THE MORPHOLOGY OF THE "WELL-DESIGNED CAMPUS": CAMPUS DESIGN FOR A SUSTAINABLE AND LIVABLE LEARNING ENVIRONMENT

by

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STATEMENT OF DISSERTATION APPROVAL

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ABSTRACT

This dissertation highlights the impact of campus form on certain university objectives, such as student satisfaction, learning outcomes, safety, and sustainability. I theorized the concept of the "Well-Designed Campus" from the current practice of campus planning and design in the United States of America, and I found significant association between certain dimensions of the "Well-Designed Campus" and the selected university objectives.

By analyzing 50 randomly selected university campus master plans in the United States, the top 10 objectives and 100 recommendations were extracted from the selected master plans. Four *big ideas* were distilled, based on the top 10 objectives: (1) From a commuter campus to a *convenient* campus; (2) from an isolated campus to a *contextual* campus; (3) from a fragmented campus to a *cohesive* campus; (4) from a brown campus to an *ecological* campus. In addition, from the top 100 recommendations, seven *morphological dimensions* of campus form were distilled: (1) land use organization (2) compactness (3) connectivity (4) configuration (5) campus living (6) greenness, and (7) context. Based on these dimensions, the "Well-Designed Campus"– the intersection of the four *big ideas*–is conceptualized as a mixed, compact, well-connected, well-structured, inhabited, green and urbanized campus.

I used Structural Equation Modeling (SEM) to evaluate the impacts of the "Well-Designed Campus," by modeling six outcome variables: (1) freshman retention

rate as a proxy for overall satisfaction with college life, (2) 6-year graduation rate as a proxy for learning outcome, (3) crime rate as a proxy for safety, (4) STARS as a proxy for sustainability, (5) students' commuting behavior, and (6) employees' commuting behavior. The statistical population was universities with high research activities in the United States of America. The hypothesized structural equation models displayed significant association between three campus form dimensions of *urbanism* (a composite variable from the three morphological dimensions of compactness, connectivity, and context), *greenness* and *campus living* with most of the outcome variables considering control variables. Moreover, the "Well-Designed Campus" can provide a theoretical framework for future empirical research on either accepting or rejecting common actions and policies related to campus design.

To my parents and my wife Mahsa

TABLE OF CONTENTS

LIST OF TABLES

Table

LIST OF FIGURES

Figure

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CHAPTER 1

INTRODUCTION

My dissertation research began from a curiosity, an interest, and a demand. Four university campuses, two in Iran and two in the United States, have been my home and sanctuary for the last 14 years. Looking back, I can clearly see how each university has enriched my life not just through academic education, but mainly through nonacademic experiences and background activities associated with college life. I have established friendships, developed social skills, and made numerous lasting memories. Of course, each university was unique. At Shahid Beheshti University, I found my lifetime friends sitting on campus grass. At the University of Tehran, I rediscovered my hometown finding all the "cool" places around the campus. In Ann Arbor, Michigan I felt what it means to be part of an academic community/village for the first time. And I will leave the University of Utah with the memory of its astonishing mountain views. Overall, I appreciate how each campus reinforces the unique quality of its institution, and I regret the presence of unfulfilled potentials. As an urban designer and planner, I'm curious to know more about the potential contributions of campuses to universities' eminence.

Evaluating urban design concepts with various analytical methods is my primary research interest. The application of spatial and GIS analysis techniques, typo-morphological approaches and statistical modeling tools for the creation and assessment of urban design conceptual frameworks is intriguing to me. This dissertation is an opportunity for me to perform an in-depth study of the interactions between analytical techniques and macroscale design concepts.

Campus design can be applied to both microscale (specific college and university projects) and macroscale designs (organizing the campus, or campus sector, as a functional and visual unit). Campus designers used to follow a few macroscale ideas or formal typologies before World War II, such as the quadrangle, Beaux-Arts, pastoral/picturesque, or a hybrid of these types. With the unprecedented expansion of university campuses in the United States of America in the post-WWII era, the main focus of campus leaders was towards individual buildings rather than master plans. Today, the result of that practice is the fuzziness of the big picture of contemporary campus design. The lack of a macroscale design idea and concentration on individual buildings produced drive-through, sprawling, fragmented, and isolated campuses (Coulson et al., 2010; Turner, 1984). Some may argue that with the complexity and diversity of modern universities' challenges, missions, and policies, it is less relevant to think about a common "big idea" for campus master plans. To some extent, that may be true. However, for practitioners, the main advantage of knowing about the common "big ideas" is to be more conscious and cautious about adopting or rejecting one of these design norms. And for campus scholars, it can provide a theoretical framework to assess the impacts of common practice.

Ultimately, the purpose of this research is to propose and evaluate the concept of the "Well-Designed Campus" as the overlap of various macroscale design concepts for creating a sustainable and livable learning environment. My dissertation research has two main stages (see Figure 1.1): (1) hypothesis making - qualitative approach, (2) hypothesis testing - quantitative approach. In the first stage, I conceptualized a normative theory from current campus planning and design practice and introduced the concept of the "Well-Designed Campus." In the second stage, I assessed the impact of the proposed macroscale design concept on the desired outcomes, such as overall student satisfaction, learning environment, safety and sustainability.

I started this research by visiting various great university campuses in the United States of America and reviewing relevant literature on the subject, which helped me refine my research question. The next step was the content analysis of 50 randomly selected campus master plans in the United States. I extracted the top common objectives and most frequent recommendations from the selected campus master plans. From the most frequent recommendations, I conceptualized seven macroscale morphological dimensions for university campuses: (1) Land use organization: How mixed is the distribution of sport, research, residence, and different academic facilities? (2) Compactness: the degree of campus density and relative proximity of buildings; (3) Connectivity: the degree of street network connectivity within the campus and to the surrounding area; (4) Configuration: the strength of campus spatial organization; (5) Campus living: the degree of on campus living; (6) Greenness: the degree of naturalness/greenness; and (7) Context: the degree of urbanism of the surrounding area.

From a literature review, I confirmed the importance of the seven morphological dimensions for campus quality. Also, from the literature review I operationalized morphological dimensions, and selected six outcome variables: (1) freshman retention rate as a proxy for overall satisfaction with college life,[1] (2) graduation rate as a proxy for

[1] About one in three 1st-year students won't make it back for sophomore year. The reasons range from personal problems and loneliness to academic struggles and expenses (Roberts, & Styron, 2010).

learning environment, (3) crime rate as a proxy for safety, (4) sustainability rate/STARS as a proxy for sustainability, (5) students' commuting behavior, and (6) employees' commuting behavior.

For the hypothesis testing phase, I measured seven morphological dimensions for 103 university campuses with high research activities in the United States (the total population is 206, according to the Carnegie classification 2010). I measured five dimensions quantitatively, but had to rate two dimensions – *Land use organization* and *Configuration* – qualitatively. My hypothesis (based on the current campus design practice) is that a mixed, compact, well-connected, well-structured, inhabited, green, and urbanized campus is a "Well-Designed Campus." Using Structural Equation Models, I modeled the four outcome variables in terms of the measured morphological dimension and an overall campus-score while considering control variables.

1.1 Purpose

Designers and planners believe that design matters and plans are helpful. That is why campus master plans, generally, recommend a set of design and planning actions to fulfill university goals and objectives as higher education institutions. The review of different campus master plans demonstrates undeniable similarities among their recommendations. However, the validity of the proposed recommendations has not been tested. Most publications about campus planning/design are by practitioners (Chapman, 2006; Coulson, Roberts & Taylor, 2010; Dober, 1996; Kenney, Dumont, & Kenney, 2005; Toor, & Havlick; 2004) and few academic studies verify the default assumptions of campus planning practice. As Dober (1996) observed, "Lacking an organized body of research or theory, campus planning is likely to be continued on a pragmatic basis" (p. 12). This research is an attempt to provide a theoretical framework for evaluating common "big ideas" in contemporary campus planning and design practice.

1.2 Research Questions

Main question:

- What are the principal features of contemporary university campus planning and design, and when implemented, are they correlated with university objectives such as student success and satisfaction, and campus safety and sustainability?

Other questions:

- What are the most common challenges, objectives, and recommendations in the campus master plans of the U.S.?
- How can the physical form of university campuses best be analyzed?
- How can the research universities be rated and ranked based on their campus quality?

1.3 Literature Review

1.3.1 Campus Planning and Design in the United States

The roots of campus planning and design go back to medieval Europe (see Coulson et al., 2010; Dober, 1996; Turner, 1984), but it was mainly in America where modern university campuses evolved. One of the significant periods in the evolution of campus form was when Thomas Jefferson, the third president of the United States and founder of the University of Virginia, embraced ideals of the Enlightenment and wanted to express these same sentiments of freedom and openness of mind through the built form of a university campus. The traditional quadrangles and built form of the universities found in the United Kingdom and Europe were reformed by architects and planners in the United States (Turner, 1984). American architects and planners adopted certain architectural styles and features from European and Oxbridge models; however the visual presence of the buildings – their connection with the landscape, a university's mission, and its connection with the broader community – were designed so as to communicate a symbolic departure from English aristocratic and medieval ways of thought (Steinmetz, 2009).

The evolution of campus form is a continuous process, and in each era it faces its unique challenges. Today, throughout North America, college and university campuses have experienced growth in numbers of students, staff, and faculty over the last 40 years. Per capita automobile use and ownership have increased significantly to the point where almost every urban campus faces serious impacts from car traffic and parking shortages. Discrete boundaries between the university and the neighborhood can create an isolated campus. Unaffordable housing can make students commute long distances. A low density campus, low quality of housing, inappropriate zoning, hostile town and gown relationships, reputation as a "party school," social injustice, the shifts in learning practices and in the global education market are also potential threats to university campuses (Chapman, 2006; Coulson, Roberts, & Taylor, 2010; Coulson, Roberts, & Taylor, 2014; Dober, 1996; Kenney et al., 2005; Mitchell & Vest, 2007; Strange & Banning, 2001; Turner, 1984).

Campus projects can address this wide range of problems and concerns in different ways. Coulson, Roberts, and Taylor (2014) discuss "trends" in contemporary campus design. These trends are adaptive reuse of buildings and facilities, starchitecture, hub buildings, interdisciplinary science research buildings, commercial urban development, large-scale campus expansions, and revitalizing master plans. This research will be focused on the last of these. Master plans express the idea or vision of institution, guide growth and change, and reinforce the strategic plan (Dober, 1996). Therefore, the scope of campus plans can be vast and diverse. But according to Kenney, Dumont, and Kenney (2005) a comprehensive campus plan should follow these nine principles:

- Giving precedence to the overall plan over individual buildings and spaces
- Using compactness (density) and mixing campus uses to create vitality and interaction
- Creating a language of landscape elements that expresses the campus's individuality and relationship to its regional context
- Embracing environmental considerations
- Taming the automobile
- Utilizing campus architecture to further placemaking
- Integrating technology
- Creating a beneficial physical relationship with the neighborhood
- Bringing meaning and beauty to the special places on campus

In the next chapter, the hypothesis making phase, I will show which of these principles are more commonly used in master plans and how practitioners address them.

1.3.2 Educating by Design

Can the physical form of universities help universities achieve their missions and objectives? The influence of physical environment on academic and nonacademic objectives of universities is an established research topic among higher education and environmental psychology scholars (Boyer, 1987; Cox & Orehovec, 2007; Griffith, 1994;

Jessup-Anger, 2012; Long, 2014; Pope et al., 2014; Schuetz, 2005; Strange & Banning, 2001; Temple, 2008; Thelin & Yankovich, 1987). The physical form of campuses is often among the most important factors in creating a positive first impression of an institution among prospective students (Boyer, 1987; Griffith, 1994; Stuner, 1973; Thelin & Yankovixh, 1987). The basic layout of the campus, the quality of open spaces, the accessibility of parking lots, and the design of buildings, such as residence halls, libraries, or student unions, can shape initial attitudes in subtle ways.

The impact of physical environment on behavior can be conceptualized as possibilism or probabilism (Lang, 2005). The physical environment can be the source of opportunities or can impact the probability of certain behaviors. For example, the presence of a convenient and attractive gathering space within the core of campus enhances the opportunity for students to socialize on campus; or having sport facilities far from campus can decrease the probability of the facilities being used. Strange and Banning (2001) argue that "although features of the (campus) physical environment lend themselves theoretically to all possibilities, the layout, location, and arrangement of space and facilities render some behaviors much more likely, and thus more probable, than others" (p. 56).

The impact of university campus design can be understood by examining the campus from the view point of a pedestrian (Banning, 1993). A good campus not only provides a safe, convenient, and pleasurable walk for pedestrians, but also adds "sense of inclusion," "sense of place," and "learning" to the walking experience (Strange & Banning, 2001). For example, crossing an active quadrangle, or a plaza can create an opportunity for students to socialize and feel the sense of belonging and inclusion (Banning & Bartels, 1993). Harmony in the architectural design of buildings and the landscaping of campus can enhance the “sense of place.” In addition, a legible campus spatial structure can increase the probability of students becoming engaged in various intellectual activities across the campus. Perhaps locating the main library on the main pedestrian pathway with a welcoming entrance can encourage students to enter the library and use its resources. However, among the many methods employed to foster learning, the use of physical environment is perhaps the most neglected aspect.

1.3.3 Measuring University Quality

To identify common measures of universities’ quality, I conducted a literature review. This literature review helped me select measurable and valid outcomes and control variables for the hypothesis testing phase. Brooks (2005) classified the assessment of university quality in three research areas: reputation, faculty research, and student experience. The most widely cited and the first reputational study was in 1925 by the president of Miami University of Ohio, which was the ranking of the 38 top Ph.D.-granting institutions out of the 65 institutions at that time (Hughes, 1925).

Many contemporary reputational assessments are in the form of rankings and ratings designed by commercial media, driven by profit motives. U.S. News and World Report is one of the private institutions that produces college rankings every year. Their ranking is mainly based on the survey data coming from the colleges and universities themselves. Their other sources of data include (1) the American Association of University Professors (faculty salaries), (2) the National Collegiate Athletic Association (graduation rates), (3) the Council for Aid to Education (alumni giving rates) and (4) the U.S. Department of Education's National Center for Education Statistics (information on financial resources, faculty, SAT and ACT admissions test scores, acceptance rates and graduation and retention rates). Table 1.1 shows their ranking model indicators, their weights and input factors. Other commercial rating systems, such as College Factual, use very similar variables in their ratings.

Brooks (2005) classified all student experience measures into four main categories: program characteristics, program effectiveness, student outcomes, and student satisfaction. The last category can be better linked with students' campus life experiences. One of the most comprehensive research studies in this field has been conducted by the Indiana University Center for Postsecondary Research. Partnering with the Carnegie Foundation for the Advancement of Teaching and the Association of American Colleges and Universities, they annually conduct the National Survey of Student Engagement (NSSE). NSSE measures the extent of student engagement with faculty, with each other, and with their studies in educationally effective activities. Unfortunately, it is not possible to use this dataset in this research because, under the terms of their institutional participation agreement, institutionally identified data cannot be provided to other researchers.

Pike (2004) has found that NSSE data do not have a strong relationship to U.S. News rankings, indicating that student impressions of their educational experiences vary irrespective of institutional characteristics. That can also suggest that cross-institutional comparisons of survey data, such as NSSE, must be made with caution, since students may have different expectations of different institutions.

University quality is a growing topic in the economics literature. Existing studies of the effects of university quality on wages typically rely on few proxy variables for university quality (Bacolod et al., 2009; Belfield et al., 2011; Black et al., 2005; Black & Smith 2004; Black & Smith, 2006; Daniel et al. 1997; Fitzgerald & Burns, 2000; Long, 2008; Monks, 2000; Zhang, 2005). In this field of research, university quality measurement typically includes three aspects of quality: student selectivity, faculty resources, and students' satisfaction. The most common variables to estimate these aspects (factors) are faculty-student ratio, rejection rate, freshman retention rate, mean SAT score, and mean faculty salaries (Bacolod et al., 2009; Belfield et al., 2011; Black & Smith 2004; Black et al., 2005; Black & Smith, 2006; Daniel et al. 1997; Fitzgerald & Burns, 2000; Monks, 2000; Long, 2008; Zhang, 2005).

The only available data on campus sustainability are from the Sustainability Tracking and Assessment Rating System (STARS). STARS is "a transparent, self-reporting framework for colleges and universities to measure their sustainability performance" (STARS website, stars.aashe.org). STARS was developed by the Association for the Advancement of Sustainability in Higher Education (AASHE). STARS participants pursue credits and may earn points in order to achieve a STARS Bronze, Silver, Gold or Platinum rating. The rating criteria are organized into four categories: Academics, Engagement, Operations, and Planning and Administration. Since STARS launched in 2010, 406 institutions have submitted STARS reports. About 40% of them are doctoral institutions in the United States of America. From the total participants, 8% of institutions choose not to participate in the rating; 22% earned Bronze, 49% Silver, and 21% Gold ratings.

Measuring university qualities is not an easy task, but as described, different proxy variables have been used for this purpose. However, quantifying physical campus qualities has no precedent in the literature. In the next chapter, through the content analysis of 50 campus master plans, I theorized seven morphological dimensions of campus form that can contribute to a “Well-Designed Campus.” This would be an essential step for measuring campus qualities.

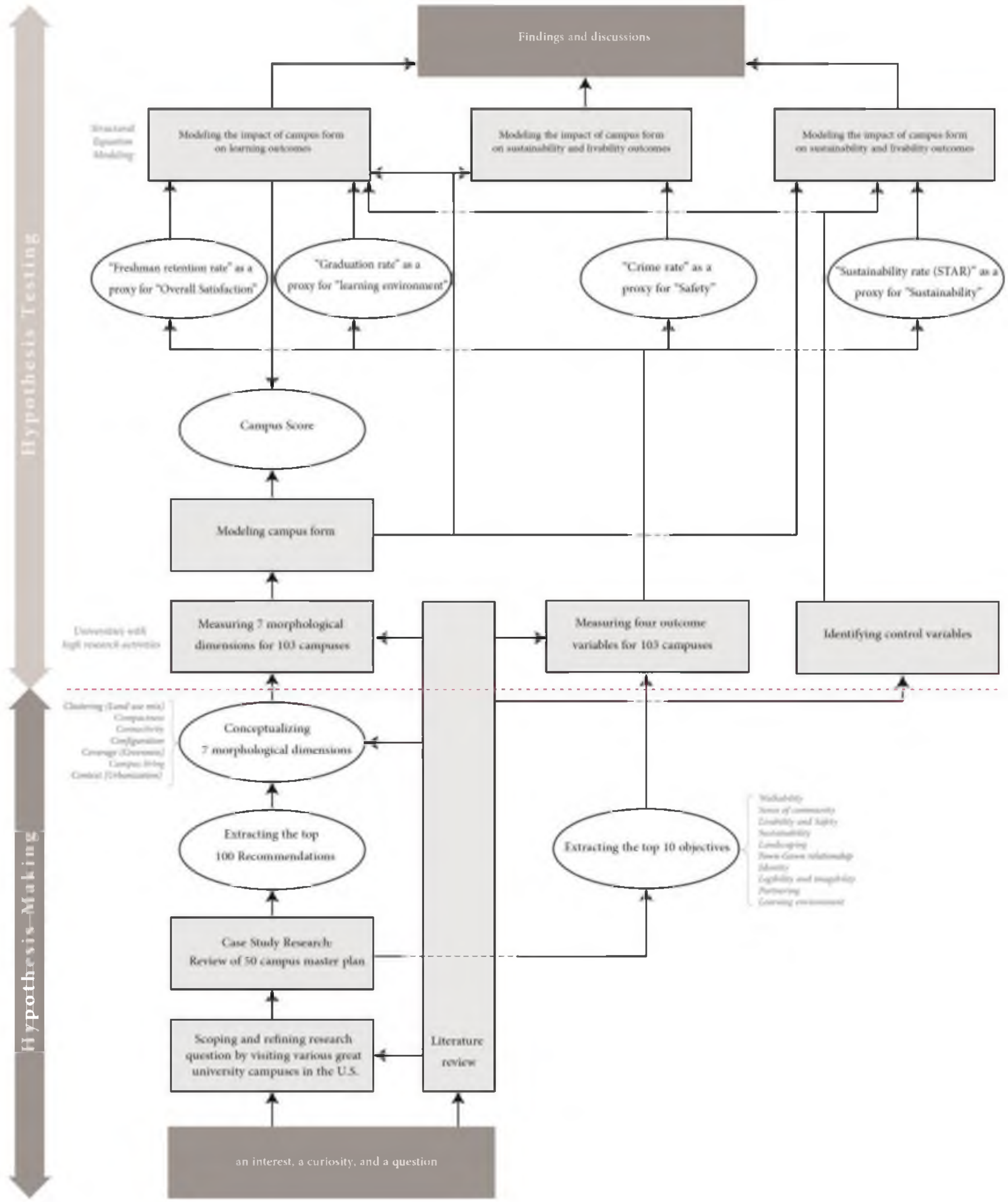

Figure 1.1 Research flowchart

Table 1.1 US News and World Report ranking model indicators and input factors[2]

Indicator	Description	Weight	Input factors	Weight
Undergraduate academic reputation	The academic peer assessment survey to account for intangibles at peer institutions, such as faculty dedication to teaching.	0.225	Reputation peer survey	1
Retention	The higher the proportion of freshmen who return to campus for sophomore year and eventually graduate, the better a school is apt to be at offering the classes and services that students need to succeed.	0.225	6-year graduation rate	0.8
			freshman retention rate	0.2
Faculty resources	Research shows that the more satisfied students are about their contact with professors, the more they will learn and the more likely they are to graduate.	0.2	the proportion of classes with fewer than 20 students	0.3
			the proportion with 50 or more students	0.1
			the average faculty pay, plus benefits[3]	0.35
			the proportion of professors with the highest degree in their fields	0.15
			the student-faculty ratio	0.05
			the proportion of faculty who are full time	0.05

[2] Summarized table from http://www.usnews.com/education/best-colleges/articles/2014/09/08/how-us-news-calculated-the-2015-best-colleges-rankings?page=1

[3] Adjusted for regional differences in the cost of living using indexes from the consulting firm Runzheimer International

Table 1.1 Continued

Indicator	Description	Weight	Input factors	Weight
Student selectivity	A school's academic atmosphere is determined in part by the abilities and ambitions of the students.	0.125	the SAT and the composite ACT score	0.65
			the proportion of enrolled freshmen at National Universities and National Liberal Arts Colleges who graduated in the top 10% of their high school classes	0.25
			the acceptance rate, or the ratio of students admitted to applicants	0.1
Financial resources	Generous per-student spending indicates that a college can offer a wide variety of programs and services.	0.1	the average spending per student on instruction, research, student services and related educational expenditures	1
Graduation rate performanc e	The effect of the college's programs and policies on the graduation rate of students after controlling for spending and student characteristics, such as test scores and the proportion receiving Pell Grants	0.075	The difference between a school's 6-year graduation rate for the class that entered in 2007 and the predicted rate for the class.	1
Alumni giving rate	This reflects the average percentage of living alumni with bachelor's degrees who gave to their school, which is an indirect measure of student satisfaction.	0.05	Alumni giving rate	1

CHAPTER 2

HYPOTHESIS-GENERATING

2.1 The Content Analysis of Campus Master Plans

> "No two campuses are alike, nor would we want them to be. The genius loci of the U.S. campus is embodied in the enormous variety of geographic, cultural, and climatic circumstances in which campuses have evolved." (Chapman, 2006, p. 30)

If each campus is unique, should we expect unique recommendations on their campus plans as well? Or should we expect some level of similarity between the challenges, objectives and recommendations? To answer this question, I reviewed 50 university campus master plans. They have been selected randomly through a web search for the keywords of "university campus master plan."[4] I had two criteria for selecting my case:

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[4] Selected universities are Auburn University, Boise State University, Brown University, Bucknell University, Carnegie Mellon University, Clemson University, Coastal Carolina University, Cornell University, Drexel University, Duke University, Indiana University, Kansas State University, Lehigh University, Longwood University, Princeton University, Purdue University at Calumet, Purdue University at West Lafayette, Radford University, South Dakota State University, Southern Oregon University, Stanford University, University of Alaska at Anchorage, University of California at Berkeley, University of Colorado at Boulder, University of Delaware, University of Illinois at Chicago, University of Iowa, University of Maine, University of Massachusetts at Amherst, University of Memphis, University of Michigan, University of New Hampshire, University of North Carolina at Charlotte, University of North Florida, University of Richmond, University of South Alabama, University of South Carolina, University of Tennessee, University of Texas at Arlington, University of Texas at Austin, University of Utah, University of Vermont, University of Washington at Seattle, University of Wisconsin at La Crosse, University of Wisconsin at Milwaukee, Valparaiso University, Villanova University, Wake Forest University, Western Illinois University, and Yale.

(1) The master plan should be produced in 2000 or later, and (2) the challenges, objectives and recommendations should be clearly stated. Table 2.1 and 2.2 show some characteristics of the selected universities. Of the selected universities, 72% are public; 28% are land-grant universities; 72% are located in an urban setting. The campuses range in size from 77 to 17,000 acres, with a median size of 550 acres. The master plans for these universities were last updated and adopted in 2010, on average.

The survey shows that there are significant similarities between universities in terms of challenges, objectives, and recommendations. This doesn't mean that generic recommendations are acceptable; it just indicates that despite all the differences, universities share related challenges and objectives. This review shows that the top challenges for university campuses are:

1. Deficits in square footage.
2. Diminished quality of buildings and educational facilities, and infrastructure.
3. Disconnected campus from its context and students' life (Placelessness).
4. Drive-through campus (uninterrupted parking areas and pedestrian unfriendly environment).
5. Poor quality of landscape.
6. Potential threat or recovering from a natural disaster.
7. Deficits in land (for potential growth).

This finding shows that almost all campuses have to solve their "deficits in square footage," but only two have "deficits in land" as a main challenge (see Figure 2.1). Remarkably, although 72% of these campuses are in urban settings, they still have enough space on campus for additional infill projects. The other finding is that four of these challenges (2 to 5), are about the *quality* of infrastructure, buildings, landscaping, and campus open spaces. However, *quality* is such a broad term and needs to be operationalized.

Looking at the common objectives of master plans can better define which qualities are more likely to be at the center of campus planners/designers' interest. The most common objectives in the reviewed campus plans are:

1. Walkability: Redefining the movement systems throughout the campus to be functional, safe, and legible.
2. Sense of community: Reinforcing a sense of community within campus by encouraging student engagement in campus activities and inspiring learning and collaboration outside the classroom.
3. Livability and safety: Expanding student housing and providing quality physical facilities and a healthy and secure environment.
4. Environmental sustainability: Planning and building in an environmentally sustainable manner.
5. Landscaping: Preserving and strengthening the identity of the campus with its natural features and maintaining a high quality memorable landscape.
6. Town-gown relationship: Integrating the campus with the surrounding neighborhoods.
7. Identity: Strengthening the identity of the campus as a continuously evolving environment while respecting campus history.
8. Imageability: Creating a memorable and beautiful campus.

9. Partnering: Partnering with private developers and communities to support local and regional prosperity and secure the University's financial future.
10. Learning environment: Cultivating a learning environment that supports intellectual curiosity, academic achievement, interdisciplinary research, and teaching and personal growth.

Figure 2.2 shows the frequency of each objective in the reviewed campus plans. At first, it is unexpected to see *walkability* and *sense of community* on the top and cultivating *learning environment* at the bottom of this list. However, two reasons can be imagined for this ranking. First, these objectives are not totally independent. For example, to create a better learning environment, we can promote livability and sense of community on campus. In other words, some objectives can be nested in the others. Second, there are not many physical interventions in a campus environment that can directly address learning outcomes. Therefore, promoting *walkability*, for example, can be more practical than improving *learning* through campus planning.

Appendix A lists the 100 most common recommendations in the reviewed campus plans. These recommendations are categorized based on the common objectives in campus plans. Instead of categorizing based on the 10 most common objectives, I used nine categories. "Learning environment" is not used as a category, because of its overlap with other objectives. Figure 2.3 shows the share of each objective from the top 100 recommendations, and the total number of recommendations repeated in all 50 master plans which is 2,508 cases. For example, the number of recommendations addressing *environmental sustainability* is only 7 out of 100; however, the frequency of these recommendations in all cases is much higher. 13% of all recommendations in all 50 master plans (326 from 2,508) addressed environmental sustainability. In contrast, 20 out of 100 recommendations are about making a livable and safe campus, while the frequency of these recommendations is only 11% in all master plans. It shows that universities may have more homogenous strategies to address environmental sustainability issues than how to make a livable and safe environment.

Partnering and *town-gown relationship* cover only 10% of total recommendations. This does not necessarily mean that campus planners place a lower weight on these objectives. It can simply be due to the smaller number of known physical interventions to meet these objectives. Also in reality, there is not a discrete boundary between different objectives. For example, adding more on campus housing is clearly about increasing the livability of campus, but it can also increase *the sense of community* and *walkability* on campus. Therefore, for conceptualizing the "big ideas" of current campus design practice, highly overlapped objectives can be combined into a broader construct.

2.2 Four "Big Ideas" in Campus Design

Four big ideas for the transformation of campus form can be distilled, based on the top objectives: : (1) *Convenient Campus*, (2) *Contextual Campus,* (3) *Cohesive Campus,* (4) *Ecological Campus*.

2.2.1 From Commuter Campus to Convenient Campus

The focus of each concept is mainly on one aspect of campus planning/design. Improving the *sense of community*, *livability, safety*, and *walkability* of the campus are all functional objectives of campus planning/design that can be categorized under the theme of *convenient campus*. A convenient campus is where students want to spend their time.

The campus is not just their school, but for most of them, it is also their home, their hangout place, and their playground. In summary, convenient campus is a convenient place to live, work, socialize, and learn. Figure 2.4 illustrates some of the most common recommendations in campus master plans for creating a convenient campus.

The campus of University of Michigan in Ann Arbor is a good example for showing both a convenient and an inconvenient campus (see Figure 2.5). North Campus and Central Campus are the two main campuses for the University of Michigan in Ann Arbor. The Central Campus is embedded inside the city. It is a dense, pedestrian friendly campus, with many housing options inside and close to the campus. It has a mixed land uses and very active public spaces. In contrast, North Campus, which is the newer campus, is an 800-acre campus with very low density and very few active open spaces. Also, there are many surface parking areas on campus which makes it an auto-oriented environment.

2.2.2 From Isolated Campus to Contextual Campus

Partnering with city and private developers and improving the relationship of the university with its surrounding neighborhood are the social and economic aspects of campus planning, highlighting the significance of campus context. Contextual campus is campus that is integrated well to the surrounding socio-economic and built environment fabric. As shown in Figure 2.3, there are fewer recommendations in campus master plans about how to create a contextual campus. However, Figure 2.6 illustrates the most common approaches in this regard.

Achieving a contextual campus is highly dependent on the policy of university administration in regards to partnering with the community, City, and private developers, and also on the socioeconomic characteristics of surrounding community. However, the physical campus can also be planned and designed in such a way that it either promotes or weakens the potential interactions between campus and its context.

For example, the central campus of Yale University like the central campus of University of Michigan is embedded inside a small city. The spatial structure of campus is the natural extension of New Haven's spatial structure. Its public spaces are highly accessible for the surrounding community, and also the retail services of neighborhood are very accessible for campus residents. In contrast, New Mexico State University is surrounded by highways, and therefore deprived of meaningful interaction with the "outside world" (see Figure 2.7).

2.2.3 From Fragmented Campus to Cohesive Campus

The physical and more artistic goals of campus planning/design are improving the legibility, imageability and identity of campus. This set of objectives can create the third theme of transformation termed *cohesive campus*. Cohesive campus is similar to what Chapman (2006) described as "a designed place, deliberately conceived by its builders to impart a distinct aesthetic effect," (p. 67) or "the campus as a work of art" (p. 4). Traditionally a big portion of campus master plans has focused on this aspect by establishing design guidelines and design codes. Figure 2.8 illustrates the most common recommendations in this regard.

Because of the rich history of campus design and planning in the U.S., there are many good examples of *cohesive campus* all around the country. University of Washington in Seattle is one of them (see Figure 2.9). The main asset of the campus is its well-designed spatial structure that has beautifully organized the entire campus. Moreover, the well-designed sequence of spaces leads to a pleasant walk on campus. The other significant features of campus are the legible and memorable courtyards and plazas, sophisticated view corridors, and elegant buildings. Even though the entire campus is not designed with the same standards, the dominant parts of the campus maintain these qualities. The University of Utah has a similar story with one difference. The well- structured part of the campus is much smaller than the rest of it. Although the historical core of the campus is well-organized, the expansion of campus does not follow a strong and cohesive plan. The spaces between buildings are not designed and connected efficiently and aesthetically; therefore, the campus, with more than 30,000 students, lacks active open spaces.

2.2.4 From Brown Campus to Ecological Campus

The last theme of transformation is about making an ecological campus through the principles of sustainability and landscape design. Some of the most common recommendations are illustrated in Figure 2.10.

There are many similarities in universities' sustainability strategies, at least on the official master plans. For example, Princeton University has three sustainability principles: (1) reduce campus gas emissions; (2) improve natural resource conservation; and (3) foster civic engagement (Beyer Blinder Belle Architects & Planners, 2008). These strategies are repeated in many master plans with a sustainability chapter. What makes a campus an ecological campus is its way of localizing global strategies, which do not just increase the feasibility of the proposed strategies, but can also act as a place-making strategy.

In the case of Princeton, the most significant ecological feature is its beautiful landscape. Although the campus looks and feels very green (see Figure 2.11), the university invests significantly in renewing the campus landscape with these four principles: (1)

invent within the traditional pattern of campus-making; (2) translate the typography into campus form; (3) reassert the presence of the woodland threshold; (4) anticipate the impact of increased land management and environmental pressures (Beyer Blinder Belle Architects & Planners, 2008). With this investment, Princeton not only maintains its unique asset (the landscape), it can address a range of sustainability objectives such as promoting walking and biking on campus, improving water quality through green storm water management systems, creating a student run organic garden, and preserving the biodiversity of natural and cultivated landscapes.

2.3 Well-Designed Campus

Can we extract a single macroscale design concept from the current practice of campus planning/design? The first step to hypothesize such a construct, termed a "Well-Designed Campus," is identifying the attributes of campus form (morphological dimensions) that are claimed to have impact on the most common objectives of campus planning and design.

I conceptualized the morphological dimensions from the most common campus master plan recommendations. I also confirmed the significance of these concepts by reference to the campus design literature. These morphological dimensions are:

(1) Land Use Organization: the degree to which sport, research, residence, and different academic facilities are mixed. Common campus recommendations for this attribute are:

- Integrating academic and research activities in shared facilities,
- Recognizing distinct communities of disciplines,

- Intensifying the overlap and magnitude of campus workplace, residential, and activities
- Relocating low-intensity land uses like athletic fields, greenhouses and barns from the campus core.

According to Kenny et al. (2005), the social, academic, and fiscal benefits of mixing campus uses include: 1) increased collegiality and community, 2) enhanced learning, 3) safety, 4) competitive admissions, and 5) flexibility for growth. Kenny et al. (2005), however, mention three factors that work against the idea of mixed use campus: 1) desire for organizational clarity, 2) academic competition and the drive for program identity, 3) separate ownership of facilities.

(2) Compactness: the density of campus and proximity of buildings. The idea of a compact campus can be very controversial, especially for those institutions that admire their pastoral campus. However, compactness is frequently encouraged by practitioners with recommendations such as:

- Locating as many university functions as possible on or close to the center of campus (without compromising the highly valued open space),
- Limiting expansion and using infill development where possible,
- Emphasizing close relationships and short travel times between related programs to encourage cross-disciplinary collaboration.

Kenny et al. (2005) argue that the "physical compactness allows students and faculty to walk more easily from one place to another, encouraging interaction and community, and reinforcing a sense of place and institutional identity" (p. 105).

(3) Connectivity: the degree of street network connectivity within campus and between campus and the surrounding area. Connectivity is frequently encouraged by practitioners with recommendations such as:

- Developing new paths, walks and passages to provide clear pedestrian routes and shorten distances between key activities and destinations;
- Creating (linear) (green) corridors to connect different parts of campus such as river fronts, boulevards, or mixed streets or main pedestrian pathways;
- Developing strong physical connections between the neighborhoods and the campus;
- Providing additional campus entries (with identifiable gateways that reflect a similar character and composition).

Street network connectivity can have an impact on the walkability of campus, the sense of community within campus, and the town-gown relationship.

(4) Configuration: the strength of campus spatial structure. There are various recommendations in this regard:

- Emphasizing constructing new buildings along the main spatial structure of campus,
- Creating semienclosed space, with many entrances,
- Creating a focal point at the end of the pedestrian axis,
- Placing towers and other prominent building elements at the ends of key streets and prominent view corridors,
- Providing changes in scale and design of outdoor rooms to emphasize passage between different spaces on campus,

- Undertaking a series of open space projects to help clarify pedestrian routes;
- Creating a hierarchy of open spaces, from formal to informal, from large to small,
- Preserving and enhancing views to and from character defining features.

A campus with weak spatial structure has buildings that were designed as essentially free-standing objects. In contrast, a campus with strong spatial structure has buildings that were visualized as being situated in some larger and articulated setting. Not all buildings need to have great architecture, but they can all be part of a great campus. There is no aesthetic rule that fits all campuses. The campus plan can be formal or informal. The campus may have various architectural styles. However, the campus should be designed and planned as a unified whole. Organizing the spatial structure of campus is a common place-making strategy.

(5) Campus living: the degree of on campus living. The most common recommendations in this regard are:

- Increasing residential housing on campus,
- Instead of creating purely residential districts, mixing them with multidisciplinary academic facilities and having them in the core campus,
- Broadening and diversifying housing options on campus.

The "living and learning" concept has always been present in higher education institutions. Yet, the essence of "living and learning" has evolved from just homing bachelor teenagers far from home to more specialized types of housing such as Mary Hufoord Hall, Texas Women's University, a traditional dormitory reconstructed for family housing, serving single mothers with children (Dober, 1996). Campus living has not only been impacted by demographic changes on higher education, but also new pedagogical strategies and new students' expectations encouraging new types of on campus housing. Increasing on campus housing can have impact on learning, livability, the sense of community, and also campus sustainability by reducing students' commutes.

(6) Greenness: the degree of naturalness/greenness. Some of the most common recommendations to bring and preserve nature on campus include:

- Landscaping to create lively open spaces,
- Preserving park-like setting of campus,
- Providing generous landscape setbacks and moats between buildings and city streets,
- Breaking parking lots with (native) trees to create more manageable parking rooms and to perform ecological functions,
- Integrating the native vegetation within future campus landscape development.

Coulson et al. (2010) explain that "recognized both for its beauty and uplifting potency, *nature* became one of the most compelling considerations in the location and planning of American colleges in the nineteenth-century… the natural environment was popularly held as beneficial to students' wellbeing and moral character" (p.13). Considering campus as a 'green rural neighborhood' is still a popular notion among many university leaders. Although there is no doubt about the benefits of naturalness and greenness on campus, this factor competes with some other important objectives such as compactness and clustering. It is critical to find a balance between these competing objectives.

(7) Context: the degree of urbanism in the surrounding area. Common recommendations in this regard include:

- Forming an alliance with the City to create a mixed-use campus town along a street corridor,
- Responding to community partnership opportunities, including: student convocation centers, student dining, student unions, theaters, and alumni centers,
- Encouraging private development and investment,
- Considering campus as a destination for the public.

This dimension, unlike the other six, is not subject to design by university planners. In other words, this dimension is beyond the control of campus designers. However, locating in an urban setting versus a rural setting may provide certain opportunities, such as city and community partnerships. Having a vital neighborhood close to campus can increase students' satisfaction with their college life (see Harr, 2011). Also, urban campuses may have more chance for applying sustainability principles (see Gilderbloom & Mullins, 2005). On the other hand, safety can be an issue for urban campuses (see Bradley, 2009; Etienne, 2012).

In Figure 2.12, I have illustrated all seven morphological dimensions with the related campus classifications to clarify these concepts. Based on these morphological dimensions, I will theorize the "Well-Designed Campus" as a campus that is (1) mixed, (2) dense, (3) well-connected, (4) well-structured, (5) inhabited, (6) green, and (7) urbanized. The hypothesis is that the "Well-Designed Campus" supports a sustainable, livable learning environment.

