tree); S (shrub); G (grass); V (vine); (n=4 farms, n=4 subdivisions)

Table 5. Extended.

Species Name	Origin	Life	Growth
Lysimachia ciliata	N	P	H
Lysimachia quadrifolia	N	P	H
Magnolia acuminata	N	P	T
Maianthemum racemosum	N	P	H
Malus coronari	N	P	T
Malus pumila	I	P	T
Malva sylvestris	I	A	H
Melilotus officinalis	I	A	H
Melissa officinalis	I	P	H
Mentha spicata	I	P	H
Microstegium vimineum	I	A	G
Mimulus ringens	N	P	H
Mitchella repens	N	P	H
Monarda clinopodia	N	P	H
Monarda didyma	N	P	H
Monotropa uniflora	N	P	H
Muhlenbergia sp. 1	U	U	G
Muhlenbergia schreberi	N	P	G
Myosotis scorpioides	I	P	H
No vegetation	U	U	U
Nyssa biflora	N	P	T
Nyssa sylvatica	N	P	T
Ocimum basilicum	I	A	H
Oenothera biennis	N	B	H
Oenothera fruticosa	N	P	H
Oenothera sp. 1	U	U	H
Orchidaceae 1	U	U	U
Osmunda cinnamomea	N	P	H
Osmunda regalis	N	P	H
Ostrya virginiana	N	P	T
Oxalis stricta	N	P	H
Oxydendrum arboreum	N	P	T
Oxydendrum sp. 1	U	P	T
Oxypolis rigidior	N	P	H
Packera anonyma	N	P	H
Packera aurea	N	P	H
Packera obovata	N	P	H
Paeonia lactiflora	I	P	H
Panicum anceps	N	P	G

Note: N (native); I (exotic/introduced); A (annual); P (perennial); B (biennial); H (herbaceous); T (tree); S (shrub); G (grass); V (vine); (n=4 farms, n=4 subdivisions)

Table 5. Extended.

Species Name	Origin	Life	Growth
Panicum capillare	N	A	G
Panax quinquefolius	N	P	H
Parthenocissus quinquefolia	N	P	V
Pastinaca sativa	I	B	H
Paspalum setaceum	N	P	G
Persicaria pensylvanica	N	A	H
Phalaris arundinacea	N	P	G
Philadelphus inodorus	N	P	S
Phlox carolina	N	P	H
Phlox sp. 1	U	U	H
Phlox paniculata	N	P	H
Phlox pilosa	N	P	H
Phleum pratense	I	P	G
Phytolacca americana	N	P	H
Physocarpus opulifolius	N	P	S
Physostegia virginiana	N	P	H
Picea glauca	N	P	T
Picea rubens	N	P	T
Pieris japonica	I	P	S
Pilea pumila	N	A	H
Pinus strobus	N	P	T
Pinus sp. 1 (cultivated)	U	P	T
Piptochaetium avenaceum	N	P	G
Pisum sativum	I	A	V
Platycodon grandiflorum	I	P	H
Plantago lanceolata	I	P	H
Plantago major	I	P	H
Platanus occidentalis	N	P	T
Plantago rugelii	N	P	H
Platanthera sp. 1	U	U	H
Poaceae 1	U	U	G
Poaceae 2	U	U	G
Poaceae 3	U	U	G
Poaceae 4	U	U	G
Poaceae 5	U	U	G
Poaceae 6	I	P	G
Poaceae 7	U	U	G
Poaceae 8	U	U	G
Poaceae 9	U	U	G

Note: N (native); I (exotic/introduced); A (annual); P (perennial); B (biennial); H (herbaceous); T (tree); S (shrub); G (grass); V (vine); (n=4 farms, n=4 subdivisions)

Table 5. Extended.