Table 2.1 General description of the selected cases for the hypothesis making phase

Public universities	72%
Land Grant university	28%
Urban setting	72%
Master plan by private consultant	80%

Table 2.2 Characteristics of the selected cases for the hypothesis making phase

	Minimum	Maximum	Median
Student number	3,655	43,426	16,750
Campus area	77	17,000	550
Established year	1701	1969	1873
On campus living	6%	92%	36%
Year of master plan	2000	2013	2010

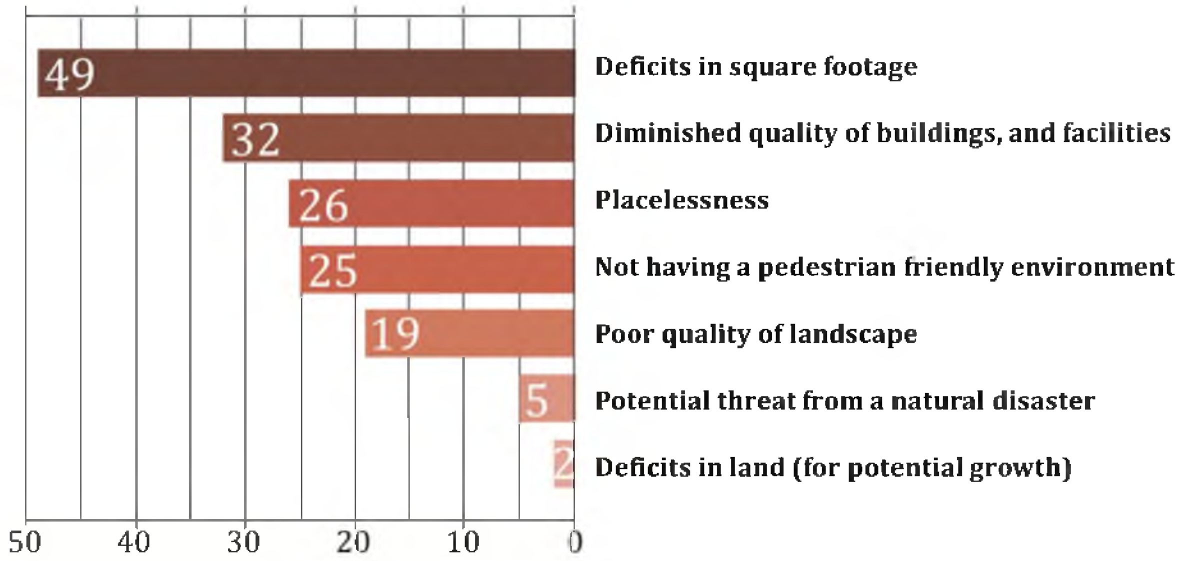

Figure 2.1 The top challenges in front of university campuses

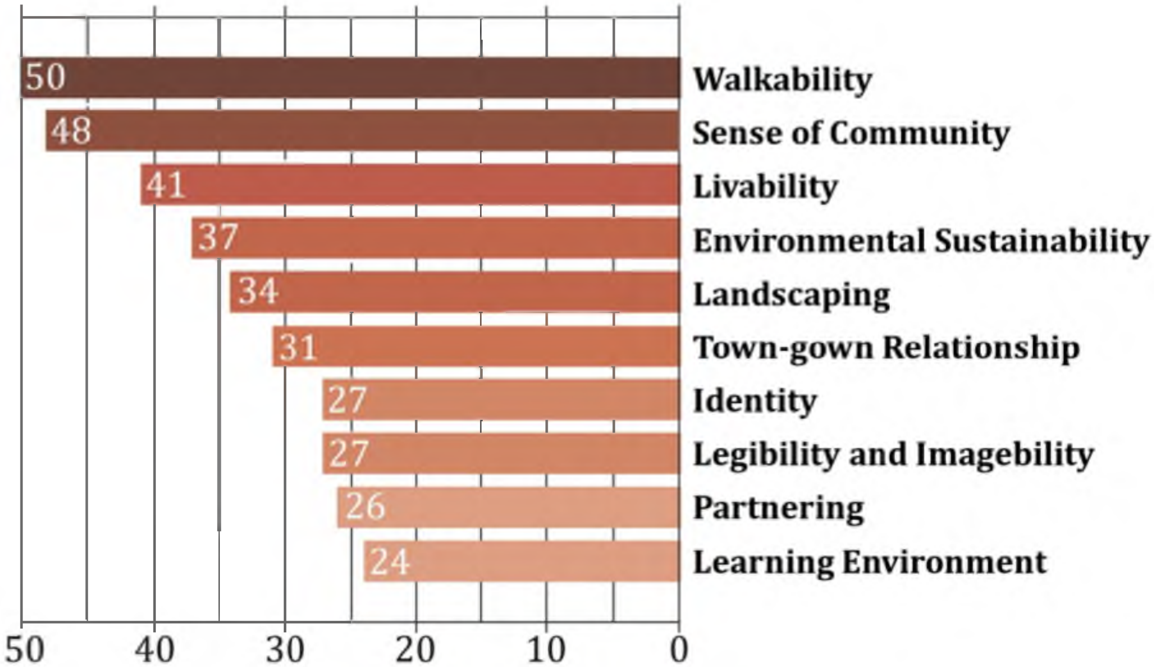

Figure 2.2 Ten most common objectives in the reviewed campus plans

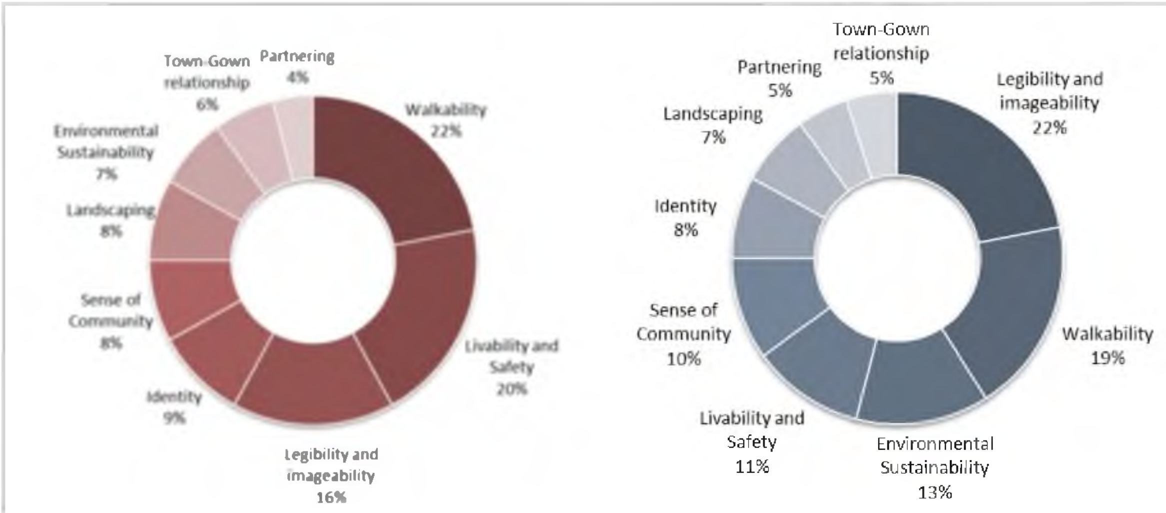

Figure 2.3 The share of each objective from the top recommendations. Left: The share of each objective from the top 100 recommendations; Right: The share of each objective from the total number of recommendations repeated in all cases

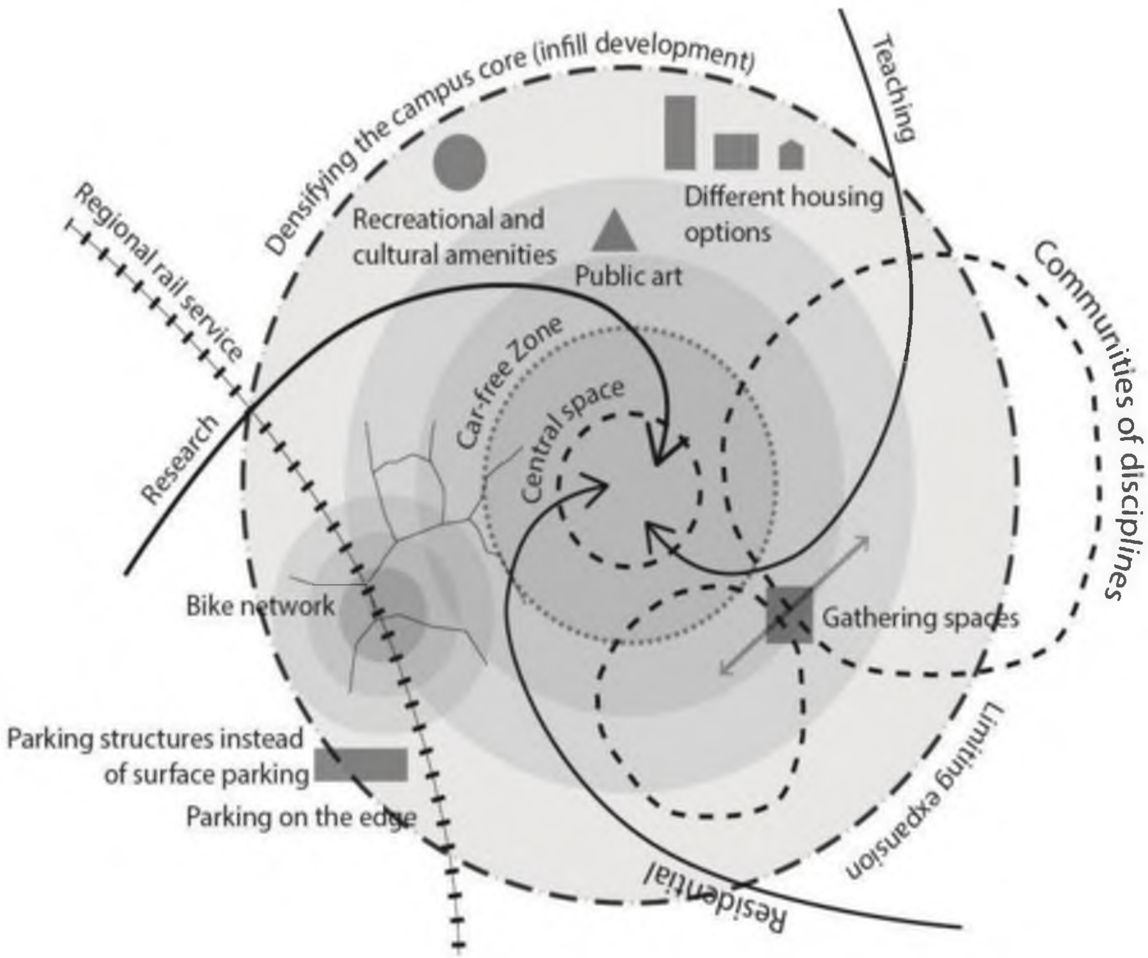

Figure 2.4 Design concept of convenient campus

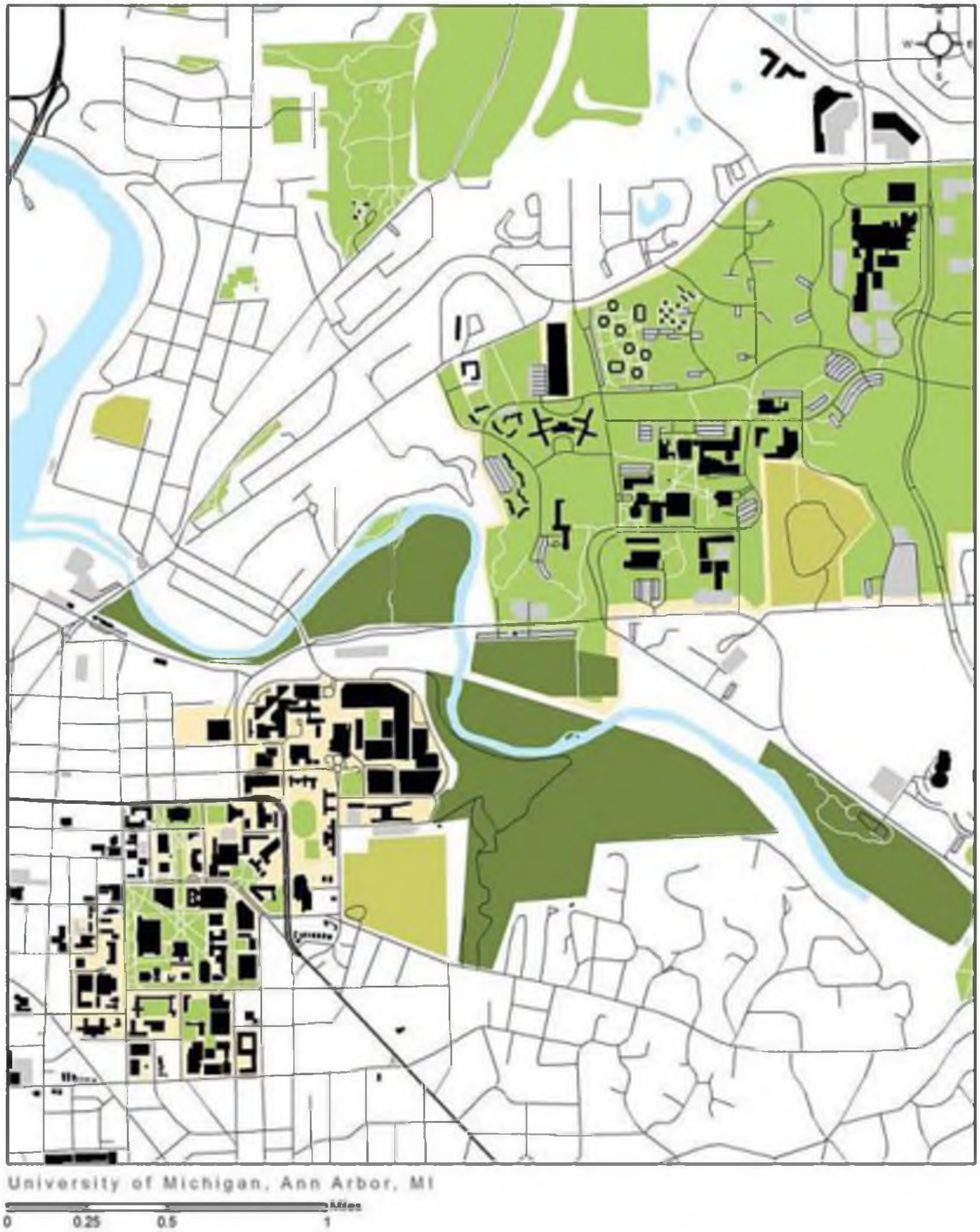

Figure 2.5 University of Michigan, Ann Arbor. North Campus is north of the river and Central Campus is south of the river

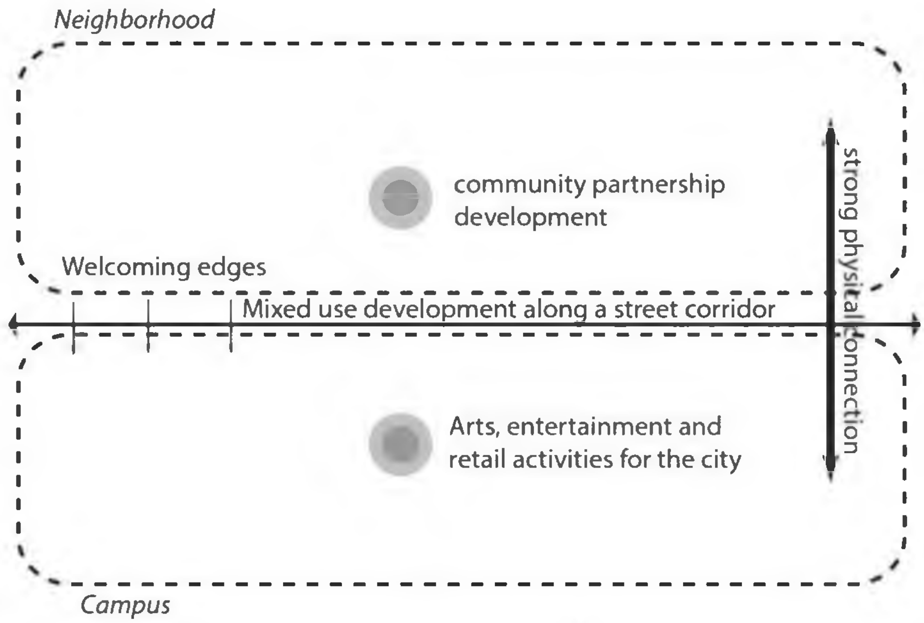

Figure 2.6 Concept diagram of contextual campus

Figure 2.7 Campus map. Left: Yale University; Right: New Mexico State University

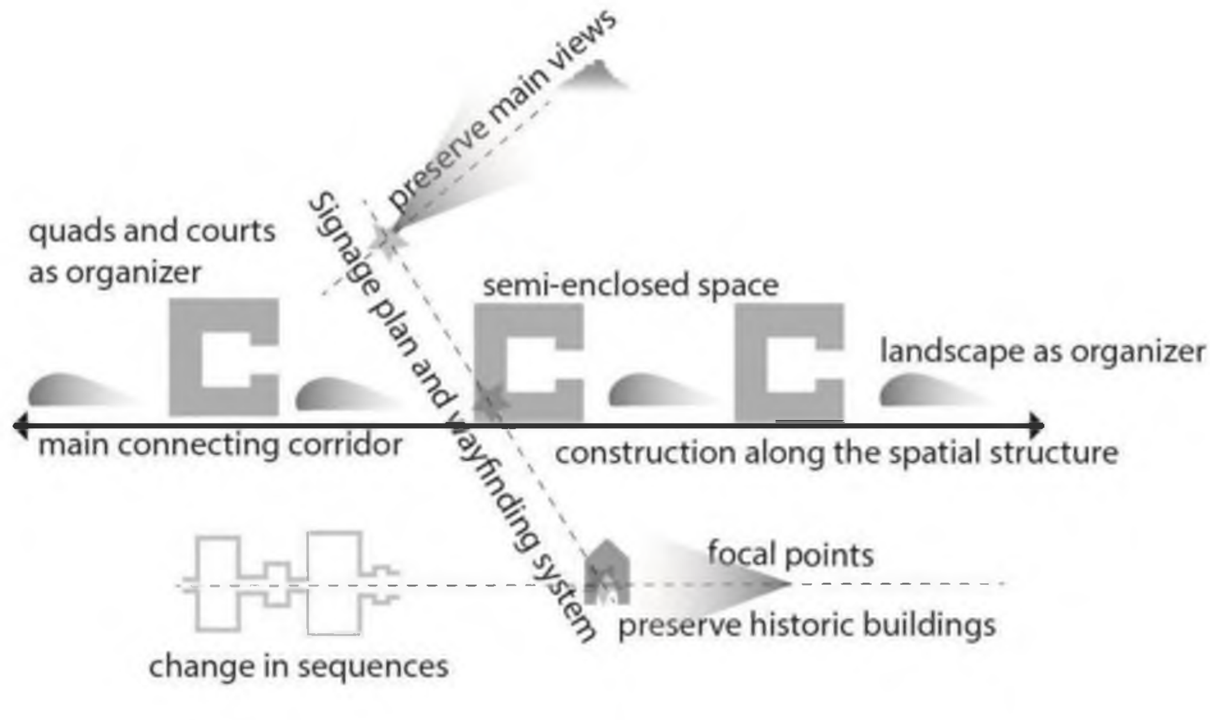

Figure 2.8 Concept diagram of cohesive campus

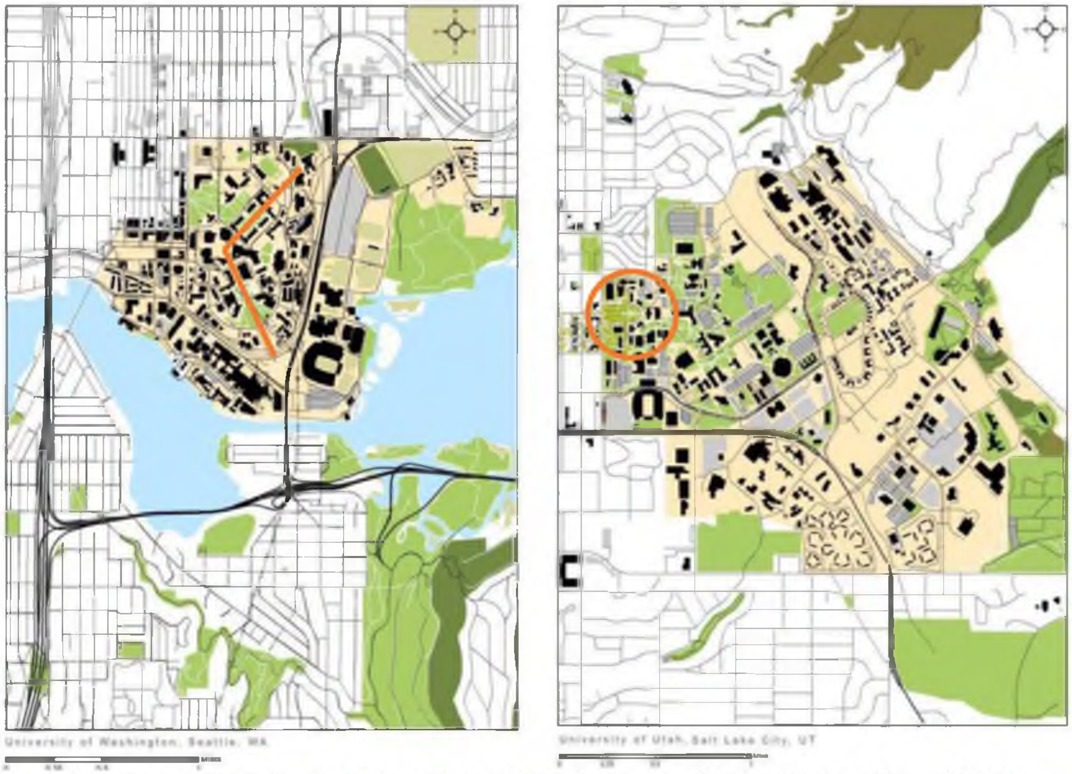

Figure 2.9 Campus map. Left: University of Washington; Right: University of Utah

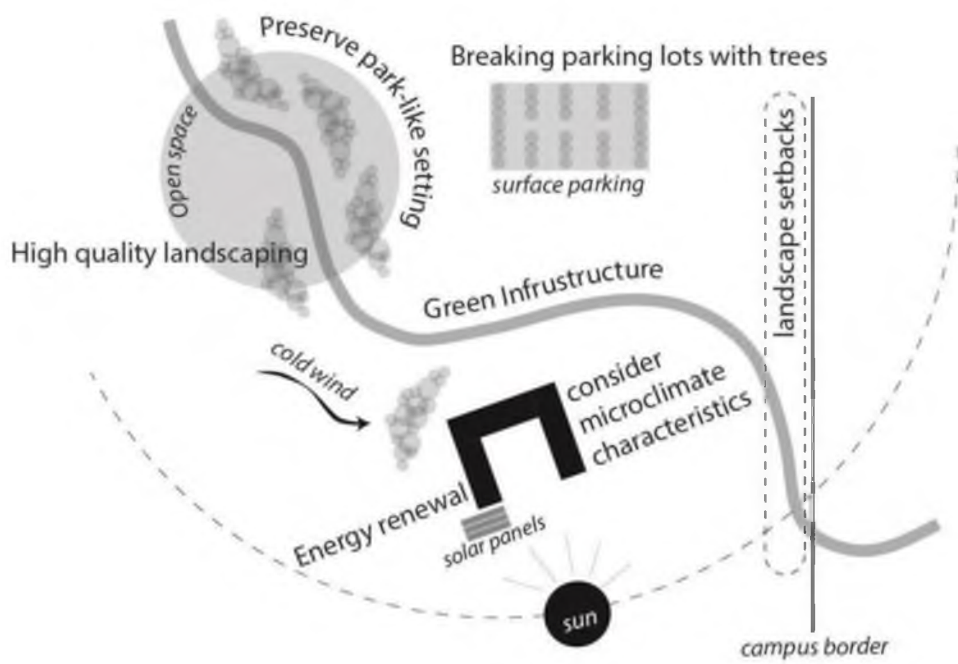

Figure 2.10 Concept diagram of ecological campus

Figure 2.11 Princeton University

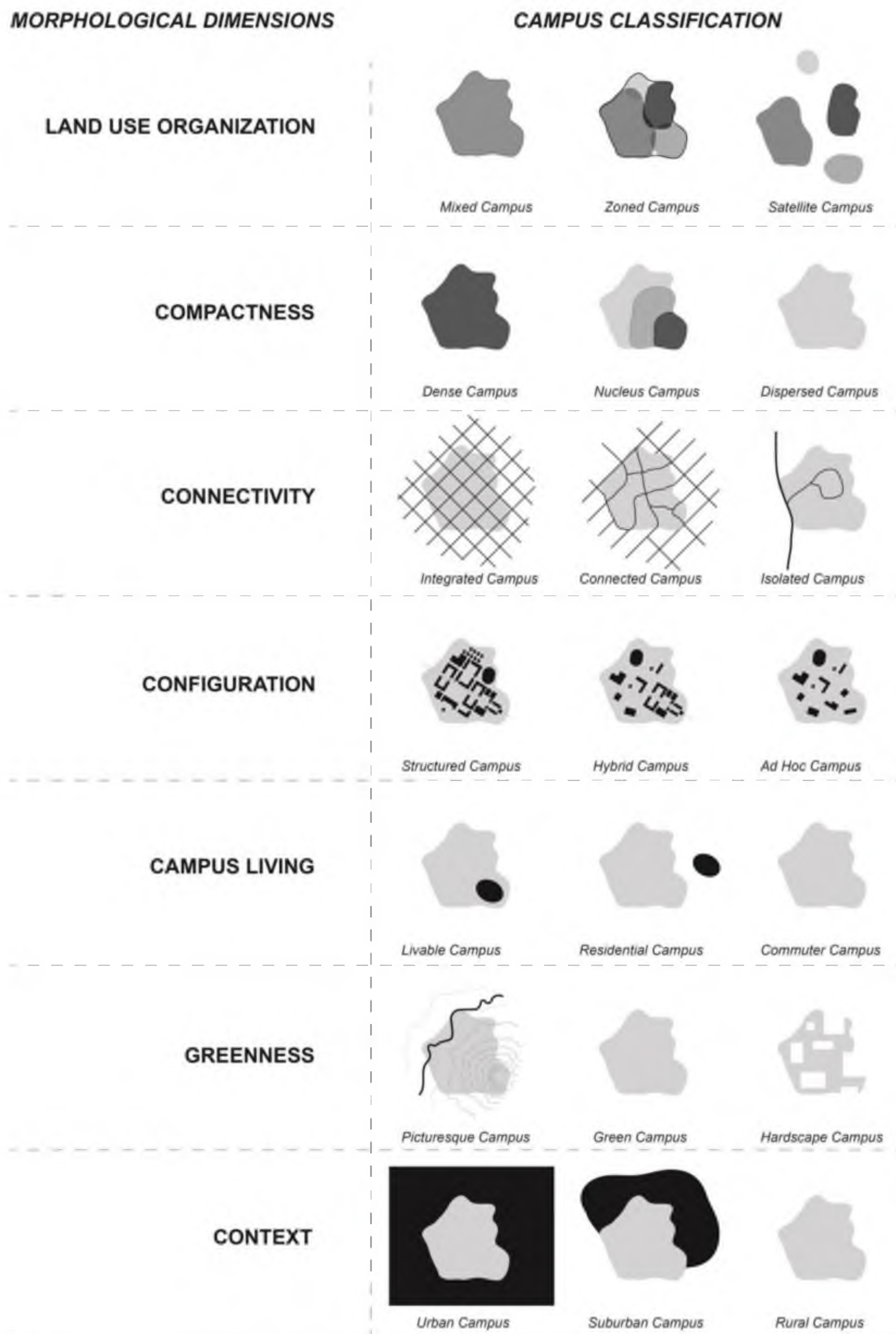

Figure 2.12 Morphological dimensions of university campus

CHAPTER 3

HYPOTHESIS-TESTING

3.1 Methodology

To test my hypothesis, I modeled certain qualities of universities such as students' satisfaction, learning outcome, safety, and sustainability in terms of the campus morphological dimensions, accounting for a set of control variables.

3.1.1 Sample

This research is on universities in the United States with *high* or *very high* research activities according to the 2010 Carnegie Classification. The total number is 206 universities. I randomly selected 103 campuses for this research, stratified by census regions: Northeast, South, Midwest, and West and their type: Research I (very high research activity), and Research II (high research activity). Universities that have more than one campus and whose campuses are formally very different were not selected. The University of Michigan in Ann Arbor was the only case with this quality in the sample, and therefore, it was replaced by another university.

Table 3.1 describes the selected sample. On average, the total enrollment in 2013 was 24,809 students, and the campus size is 797 acre. The median founding year is 1875, and 76% are public universities.

3.1.2 Data and Measures

I operationalized the morphological dimensions of campus as described in Table 3.2. Five dimensions were operationalized quantitatively with one or more variables. However, I had to rate two, land use organization and configuration, qualitatively. To test the reliability of qualitative measures, two persons rated 40 campuses according to the described principles at Table 3.2. I used intraclass correlation coefficients (ICCs), representing the ratio of between-group variance to total variance of counts, to test for interrater reliability.

The first step for measuring morphological dimensions is mapping the figure-ground of all 103 campuses in ArcGIS. I used the base-maps of OpenStreetMap in ArcGIS to map main physical features, such as building footprints, campus boundary, surface parking, pitches, paths and roads. I refined the maps according to the Google Earth images to increase the accuracy of the base-maps. I used spatial statistic tools in ArcGIS, Space Syntax software (for more information on Space Syntax see Hillier and Hanson, 1984; Hillier, 2007), and other techniques (described in Table 3.2) to measure morphological dimensions. Overall, creating different analytical maps for each campus was the fundamental stage in measuring morphological dimensions of campus. These maps were produced for all 103 cases. As examples, the analytical maps of 20 universities are presented in the appendix (see Figure B.1 to B.60).

Table 3.3 shows endogenous (outcome) variables and their data source. The underlying assumption is that the physical form of the campus can affect these outcomes, after controlling for other influential variables. I used the common proxy variables in the literature to quantify the chosen outcome variables. Freshman retention rate is a proxy for student satisfaction with college experience, and 6-year graduation rate is a proxy for learning outcomes (Belfield et al., 2011; Black et al., 2005; Black & Smith 2004; Black & Smith, 2006; Daniel et al. 1997). The total on campus crimes divided by total enrollment is a proxy for safety (Fisher & Sloan, 2014; Fox & Hellman, 1985; Hughes, 2011; Sloan, 1994). And the STARS rating is a proxy for campus sustainability (Fonseca et al. 2011; Saadatian et al., 2011; Wigmore & Ruiz, 2010). I also investigated the impact of campus form on students and employees' community behavior through six variables: The percentage of institution's students/employees[5] who walk, bicycle, or use other nonmotorized means as their primary means of transportation; the percentage of institution's students/employees who commute with only the driver in the vehicle (excluding motorcycles and scooters) as their primary means of transportation; and the percentage of institution's students/employees who take a campus shuttle or public transportation as their primary means of transportation.

Table 3.4 shows the control variables that I considered in testing the hypothesis. For quantifying the quality of universities, I took into account *student selectivity* and *university resources*. As proxy variables, I used the most common measures in the literature, which are *percentage of classes with fewer than 20 students*, *the average faculty pay*, and *the average SAT score* (Belfield et al., 2011; Black & Smith 2004; Black et al., 2005; Black & Smith, 2006; Daniel et al. 1997). To control for institutional characteristics, I considered seven variables: *age of university*, *campus size*, *research type* (Research I=1, Research II=0); *university type* (dummies for Public, Private for-Profit, Private not-for-

[5] As separate variables

profit); *enrollment profile classification* from Carnegie Classification 2010; *percentage of undergraduate enrollment*; and *average total indebtedness of 2013 graduating class* from US News and World Report to control for affordability of institutions.

I also considered three variables to control for the contextual differences among universities: The *median household income* 2009-2013 at city level from Census Bureau to control for socioeconomic status of cities; *heating and cooling day index* from NOAA's National Climatic Data Center to control for climate; and crime rate of cities in 2013 from FBI, Uniform Crime Reports.

3.1.3 Research Steps and Analytical Methods

The hypothesis testing phase has three main steps in this research: first, computing the seven morphological dimensions of 103 university campuses and data collection of outcome and control variables; second, using Structural Equation Modeling (SEM) to identify the interactions among the morphological dimensions; third, using SEM to evaluate the influence of campus form on the desired outcomes.

All the analytical methods used at step one have been explained in Table 3.2. The only method that requires further elaboration is Space Syntax technique for connectivity dimension. After a brief description of Space Syntax technique, I will present a brief definition of Structure Equation Modeling (SEM) and its application to this research.

3.1.3.1 Space Syntax

Space syntax is a set of theories and techniques for measuring the spatial configuration of street networks. By focusing on street networks rather than buildings or parcels to describe the built environment, space syntax analysis considers spatial properties of physical space (Hillier, 2007). The basic element in space syntax is the street segment between intersections, which can be derived from road center line data with the help of Depthmap software, developed by Space Syntax Limited (Turner, 2007). The street segments can be translated into a graph, in which segments and their connections turn into nodes and links. Based on this topological representation, space syntax uses two different definitions of the distance between each segment and its neighbors, and calculates two measures. Two distance definitions are: 1) metric-based, “the distance in meters between the center of a segment and the center of a neighboring segment”; and 2) geometric-based: “the degree of the angular change of direction between a segment and a neighbor” (e.g., right angle turn is counted as 1 turn; 45 degree angle is counted as 0.5 turn, and so on.) (Hillier, 2009, p. 3). Shortest path maps can be generated using the metric definition of distance, and least angle change maps can be generated using the geometrical definition. The most commonly used space syntax measure is known as *integration*, which measures how close each segment is to all others under each definition of distance (Hillier, 2009, p. 3). This measure can be analyzed at a local scale or global scale. The radius of locality, which is the number of turns departing from each segment, can also be computed in either geometric or metric distance. In case of a geometric radius of 3, for instance, only 3 complete turns are counted departing from each street segment.

There are few morphological studies on university campuses using Space Syntax measures, and correlating them to campus safety, vitality, and even sustainability (da Silva and Heitor, 2014; Greene & Penn, 1997; Thilagam, 2015; Yaylali-Yildiz et al., 2014). However, previous studies mostly relied on one case study. Therefore, these findings should be generalized with caution. To the best of my knowledge, this dissertation has one of the largest sample sizes in Space Syntax studies. To be consistent with the body of literature, I used one of the most common measures, *the geometric integration measure with radius of 3*, which is shown to be positively correlated with pedestrian movement (see Hajrasouliha & Yin, 2014; Hillier & Iida, 2005).

3.1.3.2 Structural Equation Modeling

I used Structural Equation Modeling to test my hypothesis. In the field of urban planning, this statistical technique is becoming more popular (Aditjandra et al. 2012; Cao et al., 2007; Cervero & Murakami, 2010; De Nisco & Warnaby, 2014; Ewing et al., 2014a; Ewing et al., 2014b; Liu, 2012; Liu & Shen, 2011; Martinez et al. 2011; Marzbali et al., 2012; Rutt & Coleman, 2005), because it can account for complex interrelationships among variables where some variables are both cause and effect. Byrne (2010) explained the term structural equation modelling based on two important aspects of the procedure:

> (a) that the causal processes under study are represented by a series of structural (i.e. regression) equations, and (b) that these structural relations can be modelled pictorially to enable a clearer conceptualization of the theory under study. The hypothesized model can then be tested statistically in a simultaneous analysis of the entire system of variables to determine the extent to which it is consistent with the data. If goodness-of-fit is adequate, the model argues for the plausibility of postulated relations among variables; if it is inadequate, the tenability of such relations is rejected. (p. 3)

Figure 3.3 shows the causal path diagram of one of the SEM models that were estimated in this research. Causal paths are represented by straight lines with an arrowhead pointing from the cause toward the effect. Curved lines with arrowheads at both ends represent correlations. Rectangles represent observed variables. Ovals represent latent variables: variables that are not measured directly, but are estimated in the model from several measured variables. Some latent variables, such as *Campus Living,* have only one predictor, so practically these latent variables equal their sole predictors. I could have dropped those latent variables and directly connected observed measures to endogenous variables, but I have decided to keep them only for illustrative purposes to reflect the structure of my conceptual diagram.

3.2 Results

3.2.1 Morphological Measures

I measured the seven morphological dimensions of 103 campus universities with high research activities though 13 variables. Basic descriptive statistics−mean and standard deviation−show morphological differences among universities based on their region and type of institution.

3.2.1.1 Land Use Organization

Table 3.5 shows that on average the land use organization value of our sample is 6.5 from the scale of 1 to 10. The most organized campuses are northeast Research I universities with the mean of 7.4 and the least organized campuses are northeast Research II universities with the mean of 5.6. Overall, results show that university campuses are organized based on the same principles with mixed uses at the core of campus, with the major athletic fields, greenhouses, barns and surface parking areas at the periphery. The biggest difference among campuses is how integrated the on campus housing and research facilities are to the main campus. The interrater reliability test (see Table 3.6), shows that this measure is reliable. I used a two-way mixed effects model where people effects are random and measure effects are fixed. The intraclass correlation coefficient of interrater reliability is .865 which is above the acceptable threshold of .7.

3.2.1.2 Compactness

Table 3.7 shows that on average the mass-space proportion of campuses is 1 to 4. In other words, around 20% of campus grounds are covered with buildings. In addition, on average, around 10% of campus grounds are covered with surface parking areas; 24% of campus grounds are covered with pervious open spaces; and the average nearest distance between campus buildings is 236.90 feet.

Table 3.7 also indicates that the Research I universities at Northeast region have the densest campuses with around 25% mass density, 193 ft. building proximity, and less than 6% surface parking areas. The Research II universities at South region are the most sprawling campuses with around 17% mass density, 281 ft. building proximity, and 14.5% surface parking areas. The Northeast Research II universities have the largest percentage of pervious open spaces with 33% and the West Research II universities have the smallest percentage of pervious open spaces with 15%.

3.2.1.3 Connectivity

Table 3.8 shows that on average campus connectivity (the local integration value of campus street network weighted by segment length) is .3. There are major differences among universities in regard to this dimension. While the average campus connectivity is only .11 for South Research II universities with a small standard deviation of .07, the average of campus connectivity for Northeast Research I universities is .5 with a large standard deviation of .97. These differences can be explained by the type of urbanism at each region. Campuses in more sprawling cities tend to have less street connectivity.

Campus connectivity relative to county connectivity is a measure of how integrated the campus street network is to its county. A value of more than one indicates that the campus is located at the core of its county and value less than one indicates that the campus is on the periphery. Figure 3.1 shows Yale University as an example of a university campus that is highly integrated with its county. Northeast Research I universities have the largest mean value and standard deviation. The large standard deviation can be explained by the presence of New York campuses, such as Columbia and New York University. Midwest Research I universities have the lowest mean value, 0.7, and the lowest standard deviation with .39. The mean value of all universities is 1.07.

3.2.1.4 Configuration

Table 3.5 shows that the mean value of configuration measure is 5.75 on a scale of 1 to 10. The most spatially structured campuses are northeast Research I universities with the mean value of 6.85 and the least organized campuses are northeast Research II universities with the mean value of 4.08. On average, Research I universities have more spatially structured campuses compared to Research II universities. The biggest distinction in this regard is among Northeast and Midwest universities. The interrater reliability test (see Table 3.10) shows that this measure is reliable, with an intraclass correlation coefficient of .885. Figure 3.2 is an example of spatial configuration analysis.

3.2.1.5 Campus Living

The mean value of the percentage of students living on campus is 38.7% with a standard deviation of 23.9 (see Table 3.11). Research I universities on average have more on campus living than Research II universities in all regions. In addition, Northeast Research I universities have the highest percentage of on campus living with the mean value of 66.69% and standard deviation of 19.6%. Northeast Research II universities have the second largest on campus student population with 48.92%. On average, the smallest percentage of campus living is at West Research II universities with only 20.5% and the standard deviation of 12.9%. South Research II universities have the second lowest percentage of on campus living with 26.36% and standard deviation of 18.9%.

3.2.1.6 Greenness

Greenness dimension has three indicators: the percentage of tree canopy, the percentage of pervious open spaces, and the percentage of parking surface areas. The last two indicators are shared and discussed with the compactness dimension.

Table 3.12 shows that on average 13.7% of campus grounds are covered by tree canopy. Northeast Research II universities have the highest average of tree canopy with 21.5%. Overall, campuses located at Northeast and South regions are more covered with tree canopy than Midwest and West campuses. West Research II universities have the lowest average percentage of tree canopy of only 6% with standard deviation of 4%.

3.2.1.7 Context

Table 3.13 shows that on average census tracts surrounding campuses have an activity density of 12,578[6], with land use entropy of .74, and intersection density of 110. Activity density and intersection density vary substantially among regions, but not so much in terms of land use entropy. Northeast universities have the highest activity density and intersection density surrounding their campuses. South Research II universities have the lowest activity and intersection densities. On average, South Research II universities have the activity density of 4,213 with a standard deviation of 2,420, and an intersection density

[6] The total population and employment per square mile.

of 70 with standard deviation of 35. Although entropy does not show substantial variation among regions and university types, it is positively correlated with activity density and intersection density at the significance level of .05.

3.2.2 Modeling Campus Form

The interaction among different morphological variables of university campuses has not been explored in prior studies. I used Structural Equation Modeling software, Amos 22, to model campus morphological dimensions with the observed variables described at Table 3.2. I created latent variables to represent morphological dimensions based on the proposed hypothesis. I had to slightly modify my original hypothesis, to generate the best model (in terms of goodness of fit indices and the significance of coefficient estimates). First, I had to drop the proximity variable, because it did not show significant interaction with other compactness variables. Second, I found significant interaction among compactness, connectivity, and context dimensions. Instead of creating three distinct latent variables, all related observed variables can be loaded on a broader latent variable that can represent the degree of urbanism of campus. The other option that I had was creating a second order latent variable of urbanism based on the three latent variables of compactness, connectivity, and context. However, the first option– directly loading observed variables on the urbanism latent variable–had a better model fit.

Some latent variables, such as campus living, have only one predictor, so practically these latent variables equal their sole predictors. I could have dropped those latent variables and directly correlated observed measures with the other latent variables, but I decided to keep them only for illustrative purposes to show the clear structure of my conceptual diagram.

Figure 3.3 shows the path diagram of my proposed hypothesis.[7] On the left side, the interaction of all dimensions is presented. However, I found no significant interaction between two morphological dimensions and any of the outcome variables (which will be discussed in the next sections). These two dimensions are the two qualitatively rated dimensions: configuration and land use organization. Therefore, I have decided to model campus form without these two dimensions. On the right side of Figure 3.3, the path diagram of the remaining three latent variables is presented.

I used maximum likelihood procedures for estimation and to evaluate model goodness-of-fit. Because of the relatively small number of sampled universities, I also conducted Bayesian estimates (Riginos & Grace, 2008) using Amos for confirmatory purposes, since these estimates do not depend on large-sample theory. This model generates a good model fit by maximum likelihood estimation, but only gets a good model fit with Bayesian estimates when the outliers were removed from the sample.[8]

The following results were obtained by removing outliers: The structural equation model obtained through maximum likelihood estimation had 29 degrees of freedom and a χ^2 value of 18.80 with a *P* value of 0.926. This *P* value along with all model fit indicators (CFI is 1 and RMSEA is .000) indicate good model fit. In Bayesian estimation, the Posterior Predictive *P* value has to be close to 0.5 to have a good model fit. This model had the Posterior Predictive *P* value of 0.51, which indicates good model fit.

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[7] Dropping the correlations among error terms changes the coefficients very little, and does not change their signs and the significance levels of campus form variables; however, decreases the goodness of fit of the model. Chi-square= 29.119, Degrees of freedom=31, Probability level= .563

[8] Seven cases had leverage value more than 2: Columbia University, Temple University, Fordham University, Boston University, Brandeis University, New York University, and Miami University.

Table 3.14 shows the regression weights in maximum likelihood and Bayesian estimation, *P* value of maximum likelihood estimates and 95% credible intervals for Bayesian estimates. All regression paths possessed coefficients with significance level of 0.05 or beyond in both maximum likelihood and Bayesian estimations. Coefficient estimates were close to each other with both techniques, which confirm the model. In addition, the signs of coefficients were in accordance with the hypothesis. For example, the percentage of pervious open space was positively loaded on greenness and negatively loaded on urbanism. Also, the percentage of surface parking areas is negatively loaded on both greenness and urbanism latent variables. The degree of campus living was positively correlated with the degree of greenness at the significance level of <.001 (Figure 3.4). The degree of urbanism was negatively correlated with the degree of greenness at the significance level of <.001, which means more urbanized campuses are generally less green (Figure 3.5). The degree of campus living and urbanism were not correlated (Figure 3.6).

3.2.3 Students' Satisfaction, Learning Outcome, and Campus Form

After modeling campus form through three distinct latent variables, I investigated the relationship between campus form, students' satisfaction and learning outcomes. Figure 3.7 shows the path diagram of my model. The three latent variables, the degree of urbanism, greenness and campus living, were generated from 10 observed variables, according to the confirmed model in the previous step. Similar to the previous step, I used the marker-variable strategy to specify the scale of latent variables based on one observed variable. The latent variables are fixed to have means of 0, but their variances are not fixed.

The hypothesis is that the morphological dimensions (latent variables) can have direct impacts on students' satisfaction with their college experience and their overall academic performance (learning outcomes). Also, students' satisfaction with their college experience can have a direct impact on their learning outcomes. I considered four control variables for this model: (1) the total number of undergraduate enrollment to control for the size of university; (2) the average SAT score to control for the student selectivity of university; (3) the percentage of classes with fewer than 20 students to control for the faculty resources of university; (4) the Research I or Research II university dummy variable to control for the level of research activities. I also tested other control variables, such as enrollment profile, university type (private or public), climate, crime rate, and the average total indebtedness of graduates, but they had no significant impact on either endogenous variables. In addition, I assumed that the exogenous variables are not orthogonal. Therefore, I estimated the covariance between all exogenous variables.

Because my sample size is relatively small, similar to the previous step, I estimated my model with both maximum likelihood and Bayesian estimations to support my conclusions. The structural equation model obtained through maximum likelihood estimation had 71 degrees of freedom and a χ^2 value of 70.206 with a *P* value of 0.504. This *P* value along with all model fit indicators (CFI is 1 and RMSEA is .000) indicate good model fit. The structural equation model obtained through Bayesian estimation had the Posterior Predictive *P* value of 0.45, which indicates good model fit as well.

Table 3.15 shows the direct regression weights with both maximum likelihood and Bayesian estimations. The results show that all three campus form variables have significant positive correlation with freshman retention rate. To the best of my knowledge, this is the first time that a significant correlation between the morphology of university campuses and students' satisfaction has been reported. One unit increase in the urbanism latent variable (with the range of 1.90), is associated with the increase of the freshman retention by 4.8%. One unit increase in the greenness latent variable (with the range of 37.75) is associated with the increase of the freshman retention by 0.2%. Also, 1% increase in on campus residents is associated with the increase of freshman retention by almost 0.1%. Note that even 1% increase of freshman retention rate is an important impact, considering the fact that it may change the future of 200 people per year in a university with 20,000 students.

All other control variables have significant correlation with freshman retention rate as well in both maximum likelihood and Bayesian estimations. Studying at a Research I university (with very high research activities) can have positive impact on students' satisfaction compared to being a student at a Research II university (with high research activities). Studying at a Research II university instead of Research I university is associated with the decrease of the freshman retention about 2.8%. In addition, universities which are more selective in giving admission have more chance to have higher freshman retention rate. One hundred points more on the average of SAT score is associated with the increase of the freshman retention rates 4.6%. The number of undergraduate students can also have significant positive correlation. However, it requires 10,000 more undergraduate enrollments to increase freshman retention only 1.6%. The percentage of classes with less than 20 students had significant negative correlation with freshman retention rate. Ten percent increase in the number of classes with less than 20 students can decrease freshman retention by 1.35%. This result may be explained by the fact that universities with smaller classes tend to have a more rigorous education system and, therefore, to be more demanding academically. This may cause students with lower academic abilities to drop out of school after their freshman year.

The impact of the freshman retention rate on the 6-year graduation rate is very strong and significant. One percent increase for freshman retention can increase the 6-year graduation rate by 1.355% increase. Since all variables (3 latent variables and 4 control variables) showed significant impact on the freshman retention rate, and the freshman retention rate has a significant impact on the 6-year graduation rate, we can conclude that all variables have a significant indirect impact on 6-year graduation rate. However, only two variables (greenness, and campus living) other than freshman retention rate show a significant direct impact on 6-year graduation rate. The total standardized effect of campus living on the graduation rate is .315 and the total standardized effect of greenness is .292 (see Figure 3.16). Ten percent increase of on campus residents is associated with the increase of the 6-year graduation rate by 2.43%, considering both direct and indirect effects. Also, a 10-unit increase in the greenness measure is associated with the increase of the 6-year graduation rate by 5.58%, again considering both direct and indirect effects.

3.2.4 Campus Score

In order to rank universities based on the quality of their campuses, I developed a composite score from the three latent variable of urbanism, greenness, and campus living. First, I standardized these three latent variables with the mean of 0 and the standard deviation of 1. The composite score is generated with the following formula:

$$\text{Score} = .177 \times \text{Urban} + .215 \times \text{Green} + .251 \times \text{Living}$$

The multipliers are the standardized regression weights on freshman retention rate, obtained from modeling learning outcome with maximum likelihood estimation (see Table 3.15). For ease of interpretation, I converted the overall score and latent variables to have the mean of 100 with variance of 50. The final ranking of all 103 campuses with their scores are presented at Table 3.17. Results show that the distribution of "Well-Designed Campuses" (campuses with higher score) is not geographically even. The one-way ANOVA test of means and Post-hoc analysis reveal a large and significant difference between the mean of Northeast campuses and campuses in the other three census regions (Figure 3.6). The mean of Campus Score for Northeast universities is 149.03, Midwest is 85.65, West is 91.16, and South is the lowest with 75.91. That was an expected result considering the fact that built environment is in general more urbanized in the Northeast region. Also, the Northeast region has the most historic and well-established universities in the country with a long tradition of on campus housing. In addition, by using one-way ANOVA test, I found significant difference between the mean of Campus Score for Research I universities (112.32) and Research II Universities (86.41). Also, the mean of Campus Score for private universities (161.68) is significantly higher than public schools (80.23). Figure 3.8 shows the means plot of campus score stratified by type and region. The highest mean belongs to Northeast Research I universities with 163.02 and the lowest mean belongs to South Research II with 62.79.

I also tested the predictive power of the Campus Score for students' satisfaction and graduation rate. First I conducted scatter plots to see the relationship of Campus Score, freshman retention rate, and 6-year graduation rate. Figure 3.9 and 3.10 show a strong quadratic relationship between variables. Also, Campus Score has a skewed distribution;

therefore I conducted natural log transformation on Campus Score, before exploring its predictive power.

I conducted two linear regression analyses. First, I modeled the freshman retention rate with the natural log transformed Campus Score, average SAT score, the percentage of classes with less than 20 students, university type (Research I or II), and the total number of undergraduates.[9] Second, I modeled the 6-year graduation rate with the freshman retention rate and the natural log transformed Campus Score. None of the other control variables was significant in this model. No multicollinearity nor outlier impact has been detected in these models.

The first model had the adjusted R^2 of 0.802, and all coefficient estimates were at the significance level of 0.05 or beyond. The general findings were consistent with the SEM model. The difference was having a single composite variable instead of using three distinct latent variables in the model. The unstandardized coefficient of Campus Score was 6.893, and the standardized coefficient was 0.414. This means 1% increase in Campus Score can increase the freshman retention rate by 0.0689.

The second model had the adjusted R^2 of 0.917, and all coefficient estimates were at the significance level of less than .001. The unstandardized coefficient of the freshman retention rate was 1.483 and standardized coefficient was .745. The unstandardized coefficient of the natural log transformed Campus Score was 8.989 and standardized coefficient was .271. This means 1% increase in Campus Score can increase the 6-year graduation rate by 0.0899.

[9] Same control variables as the SEM model

3.2.5 Campus Safety and Campus Form

I also investigated the relationship between campus form and campus crime. Figure 3.11 shows the path diagram of my model. Similar to the previous steps, I used the three latent variables, the degree of urbanism, greenness and campus living, to represent campus morphological dimensions. The hypothesis is that the morphological dimensions can have impact on campus crime rate after controlling for the following variables: (1) the percentage of undergraduate students from the total enrollment to control for the academic profile of university; (2) the average SAT score to control for the student selectivity of university; (3) the percentage of classes with fewer than 20 students to control for the faculty resources of university; (4) the median income of city to control for the socio-economic status of city; (5) the sum of total cooling and heating days in city to control for climate. I also tested other control variables, such as university type (private or public), crime rate of city, research type and the average total indebtedness of graduates, but they had no significant impact on the endogenous variable. Similar to the previous models, I assumed that the exogenous variables are not orthogonal, and I estimated the covariance between all exogenous variables.

Similar to the previous steps, I estimated my model with both maximum likelihood and Bayesian estimations to support my conclusions. The structural equation model obtained through maximum likelihood estimation had 71 degrees of freedom and a χ^2 value of 68.173 with a *P* value of 0.573. This *P* value along with all model fit indicators (CFI is 1 and RMSEA is .000) indicate good model fit. The structural equation model obtained through Bayesian estimation had the Posterior Predictive *P* value of 0.51, which indicates good model fit.

Table 3.18 shows the regression weights with both maximum likelihood and Bayesian estimations. The results show that the degree of urbanism and greenness are negatively correlated with the crime rate. However, the coefficient estimate of greenness is not significant at .05 level. One unit degree increase in urbanism (with the range of 1.9) can decrease the campus crime rate by 5.671 units (the number of criminal offenses per 10,000 students is the unit). The third morphological variable, campus living, is positively correlated with campus crime rate at the 0.05 significance level. One unit increase in the percentage of on campus living can increase the campus crime rate by 0.063. This is not a very strong impact, since it requires 16% increase on campus residents to only change one unit of campus crime rate.

All control variables had significant correlation with the campus crime rate. A ten thousand dollar increase in the median income of households in the city can increase the crime rate by 0.53. Also, 100-point increase on the average of SAT score can decrease the crime rate 0.9. In other words, being more selective on admissions means less crime on campus. One unit increase on the percentage of undergraduate students can decrease crime rate -0.105. One unit increase in the percentage of classes with less than 20 students can increase crime rate by .086. The last two facts are suggesting that universities with high graduate/professional students and smaller classes have higher crime rates. This result, which is to some extent unexpected, can be explained by the fact that universities with small classes and high portion of graduate students normally have fewer students; therefore, although they may have less crime on their campus, they can have more crimes per capita. In addition, although the victims are generally affiliated with the university, not all offenders necessarily are. Finally, 1,000 units increase in the climate index (with the rage of 10,500) can decrease crime rate by 1 unit. This is an interesting finding to know that there are higher crime rates at campuses with moderate climates than severe climates. This can be explained by the fact that students in moderate climates are outside more and therefore have more exposure to crime.

I also tested the predictive power of the Campus Score (generated at section 3.2.4) on campus crime using a linear regression. The results showed that the Campus Score has no significant correlation with campus crime rate, considering other control variables. This was an expected result, since the three latent variables had different signs of correlation with campus crime rate.

3.2.6 Campus Sustainability and Campus Form

Sustainability is a very broad concept. Therefore, defining sustainable campus form can be a multifaceted and exceptionally complex task. One of the most comprehensive attempts to assess and rate sustainability for university campuses has been done by the Association for the Advancement of Sustainability in Higher Education (AASHE), known as the Sustainability Tracking, Assessment & Rating System™ (STARS). I investigated the predictive power of campus form (as measured in this research) on the sustainability ratings of STARS.

From my 103 campus sample, 61 universities (59.2%) have participated in STARS program and have unexpired ratings. Twenty-eight campuses have Gold ratings, 31 have Silver ratings, and only 2 campuses have Bronze ratings. I created a dummy variable with 1 equals Gold and 0 equals non-Gold ratings. The total sample has 40.8% missing values. When missing values are present, it is essential to estimate means and intercepts (which is not the default in Amos). Amos uses full information maximum likelihood (FIML) estimation which requires using all information of the observed data unlike listwise or pairwise deletion methods.[10] In Amos, modeling binary outcome variables requires the use of Markov Chain Monte Carlo (MCMC) option. In addition, Amos uses a probit model for ordered-categorical outcomes. This means regression weights specify the effect of one unit change in the exogenous variables on the probability of observing 1 for the outcome variable.

I tested the interaction among the three morphological latent variables (the degree of urbanism, greenness and campus living) with the STARS ratings. I did not detect any significant correlation between the campus form measures and STARS rating. I also did not detect any significant correlation between other variables, such as the climate index, university type, or enrollment profile with STARS. In SPSS, I also used a binary logistic model with the Campus Score as the predictive variable; but I found no significant interaction between the Campus Score and STARS rating. STARS has a very complex credit checklist and it is heavily weighted toward sustainability programs and policies of universities. STARS credit checklist is organized under the four categories of (1) academics, (2) engagement, (3) operations, and (4) planning and administration with 18 subcategories.[11]

Another explanation can be that university programs and policies regarding sustainability do not necessarily correlate with the sustainability of the physical campus. In order to test the impact of campus form on sustainability issues it is better to be more

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[10] See FIML estimation by Jim Arbuckle in the edited volume by Marcoulides and Schumacker (2013)

[11] See STARS 2.0 Credit Checklist at: http://www.aashe.org/files/documents/STARS/2.0/stars_2.0_credit_checklist_1.pdf

specific about defining sustainability. Therefore, in the next section, I investigate the impact of campus form on the commuting behaviors of students and staff as one aspect of sustainability.

3.2.7 Students' Commuting Behavior and Campus Form

Figure 3.12 shows the path diagram of my model. The hypothesis is that the morphological dimensions can have impact on students' commuting behavior after controlling for the following variables: (1) the urbanism degree of setting; (2) the enrollment profile classification; and (3) the university type. This model had three endogenous variables (the percentage of students who walk or bike, the percentage of students who commute with only the driver in the vehicle, and the percentage of students who take a campus shuttle or public transportation as their primary method of transportation) that are highly correlated; therefore, their covariances were estimated. Note that the sum of these three variables is not necessarily 100%. For example, those who carpool were not included in any of these categories. These data are self-reported data by institution from STARS. Therefore, the issue of missing data applies for these data as well. The missing values are 30% of all cases. However, because Amos uses full information maximum likelihood (FIML), all 103 cases contribute information to the model.

I estimated my model with both maximum likelihood and Bayesian estimations. The structural equation model obtained through maximum likelihood estimation had 71 degrees of freedom and a χ^2 value of 71.792 with a P value of 0.451. This P value along with all model fit indicators (CFI is 0.999 and RMSEA is .010) indicate good model fit. The structural equation model obtained through Bayesian estimation had the Posterior Predictive P value of perfect 0.5, which indicates good model fit.

Table 3.19 shows the regression weights with both maximum likelihood and Bayesian estimations. The results of both estimations show that the only correlated variable (at the 0.05 significance level) with *the percentage of students who walk or bike* is the *percentage of on campus residents*. One unit change in the percentage of campus residents can increase the outcome variable by 0.336. With maximum likelihood estimation, all exogenous variables are correlated with *the percentage of students who commute with only the driver in the vehicle* at the 0.05 significance level, except for the *enrollment profile*. However, Bayesian estimation just confirmed the significance of three estimates: the degree of urbanism of campus, the degree of greenness, and the university type.

One unit change in the urbanism degree (with the range of 1.9) can decrease the percentage of students who drive alone by 24.068. The relationship between car usage and campus greenness can be hypothesized in both causal ways: Either less use of cars by students can make campus greener, or greener campuses can encourage students to use less cars. I assumed the latter in my model. One unit change in the greenness degree (with the range of 37.75) can decrease the percentage of students who drive alone by 1.055, which is also very substantial. In addition, being at a Research II university instead of Research I university can increase the percentage of students who drive alone by 12.5.

The degree of urbanism and the degree of greenness have significant positive impact on the percentage of students using transit. One unit change in the urbanism degree can increase the percentage of students using transit by 27.702. One unit change in the greenness degree can increase the same percentage by .883. In the maximum likelihood estimation, the degree of urbanism of setting showed significant positive correlation with the percentage of students who use transit. However, the Bayesian estimation did not confirm the significance of this correlation at the 0.05 level.

3.2.8 Employees' Commuting Behavior and Campus Form

Figure 3.13 shows the path diagram of employees' commuting behavior as a function of morphological measures of campus design, considering these control variables: (1) the urbanism degree of setting; (2) the enrollment profile classification; and (3) the university type. This model also had three endogenous variables (the percentage of employees who walk or bike, the percentage of employees who commute with only the driver in the vehicle, and the percentage of employees who take a campus shuttle or public transportation as their primary method of transportation). This information was not available for 33% of cases.

The structural equation model obtained through maximum likelihood estimation had 71 degrees of freedom and a χ^2 value of 72.544 with a P value of 0.427. This P value along with all model fit indicators (CFI is 0.998 and RMSEA is .015) indicate good model fit. The structural equation model obtained through Bayesian estimation had the Posterior Predictive P value of perfect 0.5, which indicates good model fit.

Table 3.20 shows the regression weights with both maximum likelihood and Bayesian estimations. The results of both estimations showed that none of the three morphological measures had a significant correlation with *the percentage of employees who walk or bike*. However, both estimations showed significant negative correlation between the urbanism degree of campus and *the percentage of employees who commute with only the driver in the vehicle* at the 0.05 significance level. One unit increase in the urbanism degree can decrease the percentage of employee who drive alone by 34.545 units.

Also, working at a Research II institution instead of a Research I can increase the percentage of employees who drive alone by 13.29%. This finding can be explained by the fact that Research I universities (which generally have more financial resources) may have invested more on the alternative transit modes, such as expanding their shuttle bus service, or master planning bicycle routes. In addition, the degree of urbanism and the degree of greenness of campus have significant positive impacts on the percentage of employees using transit. One unit increase in the urbanism latent variable can increase the percentage of employees using transit by 40.684. Also, one unit change in the greenness latent variable can increase that same percentage by .688.

Table 3.1 General characteristics of the selected sample

University Type	*N*	Total Enrollment 2013		Campus Size in Acre		Percentage of Public Universities	Year Founded
		Mean	Std. Dev	Mean	Std. Dev	Mean	Grouped Median
Northeast Research I	13	22338	13120	724.6	663.4	31	1852
Northeast Research II	12	15888	8667	467.1	276.2	58	1879
Midwest Research I	13	32837	15236	1006.9	690.7	77	1851
Midwest Research II	15	18224	6633	637.6	423.8	87	1890
South Research I	14	29514	13898	1026.3	655.2	79	1854
South Research II	11	25628	8877	690.3	305.7	100	1890
West Research I	14	31050	8806	1092.8	469.9	93	1885
West Research II	11	22203	8719	652.9	574.5	82	1899
All Universities	103	24809	12054	797.3	557.4	76	1875

Table 3.2 Operationalizing the Campus Morphological Dimensions

	Variable	Description	Computation Process	Data Source
(1) Land Use Organization Dimension	MIX	Land use mix	Rating land use mix on campus between 1 to 10 10= All uses are mixed on campus, however the major athletic fields, greenhouses, barns and surface parking areas are not located at the campus core 1= campus has segregated areas away from the campus core for sport, research, residence, and some academic disciplines.	The researcher's rating.
(2) Compactness Dimension	DEN1	Mass density	Computing the total area of building footprints divided by campus area	OpenStreetMap, Google Earth images
	DEN2	Proximity	Conducting *average nearest neighborhood distance* tool in ArcGIS. The input data are building footprints.	OpenStreetMap, Google Earth images
	GRN2	Pervious open spaces	Computing the percentage of pervious open spaces in a quarter mile buffer around campus buildings	NLCD2011
	GRN3	Surface parking	Computing the total area of surface parking divided by the campus area	OpenStreetMap, Google Earth images
(3) Connectivity Dimension	CON1	Campus connectivity (within campus and to the surrounding area)	1) Downloading census street lines at the county level 2) Refining the maps according to Google Earth images 3) Export maps as dxf files from ArcGIS and open it in Depthmap (Space Syntax Software) 4) Angular integration analysis with radius of 3, weighted by segment length; 5) Averaging integration values of campus street segments	Census Tiger 2010, street lines
	CON2	Campus connectivity (relative to county)	Dividing the average integration value of campus street segments with radius 3 by the average integration value of county street segment with same radius	Census Tiger 2010, street lines

Table 3.2 Continued

	Variable	Description	Computation Process	Data Source
(4) Configuration Dimension	STRU	campus spatial structure	Rating the strength of campus spatial structure from 1 to 10. 10= The entire campus has organized around most of these principles: Buildings are defining open spaces. Campus spaces are connected through main corridors, courtyards, or quads. Campus has a main central space such as a plaza or a lawn, long view corridors with a land mark at the focal point, enclosed open spaces, and the entire master plan is relatively symmetric and geometric. 1= The campus has a disorganized layout.	The researcher's rating.
(5) Campus Living Dimension	INHB	On campus living	Computing the percentage of students living on campus	US News and World Report
(6) Greenness Dimension	GRN1	tree canopy	Computing the average percentage of tree canopy in a quarter mile buffer around campus buildings	NLCD2011
	GRN2	Pervious open spaces[12]	Described under compactness dimension	
	GRN3	Surface parking[13]	Described under compactness dimension	

[12] "*Pervious open spaces"* is a shared variable among greenness and compactness dimension, but with different loading sign. More pervious open space means more greenness, but less compactness.

[13] "*Surface parking*" is a shared variable among greenness and compactness dimension, with same loading sign. More surface parking areas means less greenness and compactness.

Table 3.2 Continued

	Variable	Description	Computation Process	Data Source
(7) Context Dimension[14]	URB1	Activity density	Computing the density of population and employment of all census tracts neighboring the campus	Longitudinal Employment Household Dynamic 2010-Census 2010
	URB2	Land use entropy	Computing land use entropy of all census tracts neighboring the campus. Land use entropy was computed with the formula: entropy = -[residential share*ln (residential share) + retail share*ln (retail share) + office share*ln (office share)]/ LN (3)	LED 2010
	URB3	Intersection density	Computing intersection density of all census tracts neighboring the campus, computed as the number of intersections within all census tracts neighboring the campus divided by the area of census tracts	Census Tiger 2010, street lines and census tracts

[14] I operationalized context dimension with three common indicators, known as 3Ds: density, diversity and design (Cervero & Kockelman, 1997; Ewing & Cervero, 2010).

Table 3.3 Endogenous variables and their data source

Variable	Proxy Variable	Data Source
Student satisfaction with college experience	freshmen retention rate	College Navigator
Learning outcome	6-year graduation rate	College Navigator
Safety	Total criminal offenses on campus from 2011 to 2013, divided by total enrollments 2011-2013	The Campus Safety and Security Data Analysis Cutting Tool
Sustainability	STAR scores	The Sustainability Tracking, Assessment & Rating System
Students' commuting behavior	The percentage of institution's students who walk, bicycle, or use other nonmotorized means as their primary means of transportation.	The Sustainability Tracking, Assessment & Rating System
	The percentage of institution's students who commute with only the driver in the vehicle (excluding motorcycles and scooters) as their primary means of transportation.	
	The percentage of institution's students who take a campus shuttle or public transportation as their primary means of transportation.	
Employees' commuting behavior	The percentage of institution's employees who walk, bicycle, or use other nonmotorized means as their primary means of transportation.	
	The percentage of institution's employees who commute with only the driver in the vehicle (excluding motorcycles and scooters) as their primary means of transportation.	
	The percentage of institution's employees who take a campus shuttle or public transportation as their primary means of transportation.	

Table 3.4 Control variables and their data source

Variable	Proxy Variable	Data Source
University Resources	Percentage of classes with fewer than 20 students	US News and World Report
	The average faculty pay	American Association of University Professors (AAUP)
Student Selectivity	SAT Score	College Navigator
Age of university	Year founded	US News and World Report
Campus Size	Campus Size	OpenStreetMap refined by Google Earth images
Type of Institution	Public, Private for-Profit, Private not-for-profit	Carnegie Classification 2010
	Research II (high research activities), Research I (very high research activities)	Carnegie Classification 2010
Student Profile	Enrollment Profile Classification 2010 0=(Not classified) 1=ExU2: Exclusively undergraduate two-year 2=ExU4: Exclusively undergraduate four-year 3=VHU: Very high undergraduate 4=HU: High undergraduate 5=MU: Majority undergraduate 6=MGP: Majority graduate/professional 7=ExGP: Exclusively graduate or professional 0,1,2, and 7 are not in the samples	Carnegie Classification 2010
	Percentage of undergraduate enrollment: the total number of undergraduates divided by the total number of students	US News and World Report
Affordability of Education	Average total indebtedness of 2013 graduating class	US News and World Report
City Economic Status	The median household income of city 2013	Census Bureau
Climate Index	The total cooling days of city in 2014	NOAA's National Climatic Data Center
	The total heating days of city in 2014	NOAA's National Climatic Data Center
Safety	Crime rate of City in 2013	FBI Uniform Crime Reports

Table 3.4 Continued

Variable	Proxy Variable	Data Source
The degree of urbanism of setting	4=City 3=Suburban 2=Town 1=Rural	Carnegie Classification 2010

Table 3.5 The mean and std. deviation of land use organization measure of campuses, categorized by their region and type

University Type	*N*	Land Use Organization	
		Mean	Std. Deviation
Northeast Research I	13	7.38	1.981
Northeast Research II	12	5.58	2.644
Midwest Research I	13	6.08	2.178
Midwest Research II	15	5.93	2.086
South Research I	14	6.36	2.620
South Research II	11	6.45	1.916
West Research I	14	7.00	2.353
West Research II	11	7.09	2.166
All Universities	103	6.48	2.262

Table 3.6 Intraclass correlation coefficient for interrater reliability of the land use organization measure

	Intraclass Correlation[b]	95% Confidence Interval		*F* Test with True Value 0			
		Lower Bound	Upper Bound	Value	*df1*	*df2*	Sig
Single Measures	.762[a]	.579	.869	8.172	40	40	.000
Average Measures	.865[c]	.733	.930	8.172	40	40	.000

Two-way mixed effects model where people effects are random and measure effects are fixed.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type A intraclass correlation coefficients using an absolute agreement definition.

c. This estimate is computed assuming the interaction effect is absent, because it is not estimable otherwise.

Table 3.7 The mean and std. deviation of compactness measures of universities, categorized by their region and type

University Type	*N*	Mass Density		Proximity (in feet)		Percentage of pervious open spaces		Percentage of surface parking area	
		Mean	Std. D	Mean	Std. D	Mean	Std. D	Mean	Std. D
Northeast Research I	13	.247	.128	193	59	28	21	5.96	3.87
Northeast Research II	12	.201	.092	239	51	33	25	8.90	3.65
Midwest Research I	13	.208	.079	253	48	19	15	8.45	3.13
Midwest Research II	15	.180	.092	292	41	16	12	9.42	4.81
South Research I	14	.195	.067	205	51	27	20	10.36	4.29
South Research II	11	.170	.053	234	59	29	15	14.42	6.26
West Research I	14	.213	.055	198	44	27	10	11.25	4.57
West Research II	11	.230	.065	281	95	15	11	13.42	5.60
All Universities	103	.205	.083	236	65	24	17	10.14	5.06

Table 3.8 The mean and std. deviation of connectivity measures of universities, categorized by their region and type

University Type	*N*	Campus connectivity		Campus connectivity relative to county connectivity	
		Mean	Std. Deviation	Mean	Std. Deviation
Northeast Research I	13	.50	.97	1.56	1.75
Northeast Research II	12	.41	.73	1.00	.90
Midwest Research I	13	.39	.59	.70	.39
Midwest Research II	15	.34	.39	.93	.92
South Research I	14	.14	.22	.87	.67
South Research II	11	.11	.07	.99	.62
West Research I	14	.19	.26	1.41	2.35
West Research II	11	.27	.30	1.16	.67
All Universities	103	.30	.52	1.07	1.21

Table 3.9 The mean and std. deviation of the configuration measure of universities, categorized by their region and type

University Type	*N*	Spatial Structure	
		Mean	Std. Deviation
Northeast Research I	13	6.85	2.882
Northeast Research II	12	4.08	1.443
Midwest Research I	13	6.38	2.293
Midwest Research II	15	4.93	2.251
South Research I	14	5.71	2.463
South Research II	11	5.45	1.753
West Research I	14	6.29	2.785
West Research II	11	6.27	2.102
All Universities	103	5.75	2.392

Table 3.10 Intraclass correlation coefficients for the configuration measure

	Intraclass Correlation[b]	95% Confidence Interval		*F* Test with True Value 0			
		Lower Bound	Upper Bound	Value	*df1*	*df2*	Sig
Single Measures	.793[a]	.609	.890	10.042	40	40	.000
Average Measures	.885[c]	.757	.942	10.042	40	40	.000

Two-way mixed effects model where people effects are random and measure effects are fixed.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type A intraclass correlation coefficients using an absolute agreement definition.

c. This estimate is computed assuming the interaction effect is absent, because it is not estimable otherwise.

Table 3.11 The mean and std. deviation of campus living measure of universities, categorized by their region and type

University Type	*N*	Percentage of students living on campus	
		Mean	Std. Deviation
Northeast Research I	13	66.69	19.653
Northeast Research II	12	48.92	22.633
Midwest Research I	13	38.23	26.768
Midwest Research II	15	30.33	20.056
South Research I	14	40.29	20.398
South Research II	11	26.36	18.917
West Research I	14	33.14	19.159
West Research II	9[15]	20.56	12.943
All Universities	101	38.70	23.915

[15] Idaho State University and Portland State University were the missing data.

Table 3.12 The mean and std. deviation of campus living measure of universities, categorized by their region and type

University Type	*N*	The average percentage of tree canopy	
		Mean	Std. Deviation
Northeast Research I	13	18.03	10.13
Northeast Research II	12	21.48	16.11
Midwest Research I	13	8.78	5.24
Midwest Research II	15	10.33	8.56
South Research I	14	19.29	17.09
South Research II	11	19.43	14.15
West Research I	14	6.64	4.44
West Research II	11	5.99	4.12
All Universities	103	13.71	12.26

Table 3.13 The mean and std. deviation of campus living measure of universities, categorized by their region and type

University Type	*N*	Activity Density		Entropy		Intersection Density	
		Mean	Std. D.	Mean	Std. D.	Mean	Std. D.
Northeast Research I	13	21833	23045	.74	.14	132	90
Northeast Research II	12	17628	18723	.71	.18	138	125
Midwest Research I	13	12848	6428	.72	.11	131	32
Midwest Research II	15	10275	9650	.76	.12	104	47
South Research I	14	10195	9196	.75	.12	108	50
South Research II	11	4213	2420	.72	.11	70	35
West Research I	14	9106	3507	.79	.06	98	34
West Research II	11	14767	16168	.75	.13	99	50
All Universities	103	12578	13479	.74	.12	110	66

Table 3.14 The regression weights (ML and Bayesian) in modeling campus form

			Maximum Likelihood		Bayesian		
			Regression Weights	*P* value	Regression Weights	95% Lower bound	95% Lower bound of
GRN1	<---	Green	1.000		1.000		
GRN3	<---	Green	-.286	.000	-.295	-0.467	-0.154
GRN2	<---	Green	1.149	.000	1.159	0.771	1.649
CON1	<---	Urban	1.000		1.000		
CON2	<---	Urban	.878	.020	1.050	0.271	1.845
URB1	<---	Urban	34.132	.000	37.117	27.220	51.123
URB2	<---	Urban	.117	.048	.129	0.044	0.233
URB3	<---	Urban	150.570	.000	164.637	117.294	232.034
DEN1	<---	Urban	20.385	.000	22.356	16.391	30.852
GRN3	<---	Urban	-10.127	.002	-11.241	-17.536	-6.538
GRN2	<---	Urban	-15.798	.002	-17.271	-30.207	-5.286

Table 3.15 The regression weights (ML and Bayesian) in modeling students' satisfaction and learning outcome[16]

			Maximum Likelihood			Bayesian		
			Regression Weights	Standardized Regression Weights	*P* value	Regression Weights	95% Lower bound	95% Lower bound of
FRR	<--	Urban	4.809	.177	.034	5.101	.393	10.877
FRR	<--	Green	.206	.215	.023	.208	0.429	0.449
FRR	<--	Living	.097	.251	.004	.097	0.026	0.167
FRR	<--	Research	-2.773	-.151	.022	-2.827	-5.364	-0.339
FRR	<--	Faculty	-.135	-.199	.005	-.134	-0.235	-0.034
FRR	<--	SAT	.046	.629	***	.045	0.031	0.059
FRR	<--	UnderGr	.162	.169	.015	.164	0.023	0.305
GRA6	<--	FRR	1.355	.068	***	1.365	1.084	1.640
GRA6	<--	Urban	3.662	.146	.210	3.848	-2.415	11.651
GRA6	<--	Green	.278	.144	.023	.276	0.022	0.583
GRA6	<--	Living	.111	.007	.010	.111	0.018	0.203
GRA6	<--	SAT	.017	.036	.094	.016	-0.004	0.037
GRA6	<--	Research	.252	.116	.871	.281	-3.012	3.494
GRA6	<--	Faculty	.048	.078	.442	.051	-0.085	0.180
GRA6	<--	UnderGr	.148	.681	.082	.152	-0.027	0.335

[16] Dropping the covariates/control variables increases the coefficients, but does not change their signs and the significance levels of campus form variables. The coefficient estimates would be: Urban -> FRR: 9.764; Green -> FRR .376; Living -> FRR .168; Urban ->4.50; Green -> GRA6: .285; Living -> GRA6: .106.

Table 3.16 The total effects of exogenous variables on 6-year graduation rate.

	Maximum Likelihood		Bayesian	
	Total Effects	Standardized Total Effects	Total Effects	Standardized Total Effects
Urban	10.181	.189	10.754	.189
Green	.558	.292	.558	.291
Living	.243	.315	.245	.315
Research	-3.507	-.096	-3.575	-.098
Faculty	-.135	-.100	-.132	-.097
SAT	.078	.544	.078	.542
UnderGr	.367	.193	.377	.198
FRR	1.355	.681	1.365	.685

Table 3.17 Ranking universities based on their campus score

Rank	University Name	Urban Score	Green Score	Living Score	Campus Score (Composite score)
1	Columbia University	248.84	93.52	216.79	238.25
2	Princeton University	100.17	187.36	223.12	226.66
3	Lehigh University	97.86	219.43	161.89	204.03
4	Duke University	63.93	193.08	191.45	193.20
5	Emory University	69.06	223.07	159.78	191.68
6	Boston University	200.79	89.84	176.67	188.92
7	Stanford University	106.34	126.42	210.45	187.96
8	Yale University	153.21	86.96	202.01	182.08
9	College of William & Mary	36.62	217.00	172.45	181.83
10	Clarkson University	15.08	209.99	193.56	181.79
11	Case Western Reserve University	112.79	91.77	206.23	169.19
12	Brandeis University	82.29	140.63	185.12	168.70
13	University of Connecticut	35.84	195.96	170.33	168.61
14	Fordham University	204.34	91.97	138.66	167.37
15	New York University	310.10	29.44	117.55	167.32
16	Washington University in St. Louis	132.01	94.16	183.00	164.32
17	University of Notre Dame	93.06	119.44	187.23	163.30
18	Syracuse University	122.25	98.13	176.67	158.04
19	Rice University	130.59	89.93	168.22	151.91
20	Cornell University	52.27	186.92	134.44	148.11
21	University of Massachusetts Amherst	42.95	172.06	153.44	147.92
22	University of New Hampshire, Main Campus	41.27	187.75	140.77	147.66
23	Binghamton University	48.26	177.14	142.89	146.34
24	Tufts University	159.42	75.27	151.33	146.08
25	University of Dayton	87.30	111.31	170.33	145.45

Table 3.17 continued

Rank	University Name	Urban Score	Green Score	Living Score	Campus Score (Composite score)
26	University of Virginia, Main Campus	72.44	178.72	104.88	133.81
27	University of Vermont	81.49	135.88	123.88	126.58
28	University of California, Los Angeles	137.01	108.46	100.66	121.74
29	University at Albany, SUNY	55.85	124.54	142.89	120.96
30	University of Rhode Island	38.80	174.15	111.21	120.19
31	Miami University	68.41	139.63	117.55	118.68
32	Illinois Institute of Technology	134.05	51.03	142.89	115.95
33	Georgia Institute of Technology	151.54	51.06	128.11	114.41
34	University of California, Santa Barbara	75.58	147.91	98.54	114.30
35	Carnegie Mellon University	149.96	85.60	98.54	113.71
36	University of Denver	129.23	84.81	113.32	113.38
37	University of Maryland, College Park	75.96	130.28	111.21	112.92
38	University of Illinois at Urbana Champaign	102.53	91.64	123.88	111.83
39	University of Maine	33.93	162.83	102.77	106.39
40	North Carolina State University	55.92	170.70	75.32	103.07
41	Pennsylvania State University	77.73	126.18	96.43	102.02
42	University of Florida	69.70	166.82	66.87	101.75
43	University of California, San Jose	82.61	98.25	113.32	99.72
44	George Mason University	53.84	161.37	75.32	97.02
45	University of California, Irvine	90.93	90.51	109.10	96.53
46	Indiana University Bloomington	87.43	129.61	77.43	96.12
47	Ball State University	77.55	105.58	104.88	96.05
48	Portland State University	157.20	47.12	98.54	95.89
49	University of North Carolina at Greensboro	120.11	91.80	85.88	95.54

Table 3.17 continued

Rank	University Name	Urban Score	Green Score	Living Score	Campus Score (Composite score)
50	University of Wisconsin, Madison	104.34	119.54	71.10	94.18
51	Missouri University of Science	76.43	95.94	109.10	92.96
52	Drexel University	194.81	38.92	73.21	92.16
53	Oklahoma State University, Stillwater	84.26	80.41	113.32	90.69
54	Bowling Green State University	69.46	90.64	111.21	88.27
55	Temple University	216.54	33.31	56.31	88.09
56	University of Washington, Seattle	118.37	99.23	68.98	88.03
57	University of California, Davis	90.52	113.24	71.10	84.49
58	San Diego State University	176.84	61.56	52.09	82.96
59	University of Tennessee	96.20	75.07	96.43	82.35
60	University of Cincinnati, Main Campus	144.93	69.69	62.65	79.77
61	Texas A&M University	70.97	119.06	71.10	78.87
62	University of Iowa	72.43	114.62	71.10	77.09
63	Ohio State University, Main Campus	128.05	65.56	73.21	76.65
64	Southern Illinois University	28.34	134.80	83.76	76.37
65	University of Kansas	65.95	114.80	71.10	74.27
66	University of Oregon	116.40	83.78	60.54	73.27
67	University of Alabama	71.37	105.51	73.21	72.97
68	Virginia Commonwealth University	157.57	34.70	71.10	71.71
69	University of Colorado Boulder	84.91	83.43	77.43	69.69
70	University of Memphis	63.79	134.88	45.76	68.09
71	Rutgers–Newark	193.58	37.36	37.31	67.80
72	Kansas State University	71.47	96.94	71.10	66.97
73	University of California, Riverside	73.78	79.83	83.76	66.75
74	University of Wyoming	78.16	94.71	66.87	66.07

Table 3.17 continued

Rank	University Name	Urban Score	Green Score	Living Score	Campus Score (Composite score)
75	Idaho State University	70.28	63.41	98.54	65.63
76	University of Minnesota, Twin Cities	113.66	61.54	66.87	63.91
77	Auburn University, Main Campus	57.96	111.08	62.65	63.22
78	Colorado State University	79.57	82.53	71.10	62.73
79	Brigham Young University	107.16	74.08	58.43	62.45
80	Northern Arizona University	73.85	67.77	85.88	61.52
81	Cleveland State University	197.32	22.00	37.31	61.07
82	Louisiana State University	53.22	101.11	71.10	61.03
83	University of North Dakota	74.56	77.17	75.32	60.24
84	University of Illinois at Chicago	158.17	25.50	54.20	56.14
85	University of Wisconsin, Milwaukee	122.07	53.82	52.09	54.02
86	University of Alaska Fairbanks	43.55	90.79	75.32	53.72
87	Oregon State University	71.76	83.72	58.43	51.76
88	University of Louisville	100.04	40.56	75.32	51.68
89	Utah State University	76.44	90.88	45.76	49.69
90	University of Akron, Main Campus	135.60	36.27	47.87	47.81
91	Arizona State University, Tempe	103.29	37.79	66.87	46.22
92	University of Utah	72.93	83.16	45.76	43.88
93	University of North Texas	63.61	74.08	58.43	42.81
94	University of Missouri, Kansas	120.36	51.25	35.20	41.04
95	University of Missouri, St. Louis	67.64	91.95	37.31	40.91
96	Indiana University, Purdue University	114.46	48.00	39.42	39.30
97	University of Houston	110.98	29.67	56.31	38.49
98	New Mexico State University, Main Campus	53.13	68.82	56.31	33.85
99	Wayne State University	130.37	9.73	39.42	25.51

Table 3.17 continued

Rank	University Name	Urban Score	Green Score	Living Score	Campus Score (Composite score)
100	University of Texas at San Antonio	32.94	101.29	28.87	24.98
101	University of Texas at Arlington	78.95	41.56	41.53	21.11
102	University of Colorado Denver	118.89	22.05	28.87	20.33
103	University of Nevada, Las Vegas	121.34	17.87	28.87	19.15

Table 3.18 The regression weights (ML and Bayesian) in modeling campus crime[17]

			Maximum Likelihood			Bayesian		
			Reg. Weights	St. Reg. Weights	*P* value	Reg. Weights	95% Lower bound	95% Upper bound
GRN1	<--	Green	1.000	.796		1.000		
GRN2	<--	Green	1.168	.661	***	1.116	0.748	1.578
GRN3	<--	Green	-.300	-.575	***	-0.282	-0.441	-0.149
CON1	<--	Urban	1.000	.665		1.000		
CON2	<--	Urban	.853	.245	.012	0.856	0.130	1.584
URB1	<--	Urban	33.160	.854	***	33.695	25.58	45.11
URB2	<--	Urban	.113	.306	.004	0.115	0.038	0.201
URB3	<--	Urban	149.479	.785	***	151.877	112.5	205.4
DEN1	<--	Urban	19.881	.825	***	20.187	15.18	27.13
GRN3	<--	Urban	-10.144	-.696	***	-10.031	-15.23	-6.050
GRN2	<--	Urban	-16.148	-.327	.001	-17.110	-28.04	-6.460
INHB	<--	Living	1.000	1.000		1.000		
CrimeRate	<--	SAT	-.009	-.290	.033	-0.009	-0.018	0.000
CrimeRate	<--	Profile	-.105	-.341	.011	-0.106	-0.193	-0.020
CrimeRate	<--	Faculty	.086	.286	.015	0.086	0.012	0.160
CrimeRate	<--	Urban	-5.671	-.487	.002	-5.740	-10.25	-2.032
CrimeRate	<--	Green	-.089	-.214	.164	-0.084	-0.228	0.042
CrimeRate	<--	Living	.063	.371	.005	0.062	0.017	0.110
CrimeRate	<--	Climate	-.001	-.216	.018	-0.001	-0.001	0.000
CrimeRate	<--	Income	.053	.211	.017	0.054	0.012	0.124

[17] Dropping the covariates/control variables changes the coefficients, but does not change their signs and the significance levels of campus form variables. The coefficient estimates would be: Urban: -2.912; Green: -.081; Living: 0.90

Table 3.19 The regression weights (ML and Bayesian) in modeling students' commuting behavior[18]

	Maximum Likelihood			Bayesian		
	Reg. Weights	Std. Reg. Weights	*P* value	Reg. Weights	95% Lower bound	95% Upper bound
Walk Student<--Urban	3.477	.057	.737	4.493	-21.54	32.701
Walk Student<--Green	.309	.140	.467	.336	-.695	1.478
Walk Student<--Living	.367	.416	.008	.364	.046	.672
Walk Student<--Locale	.224	.007	.951	.263	-9.402	10.040
Walk Student<--Profile	-4.738	-.151	.278	-4.742	-14.06	4.661
Walk Student<--Research	-8.550	-.205	.071	-8.524	-19.39	2.407
Car Student<--Urban	-24.068	-.382	.022	-27.560	-58.73	-2.828
Car Student<--Green	-1.055	-.460	.012	-1.113	-2.346	-.129
Car Student<--Living	-.294	-.321	.025	-.288	-.578	.025
Car Student<--Locale	-6.951	-.221	.042	-6.956	-16.19	2.154
Car Student<--Profile	7.970	.245	.053	7.953	-.912	16.757
Car Student<--Research	12.499	.289	.005	12.567	2.168	22.892
Transit Student<--Urban	27.702	.571	.003	30.985	9.699	58.426
Transit Student<--Green	.883	.500	.015	.921	.082	1.953
Transit Student <--Living	-.055	-.078	.628	-.059	-.326	0.192
Transit Student <--Locale	6.836	.281	.021	6.802	-1.095	14.876
Transit Student <--Profile	-3.646	-.145	.305	-3.608	-11.20	4.049
Transit_Student<--Research	-4.787	-.143	.215	-4.879	-13.85	4.157

[18] Dropping the covariates/control variables changes the coefficients, but does not change their signs and the significance levels of campus form variables, except for two. The coefficient estimates of "percentage of students living on campus" on "percentage of students who drive alone", and "the degree of greenness" on "percentage of students who use transit" are not significant after dropping the covariates. The coefficient estimates would be: Urban -> Walk_Student: 1.599; Green-> Walk_Student: .333; Living -> Walk_Student: .342; Urban -> Car_Student: -24.380; Green-> Car_Student: -1.035; Living -> Car_Student: -1.93; Urban -> Transit_Student: 24.018; Green-> Transit_Student: .670; Living -> Transit_Student: -.056.