Species Name	Origin	Life	Growth
Poaceae 10	U	U	G
Poaceae 11	U	U	G
Poaceae 12	U	U	G
Poaceae 13	U	U	G
Poaceae 14	U	U	G
Poaceae 15	U	U	G
Poaceae 16	U	U	G
Poaceae 17	U	U	G
Poa compressa	I	P	G
Poa pratensis	I	P	H
Poa sp. 1	U	U	G
Poa trivialis	I	P	G
Podophyllum peltatum	N	P	H
Polystichum acrostichoides	N	P	H
Polygonum aviculare	I	A	H
Polygonum capitatum	I	P	H
Polygonum cespitosum	I	A	H
Polygonum convolvulus	I	A	V
Polygonum cuspidatum	I	P	S
Polygonum hydropiper	I	A	H
Polygonum sagittatum	N	A	V
Polygonum scandens	N	P	V
Polygonum setaceum	N	P	H
Polygonum virginianum	N	A	H
Polygonum sp. 2	U	U	H
Populus deltoides	N	P	T
Portulaca oleracea	I	A	H
Potentilla norvegica	N	A	H
Potentilla recta	I	P	H
Potentilla simplex	N	P	H
Prenanthes altissima	N	P	H
Prunus americana	N	P	T
Prunus hortulana	N	P	T
Prunus sp. 1	U	P	T
Prunus serotina	N	P	T
Prunella vulgaris	N	P	H
Pulmonaria saccharata	I	P	H
Pyrus calleryana	I	P	T
Quercus alba	N	P	T

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Table 5. Extended.

Species Name	Origin	Life	Growth
Quercus coccinea	N	P	T
Quercus muehlenbergii	N	P	T
Quercus rubra	N	P	T
Quercus stellata	N	P	T
Quercus velutina	N	P	T
Ranunculus allegheniensis	N	P	H
Ranunculus hispidu	N	P	H
Ranunculus repens	U	P	H
Ranunculus sp. 1	U	U	H
Raphanus sativu	I	A	H
Rhododendron calendulaceum	N	P	S
Rhododendron catawbiense	N	P	S
Rhododendron sp. 1	U	P	S
Rhododendron sp. 2	U	U	S
Rhododendron sp. 3	I	P	H
Rhododendron maximum	N	P	S
Rhus glabra	N	P	T
Robinia sp. 1	U	U	T
Robinia pseudoacacia	N	P	T
Rosa sp. 1 (cultivated)	I	P	S
Rosa ‘Escapade’	I	P	S
Rosa multiflora	I	P	V
Rosa palustris	N	P	S
Rubus allegheniensis	N	P	S
Rubus argutus	N	P	S
Rubus bifrons	I	P	S
Rubus flagellaris	N	P	S
Rubus idaeus	I	P	S
Rubus occidentalis	N	P	S
Rubus phoenicolasius	I	P	S
Rubus sp. 2	U	P	S
Rubus sp. 3	U	P	S
Rubus sp. 4	U	P	S
Rubus sp. 5	U	P	S
Rubus sp. 6	U	P	S
Rubus sp. 7	U	P	S
Rudbeckia hirta	N	A	H
Rudbeckia laciniata	N	P	H
Rumex acetosella	I	P	H

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Table 5. Extended.

Species Name	Origin	Life	Growth
Rumex sp. 1	U	U	H
Rumex hastatulus	N	P	H
Rumex obtusifolius	I	P	H
Salix babylonica	I	P	T
Salvia guaranitica	I	A	H
Salvia lyrata	N	P	H
Salix nigra	N	P	T
Sambucus canadensis	N	P	S
Sanguisorba canadensis	N	P	H
Saponaria officinalis	I	P	H
Sassafras albidum	N	P	H
Sceptridium sp. 1	U	U	S
Schedonorus arundinaceus	I	P	G
Schoenoplectus tabernaemontani	N	P	G
Scirpus atrovirens	N	P	G
Scirpus cyperinus	N	P	G
Scirpus polyphyllus	N	P	H
Scleranthus annuus	I	A	H
Secale cereale	I	A	G
Securigera varia	I	P	V
Sedum 'Autumn Joy'	I	P	H
Sedum kamtschaticum	I	P	H
Sedum ternatum	N	P	H
Sedum sp. 1	U	U	H
Sempervivum tectorum	I	P	H
Senecio anonymus	N	P	H
Setaria parviflora	N	P	G
Silene latifolia	I	P	H
Silene vulgaris	I	P	H
Sisyrinchium angustifolium	N	P	H
Sisyrinchium mucronatum	N	P	H
Sisymbrium officinale	I	A	H
Smallanthus uvedalius	N	P	H
Smilax rotundifolia	N	P	V
Solidago altissima	N	P	H
Solanum carolinense	N	P	H
Solidago curtisii	N	P	H
Solidago gigantea	N	P	H
Solidago sp. 1	U	U	H

Note: N (native); I (exotic/introduced); A (annual); P (perennial); B (biennial); H (herbaceous); T (tree); S (shrub); G (grass); V (vine); (n=4 farms, n=4 subdivisions)

Table 5. Extended.