Table 3.20 The regression weights (ML and Bayesian) in modeling employees' commuting behavior[19]

	Maximum Likelihood			Bayesian		
	Reg. Weight	Std. Reg. Weight	*P* value	Reg. Weight	95% Lower bound	95% Upper bound
Walk Employee <--Urban	-.179	-.007	.967	0.021	-11.16	11.306
Walk Employee <--Green	-.225	-.276	.176	-0.210	-0.653	0.249
Walk Employee <--Living	.077	.217	.215	0.074	-0.068	0.216
Walk Employee <--Locale	-.824	-.067	.615	-0.758	-5.275	3.778
Walk Employee <--Profile	-3.429	-.271	.083	-3.447	-7.838	0.907
Walk_Employee<-Research	-4.600	-.273	.032	-4.590	-9.505	0.346
Car Employee <--Urban	-34.545	-.609	.000	-38.400	-66.10	-16.11
Car Employee <--Green	-.358	-.185	.284	-0.401	-1.355	0.428
Car Employee <--Living	-.126	-.149	.312	-0.120	-0.400	0.168
Car Employee <--Locale	-1.824	-.063	.580	-1.839	-10.50	6.893
Car Employee <--Profile	7.011	.234	.078	6.811	-1.936	15.624
Car_ Employee <--Research	13.295	.333	.002	13.084	3.179	23.100
Transit Employee <--Urban	40.684	.865	.000	44.977	27.423	69.174
Transit Employee <--Green	.688	.429	.008	0.721	0.120	1.458
Transit Employee<--Living	.050	.071	.587	0.047	-0.168	0.249
Transit Employee<--Locale	1.715	.071	.470	1.643	-4.850	8.105
Transit Employee<--Profile	-1.867	-.075	.514	-1.618	-8.105	4.786
Transit_Employe<-Research	-5.142	-.155	.097	-4.919	-12.21	2.384

[19] Dropping the covariates/control variables changes the coefficients, but does not change their signs and the significance levels of campus form variables. The coefficient estimates would be: Urban -> Walk_Employee: -1.972; Green-> Walk_Employee: -.207; Living -> Walk_Employee: .053; Urban -> Car_ Employee: -35.088; Green-> Car_ Employee: -4.75; Living -> Car_ Employee: -.059; Urban -> Transit_ Employee: 40.326; Green-> Transit_ Employee: .670; Living -> Transit_ Employee: .043.

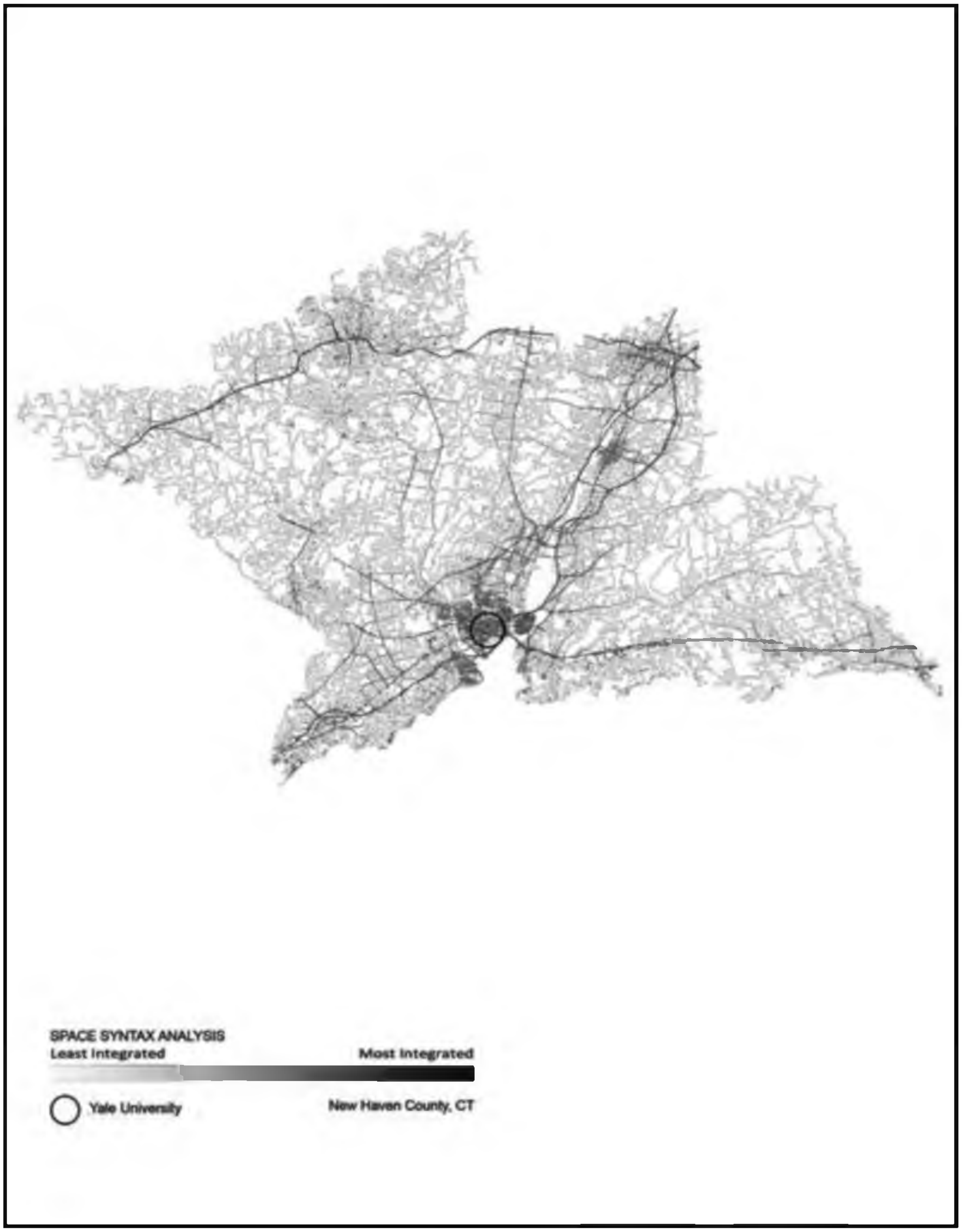

Figure 3.1 Connectivity map. The Integration R3 measure of street network of New Haven County

Figure 3.2 Configuration map. The spatial configuration of Yale University

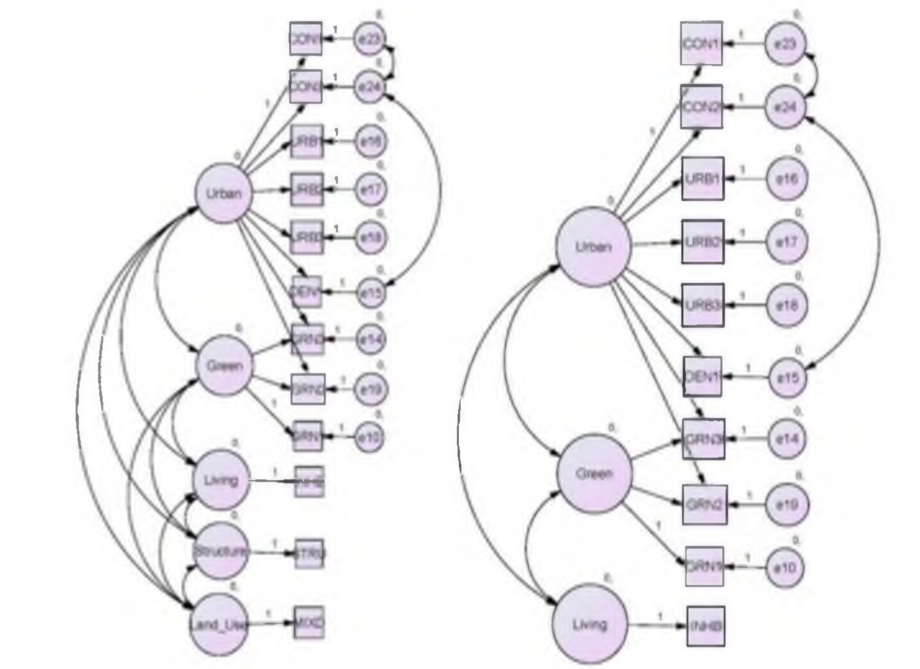

Figure 3.3 Modeling Campus Form. Left: the interaction of all dimensions, Right: all dimensions without land use organization and configuration. The remaining latent variables are: Urban= the degree of urbanization, Green= the degree of greenness, and Living= the degree of campus living

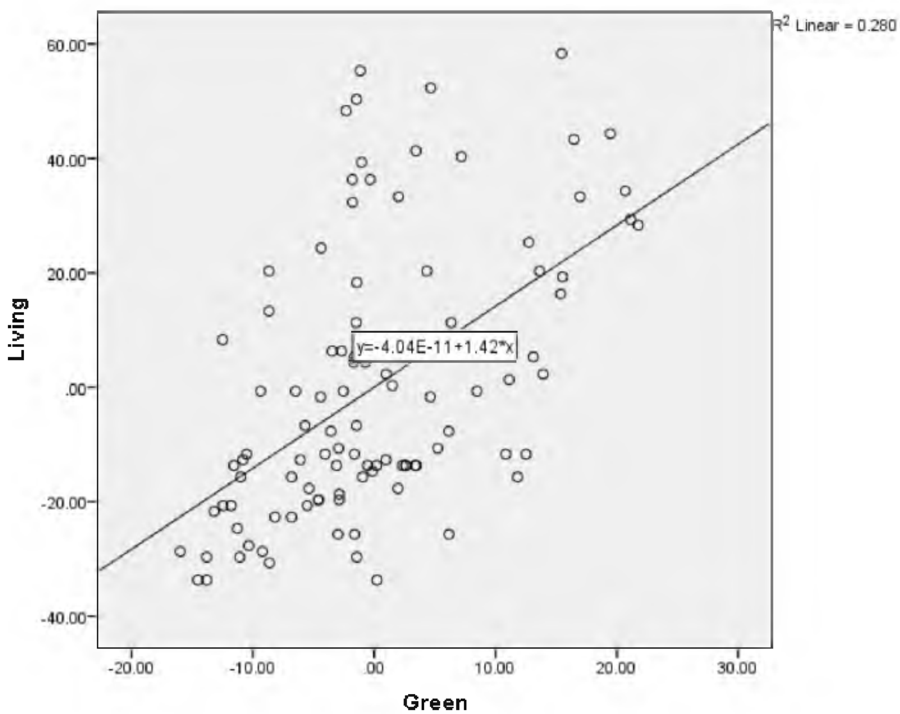

Figure 3.4 Scatter plot. X: Green Score, Y: Living Score. R^2=0.280

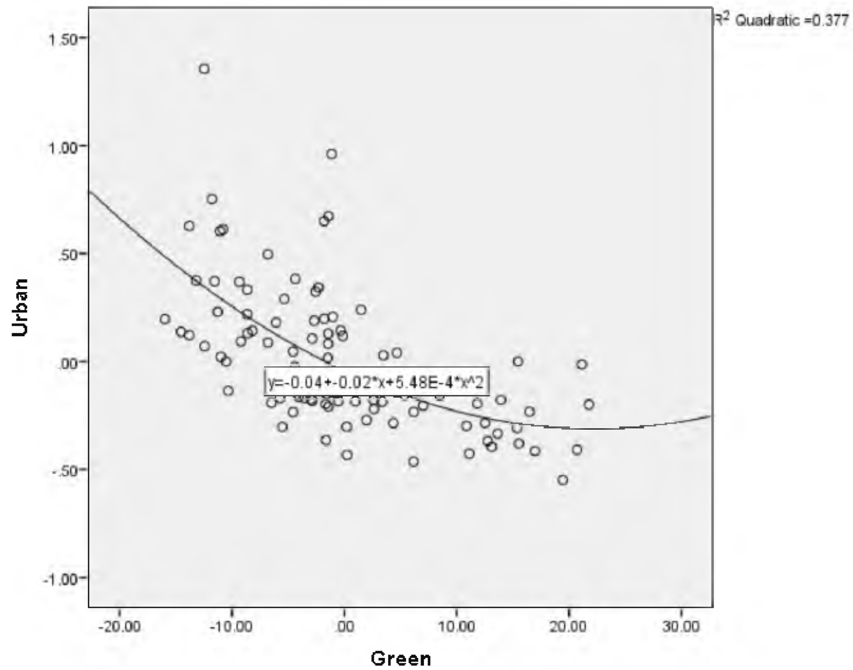

Figure 3.5 Scatter plot. X: Green Score, Y: Urban Score. R^2=0.377

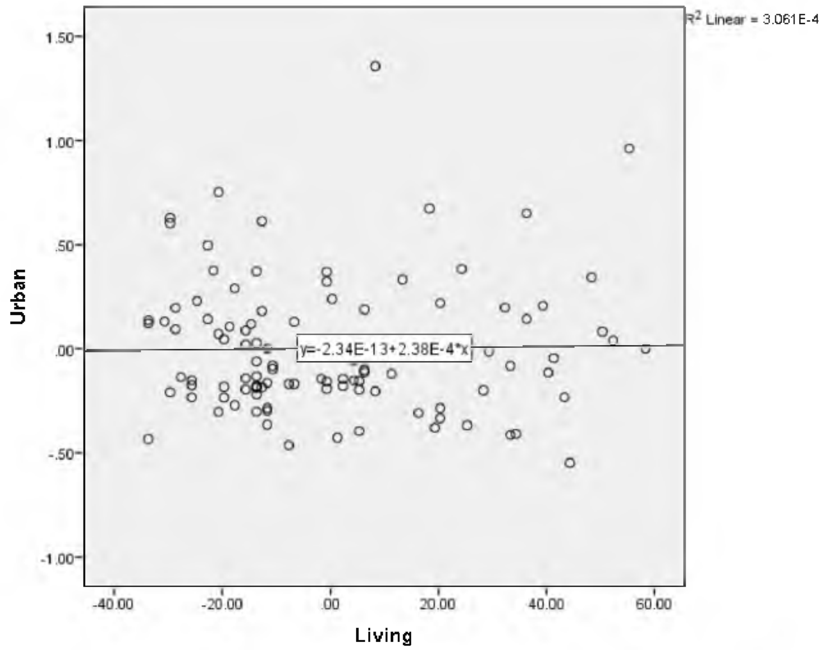

Figure 3.6 Scatter plot. X: Living Score, Y: Urban Score. $R^2 \cong 0$

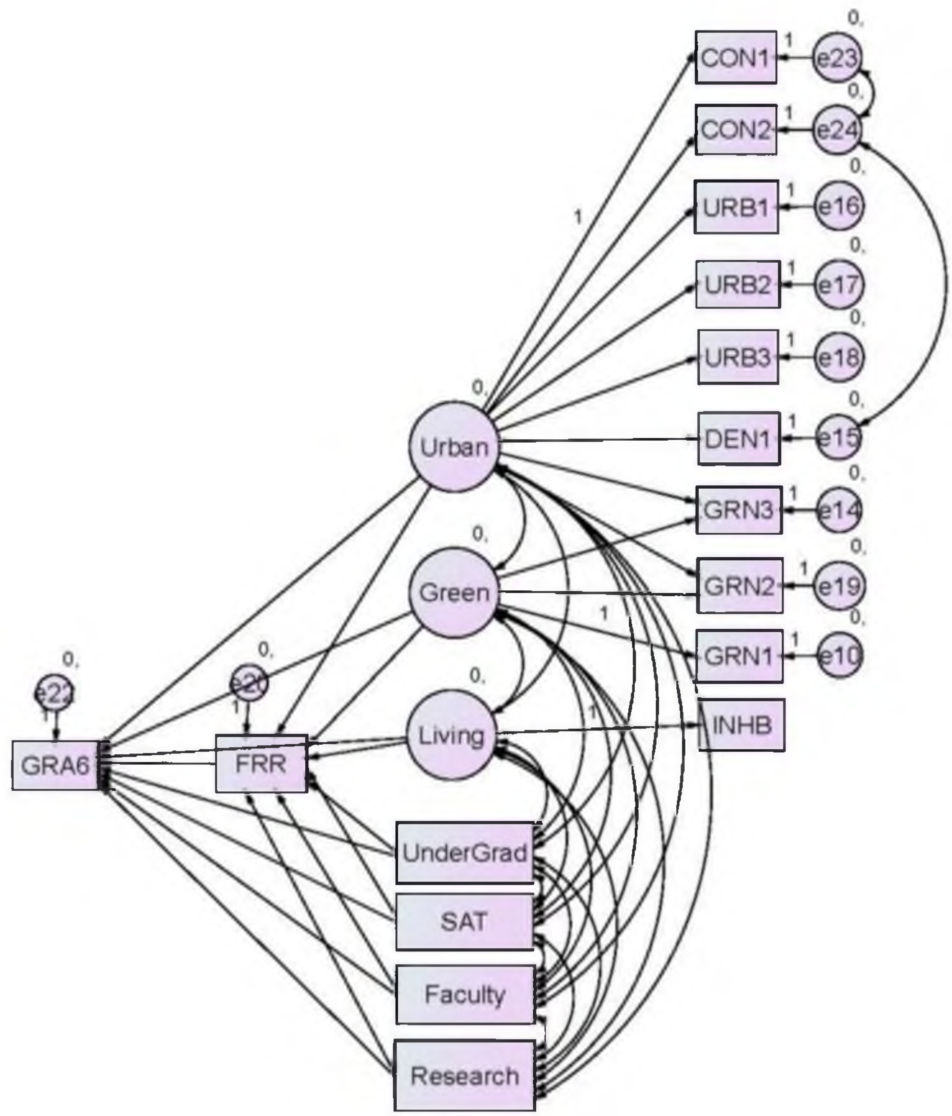

Figure 3.7 Modeling students' satisfaction and learning outcome. FRR: freshman retention rate; GRA6: percentage of students graduating in 6 years; UnderGrad: the total number of undergraduate enrollment (1 equals 1000 students); SAT: average SAT score; Faculty: percentage of classes with fewer than 20 students; Research: Type of university (Research I or Research II)

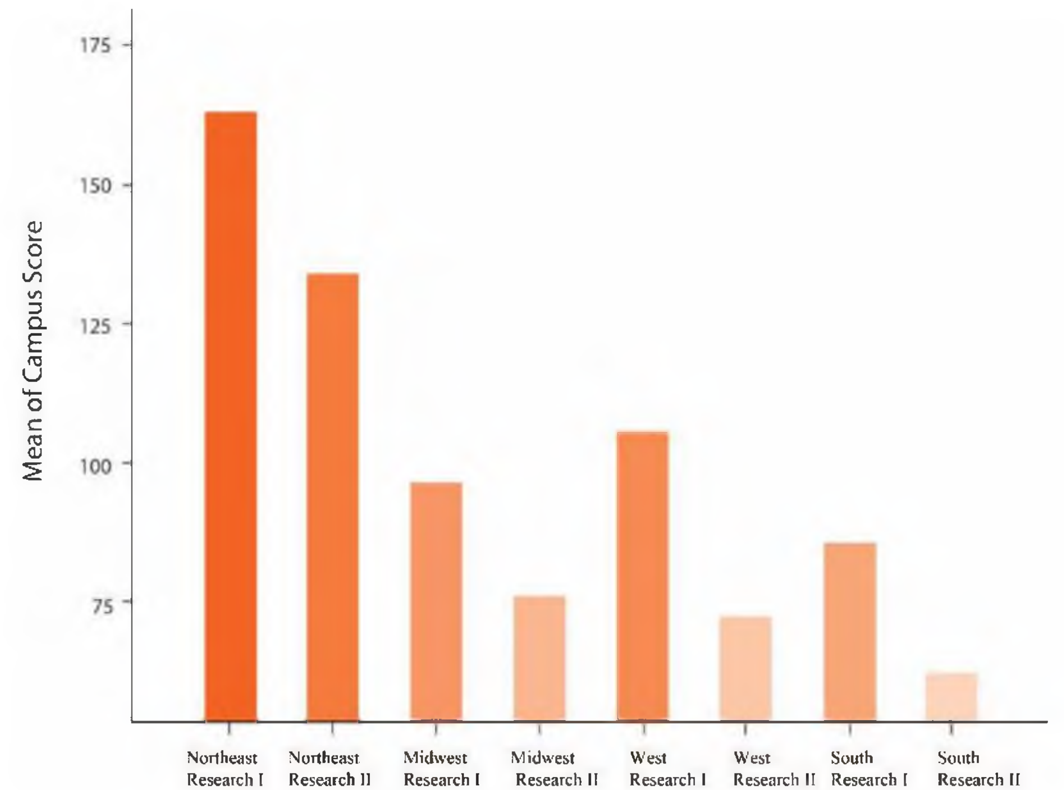

Figure 3.8 Means of Campus Score for each census region and university type.

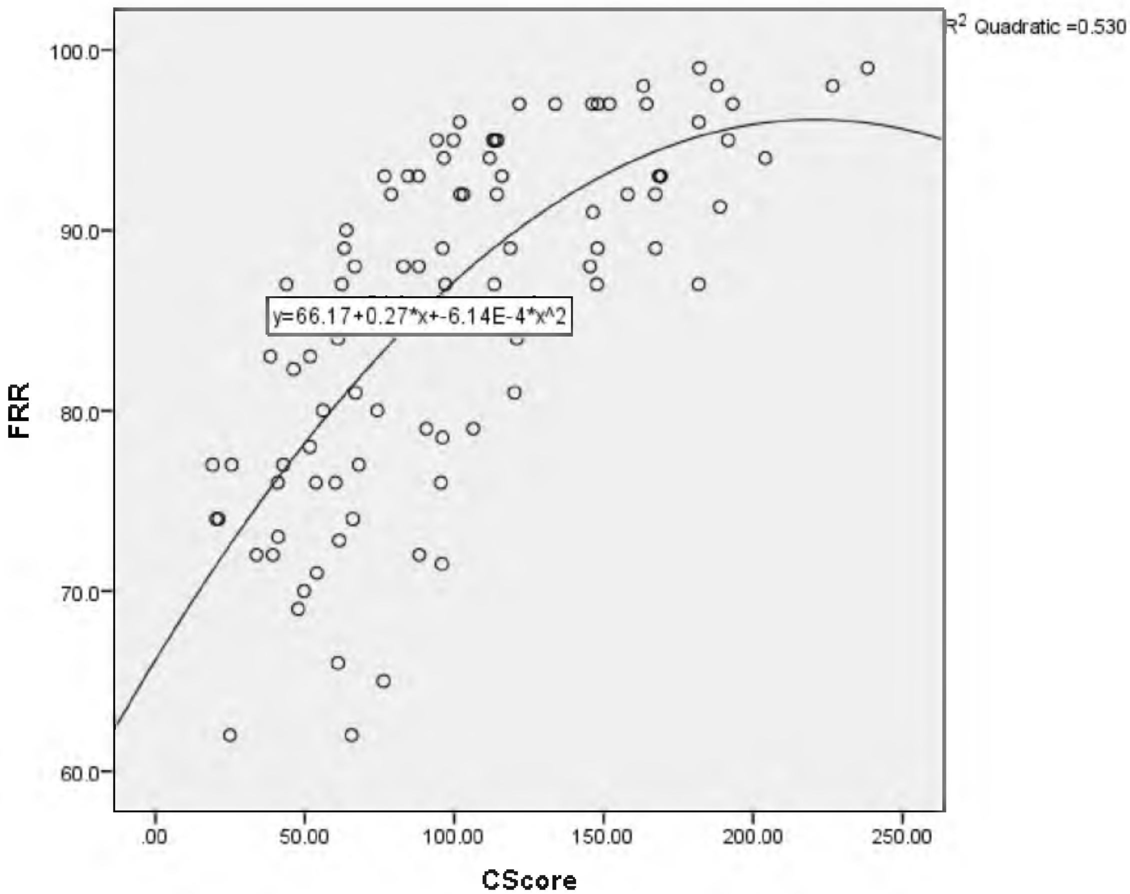

Figure 3.9 Scatter plot. X: Campus Score, Y: Freshman Retention Rate. R2=0.530

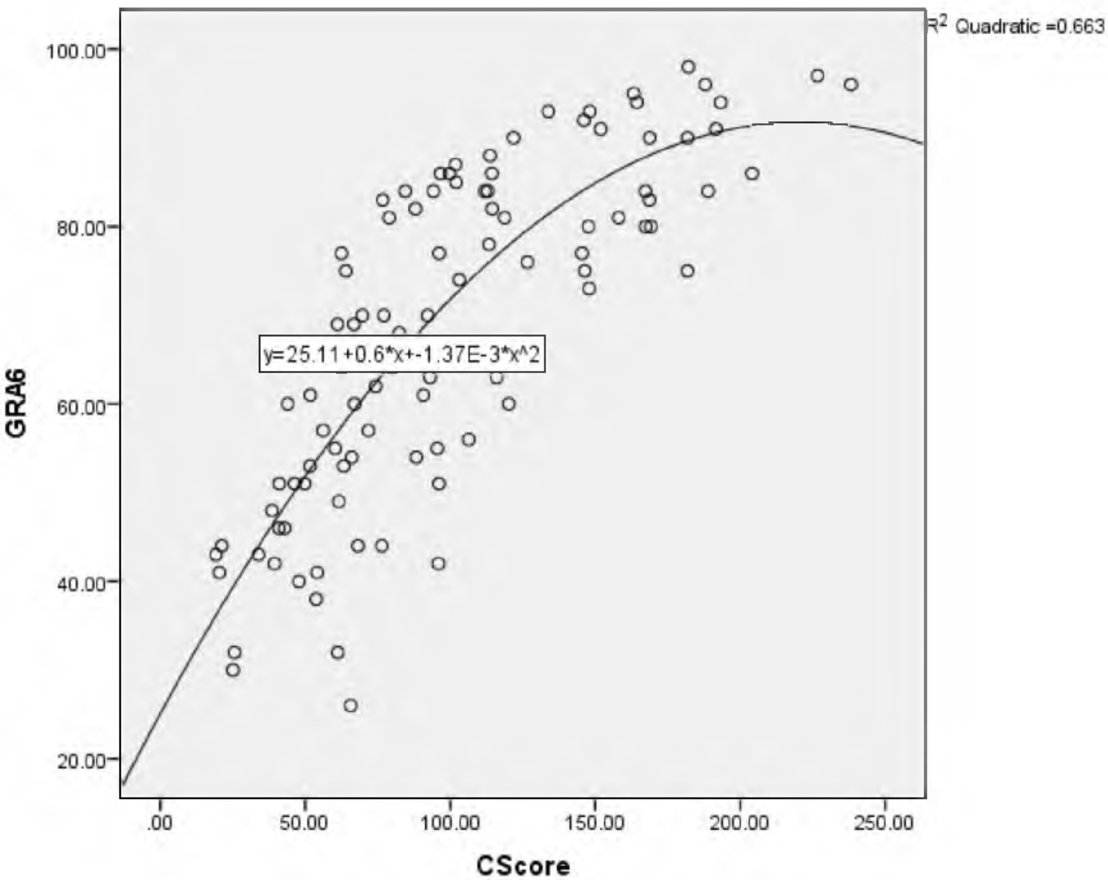

Figure 3.10 Scatter plot. X: Campus Score, Y: 6-Year Graduation Rate. R2=0.663

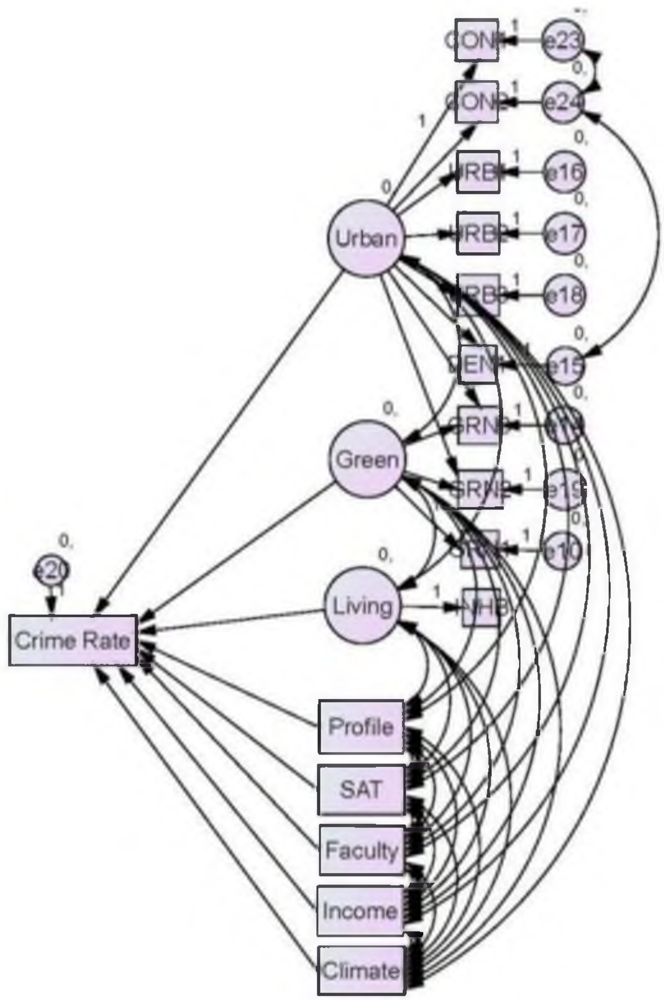

Figure 3.11 Modeling campus crime rate. Profile: the percentage of undergrad students, SAT: Average of SAT score, Faculty: the percentage of classes with fewer than 20 students, Income: the median household income of city; Climate: sum of cooling and heating days index

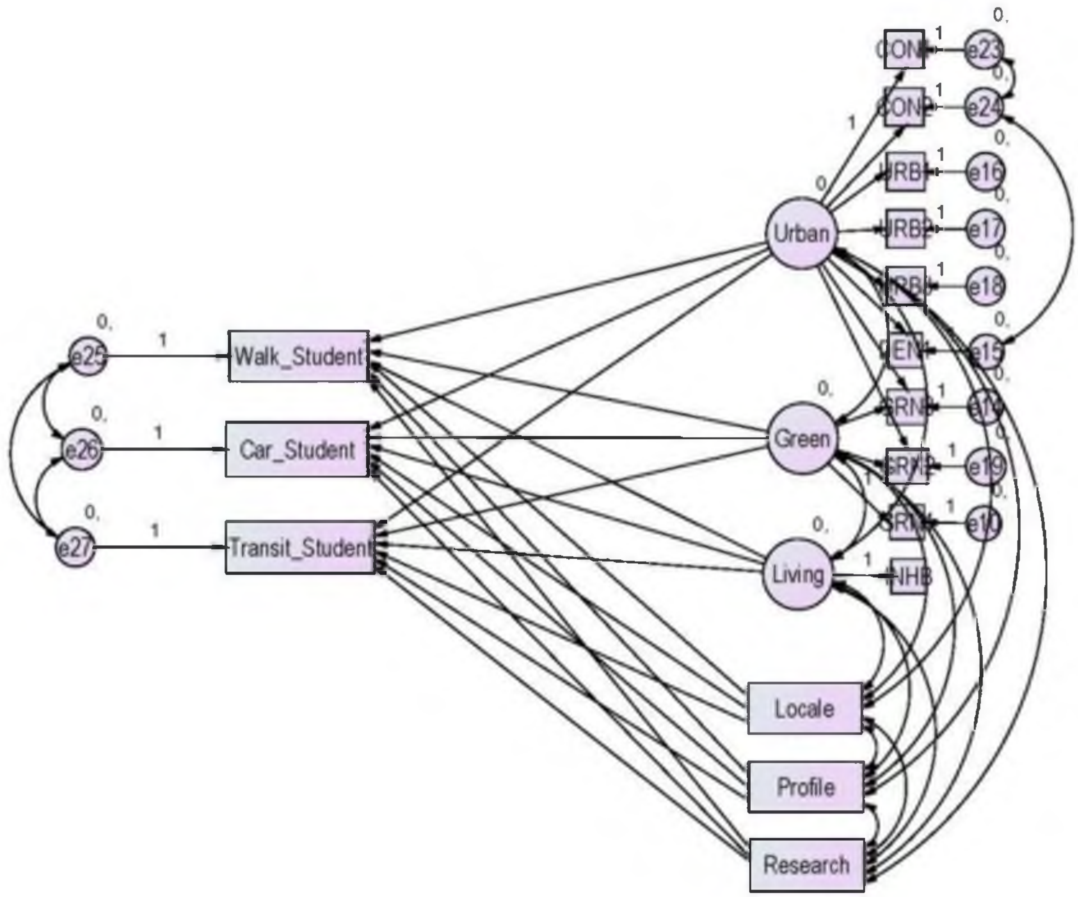

Figure 3.12 Modeling students' commuting behavior. Locale: the degree of urbanism of location, Profile: Enrollment profile classification, Research: Research I or Research II

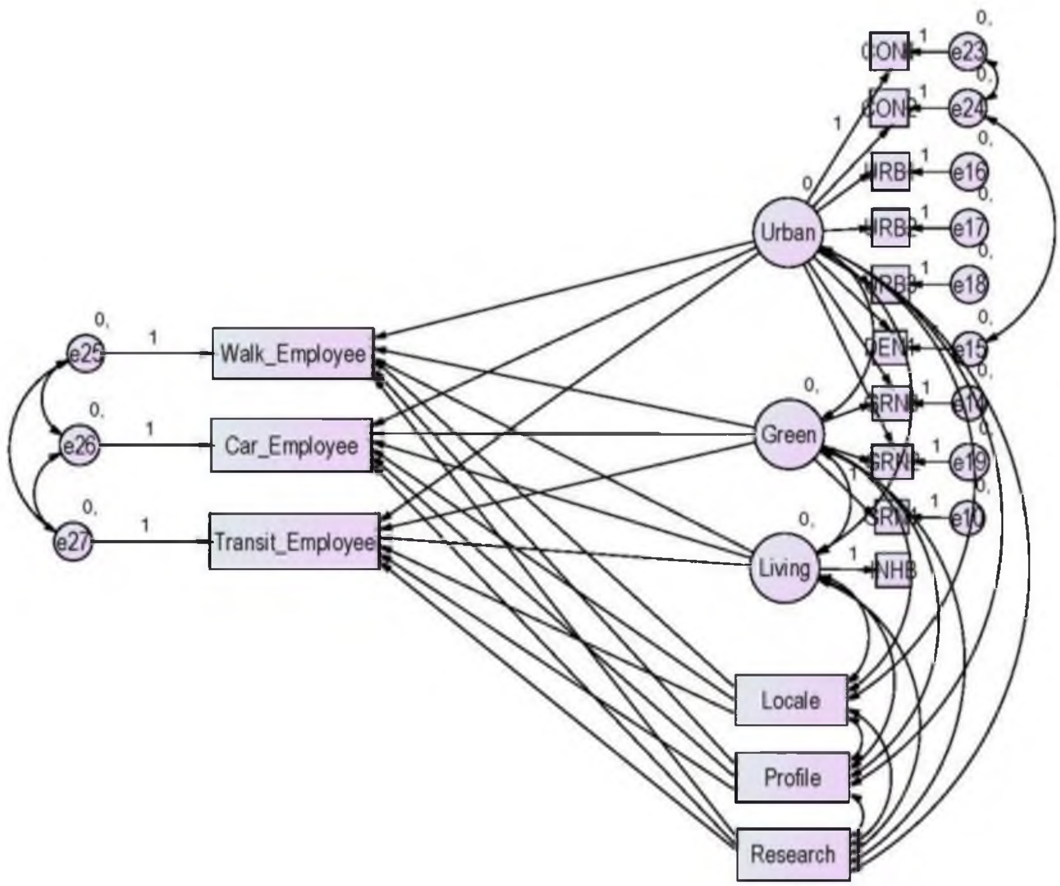

Figure 3.13 Modeling employees' commuting behavior. Locale: the degree of urbanism of location, Profile: Enrollment profile classification, Research: Research I or Research II

CHAPTER 4

SUMMARY AND PERSPECTIVES

The United States of America has a rich history of campus planning and design. Some of the best university campuses in U.S. were almost fully developed in the 19th century and early 20th century. Before World War II, campus designers would follow certain formal typologies such as quadrangle campus (e.g., University of Washington in Seattle), picturesque campus (e.g., University of Vermont), or Beaux-Arts campus (e.g., Columbia University). After World War II, with the vast expansion of university campuses, the emphasis was more on the design of freestanding buildings than on campus master plans. In recent years, most universities re-embraced the idea of campus master plans to address their institutional objectives, such as attracting more prospective students, increasing the quality of life of current students and faculty, promoting a learning and research environment, creating a sustainable environment, and benefiting the surrounding communities.

It became clear from the literature review that although campus planning and design have received extensive attention in the profession in recent years, this field is understudied in academia. In this research, I distilled a normative theory about the morphological dimensions of the "Well-Designed Campus" through the content analysis of 50 randomly selected campus plans, and also evaluated this theory quantitatively, using structural equation modeling. In other words, I conceptualized the "well-designed" campus—in the hypothesis-generating phase—to answer my first research question: *What are the principal features of contemporary university campus planning and design?* I then evaluated the "well-designed" campus—in the hypothesis-testing phase—to answer my second research question: *And when implemented, are they correlated with university objectives such as student success and satisfaction, campus safety and sustainability?*

In this section, I summarize and discuss the main findings of both phases. In addition, I briefly describe the limitations of study and the future research projects that can be initiated based on the theoretical framework of this dissertation.

4.1 The Main Findings of the Hypothesis-Generating Phase

My first observation was the high degree of similarities between the challenges, objectives, and recommendations of the reviewed master plans, which was surprising. These similarities point to certain threats and opportunities for campus planning and design practice. First, it may suggest that most campus planners have reached a shared, though unstated, normative theory in their practice. I have distilled four big ideas from the most common recommendations: 1) transition from a commuter campus to a convenient campus; 2) from an isolated campus to a contextual campus; 3) from a segregated campus to a cohesive campus; and 4) from a brown campus to a green campus. However, due to the scope of these similarities, the biggest challenge facing campus planners is the predictability of the master plans. Campuses may lose their distinct character and identity if they only adopt generic recommendations. The most successful campuses would be those that keep the element of uniqueness and sense of place in their master plans, while simultaneously following the common norms of practice.

Another key lesson from the content analysis of master plans is the high chance of infill development over campus expansion, at least in the near future. While almost all campus plans pointed out *the deficits in square footage* as their top challenge, only four percent of campus plans mentioned *the deficits in land for potential growth* in their documents. In addition, it was unexpected that *promoting walkability* was a shared objective in all reviewed master plans, while *promoting a learning environment* was mentioned in less than half of the plans. This finding indicates that campus planners may not fully treat the physical campus as an asset to enhance learning, or there are fewer known physical interventions at the campus level that can address this objective.

In order to avoid a subjective definition of what constitutes a "well-designed" campus, I referred to the most common recommendation in the selected master plans. Therefore, one of the biggest contributions to this dissertation research is providing a theoretical framework to study campus form through the lens of practitioners. To evaluate campus form, seven dimensions are suggested: land use organization, compactness, connectivity, configuration, campus living, greenness, and context. These dimensions are measurable; therefore, it was possible to test their relationship to the desired outcomes quantitatively.

4.2 The Main Findings of the Hypothesis-Testing Phase

Exploring the relationships between campus form and the desired outcomes, such as students' satisfaction, safety, and campus sustainability, gives campus planners fresh insight into the possible consequences of their actions. In addition, quantifying dimensions of campus form can inform campus planners about the norms of campus design for different university types in different census regions. For example, the percentage of surface parking areas or the percentage of pervious surfaces of one campus can be compared to the mean value of these variables for similar institutions. Furthermore, mapping 103 campuses in ArcGIS (half of the total research universities in the U.S.), a main step in the quantifying process, can be a valuable source of information for those who want to study campus plans at the national level.

Three dimensions are highly correlated to each other: compactness, connectivity, and context. I could generate more stable models by creating a new latent variable from these three dimensions. This latent variable is measuring "the degree of urbanism" of a campus. In other words, campuses that are more compact, better connected internally and to their surroundings, and are located in a more urban context, have a higher degree of urbanism. I found this latent variable, along with "the degree of greenness" and "campus living," to have significant association with more than one of the outcome variables. The tested models did not show any significant association between two campus form dimensions—configuration and land use organization—and the outcome variables. These two dimensions were the only dimensions that I had to rate subjectively. Therefore, although I tested for the reliability of these measurements, the possibility of a substantial measurement error as a contributing factor for the observed results is likely. However, the fact that these factors have truly no significant association with the outcome variables is also very much possible.

One of the interesting findings of this research is that although *greenness* and *urbanism* are negatively correlated to each other, both are positively associated with students' satisfaction with their college experience, controlling for the other university qualities. This finding can shed light on a classic debate among campus planners and designers about the dichotomy of a green and pastoral campus versus an urban campus. The results show that campuses must have a fair amount of both qualities to get a high design score. It is important to note that greenness is measured in a quarter mile buffer around campus buildings and not just on the campus ground, since accessibility is more important than ownership. Therefore, universities that are located in an urban setting should be sensitive not just about the greenness of their campus, but also the accessibility to local parks and green spaces. Likewise, universities with rural and suburban campuses should plan for and support more activities in their adjacent urban areas.

Another major finding is the strong association of on campus living with student satisfaction and graduation rate, after controlling for other influential factors. As described in the result section, a 10% increase in on campus residents is associated with the increase of the 6-year graduation rate of 2.43%. This finding suggests that campus housing may not just provide a convenient residence for students, but it can also largely impact the quality of life and education. Most importantly, improvement in this aspect of campus form is more feasible and economical than greenness or urbanism. I should note that while the number of students living on campus is important, their quality of living is even more so. I did not measure the quality of students' living in university housing of the selected campuses, but in the reviewed master plans, certain qualities were highlighted. For example, student housing should be close enough to the campus core to make it convenient for students to walk or bike to major destinations on campus. Students should also have reasonable housing choices in respect to housing type, style, and cost. In addition, universities should pursue innovative housing typologies. For example, the University of Utah launched an ambitious plan to recruit the "400 best student entrepreneurs" to live in a $45 million residential building starting Fall 2016. The goal is to create a place where student entrepreneurs "live, create, launch."[20]

Based on the qualities of urbanism, greenness, and campus living, I ranked my sample population (103 campuses). I developed a composite score—*Campus Score*—from the following formula: $0.177 \times \text{Urban} + 0.215 \times \text{Green} + 0.251 \times \text{Living}$. The three latent variables were standardized with the mean of 0 and standard deviation of 1. The multipliers are adopted from the standardized regression weights of the freshman retention rate model. Columbia University, Princeton University, Lehigh University, Duke University, and Emory University had the highest Campus Scores and University of Nevada at Las Vegas, University of Colorado at Denver, University of Texas at Arlington, University of Texas at San Antonio, and Wayne State University had the lowest Campus Scores.