Species Name	Origin	Life	Growth
Solidago sp. 2	U	U	H
Solidago sp. 3	U	U	H
Solidago sp. 4	U	U	H
Solidago juncea	N	P	H
Solanum lycopersicum	I	A	H
Solidago nemoralis	N	P	H
Solidago roanensis	N	P	H
Solidago rugosa	N	P	H
Solanum tuberosum	I	P	H
Sonchus asper	I	A	H
Sorghum halepense	I	P	G
Spiraea japonica	I	P	S
Spinacia oleracea	I	A	H
Spiraea × vanhouttei	I	P	S
Spiranthes vernalis	N	P	H
Stachys byzantina	I	P	H
Stellaria corei	N	P	H
Stellaria graminea	I	P	H
Stellaria sp. 1	U	U	H
Stellaria media	I	A	H
Stellaria pubera	N	P	H
Streptopus lanceolatus	N	P	H
Styrax grandifolius	N	P	S
Symphyotrichum cordifolium	N	P	H
Symplocarpus foetidus	N	P	H
Symphyotrichum lateriflorum	N	B	H
Symphyotrichum novae-angliae	N	P	H
Symphytum officinale	I	P	H
Symphoricarpos orbiculatus	N	P	S
Symphyotrichum sp. 1	U	U	H
Symphyotrichum pilosum	N	P	H
Symphyotrichum prenanthoides	N	P	H
Symphyotrichum puniceum	N	P	H
Syringa vulgaris	I	P	S
Taraxacum officinale	I	P	H
Thaspium barbinode	N	P	H
Thuja occidentalis	N	P	T
Thymus vulgaris	I	P	S
Tiarella cordifolia	N	P	H

Note: N (native); I (exotic/introduced); A (annual); P (perennial); B (biennial); H (herbaceous); T (tree); S (shrub); G (grass); V (vine); (n=4 farms, n=4 subdivisions)

Table 5. Extended.

Species Name	Origin	Life	Growth
Tilia americana	N	P	T
Toxicodendron pubescens	N	P	S
Toxicodendron radicans	N	P	V
Tradescantia subaspera	N	P	H
Trifolium aureum	I	A	H
Trifolium campestre	I	A	H
Tridens flavus	N	P	G
Trifolium incarnatum	I	A	H
Trifolium pratense	I	P	H
Trifolium repens	I	P	H
Trillium simile	N	P	H
Tsuga canadensis	N	P	T
Tsuga caroliniana	N	P	T
Typha latifolia	N	P	H
Unknown 10 (cultivar)	I	U	S
Unknown 11 (dicot)	U	U	H
Unknown 12 (dicot)	U	U	H
Unknown 13 (dicot)	U	U	H
Unknown 14 (cultivar)	I	U	H
Unknown 15 (dicot)	U	U	H
Unknown 16 (dicot)	U	U	H
Unknown 17 (dicot)	U	U	H
Unknown 18 (dicot)	U	U	H
Unknown 19 (dicot)	U	U	H
Unknown 20 (dicot)	U	U	H
Uknown 21 (monocot)	U	U	G
Uknown 22 (monocot)	U	U	G
Uknown 23 (dicot)	U	U	H
Unknown 24 (dicot)	U	U	H
Unknown 25 (dicot)	U	U	H
Unknown 26 (dicot)	U	U	H
Unknown 27 (dicot)	U	U	H
Unknow 28 (monocot)	U	U	U
Unknown 29 (seedling)	U	U	H
Unknown 30 (seedling)	U	U	H
Unknown 31 (seedling)	U	U	H
Unknown 32 (seedling)	U	U	H
Unknown 33 (monocot)	U	U	H
Unknown 34 (monocot)	U	U	G

Note: N (native); I (exotic/introduced); A (annual); P (perennial); B (biennial); H (herbaceous); T (tree); S (shrub); G (grass); V (vine); (n=4 farms, n=4 subdivisions)

Table 5. Extended.