The ANOVA test for the *Campus Score* of each census region and university type reveals that there is a significant difference between different categories. Private universities have significantly higher mean scores than public schools, Research I universities have significantly higher mean scores than Research II universities, and universities in the Northeast census region have significantly higher mean scores than universities in other census regions. This finding may raise certain questions, such as whether campus form has any true influence on freshman retention rate and 6-year graduation rate, or is it simply that better institutions have better campuses, and physical campus has no true influence on students' overall satisfaction and graduation rate.

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[20] For more information about this project go to http://lassonde.utah.edu/u-of-utah-recruiting-the-400-best-student-entrepreneurs/

To answer this question I controlled for all the main control variables in the literature for measuring university qualities, such as average SAT score as a proxy for student selectivity, the percentage of classes with fewer than 20 students as a proxy for faculty resources, a dummy variable for Research I or Research II universities as a proxy for research capacity, and finally the total number of undergraduate students as a proxy for the size of the institution. After controlling for these factors, campus form factors still have significant association with freshman retention rate and 6-year graduation rate. There might be a simple explanation for these relationships. Although it is hard to imagine that one student decides not to continue his or her education solely due to the campus qualities, it is much more likely that a green, urban, and livable campus provides such an enriching experience that students are convinced to pursue their education against all the potential negative factors, such as financial or academic issues.

The fact that the universities in the northeast region have higher *Campus Scores* is not just because of the eminence of their institutions in general; it can also be due to the type of urbanism in that region and, most importantly, the age of the campuses. Most campuses in that region were almost fully developed before the mid-20th century when campus planning was following certain established formal typologies rather than being dominated by auto-oriented development patterns and star architects. In addition, not all universities in the northeast region have high Campus Score. For example, Rutgers campus ranking is 71. Also, from the top 20 campuses, seven of them are not in the northeast: Emory University (rank 5), Stanford University (rank 7), College of William & Mary (rank 9), Case Western Reserve University (rank 11), Washington University in St. Louis (rank 16), University of Notre Dame (rank 17), and Rice University (rank 19).

The most interesting lesson from studying the relationship of campus safety and campus form was that more urbanized campuses are actually associated with less crime on campus, not more crime. This finding can be explained by the concept of "eyes on the street" coined by Jane Jacobs in her classic book, *The Death and Life of Great American Cities*. More activities surrounding a campus mean more potential witnesses or interveners, which can enhance the level of safety. On the other hand, one of the challenges with a higher percentage of students living on campus is potentially more crime on campus. This may seem to counter the "eyes on the street" argument, but it can be justified by the fact that it is more difficult to provide security for a large population than a small one. The important and logical lesson for university administrators is the necessity of providing adequate security services if a large percentage of students live on campus.

One of the benefits of a higher percentage of students living on campus, however, is the opportunity for more sustainable modes of transit, such as a higher percentage of students who walk or bike to class and a lower percentage of students who commute with only the driver in the vehicle.

The degree of campus greenness and urbanism are also both associated with more sustainable modes of travel. There are explanations to justify these associations. First, turning surface parking areas into green spaces or new buildings can increase the degree of campus greenness, and also make finding parking spaces harder and probably more costly for students and employees; therefore, they may find alternative modes of transportation to be more convenient.[21] In addition, there are more housing opportunities surrounding an

[21] This is a concept similar to the "reduced demand" phenomenon (the opposite of "induced demand") in transportation: decreasing road capacity increases the cost of travel so demand is reduced (Cervero and Hansen, 2002).

urban campus, and probably more transit opportunities; therefore, a lower percentage of students and employees may choose to commute by their own vehicles. Finally, a greener campus can provide a more pleasant walking and biking experience, and therefore, can increase the probability of walking and biking. For example, a 15-minute walk across parking lots and unplanted sidewalks can be undesirable, while a 15-minute walk across a green campus can become a pleasant daily ritual.

Overall, I theorized the “Well-Designed Campus” as a campus that is mixed, dense, well-connected, well-structured, inhabited, green, with an urbanized setting. The hypothesis was that the “Well-Design Campus” supports sustainable, livable learning environment. From the Structural Equation Models, I concluded that certain morphological aspects of “Well-Designed Campus” are significantly associated with the selected university objectives. It is important to understand that I evaluated a common big concept in the practice of campus design, not any specific recommendation. For example, this research does not specifically assess the validity of a recommendation such as “encouraging mixed-use development along a street corridor at the campus border”; however, this recommendation may increase the degree of urbanism of campus, which is proved to be a positive quality. Although, I extracted 100 recommendations from the reviewed campus plans, clearly they don’t have the same power and impact on campus quality. If I want to further translate my findings into lessons for practitioners, I should stress those recommendations that are most crucial for creating a “Well-Designed Campus.” The first and foremost recommendation would be to increase on campus housing. The second recommendation would be to decrease surface parking areas. And the third recommendation depends on the campus setting. For the urban campuses, the third recommendation would be to invest in green spaces on and adjacent to campus. For suburban and rural campuses, the third recommendation would be to encourage infill and mixed-use development on and adjacent to campus.

4.3 Limitations of Study

The biggest limitation of this research is data availability. Although data on institutional characteristics are diverse and relatively accessible, very little information on the built environment characteristics of university campuses is available. Information such as building height and architectural quality of campus buildings is not available and therefore, not included in this research. The lack of data availability is the main limitation for operationalizing morphological constructs, such as land use organization and configuration.

Although this study provides a theoretical framework for analyzing normative dimensions of campus form, testing the validity of these dimensions requires more research on measuring outcome variables, such as livability, sustainability and learning outcomes. For this dissertation, I have had to rely on the available proxy variables. For example, the validity of STARS can be a problem because this index has been produced through a self-report survey by universities without any inspection or validation by AASHE. Measuring control variables is also challenging. For example, a key control factor—administrative policy—is missing in this study. The administrative policy of universities can have a critical impact on achieving different institutional objectives. Proxies such as “type of institution” or “enrollment profile” cannot fully represent the complexity of administrative policies in addressing institutional missions. The final limitation relates to the unit of analysis of this research. Because of data availability, I have to use the campus as the unit of analysis, which is a highly aggregated unit.

4.4 Future Research

As Brenda Scheer (2010) described:

> It is easy to see that a campus is a very different construct than a piece of a city. It mimics only the look, not any of the other urban qualities or conditions that provide the resilience of naturally evolved places and types. Those qualities include regular and divided lot patterns, public streets, relatively simple building types situated individually on lots, and multiple connections to surrounding fabrics (p. 46).

Overall, a campus is not a city, a neighborhood, or a block. Therefore, describing and analyzing the morphology of a campus should be different from other aspects of the built environment. This study, for the first time, has proposed seven morphological dimensions for analyzing campus form. The proposed theoretical framework can be related to different research topics in regards to university campuses.

Based on the proposed morphological dimensions, it is possible to propose the typology of university campuses. Understanding the typology of university campuses can inform campus planners and university administrators about the potential challenges and opportunities that are associated with their specific campus type. In addition, proposing a campus typology is a key step in investigating the potential relationship between different campus types and the institutional identity of universities. Finally, the typology of university campuses can shed light on the dynamics of town-gown relationships.

Research on the impact of university interventions on surrounding neighborhoods is limited. There are some detailed case studies on campus expansion and neighborhood revitalization in the past decades; some of them were successful projects, some of them were not. However, we don’t really know if the morphology of the campus and neighborhood and their physical interaction are the influential factors for the success of university interventions. To conduct systematic research in this area, the proposed theoretical framework for analyzing campus form is critical.

Other possibilities for related future research include exploring the relationships between campus scare and various university rankings such as *U.S. news and world report, Times Higher Education*, and *Shanghai* rankings; applying the same basic methodology to nonresearch institutions such as community colleges and regional universities; applying the technique of propensity score matching to see if it is campus design or "the northeast effect" that causes schools such as the Ivy Leagues to score so high in terms of outcomes.

APPENDIX A

THE TOP 100 CAMPUS MASTER PLAN RECOMMENDATIONS

Recommendations for transforming university campuses, sorted by their theme, objective, and frequency: * =1-9 cases, **=10-19 cases, ***=20-29 cases, ****=30-39 cases, *****=40-50 cases.

		CONVENIENT CAMPUS
		LIVABILITY
1	*****	Increase residential housing on campus.
2	*****	Locate as many university functions as possible on or close to Central Campus (without compromising the highly valued sense of openness in some cases).
3	*****	Increase recreational and cultural amenities like fitness-exercise facilities, performing arts center, and visual arts facilities.
4	****	Increase and Improve gathering spaces (with quality furniture).
5	***	Enhance the quality of the campus environment by including quality public art that reflects the spirit and creativity of University.
6	***	Encourage mixed-use development and buildings with active ground-level uses.
7	**	Broaden and diversifying housing options on campus.
8	*	Dining services will be distributed throughout the campus. Introduce smaller food venues within the academic core.
9	*	Install lighting in parking lots and garages, for comfort and security, but with minimal glare to the immediate surroundings.
10	*	Reasonable accommodations for students with physical disabilities; Installing ADA compliant ramps • Making curb cuts in sidewalks and entrances • Widening doors • Installing offset hinges to widen doorways • Installing accessible door hardware.
11	*	Designated zones on campus, selected on the basis of location, proximity of resources and amenities, and safety, will host a range of academic and social activities during extended hours to encourage activities 24/7.
		SENSE OF COMMUNITY
12	***	Create an academic neighborhood hub by providing a central space for student-focused and student-led activities.
13	***	Integrate academic and research activities in shared facilities.

14	***	Instead of creating pure residential districts, mix them with multidisciplinary academic facilities and have them on the core campus.
15	**	Recognize and support distinct communities of disciplines within the context of the larger University.
16	*	Emphasize close relationships and short travel times between related programs to encourage cross-disciplinary collaboration.
17	*	Creating a more transparent addition along the pedestrian path – so that building users and passersby can "see and be seen."
18	*	Creates a system of internal circulation corridors with learning/social spaces.
19	*	Consolidate undergraduate academic divisions, as well as the facilities of individual professional schools as much as possible, to increase efficiency and maximize convenience for both faculty and students.
20	*	Intensify the overlap and magnitude of campus, workplace, residential, and amenity activities to foster creative innovation with a mix of people engaged in living, working, learning, and relaxing.
21	*	Protect and enhance outdoor teaching and research facilities.
		WALKABILITY
22	*****	Limiting expansion and using infill development where possible.
23	*****	Changing some surface parking areas (mainly at the core of campus) into parking structures or other utilities.
24	****	Promote the use of alternative modes of transportation including shuttle and bicycles to reduce vehicular traffic.
25	****	Creating car-free zone -reducing vehicular through-traffic on campus.
26	***	Locate new parking to intercept traffic at the campus edge to reduce internal traffic and the need for shuttles.
27	***	Incorporate comprehensive bike network. Provide dedicated bike lanes, in both directions, on campus streets that are contiguous and easily understood by cyclists.
28	**	Plan and advocate for potential future regional passenger rail service and locate a future station to support campus circulation patterns.
29	**	Selectively redistribute parking capacity to be closer to high demand areas in and around the campus core and projected development areas.
30	*	Concentrate development around transit nodes.

31 * Improving parking area efficiencies, maintenance and appearance through consolidation and screening.

32 * Price parking to ensure financial sustainability and to encourage alternative mode use.

33 * Reposition select campus bus stops to better align with primary pedestrian circulation routes and major roadway intersections.

34 * The introduction of a car-share program to the university. This could provide options for resident students without cars to make trips to the grocery store or to frequent off-campus retail destinations.

35 * Support efforts to make streets narrower to slow traffic and minimize the crosswalk distance.

36 * Consolidate and reorganize service access routes to reduce potential pedestrian/vehicle conflicts.

37 * Make the most efficient use of parking supply by locating facilities in places that support complementary uses during evenings and weekends. Also develop a hierarchy of parking as it applies to hourly commuters, daily commuters and residential customers.

38 * Locate support structures, such as physical plant and grounds maintenance, at the perimeter of the campus, where they can meet functional and circulation needs more easily.

39 * Align and simplify many existing pedestrian movements to ease navigation and to improve safety.

40 * Increasing campus safety through separation of vehicles from many heavily-used pedestrian areas.

CONTEXTUAL CAMPUS

PARTNERING

41 *** Respond to community partnership opportunities, including: student convocation center, student dining, student union, theater, large banquet space, and alumni center.

42 *** An alliance with the City to create a mixed-use campus town along a street corridor which will provide both additional residential beds and needed retail services like restaurants, coffee shops, and potentially the university book.

43 * Provides educational access opportunities throughout the region by establishing multiple locations.

44 * Provide community input where appropriate into the University Campus Master Plan process.

45 * Encourage private development and investment.

TOWN-GOWN RELATIONSHIP

46 **** Welcoming edges where campus meets community; Provide additional campus entries (with identifiable gateways that reflect a similar character and composition).

47 ** Develop strong physical connections between the main street of neighborhood and the main campus.

48 ** Reinforce arts, entertainment and retail activities for the City as well as the University by designing new facilities with active uses (at the ground level).

49 * Consider campus as a destination for the public.

50 * Grow the campus without adversely affecting surrounding neighborhoods. Pursue optimal development and use of existing facilities and strategic expansion off-campus.

COHESIVE CAMPUS

LEGIBILITY AND IMAGABILITY

51 *** (linear) (green) corridor to connect different parts of campus such as river fronts, boulevards, or mixed streets or main pedestrian pathways.

52 *** Emphasis on constructing new buildings along the main spatial structure of campus.

53 *** Create semienclosed space, with many entrances. The ratio of building height to open space shall be 1:1.5 or 1:2 to create comfortable enclosed spaces rather than wide open sprawl.

54 *** Develop a signage plan. Accommodate the differing viewpoints of drivers, cyclists, and pedestrians to whom signs are addressed. This will influence placement and scale of signs.

55 ** Create a wayfinding system that integrates with the surrounding landscape, architecture and urban environment.

56 ** Create a focal point at the end of the pedestrian axis. Place towers and other prominent building elements at the ends of key streets and prominent view corridors.

57 ** Provide changes in scale and design of outdoor rooms to emphasize passage between different spaces on campus. For example, create a campus of shaded gardens, plazas, activity hubs, punctuated with water features.

58 ** Landscaped open spaces and the natural setting organize the campus. The character of the campus as a whole and the places within it should be

distinguished first and foremost by the landscape, both natural and designed.

59 * Develop a lighting system that illuminates destinations and reduces glare between destinations with low-level, white, metal halide light.

60 * The use of topographic relief to break up views and create a series of smaller terraces within the bigger space.

61 * Building iconic buildings as the new image of campus.

62 * Orient building entrances, whether in new construction or renovation projects, toward those streets or walkways that support the primary pedestrian system within the area and throughout the campus.

63 * Develop new paths, walks and passages through buildings to provide clear pedestrian routes and shorten distances between key activities and destinations.

64 * Undertake a series of open space projects to help clarify pedestrian routes; a hierarchy of open spaces; from formal to informal, from large to small.

65 * Design new buildings to shape open spaces rather than merely sit as an object in them.

66 * Framing streets in the densest parts of campus with building walls that are punctuated with distinctive gateways and passages to interior spaces and courtyards.

67 * Prominently light building entrances or ground floors, important architectural features and supporting landscape elements to reinforce the pedestrian system throughout campus.

68 * Find the best locations for low-intensity land uses like athletic fields, greenhouses and barns displaced from the Core, given the need for proximity.

69 * A new building's mass will be complementary to adjacent long-term structures through its use of scale, materials, color, or detail.

70 * Design and select paving to provide visual consistency, to create site-specific character, and for sustainability.

71 * Trees and plantings can provide structure to a space, creating the "walls" and "ceiling" of an outdoor room.

72 * Select site furnishings that give definition to campus outdoor spaces, provide places for social gathering, maintain cleanliness, and lend to the unified character.

IDENTITY

73 **** Preserving historic identity and renovation of historic buildings.

74	***	Preserve and enhance views to and from character defining features.
75	***	Extend the formal pattern of quads, and courts as the character of campus.
76	**	Select materials that are consistent with campus standards.
77	**	Proposing design guidelines (based on typological studies of existing buildings and campus features such as benches, trash and recycling receptacles, tables, bicycle racks, fences, fighting, pavements, signage, emergency telephones).
78	*	Avoiding rectangular corporate looking buildings on campus.
79	*	Consider opportunities to demolishing old and small buildings and constructing more efficient buildings, in harmony with the campus character.
80	*	Develop at a higher density outside the core to preserve the historical character of core campus.
		GREEN CAMPUS
		ENVIRONMENTAL SUSTAINABILITY
81	***	Develop a green infrastructure from an ecological and aesthetic perspective, as well as engineering.
82	**	Site buildings and plant materials for microclimate characteristics such as cooling summer breezes, protection against winter winds, sunlight, and shade.
83	**	Promote on-site renewable energy from sources such as biomass and solar power to meet energy demand.
84	*	Orient (and pitch) roofs for solar thermal and photovoltaic applications (immediate or future).
85	*	Support long-term utilities planning and life cycle costing.
86	*	Technology is implemented in transportation including: clean fuels and vehicles; traffic operation systems that manage traffic flow and reduce delay and congestion on nearby roadways; advanced and accessible traveler information.
87	*	Easing campus maintenance through better unified and longer lasting amenities.
88	*	Plan campus growth on the most suitable sites possible, avoiding unnecessary environmental impacts to existing campus open space and natural resources.
89	*	Provide site lighting that is sensitive to light pollution of the night sky and minimizes impacts on nocturnal environments.

90	*	Reduce potable water consumption associated with landscape irrigation.
91	*	Create a campus-wide network of small scale storm water measures, such as constructing check-dams in forested swales; establishing rain gardens and bio retention; installing permeable pavements.
92	*	Use passive strategies such as insulation and shading to minimize energy demand.
93	*	Optimize buildings' energy performance by using efficient mechanical and electrical systems.
		LANDSCAPING
94	****	Addition of high-quality landscaping and site furnishings to create comfortable and lively open spaces.
95	***	Preserve park-like setting of campus.
96	**	Generously landscape setbacks and moats between buildings and city streets.
97	**	Breaking parking lots with (native) trees to create more manageable parking rooms and to perform ecological functions.
98	*	Be open to its natural features–a river or a hill–and remove obstacles to seamless integration. Integrate the planned and natural environments more fully with one another.
99	*	Integrate the native vegetation within future campus landscape development.
100	*	Setbacks and buffers from water bodies, streams, and wetlands to protect wildlife corridors, sensitive riparian zones, and water quality. Setbacks and buffers generally range from 25 feet to 100 feet.

APPENDIX B

ANALYTICAL MAPS FOR SELECTED CAMPUSES

Figure B.1 Figure ground map, Oklahoma State University

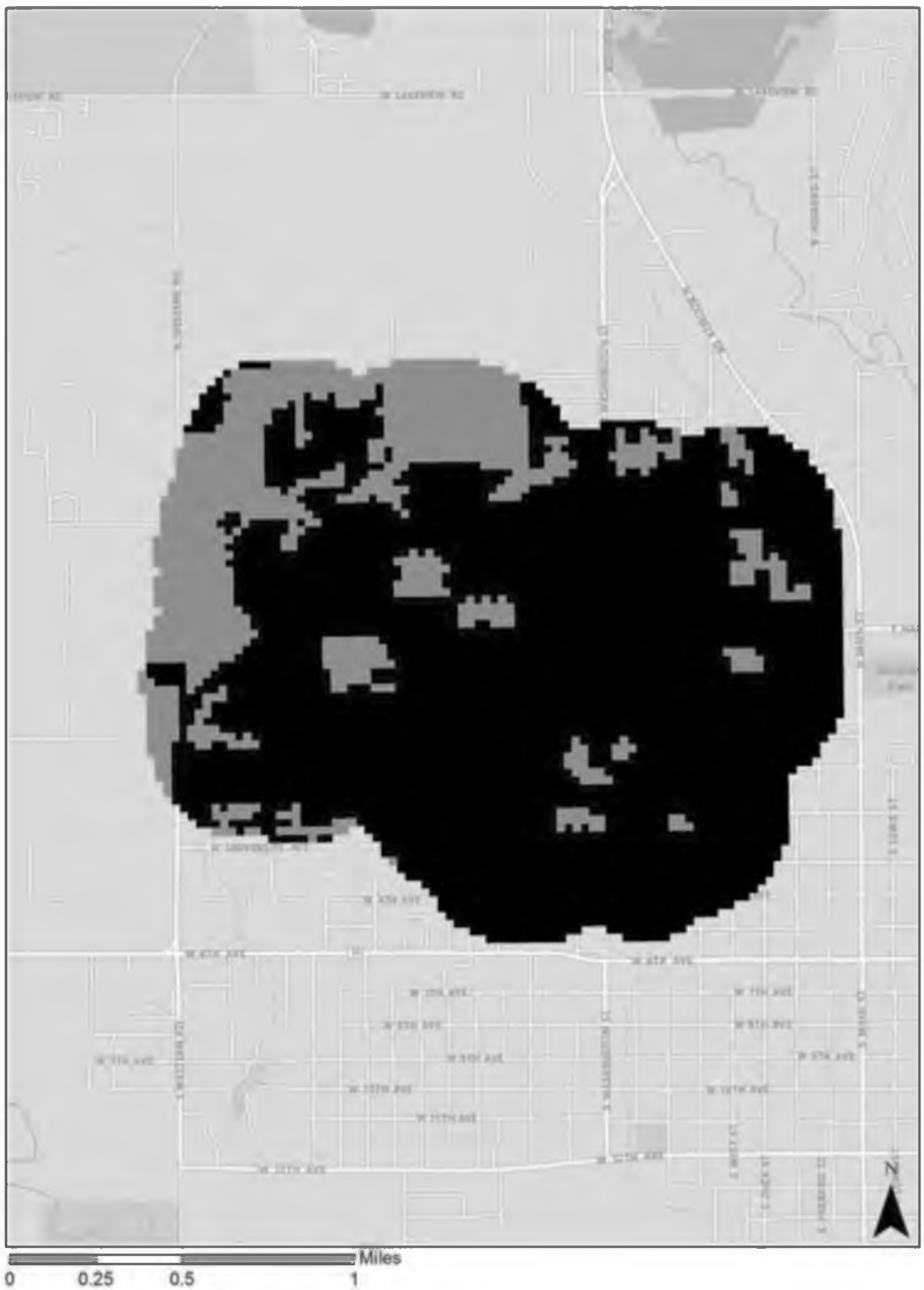

Figure B.2 Pervious open space, Oklahoma State University[22]

[22] In all “pervious open space” maps, black is impervious space.

Figure B.3 The intensity of tree canopy, Oklahoma State University

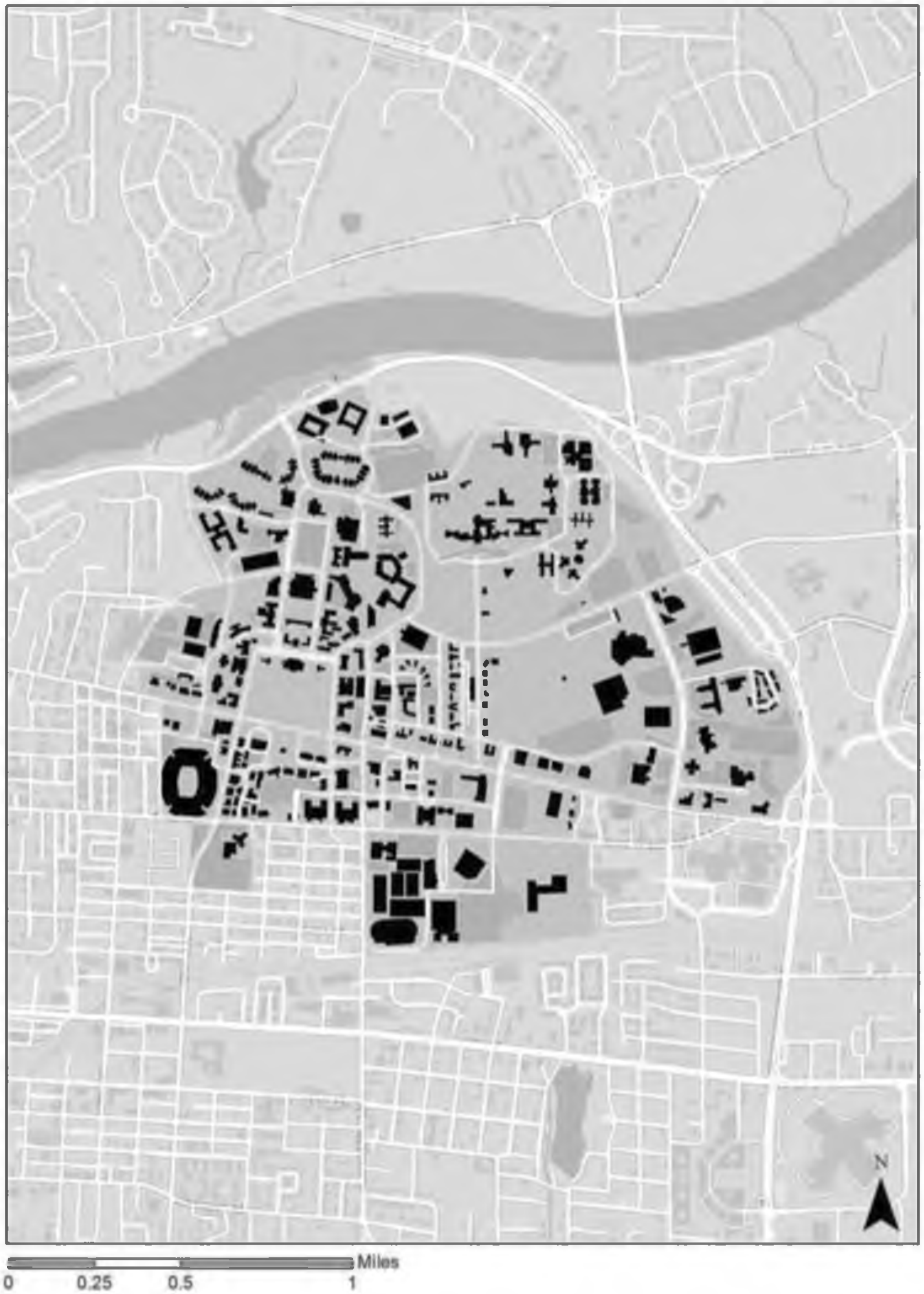

Figure B.4 Figure ground map, University of Alabama

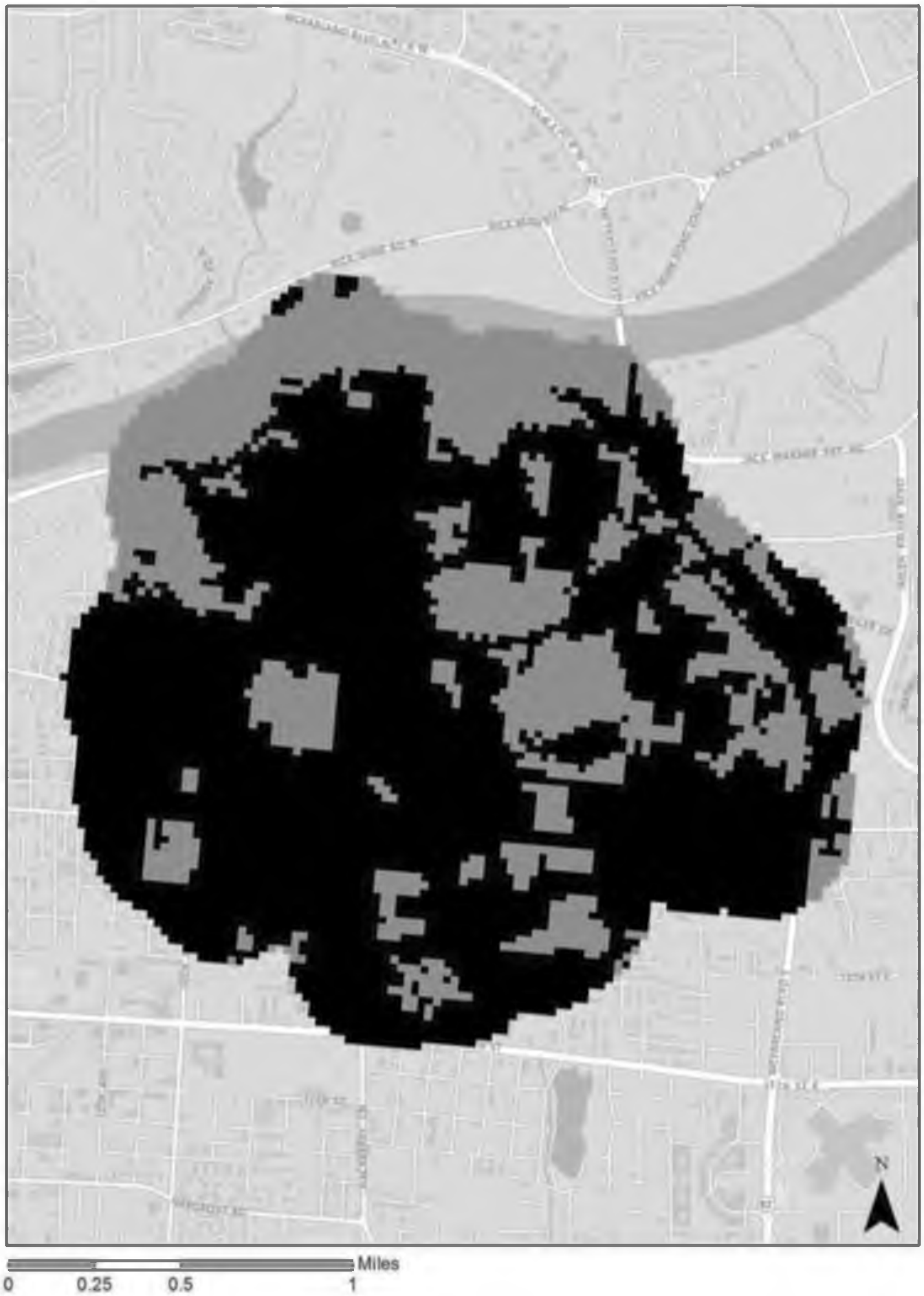

Figure B.5 Pervious open space, University of Alabama

Figure B.6 The intensity of tree canopy, University of Alabama

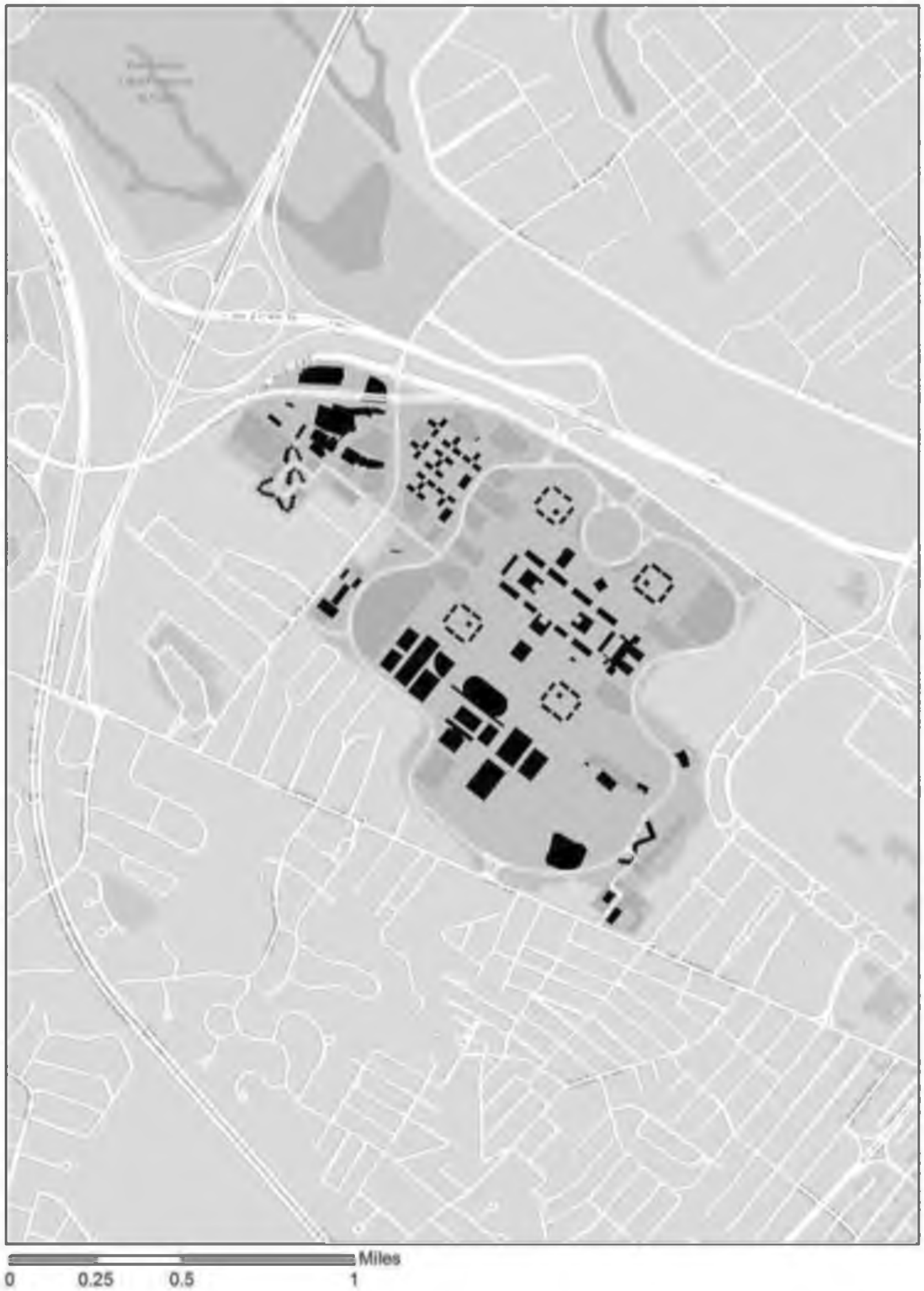

Figure B.7 Figure ground map, University of Albany, SUNY

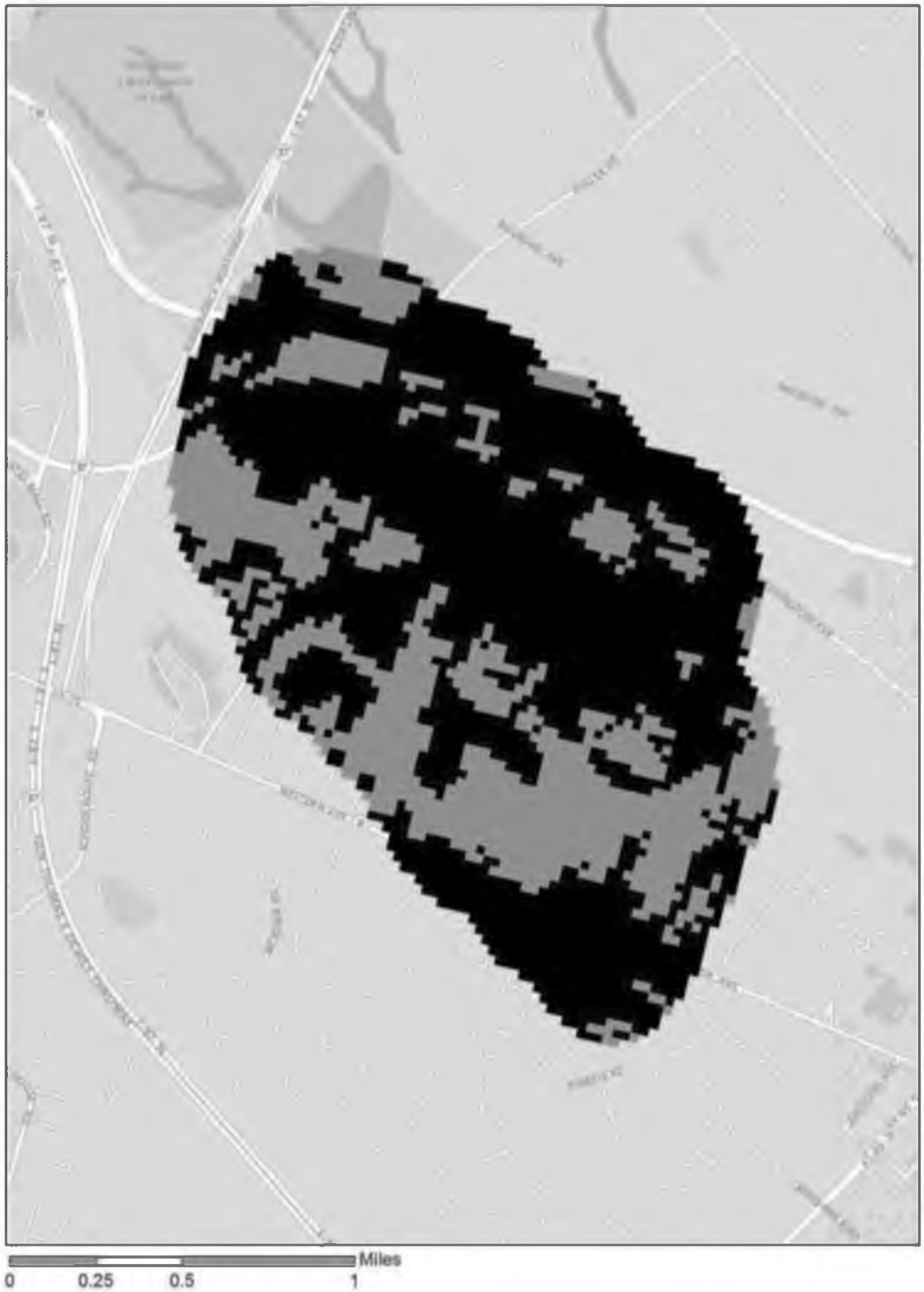

Figure B.8 Pervious open space, University of Albany, SUNY

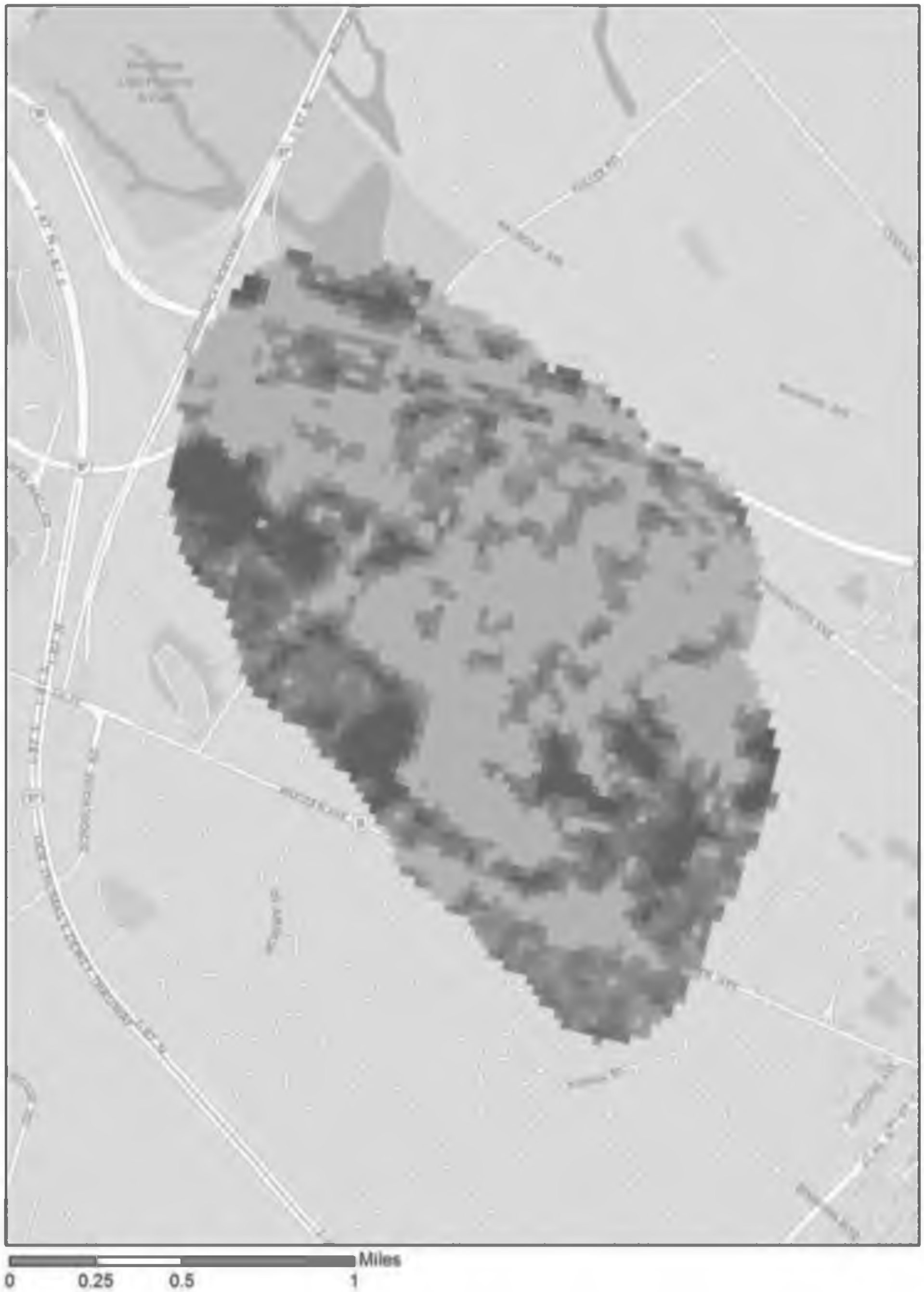

Figure B.9 The intensity of tree canopy, University of Albany, SUNY

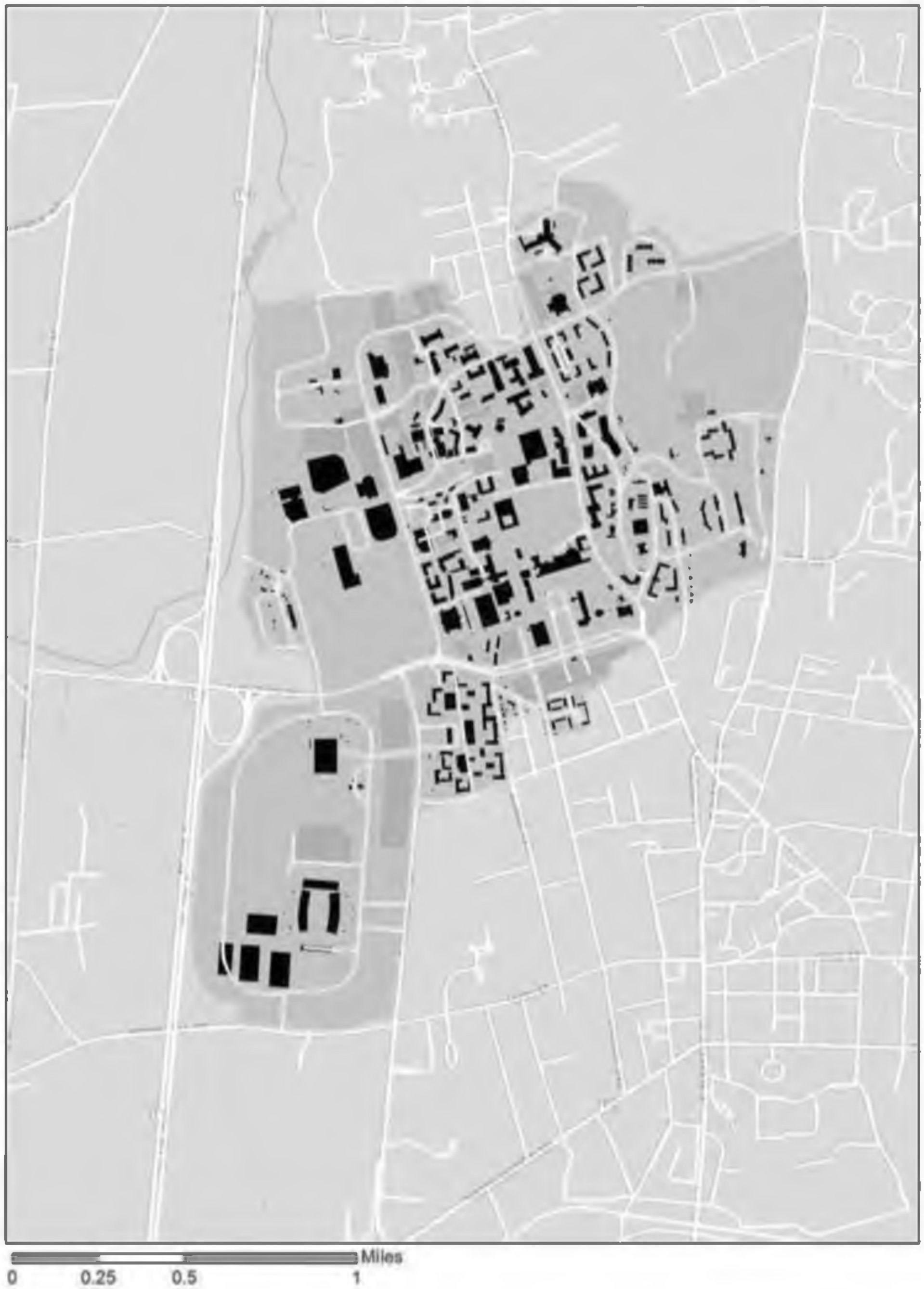

Figure B.10 Figure ground map, University of Massachusetts Amherst

Figure B.11 Pervious open space, University of Massachusetts Amherst

Figure B.12 The intensity of tree canopy, University of Massachusetts Amherst

Figure B.13 Figure ground map, Arizona State University, Tempe

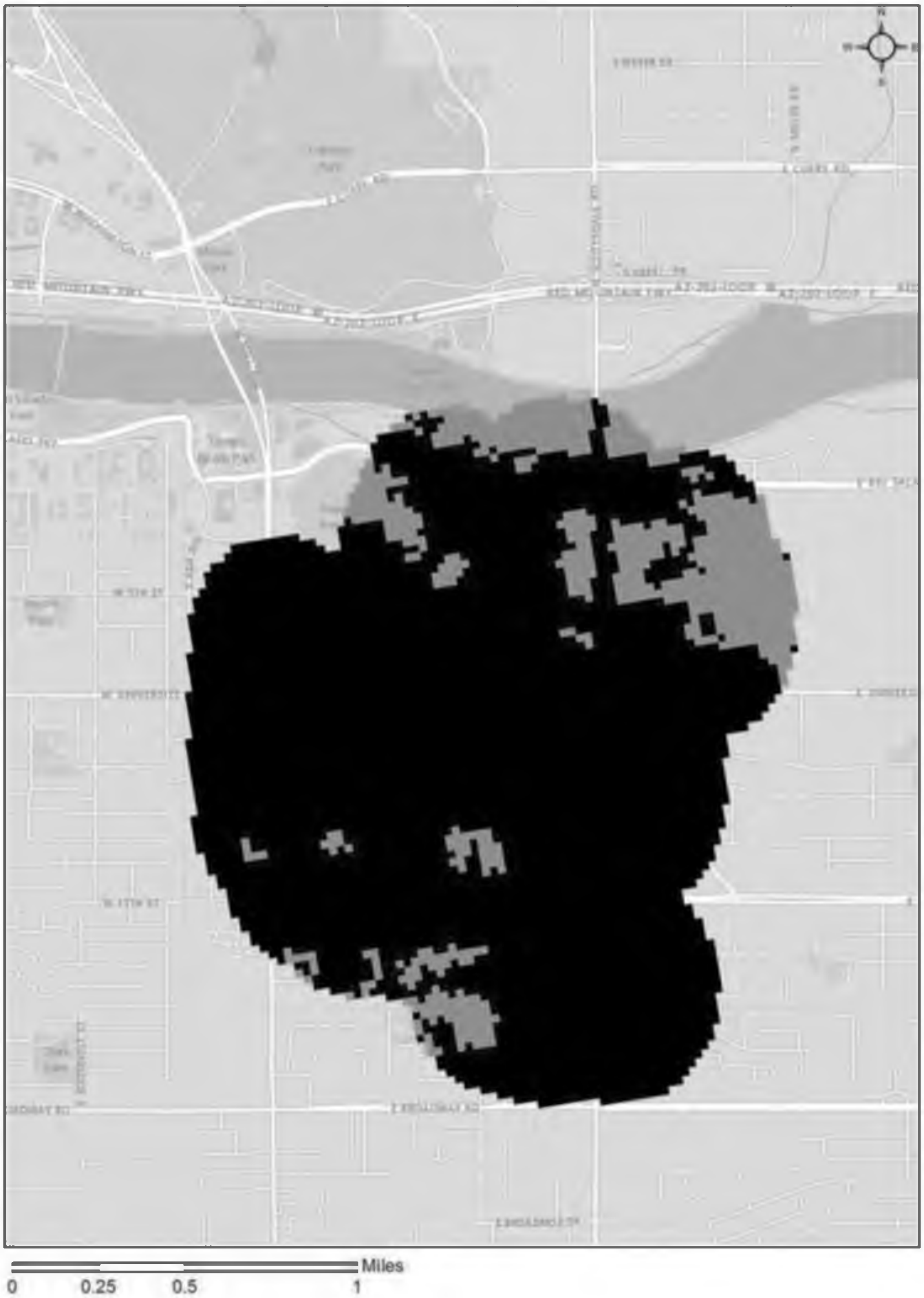

Figure B.14 Pervious open space, Arizona State University, Tempe

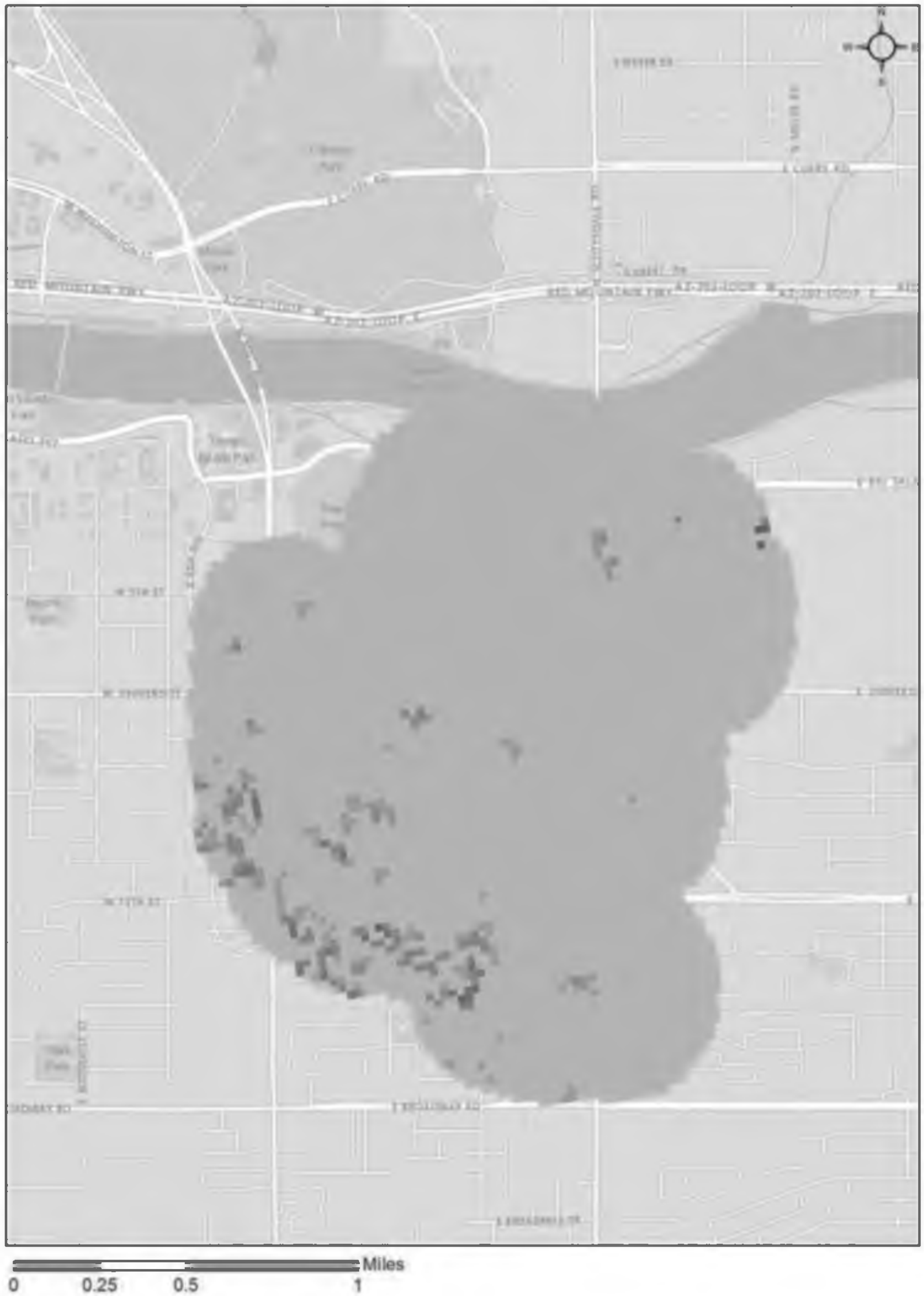

Figure B.15 The intensity of tree canopy, Arizona State University, Tempe

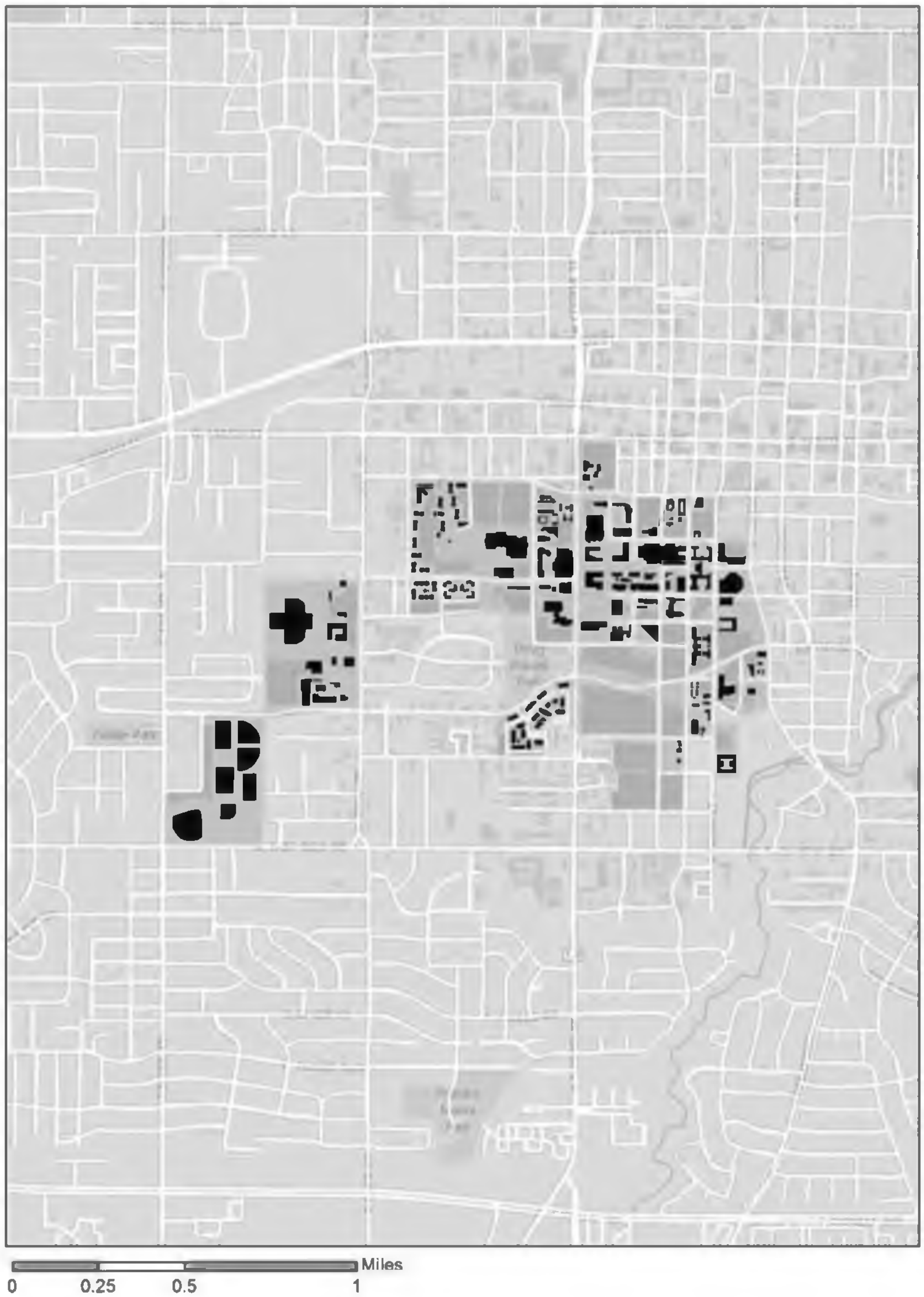

Figure B.16 Figure ground map, University of Texas at Arlington

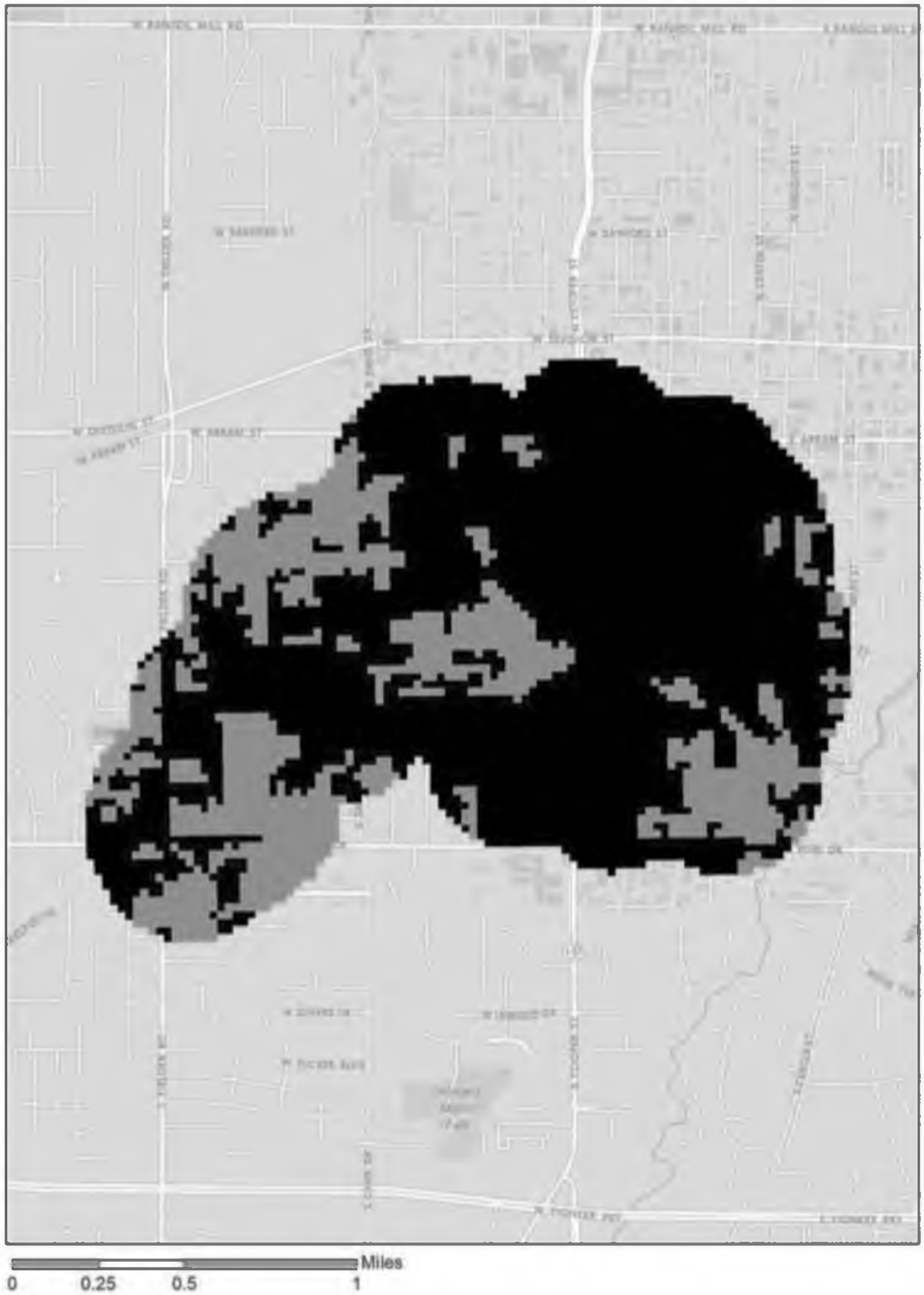

Figure B.17 Pervious open space, University of Texas at Arlington

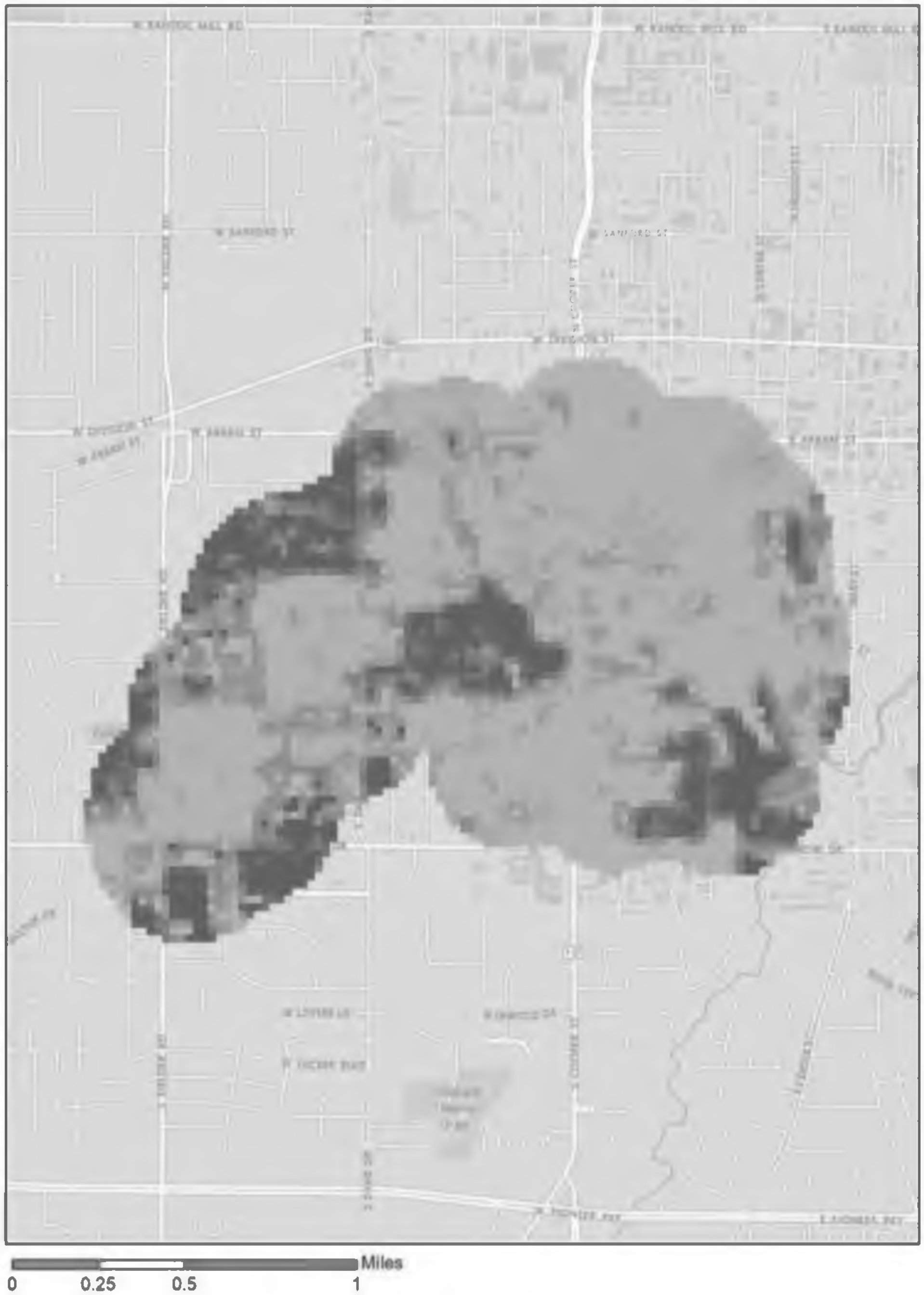

Figure B.18 The intensity of tree canopy, University of Texas at Arlington

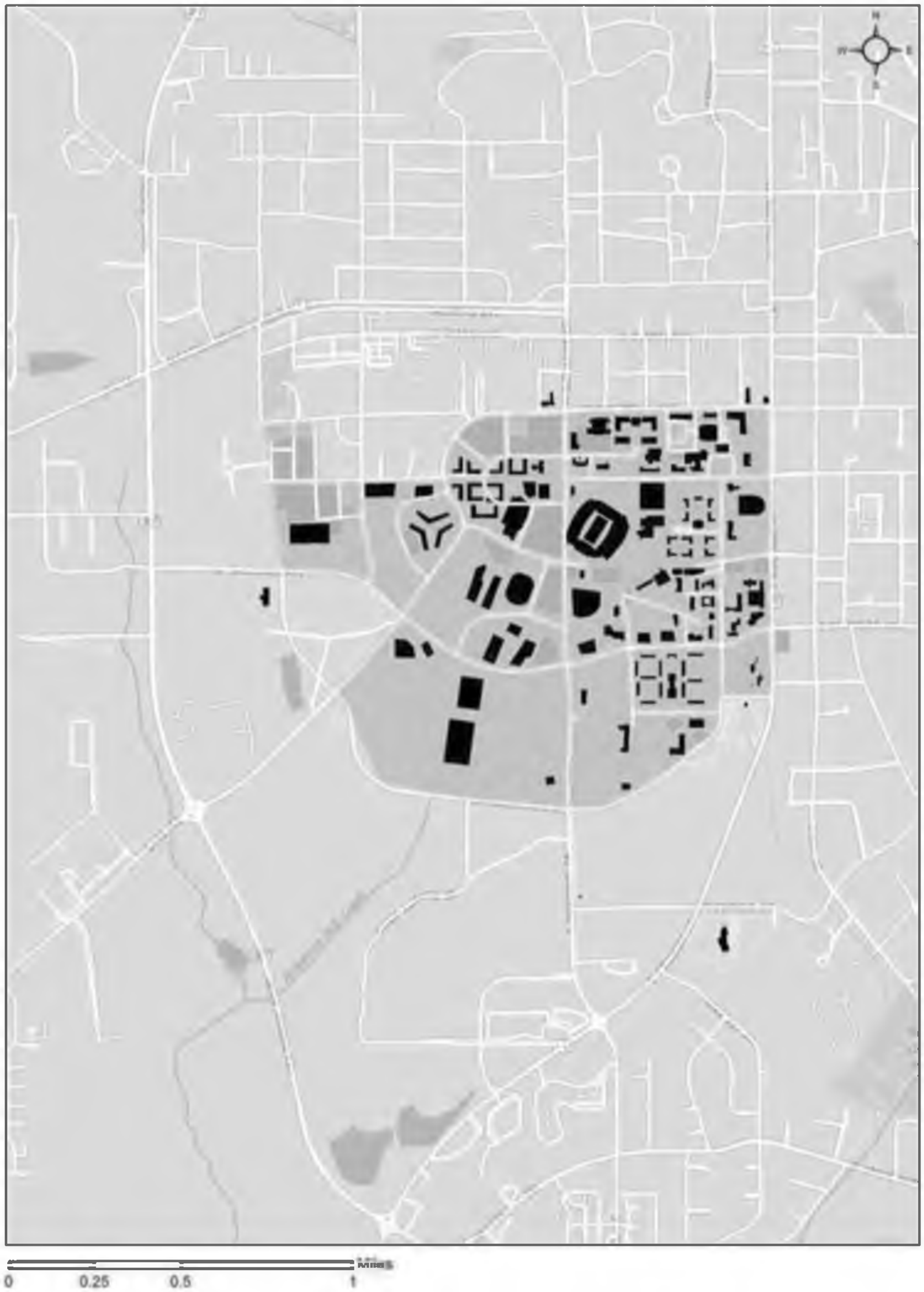

Figure B.19 Figure ground map of Auburn University

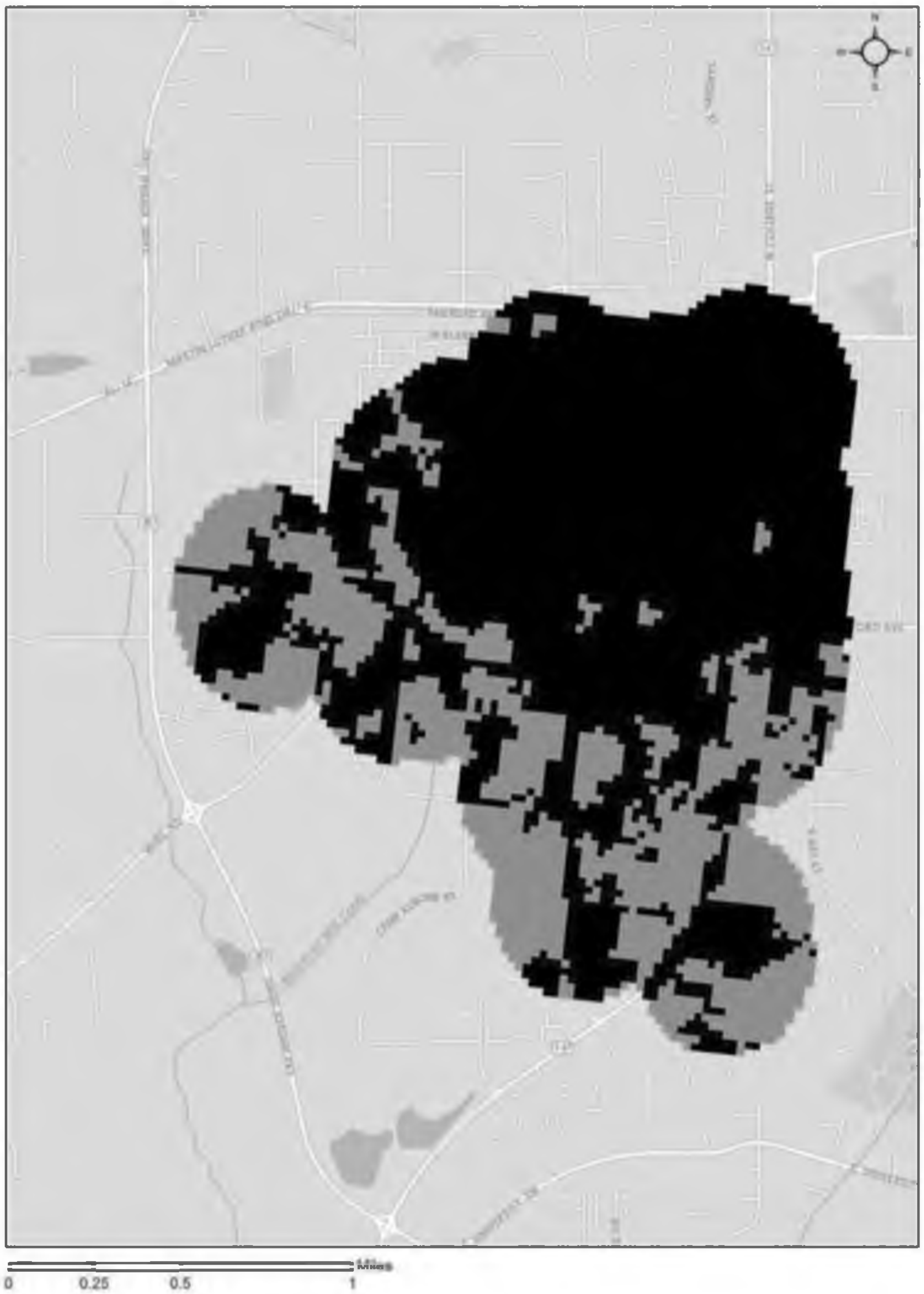

Figure B.20 Pervious open space, Auburn University

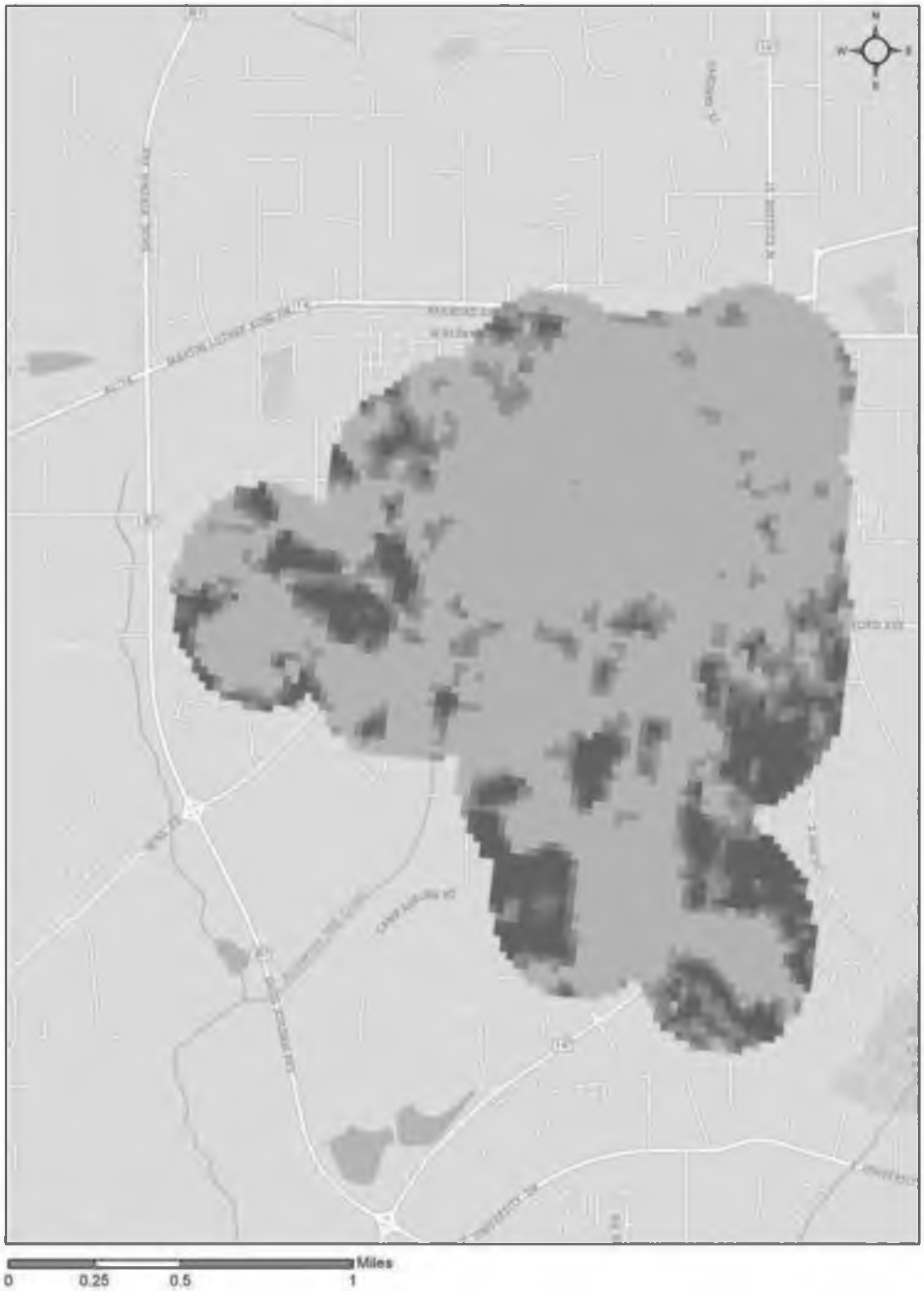