Species Name	Origin	Life	Growth
Unknown 35 (dicot)	U	U	H
Unknown 36 (monocot)	U	U	G
Unknown 37 (dicot)	U	U	H
Unknown 38 (dicot)	U	U	S
Unknown 39 (cultivated monocot)	I	U	S
Unknown 40 (monocot)	U	U	G
Unknown 42 (dicot)	U	U	H
Unknown 44 (dicot)	U	U	H
Unknown 45 (monocot)	U	U	G
Unknown 47 (monocot)	U	U	G
Unknown 48 (dicot)	U	U	H
Unknown 49 (monocot)	U	U	G
Unknown 50 (conifer)	I	P	S
Unknown 52 (cultivar)	I	A	H
Unknow 53	U	U	H
Unknown 54 (seedling)	I	A	H
Unknown 55 (cultivar)	I	A	H
Unknown 56 (seedling)	I	A	H
Unknown 1	U	U	H
Unknown 2 (dicot)	U	U	H
Unknown 4 (dicot)	U	U	H
Unknown 6 (dicot)	U	U	H
Unknown 7 (dicot)	U	U	H
Unknown 8 (dicot)	U	U	H
Unknown 9	U	U	S
Vaccinium corymbosum	N	P	S
Verbesina alternifolia	N	P	H
Vernonia gigantea	N	P	H
Verbena hastata	N	B	H
Vernonia noveboracensis	N	P	H
Veronica officinalis	I	P	H
Veronica persica	I	A	H
Verbascum thapsus	I	B	H
Verbena urticifolia	N	P	H
Veratrum viride	N	P	H
Viburnum nudum	N	P	H
Viburnum rhytidophyllum	I	P	S
Vicia sp. 1	U	U	H
Vicia villosa	I	A	V

Note: N (native); I (exotic/introduced); A (annual); P (perennial); B (biennial); H (herbaceous); T (tree); S (shrub); G (grass); V (vine); (n=4 farms, n=4 subdivisions)

Table 5. Extended.

Species Name	Origin	Life	Growth
Vinca major	I	P	V
Vinca minor	I	P	H
Viola sp. 1	N	P	H
Viola sp. 2	N	P	H
Viola primulifolia	N	P	H
Viola rotundifolia	N	P	H
Viola sagittata	N	P	H
Viola sororia	N	P	H
Viola striata	N	P	H
Viola tricolor	I	A	H
Viola wittrockiana	I	A	H
Vitis aestivalis	N	P	V
Vitis sp. 1	I	P	V
Vitis labrusca	N	P	V
Weigela floribunda	I	P	S
Xanthorhiza simplicissima	N	P	H
Zea mays	I	A	G
Zinnia violacea	I	A	H

Note: N (native); I (exotic/introduced); A (annual); P (perennial); B (biennial); H (herbaceous); T (tree); S (shrub); G (grass); V (vine); (n=4 farms, n=4 subdivisions)

BIOGRAPHICAL INFORMATION

Stephanie Laura Smith was born on August 27, 1982 and raised on a rural family farm in Wilkes County, North Carolina. Throughout her entire childhood, she enjoyed such pleasures as climbing trees, fishing and interacting with all the different animals on and around the farm. Maintaining this love for the outdoors and the natural surroundings, she would later pursue an educational path in ecological conservation.

Early in Stephanie's academic career, she sought ambitious paths that would help push her towards greater achievements. After traumatic injuries from a grease fire at the age of fifteen, she began homeschooling where she showed great motivation by directing and completing all high school requirements from eleventh to twelfth grade, while duel enrolled in college level courses at Wilkes Community College. In the fall of 2004, she enrolled in Appalachian State University to study environmental ecology, but soon realized her love for the geographic perspective and the following autumn, would switch her major to Geography. In May 2007 she was awarded the Bachelor of Science degree and graduated *Magna Cum Laude* from Appalachian State University. Within this same spring semester, she continued the ambitious academic trend and became the first undergraduate student in the Department of Geography and Planning to enroll in graduate level courses while maintaining a full undergraduate course load, working full-time, and being actively involved with honor societies such as Gamma Theta Upsilon Geographical Honors Society.

In the spring of 2007, she accepted a research assistantship in Geography at Appalachian State University and began study toward a Master of Arts degree, which she was awarded in May 2010. Throughout her graduate career, Stephanie achieved high honors by graduating *Suma Cum Laude* and received acceptance into Phi Kappa Phi National Honors Society. She was also awarded several honors and awards including the More Fellowship for Environmental Stewardship, Stephen Vacendak Graduate Fellowship in Geography and Julian Yoder Scholarship for Geography. She also served at the graduate student senator on behalf of the Department of Geography and Planning from 2008-2009.