Figure B.21 The intensity of tree canopy, Auburn University

Figure B.22 Figure ground map, University of Colorado, Boulder

Figure B.23 Pervious open space, University of Colorado, Boulder

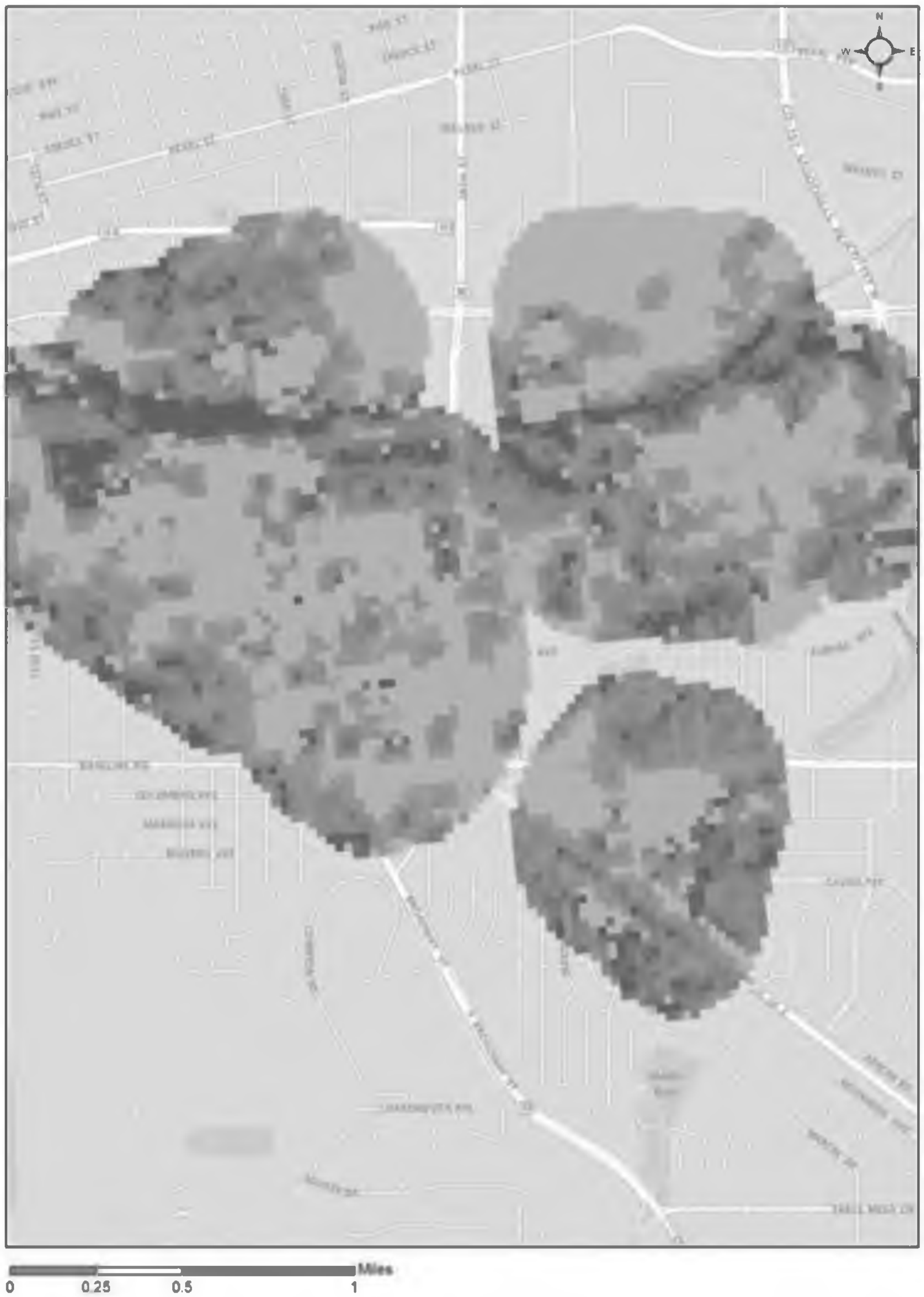

Figure B.24 The intensity of tree canopy, University of Colorado, Boulder

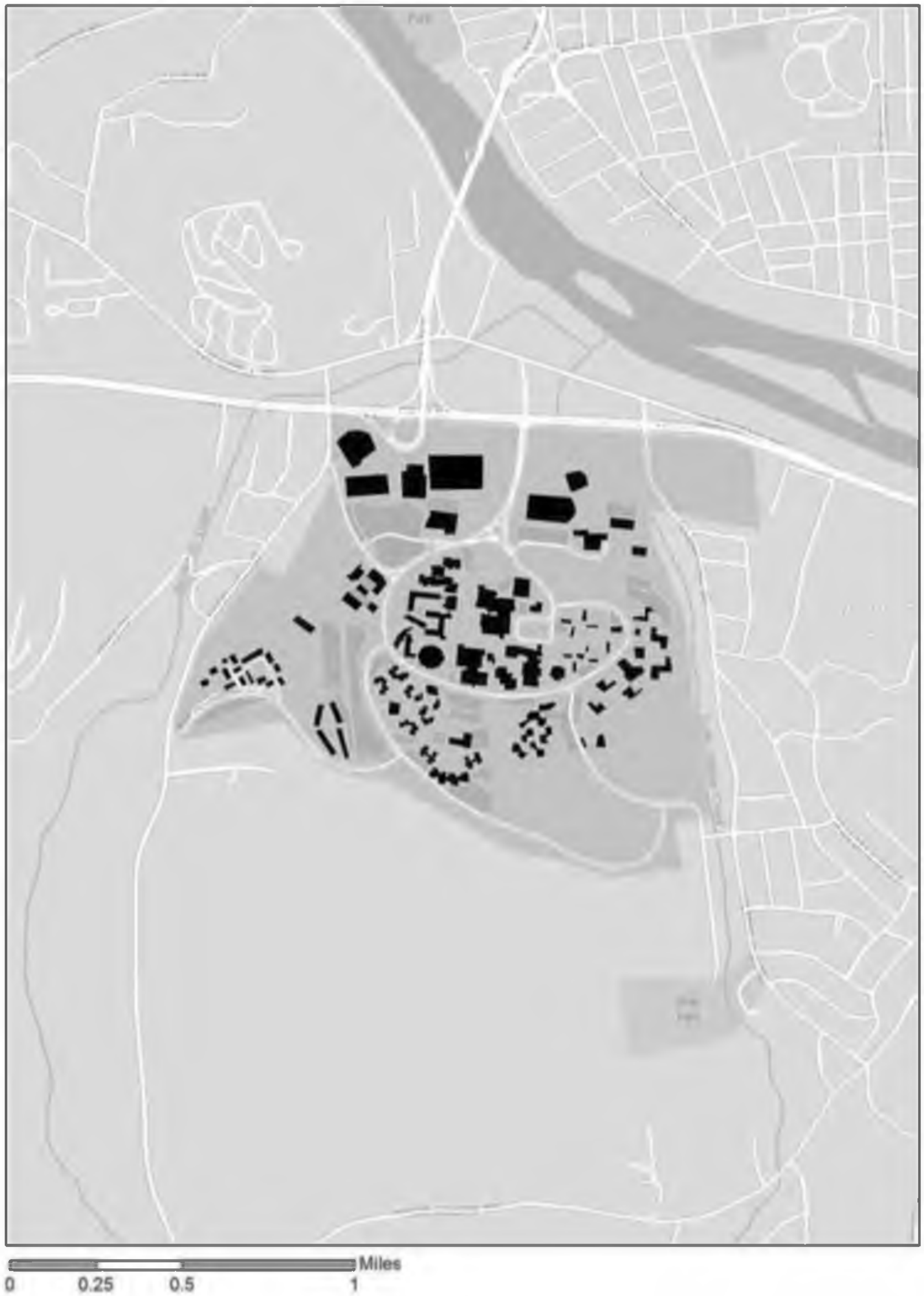

Figure B.25 Figure ground map, Binghamton University

Figure B.26 Pervious open space, Binghamton University

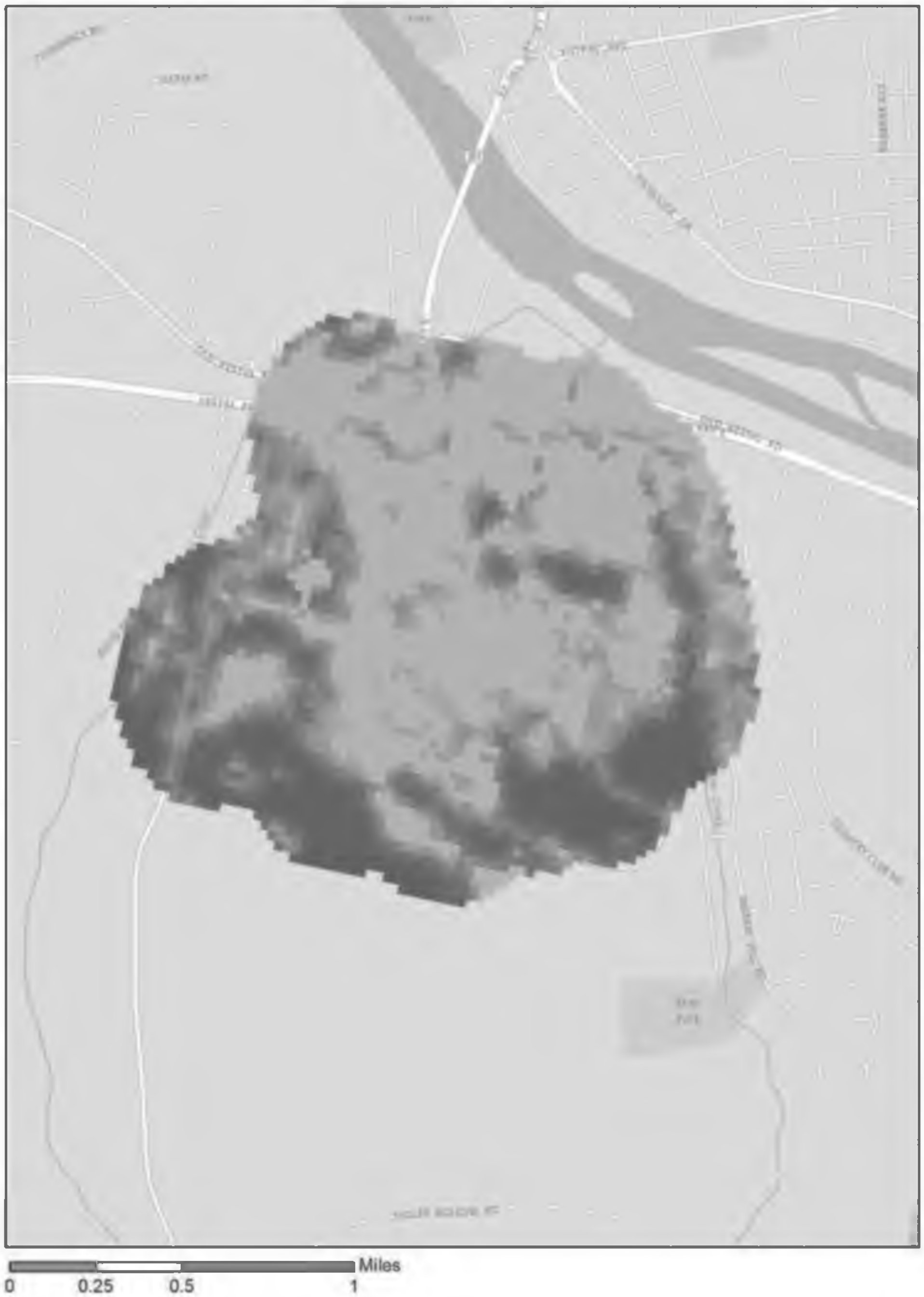

Figure B.27 The intensity of tree canopy, Binghamton University

Figure B.28 Figure ground map, Carnegie Melon University

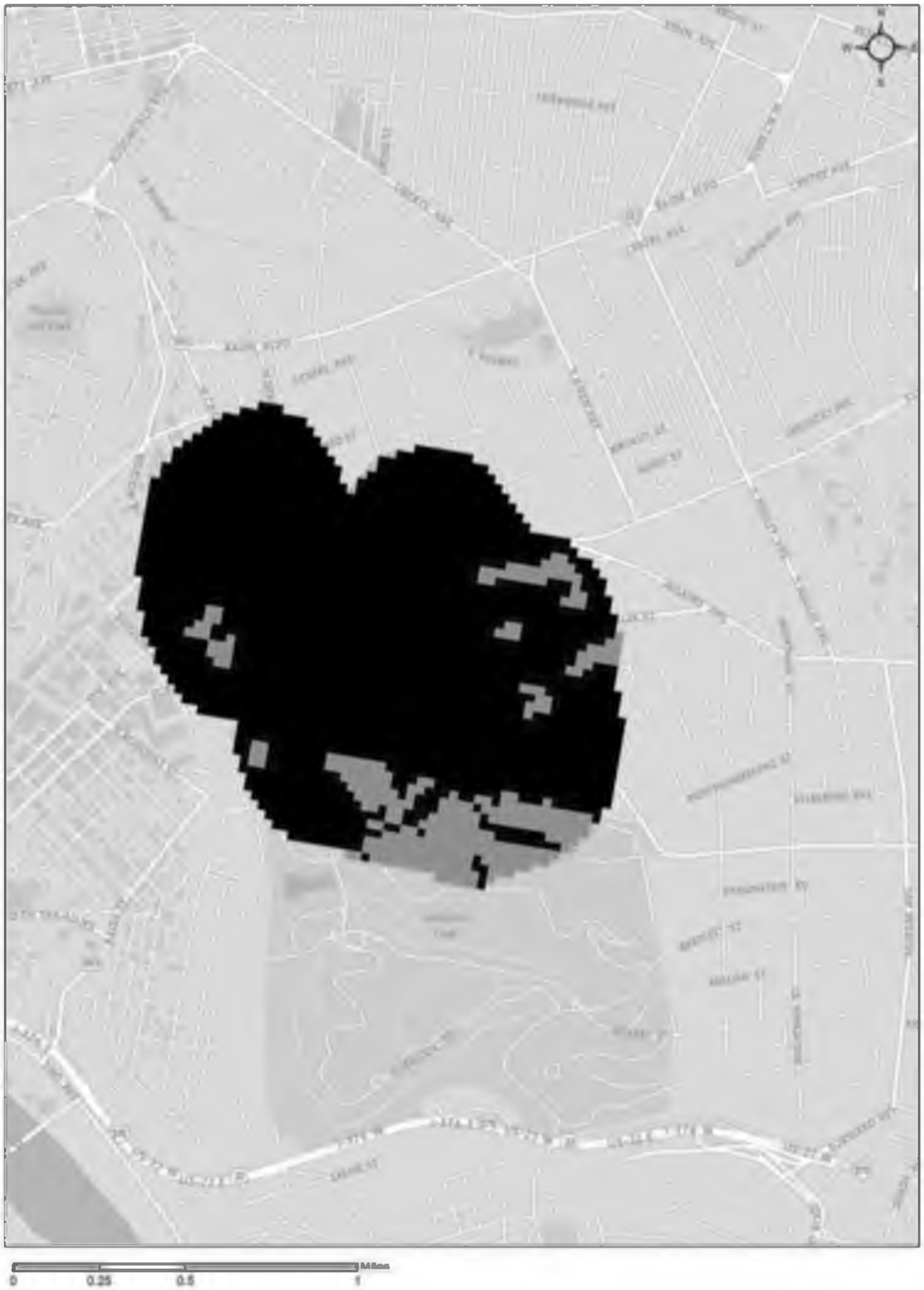

Figure B.29 Pervious open space, Carnegie Melon University

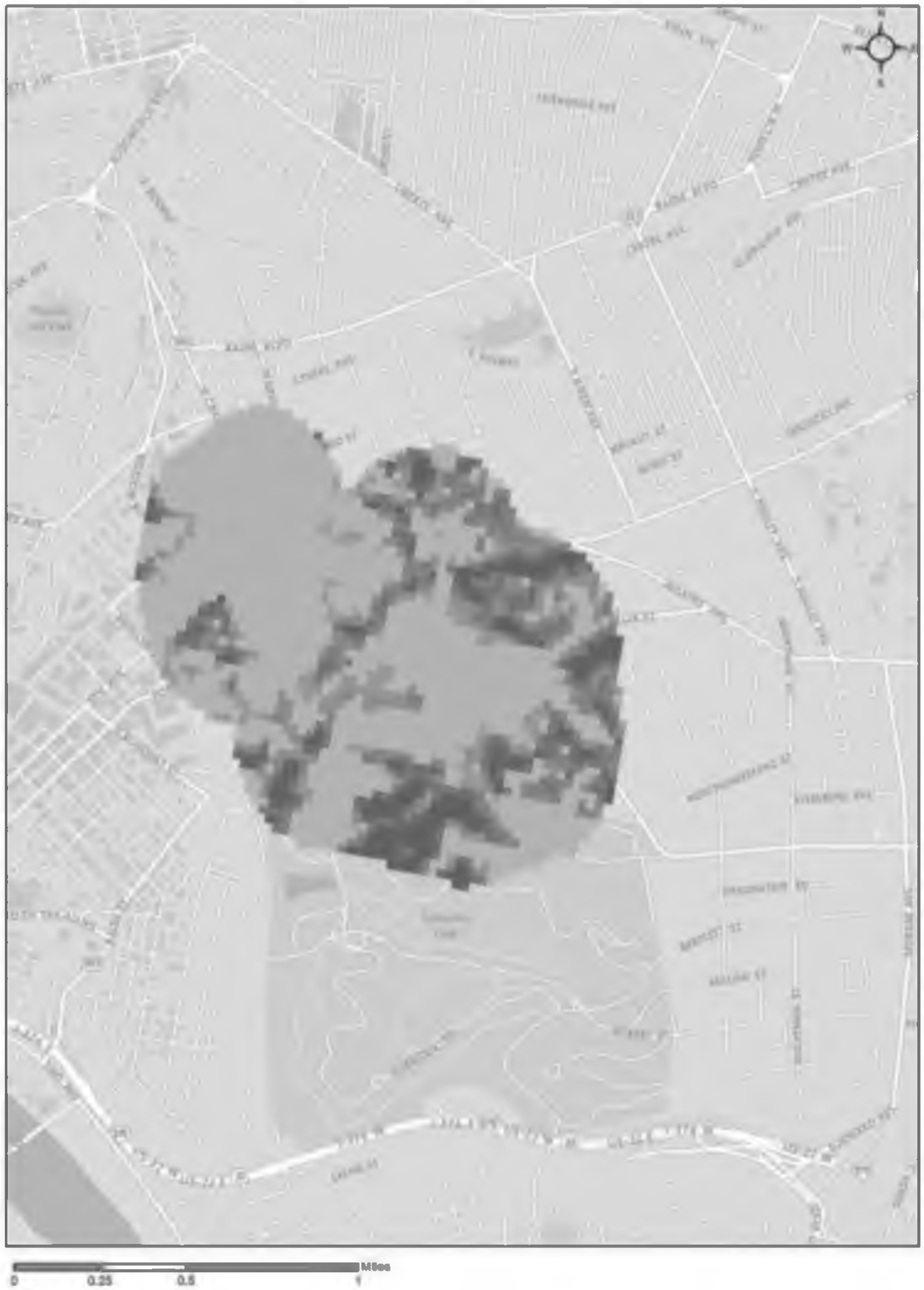

Figure B.30 The intensity of tree canopy, Carnegie Melon University

Figure B.31 Figure ground map, Case Western Reserve University

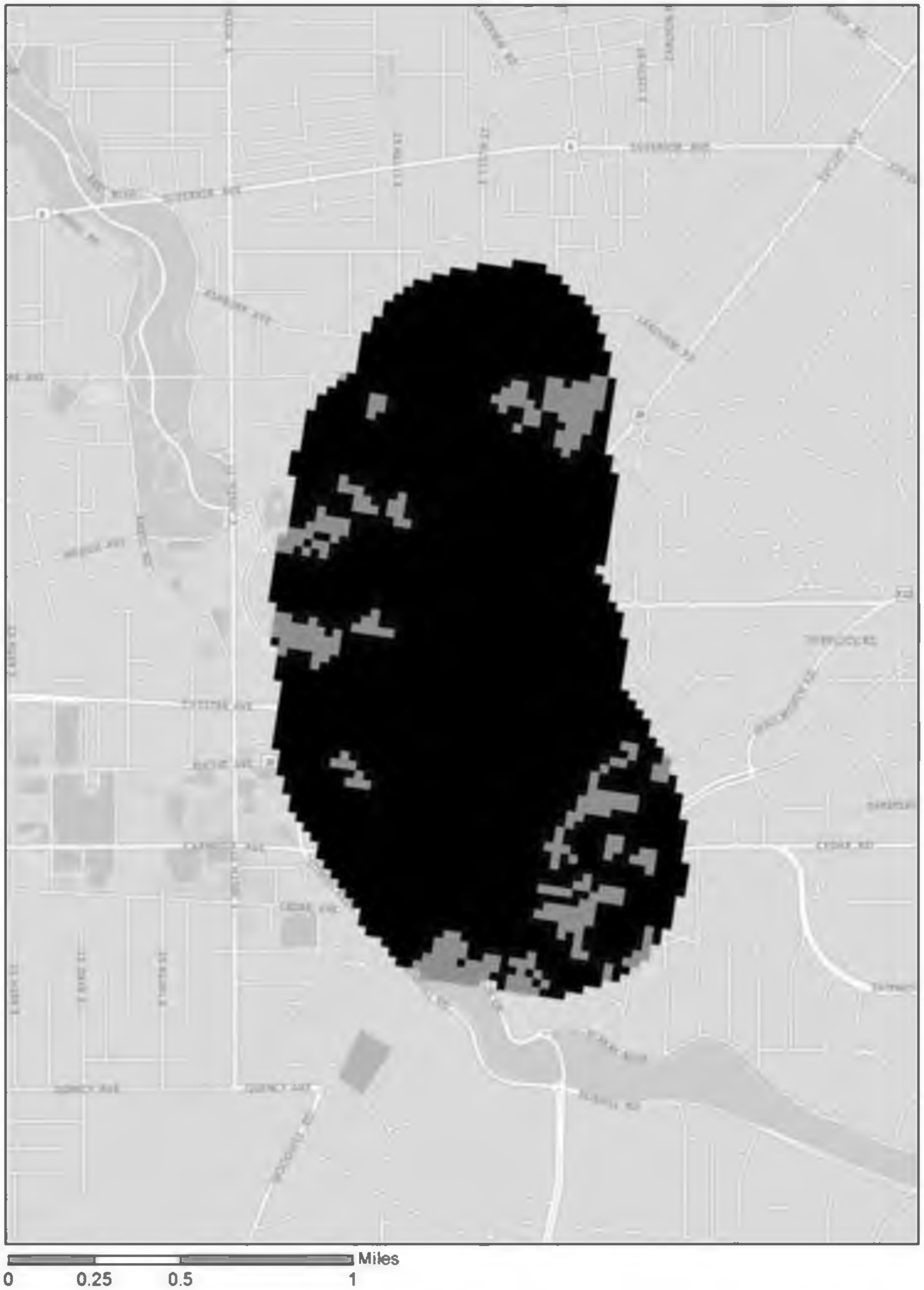

Figure B.32 Pervious open space, Case Western Reserve University

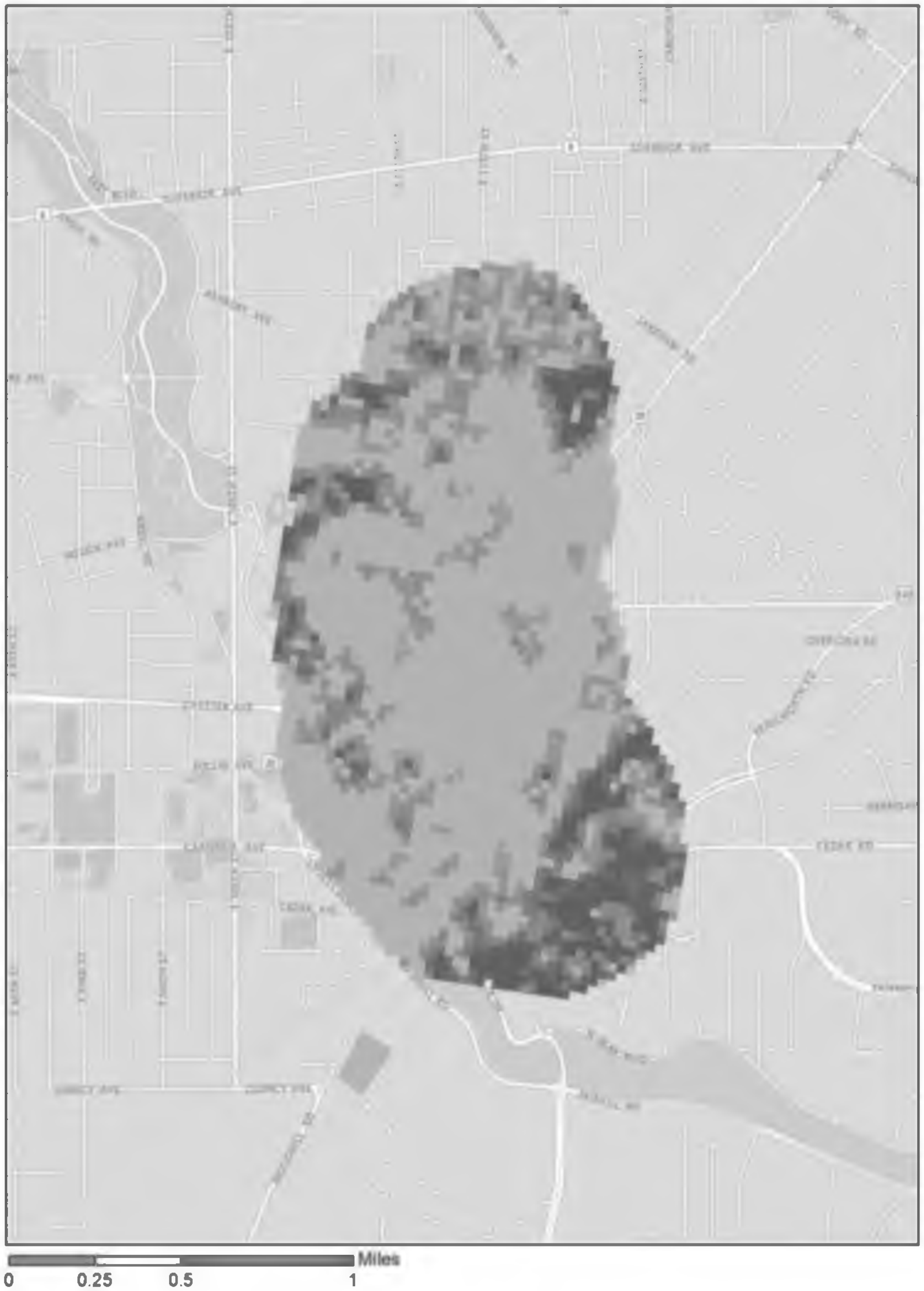

Figure B.33 The intensity of tree canopy, Case Western Reserve University

Figure B.34 Figure ground map, University of Colorado Denver

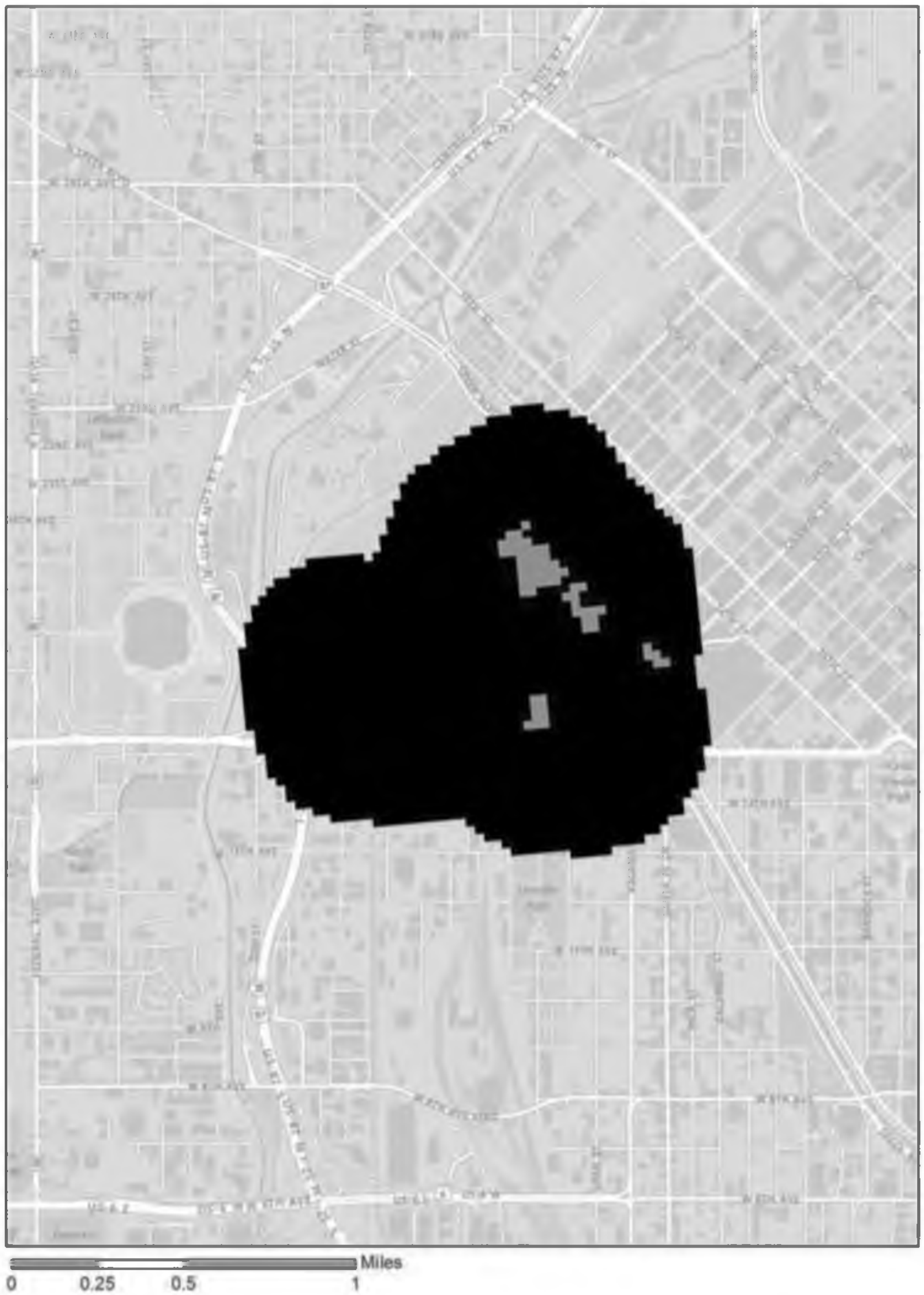

Figure B.35 Pervious open space, University of Colorado Denver

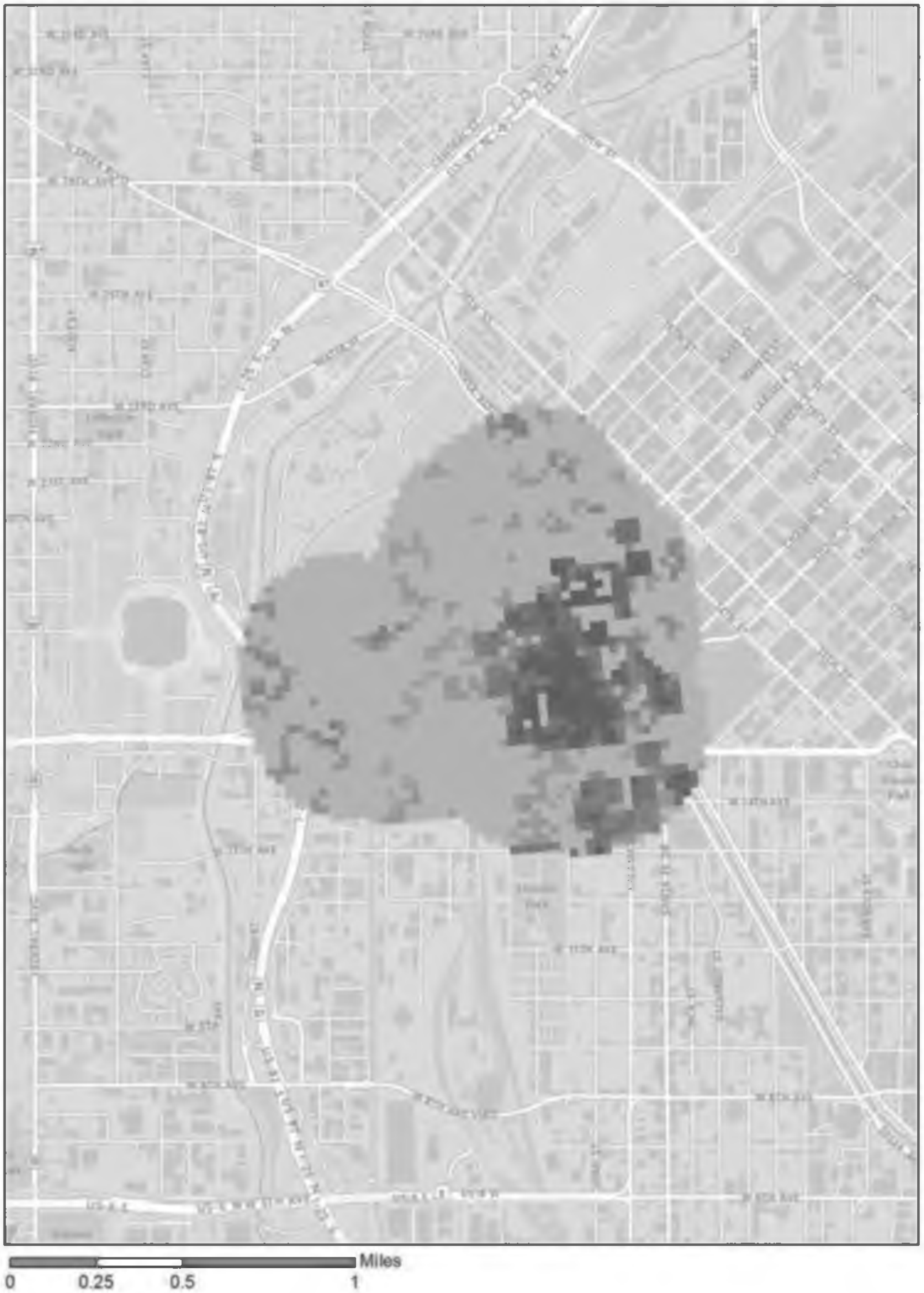

Figure B.36 The intensity of tree canopy, University of Colorado Denver

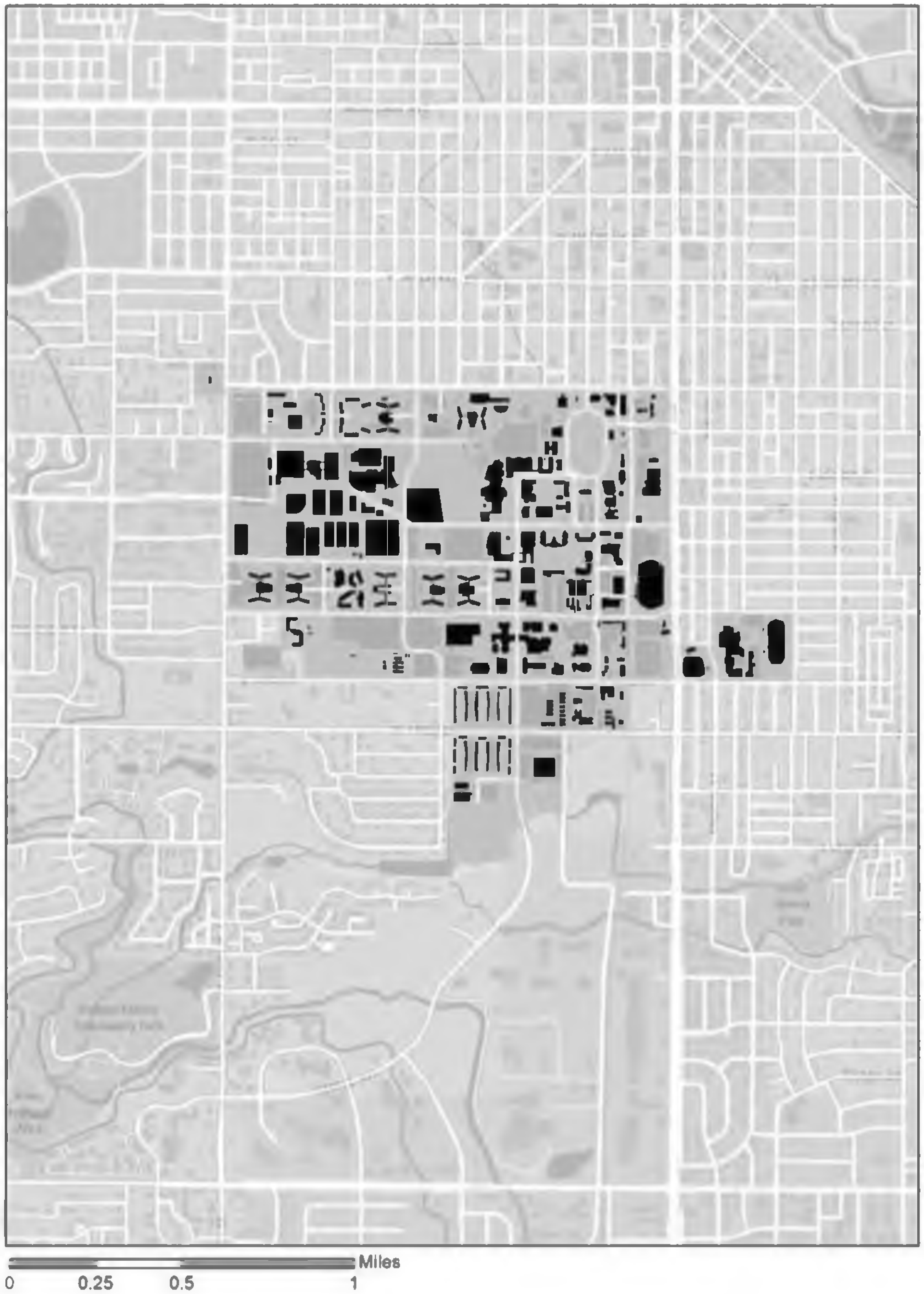

Figure B.37 Figure ground map, Colorado State University

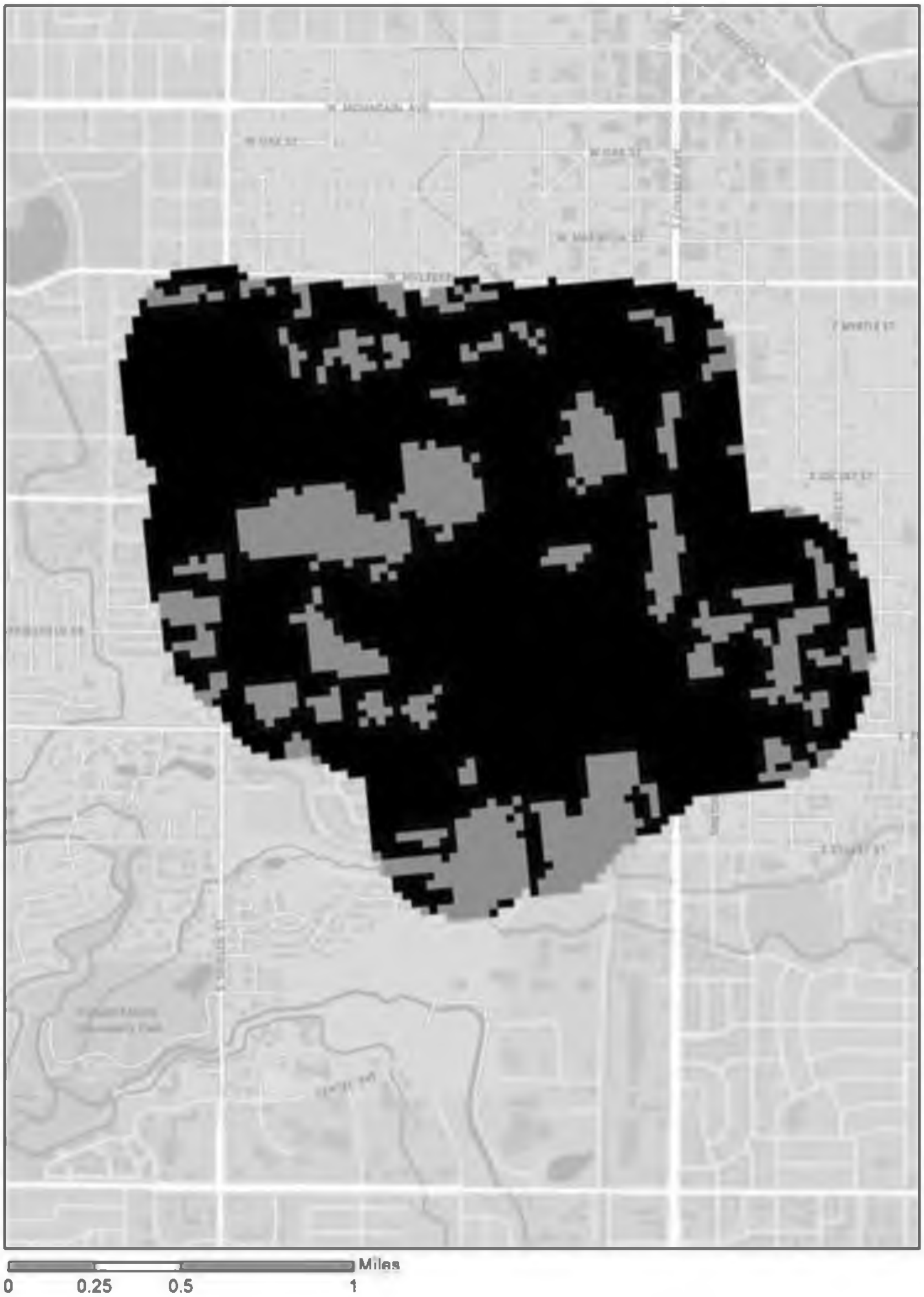

Figure B.38 Pervious open space, Colorado State University

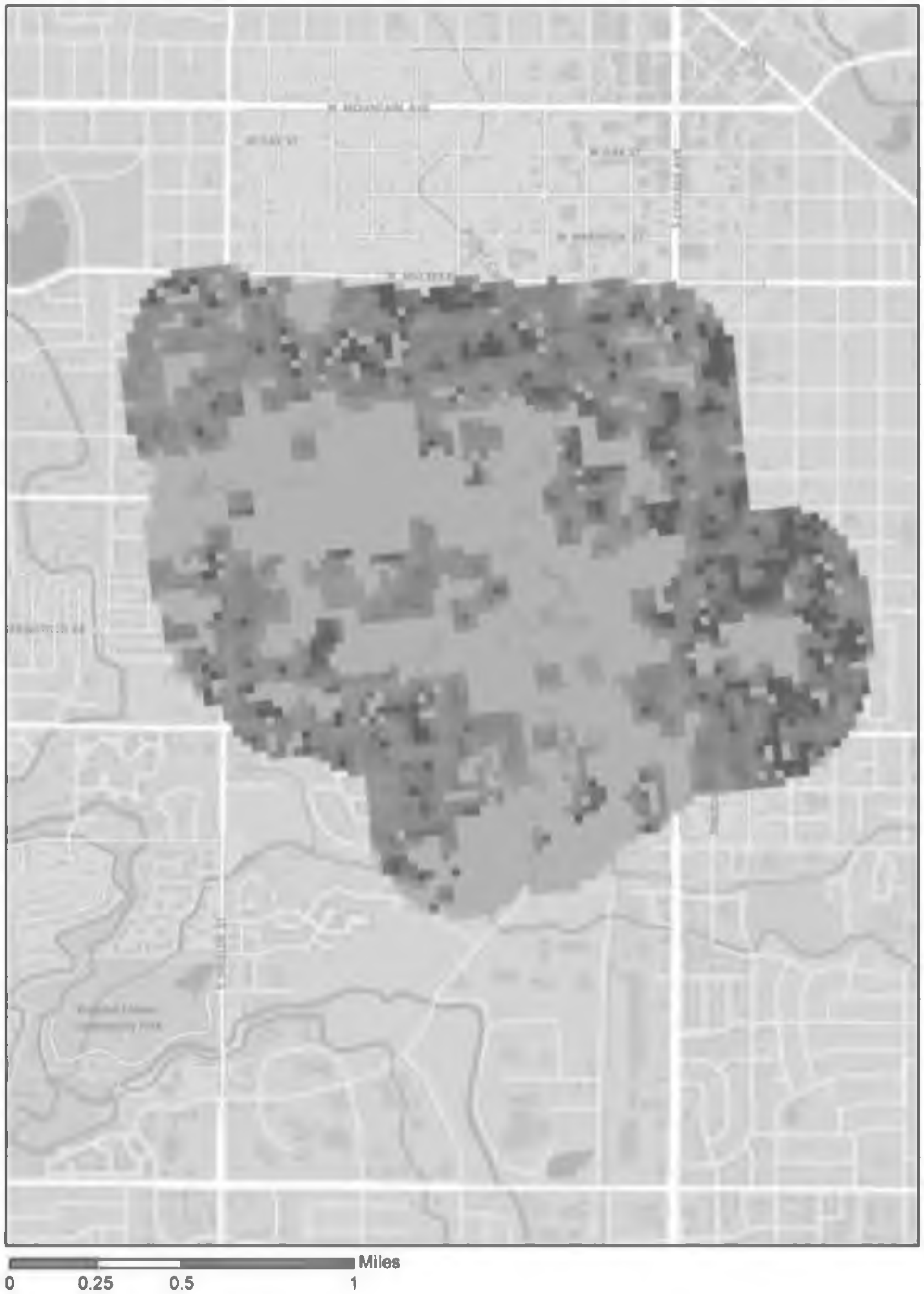

Figure B.39 The intensity of tree canopy, Colorado State University

Figure B.40 Figure ground map, University of Connecticut

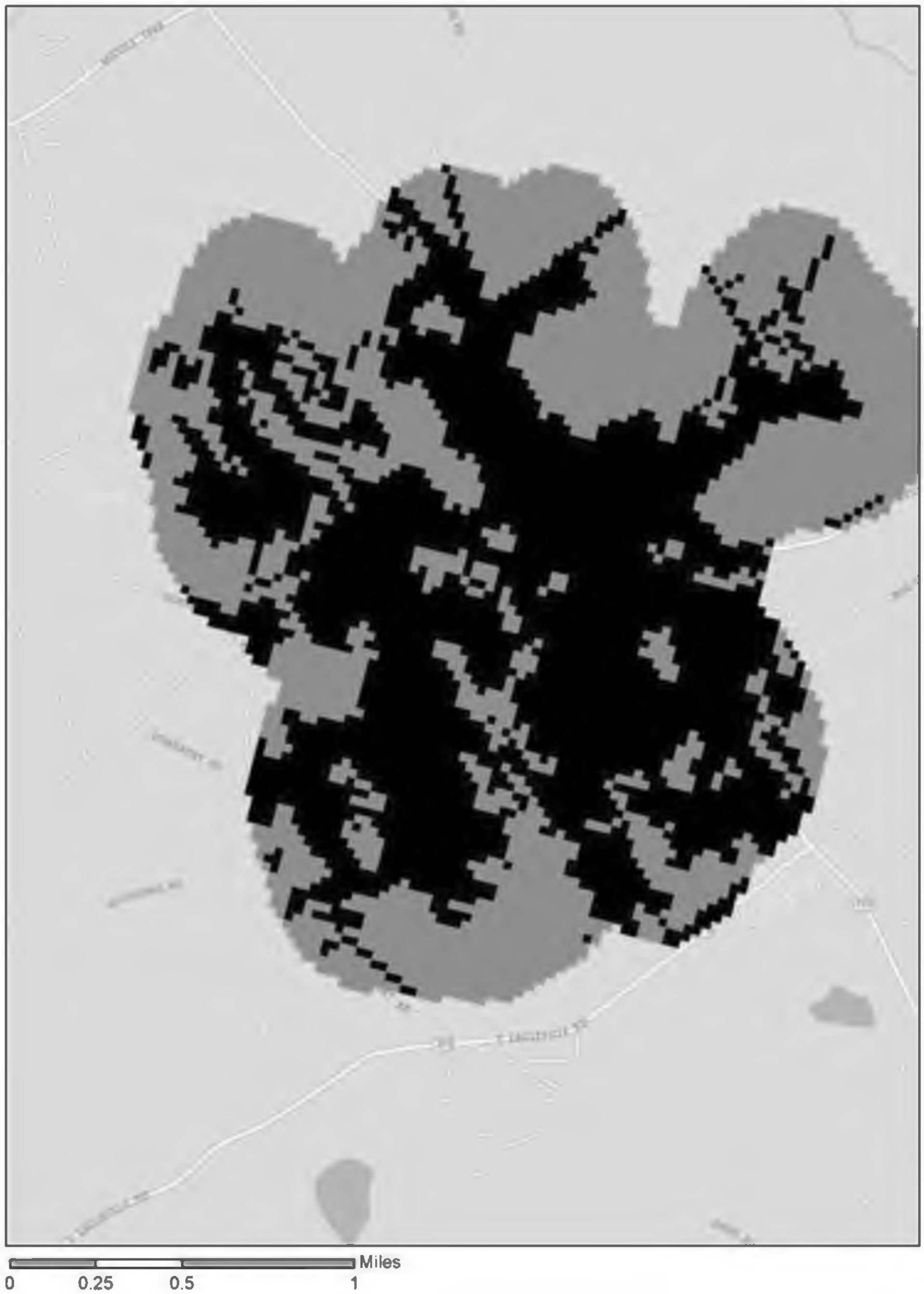

Figure B.41 Pervious open space, University of Connecticut

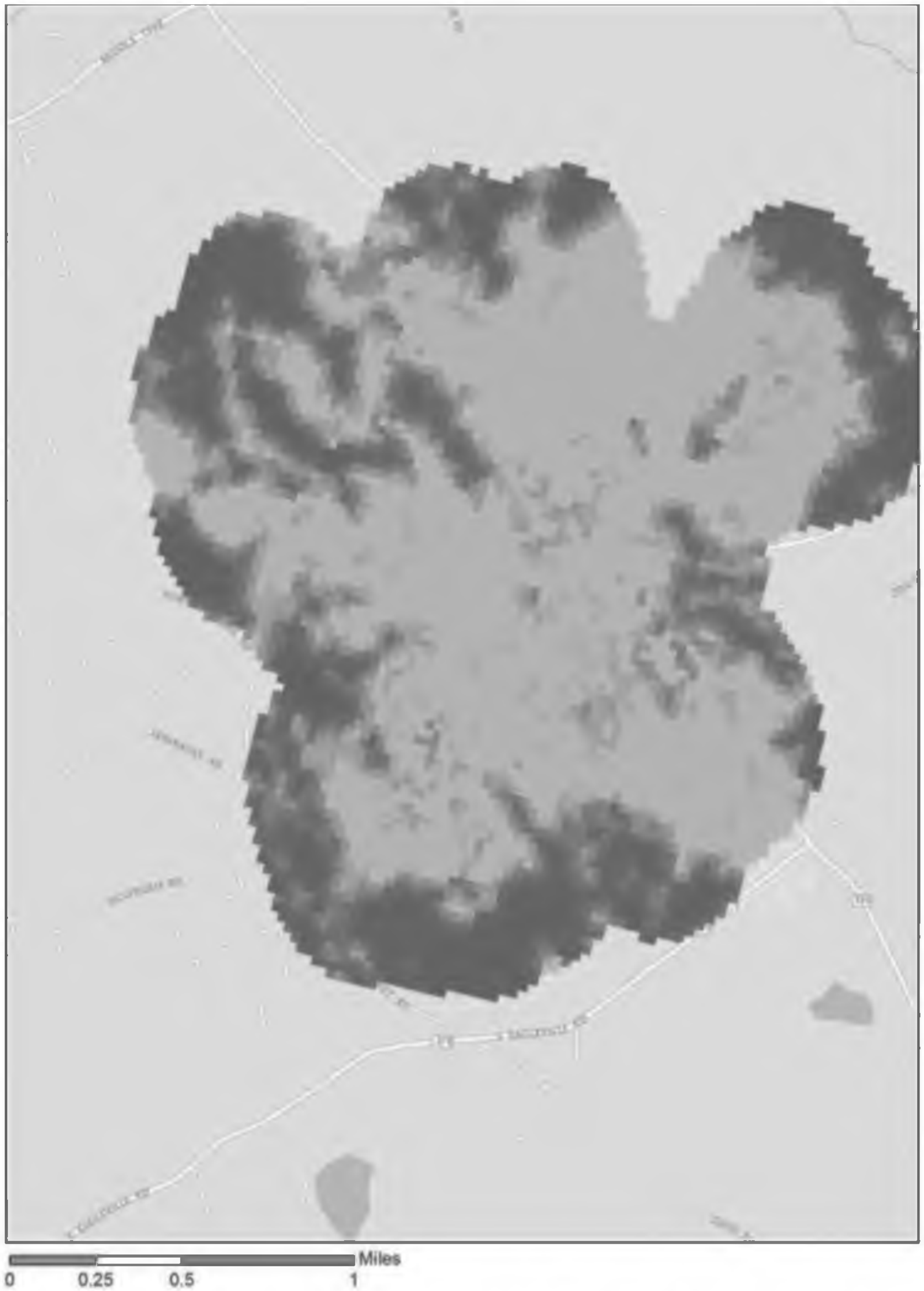

Figure B.42 The intensity of tree canopy, University of Connecticut

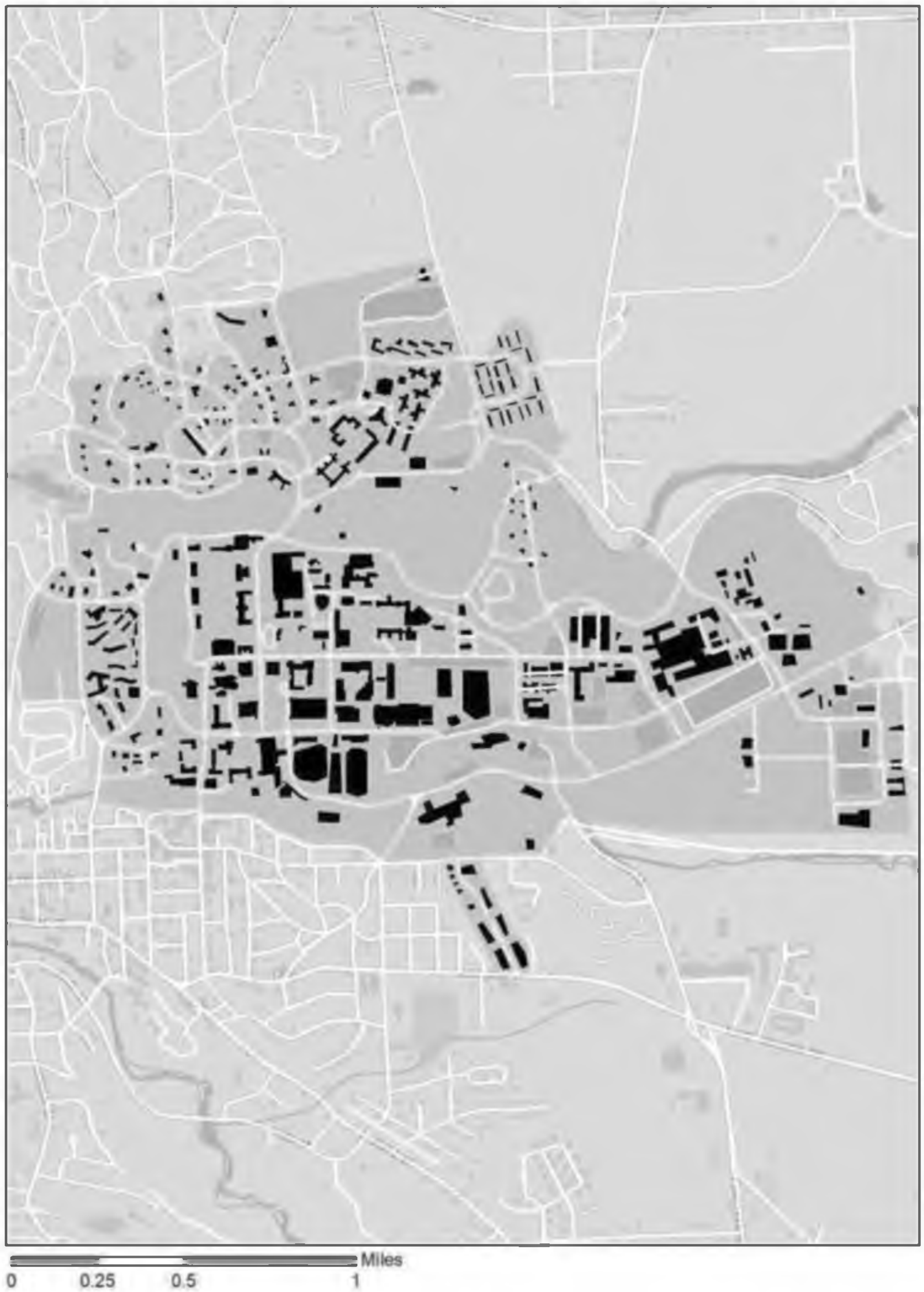

Figure B.43 Figure ground map, Cornell University

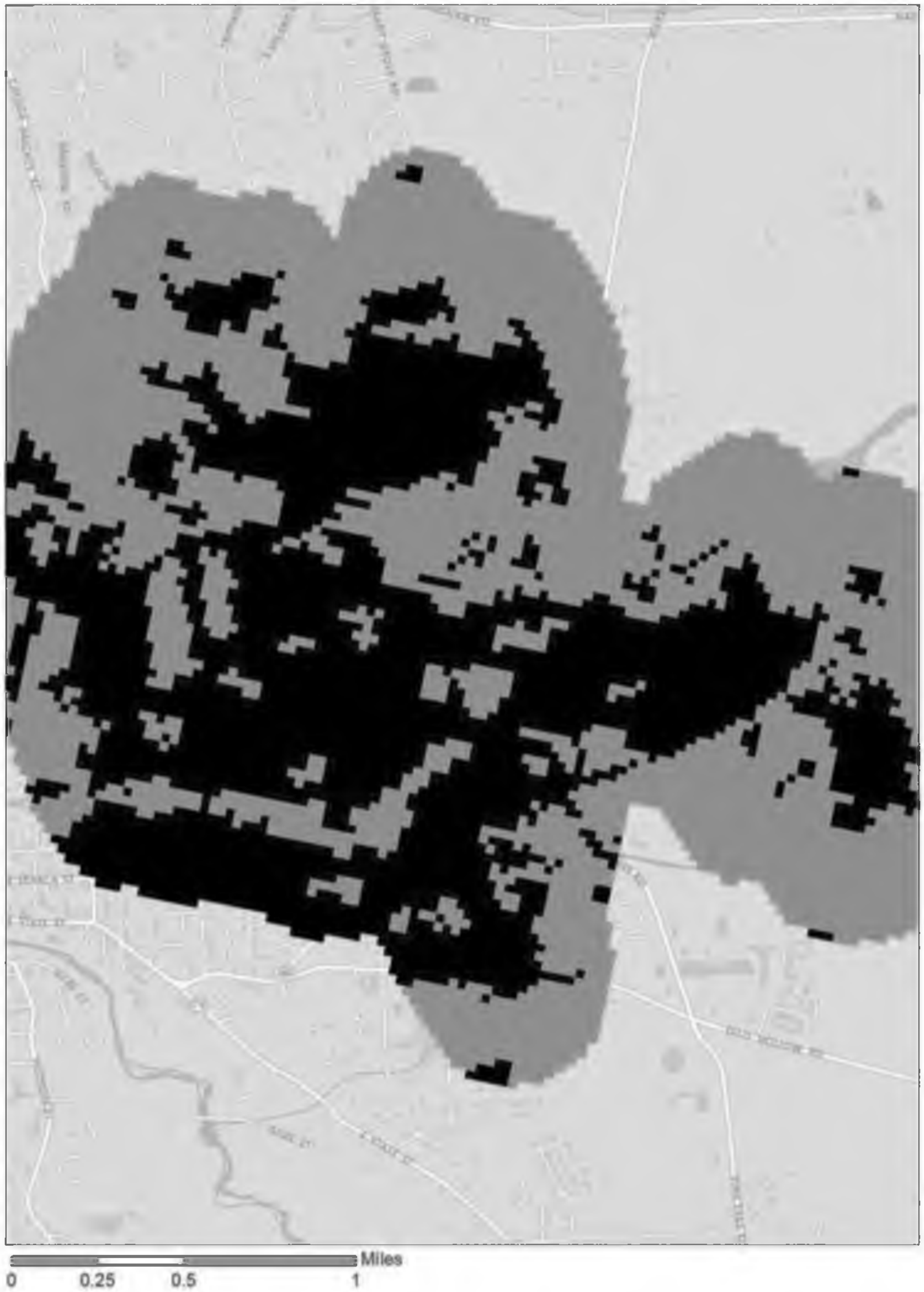

Figure B.44 Pervious open space, Cornell University

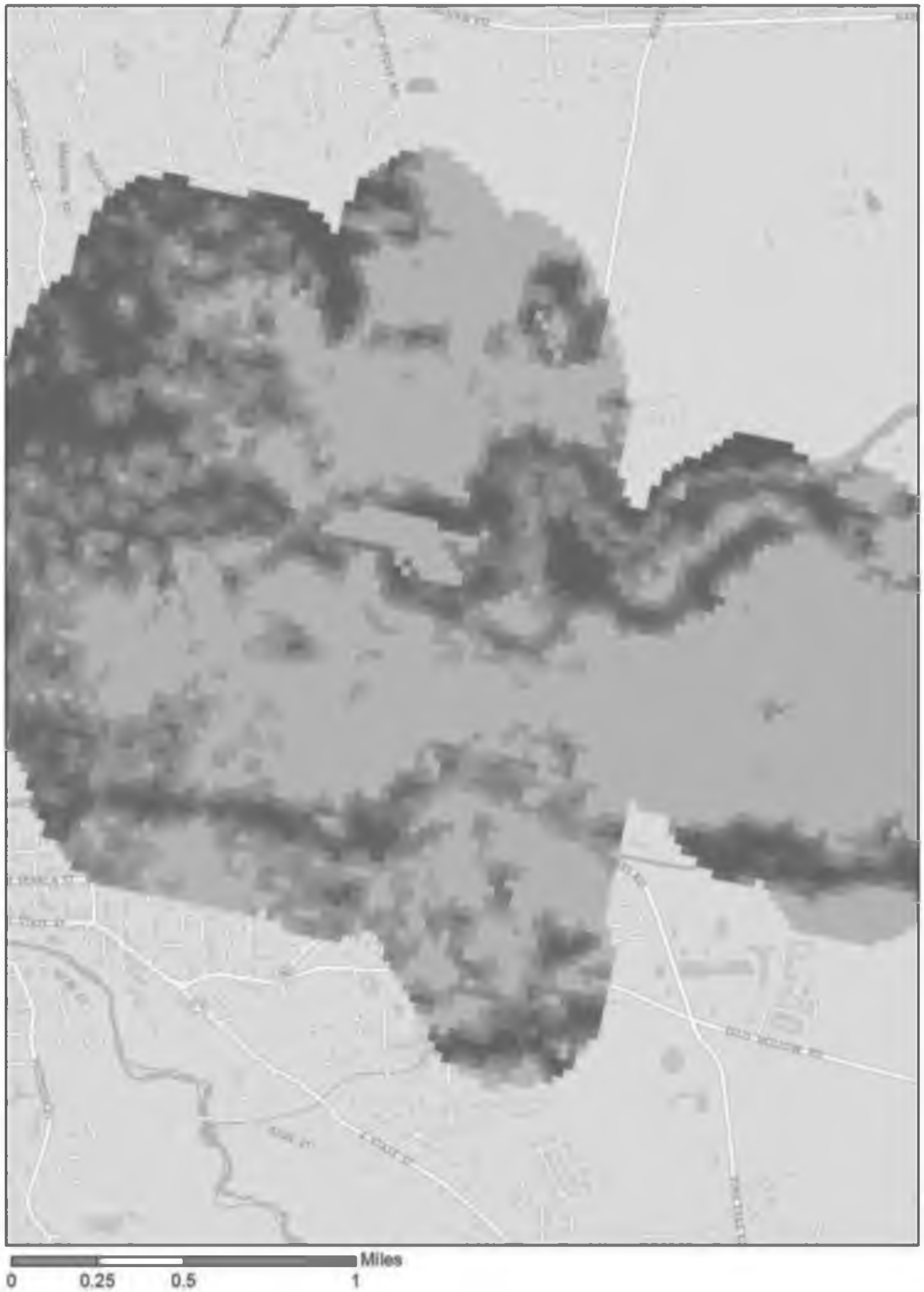

Figure B.45 The intensity of tree canopy, Cornell University

Figure B.46 Figure ground map, Duke University

Figure B.47 Pervious open space, Duke University

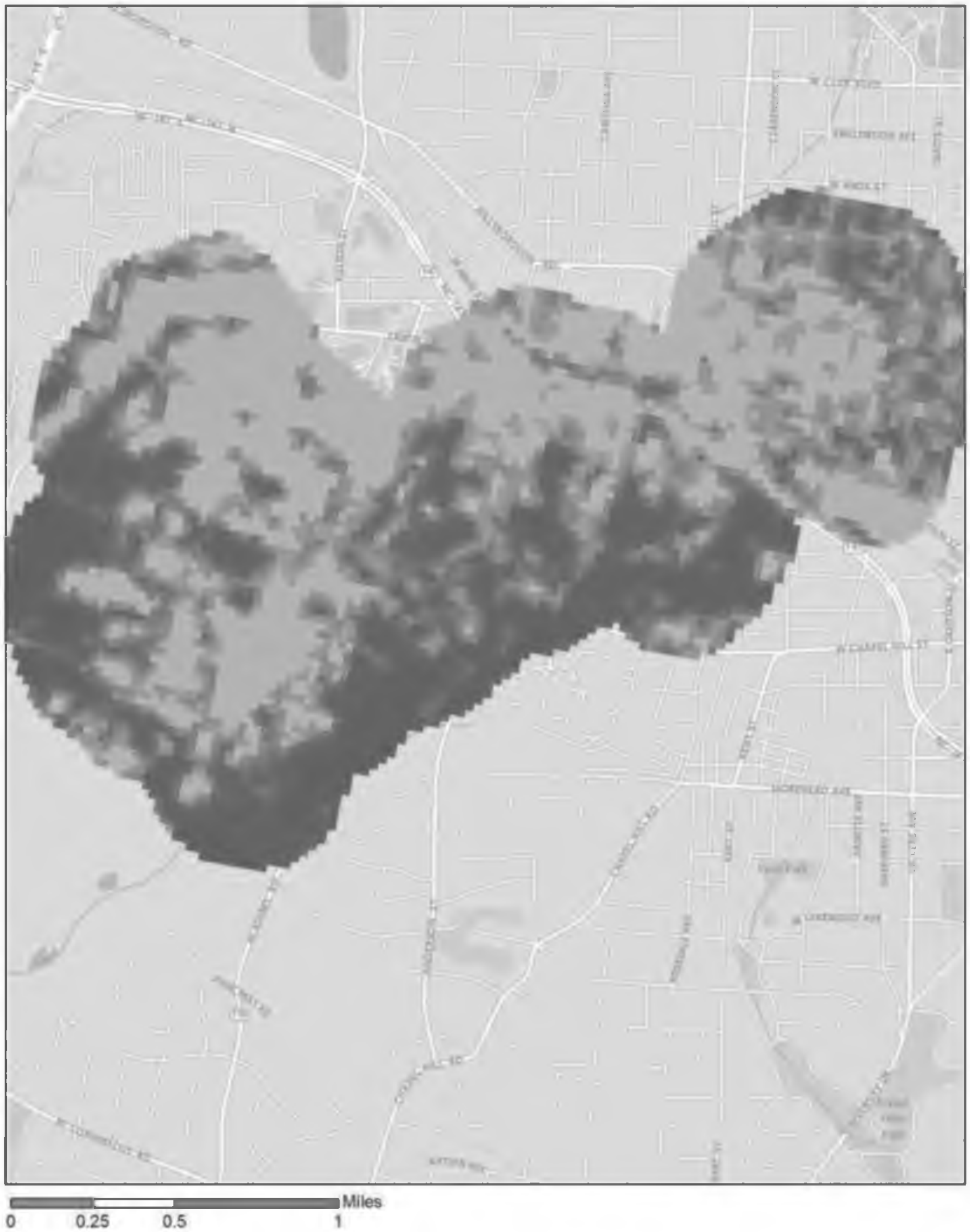

Figure B.48 The intensity of tree canopy, Duke University

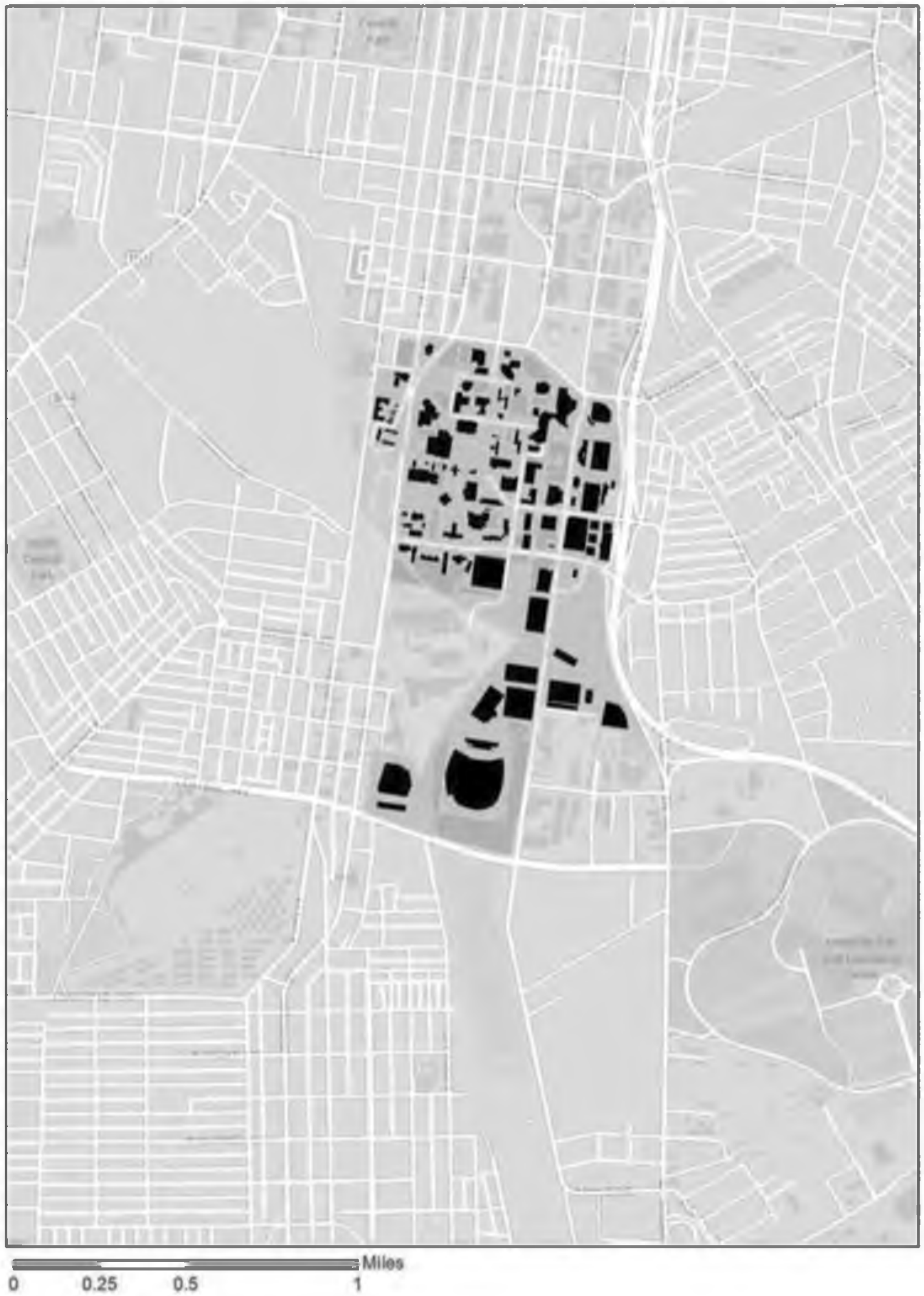

Figure B.49 Figure ground map, University of Louisville

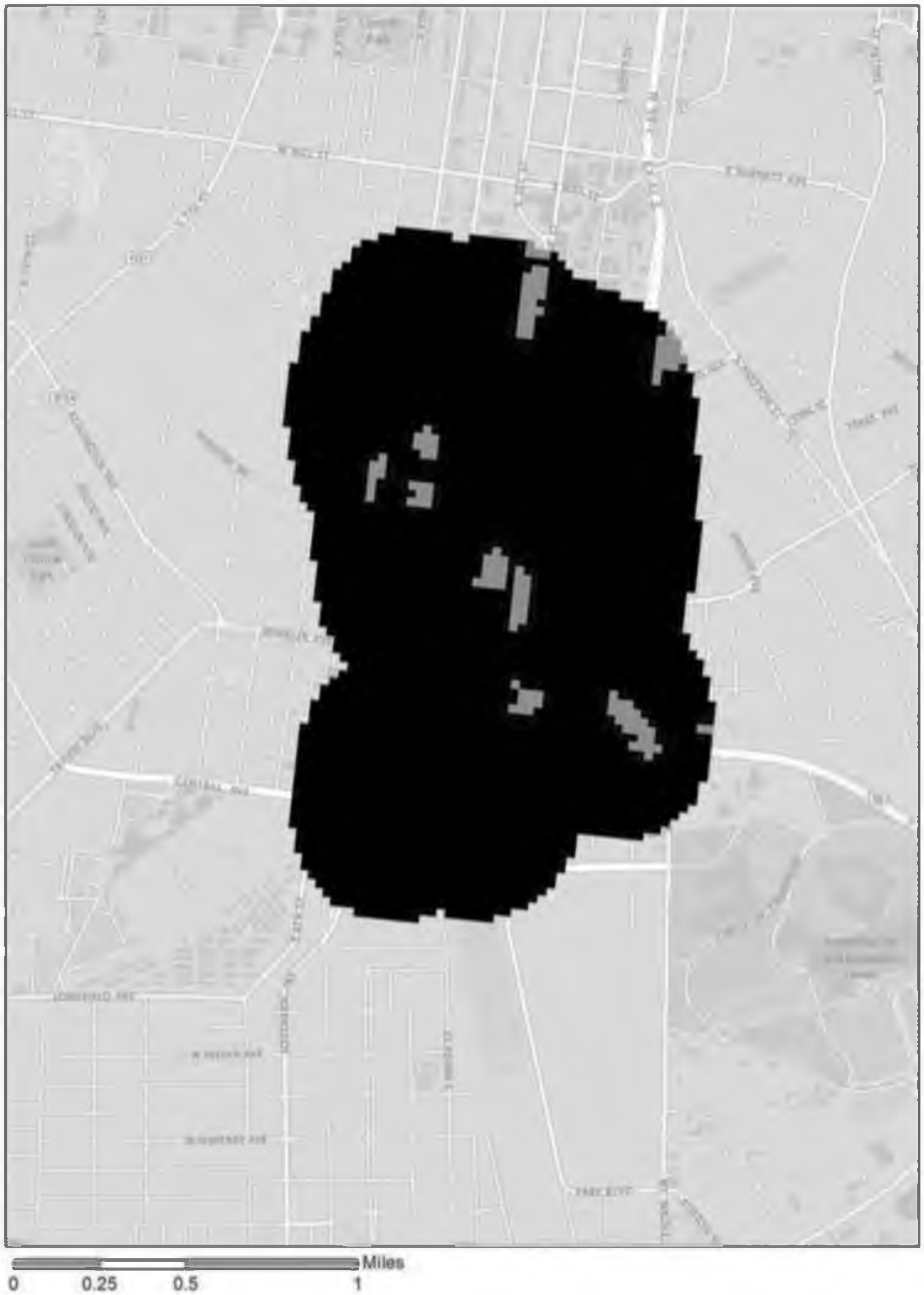

Figure B.50 Pervious open space, University of Louisville

Figure B.51 The intensity of tree canopy, University of Louisville

Figure B.52 Figure ground map, University of Nevada

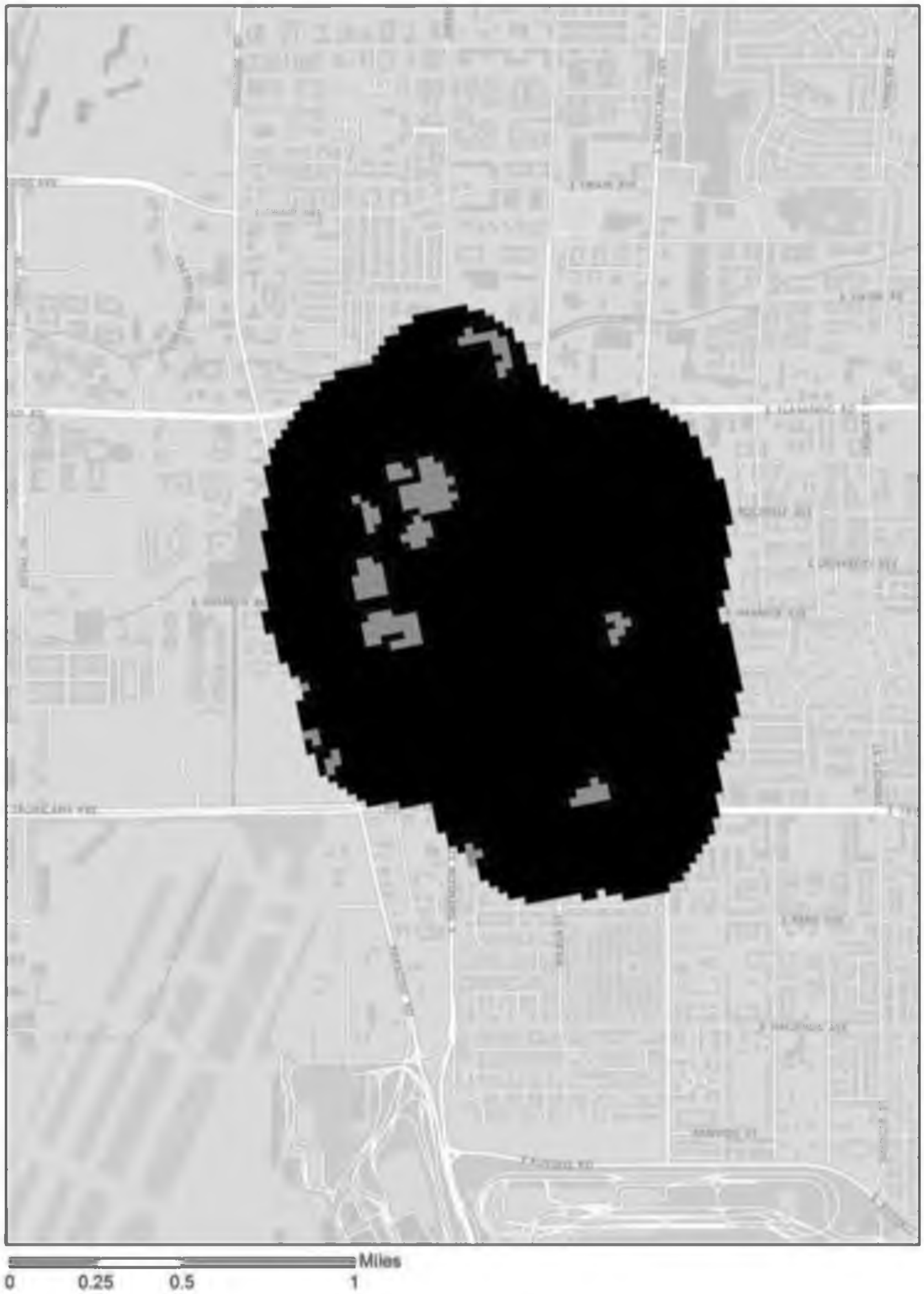

Figure B.53 Pervious open space, University of Nevada

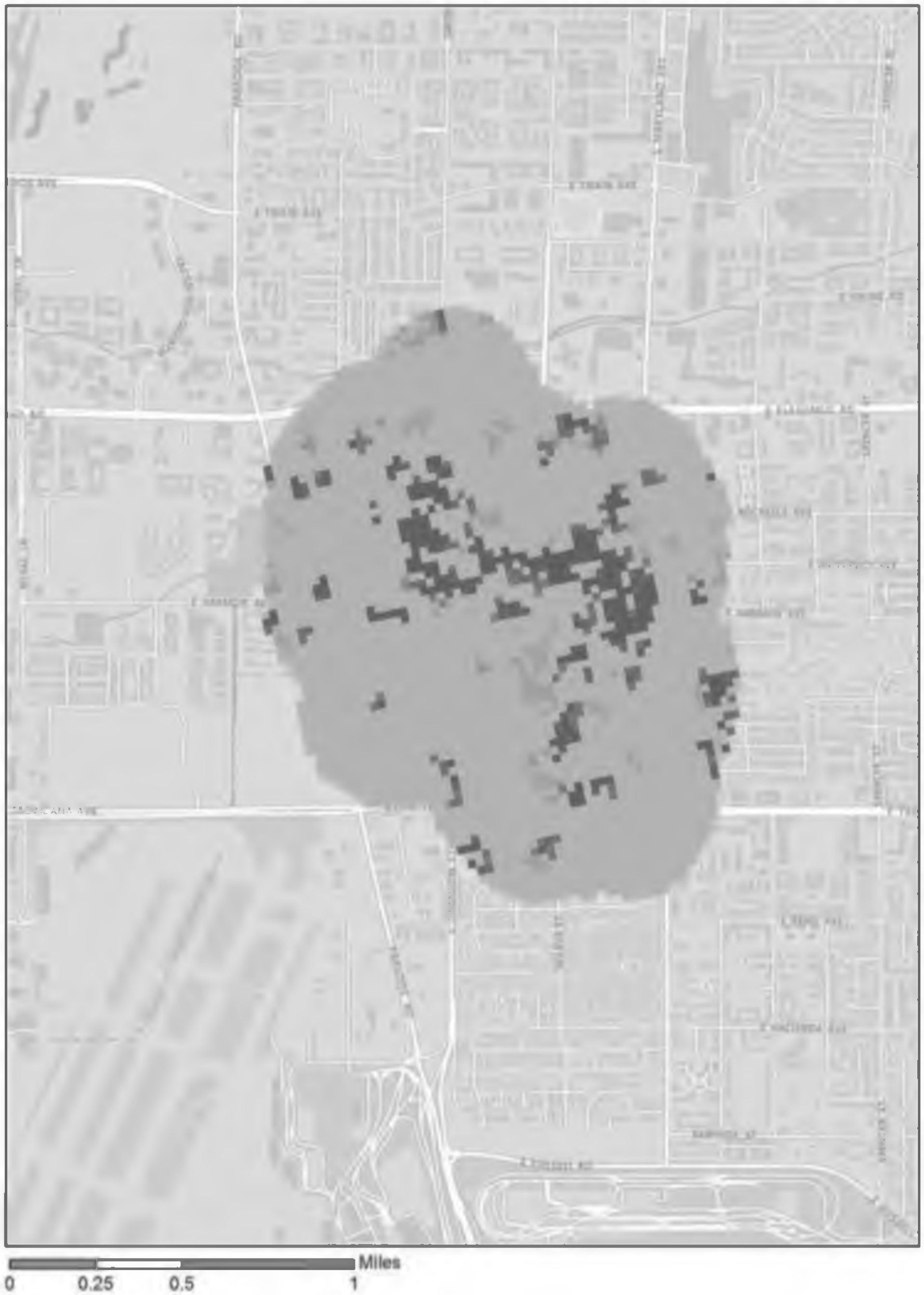

Figure B.54 The intensity of tree canopy, University of Nevada

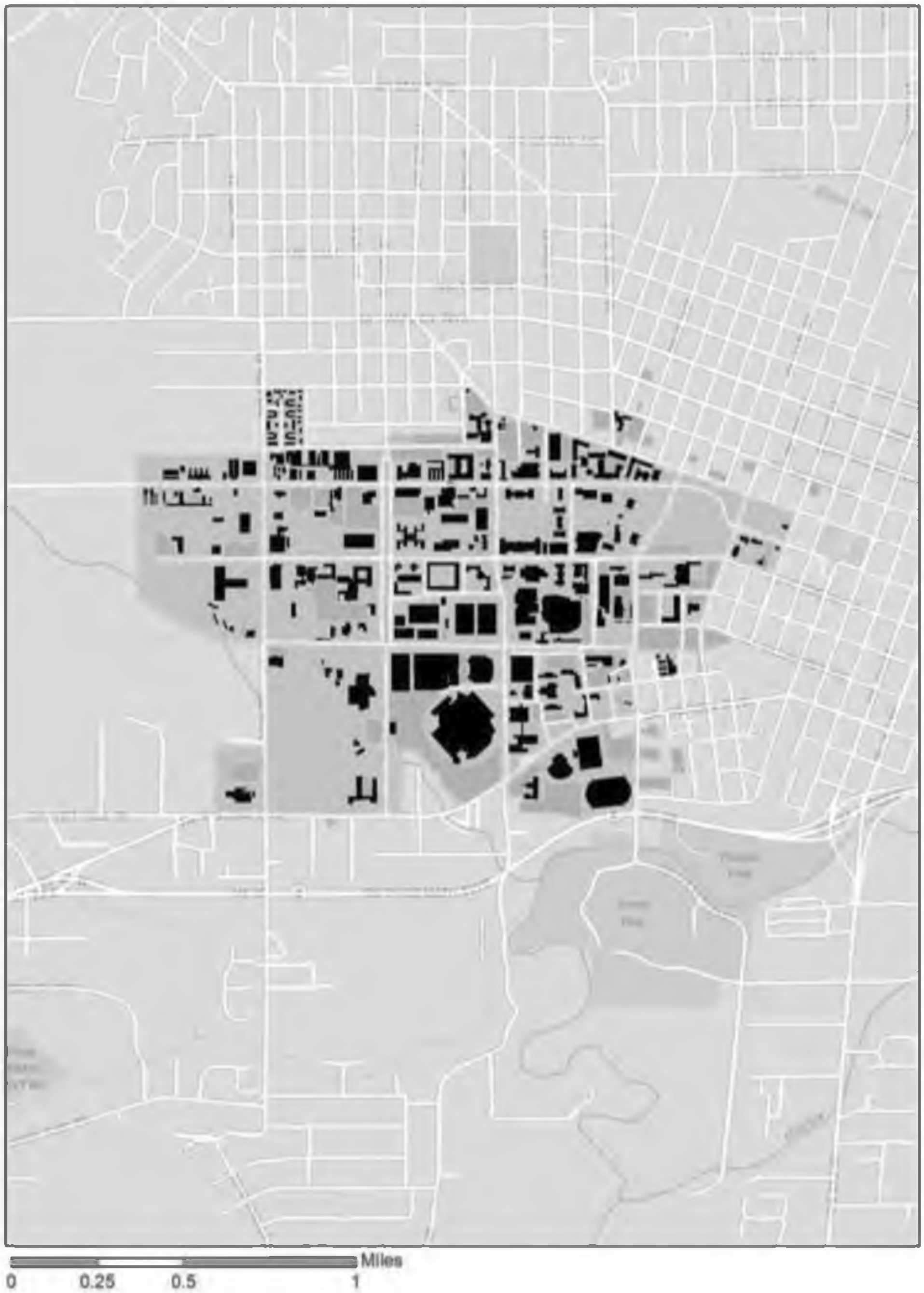

Figure B.55 Figure ground map, Oregon State University

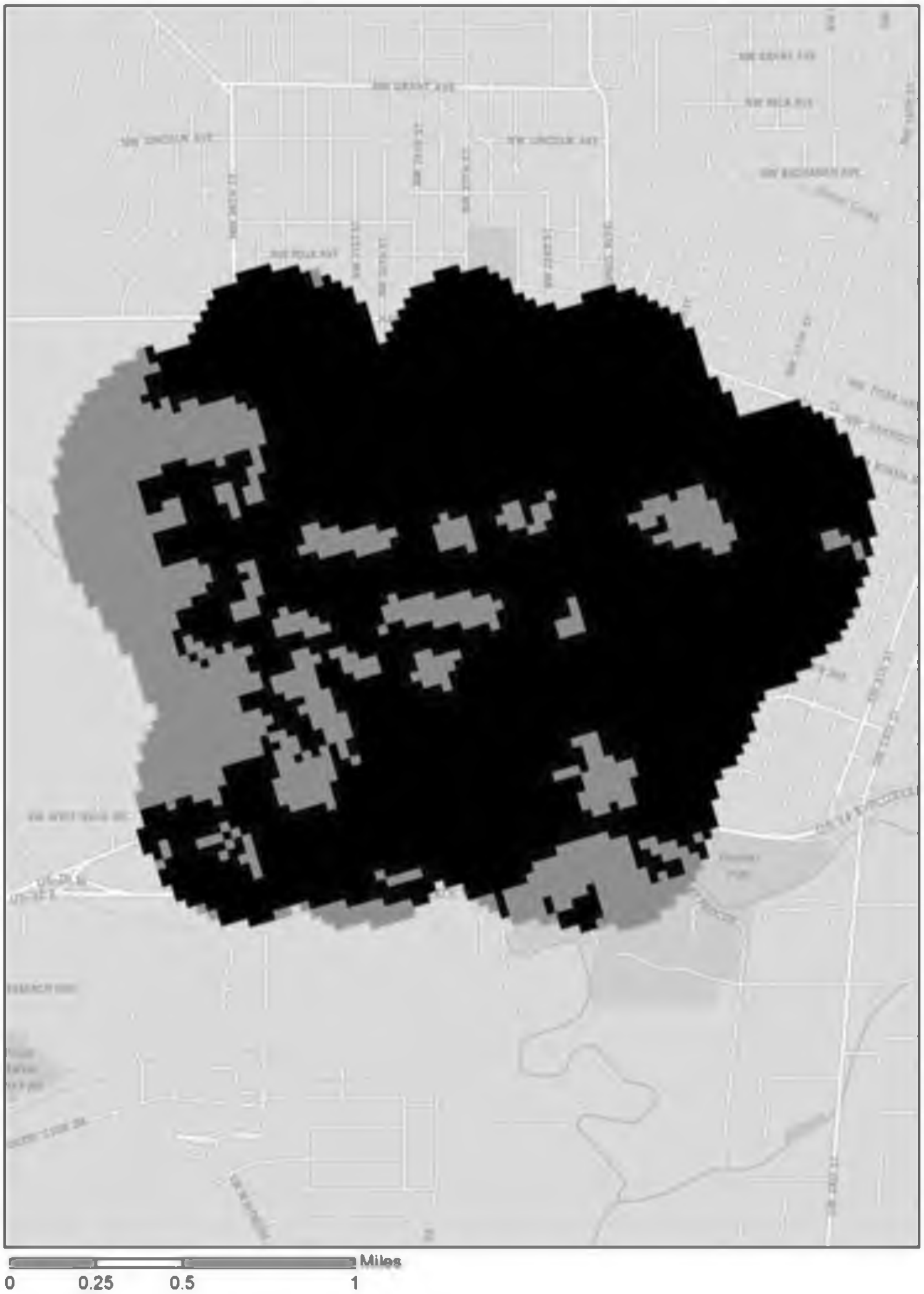

Figure B.56 Pervious open space, Oregon State University

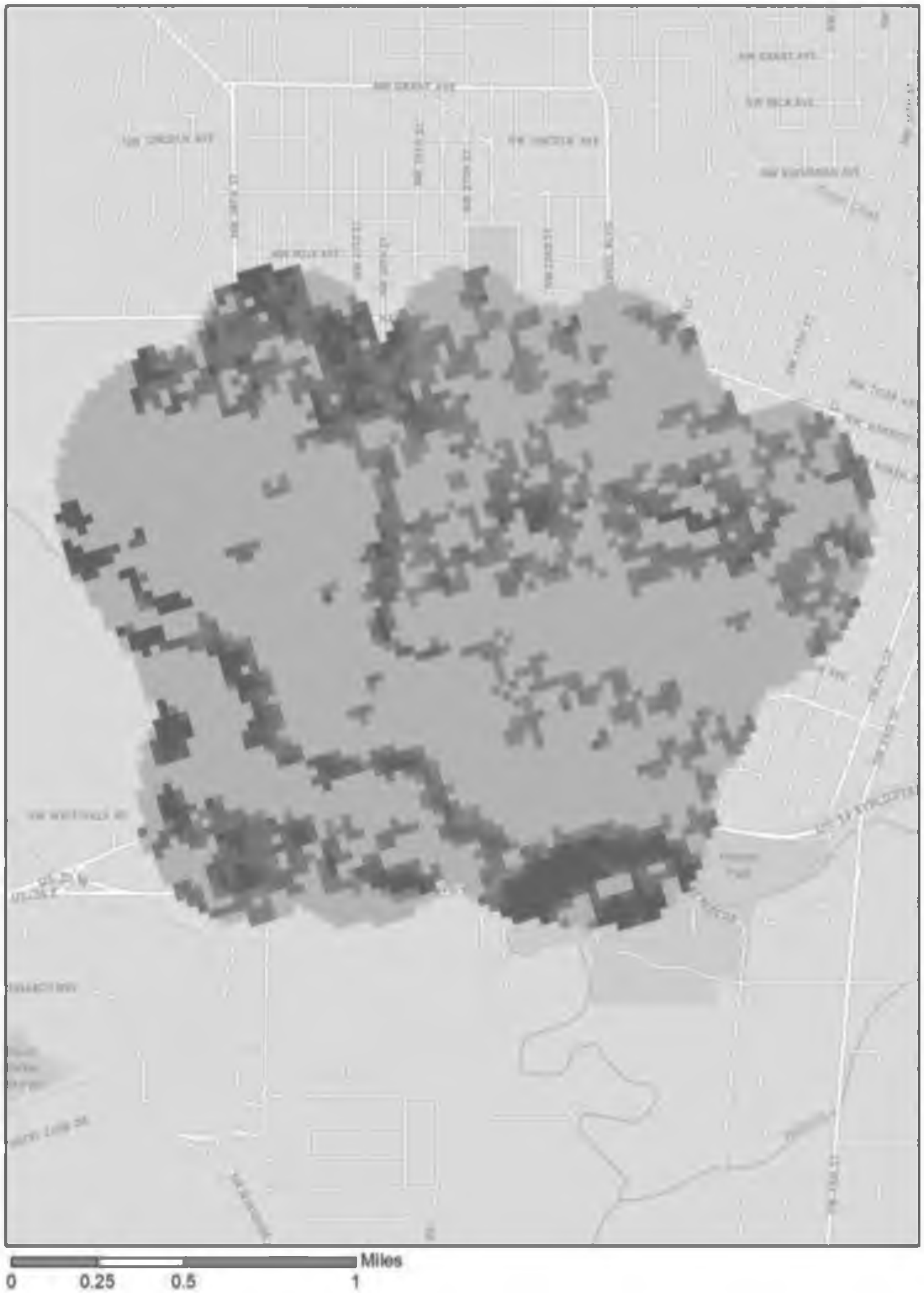

Figure B.57 The intensity of tree canopy, Oregon State University

Figure B.58 Figure ground map, University of Tennessee

Figure B.59 Pervious open space, University of Tennessee

Figure B.60 The intensity of tree canopy, University of Tennessee

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