An Analysis of Urban Development Pressure on the Edge of South Mountain Park in Phoenix, Arizona

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도시개발 압력에 따른 피닉스 South Mountain Park 주변의 훼손 및 현황에 대한 분석

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ABSTRACT : Edges have long been discussed as a topic of interest for research on fauna, but few studies have really focused on edges with a high urban development density. This paper focuses on the edge change of the South Mountain Park, Phoenix, by analyzing different temporal and spatial scales of maps. The analyses were conducted in three steps. The first step was to examine the types and changes of land cover around the edge at the scale 1:100,000 using GIS. The second step was to understand the changes in levels of disturbance in highly disturbed areas identified from the previous step, using aerial photographs. The third step was to investigate disturbance patterns in residential areas, at a larger scale, by measuring the two indicators: native vegetation and impervious cover. The research found that the edge disturbance around the urban preserve is mostly caused by low or very low density residential development, indicating that the zonings around the South Mountain Park are not ecologically sound. The study also found that the low density residential zoning (5.3 residential units/acre) disturbs the native vegetation more significantly than the very low density residential zoning. Finally, the current patterns of disturbance in very low density residential zoning (4.3 residential units/acre) have caused more significant introduction of exotic vegetation than in the low density residential, reflecting unsustainable ecological process in the desert environment. Since few studies have been conducted to understand how different types of land uses affect the edges of mountain parks, it is important to focus on examining characteristics of edge disturbance and understanding how different land use patterns are associated with a particular type of the disturbance.

Key Words : **Edge, Disturbance, Zoning, Density**

요약 : 생물 군집들 간의 경계를 이루는 가장자리(Edge)의 특성과 중요성에 대해서는 생태학 분야에서 이미 많은 연구가 이루어진 데 반해, 도시계획 분야에서는 정주 환경과 생태적으로 중요한 지역을 나누는 다양한 경계의 특징과 관리에 대해 많은 연구가 이루어지지 못했다. 본 연구는 애리조나주의 수도인

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피닉스에서 가장 큰 규모로 보존되고 있는 South Mountain Park의 경계부분이 각종 주택 및 토지 개발로 인해 어떻게 훼손되어 왔고, 또 그 훼손이 어떤 패턴을 보이고 있는지 이해하는 데 초점을 두고 있다. 본 연구는 이를 위해 다양한 규모의 지도를 활용, 크게 세 가지 과정을 통해 분석했다. 첫째, GIS를 활용, 지역적(Regional) 규모에서 공원 전체 경계부분의 토지 피복(land cover) 현황을 분석해 훼손(disturbance) 정도가 가장 심한 부분을 찾아냈다. 둘째, 훼손 정도가 가장 심한 경계부분, 즉 Awatukee 개발지역의 항공사진들(aerial photos)을 분석, 지난 40여 년간 어떠한 토지이용을 통해 어떤 방식으로 경계 훼손이 진행되어 왔는지를 조사했다. 마지막으로는 경계 훼손이 심한 Awatukee 지역 내 전형적인 주택개발지역을 선정, 지역 고유의 생태계에 적합한 식재(native vegetation) 현황과 불투수성 포장(impervious cover)의 분포 등 두 가지 지표 분석을 통해 경계지역의 훼손 정도를 파악했다. 분석 결과, 공원 주변의 훼손은 저밀도 주택지에서 가장 많이 일어났고, 이는 피닉스시가 공원 훼손을 최소화하기 위해 공원 경계부분의 토지이용을 저밀도 주택구역(very low density housing)으로 지정해 해결하려던 토지이용 정책에 문제가 있음을 제기했다. 본 연구는 이 같은 한계를 극복하기 위한 하나의 방안으로 시정부가 사막 환경에 맞는 고유 수종 보호 및 선정에 대한 가이드라인을 제공하고, 불투수성 포장면적을 줄이기 위해 주택 개발 시 다양한 인센티브를 제공할 것을 제안하고 있다. 비록 자연 및 사회환경이 다르지만, 본 피닉스 지역의 연구사례는 다양한 산과 공원을 포함하고 있는 서울지역 내 자연공원 경계지역의 토지이용 및 자연환경영향 분석의 필요성과 생태적으로 지속가능한 토지이용관리에 좋은 시사점을 제공하고 있다.

주제어 : 도시공원, 공원경계 훼손, 토지이용

Ⅰ. Introduction

Metropolitan Phoenix, Arizona has grown faster than any other large metropolitan regions in the U.S., and the very large population increases are driving the rapid expansion of the urbanized area. This expansion continually causes the fringe of metropolitan Phoenix to expand. In the southeast portion of the Phoenix metropolitan area, the edge has moved outward at three-fourths of a mile each year affecting natural desert and agricultural land(Morrison Institute for Public Policy, 2000; Lang and Dhavale, 2005). Urbanization in Metropolitan Phoenix has negative impact on natural desert land including mountain preserves(Figure 1). Calculations from aerial photographs show that between 1975 and 1995 some 40 percent of all agricultural land and 32 percent of all undeveloped desert land were lost to urbanization(Pack, 2005). Among many types of development, residential development is the one that is moving outward most rapidly. The region's heaviest home building is now occurring in a ring 18 to 21 miles from downtown Phoenix(Morrison Institute for Public Policy, 2000). An analysis of housing types and sizes explains the notable rapid urbanization. Predominantly, low density single family housing is the preferred typology in the area, but this land use is land consumptive. It is notable that much of the Phoenix area's growth occurs at the edge because of people's preference to be near the desert(Gammage, 1999, 2007). Many new residents are attracted by the ability to access the desert quickly and easily, and the vacant desert is thought to be mitigation for the impact of relatively small single family lots within the developed areas(Gammage, 2007). Due to the favorable tax rules in the 1980s, an unusually high proportion of multifamily housing unit was constructed. During the 1980s, much of the multifamily and single-family houses were constructed on the parcels that had been initially skipped over(Morrison Institute for Public Policy, 2008). Currently, over 27,000 acres of mountain preserves and desert parks are operated and maintained by City of Phoenix. Those are hosting many recreational and outdoor activities-hiking, picnicking, mountain biking, horseback riding, outdoor education, bird watching, and biological field studies(PRLD, 1998). However, mountain preserves are being isolated by urban development, and Sonoran desert, which makes the metropolitan Phoenix unique and gives it a special character, is being threatened by the edge encroachment from the development area(Morrison Institute for Public Policy, 2008). Along with this explosive growth, City of Phoenix has an aggressive tradition of preserving desert open space in the form of preserves and desert parks(Morrison Institute for Public Policy, 2008). The combination of these two efforts generates a lot of edges between the preserves and developed areas. These kinds of edge are not recognized as the bridge connecting the preserve and developed area, but can be more accurately described as an awkward boundary. Historically, this edge has been considered nothing more than the edge of a developable area(PRLD, 1998).

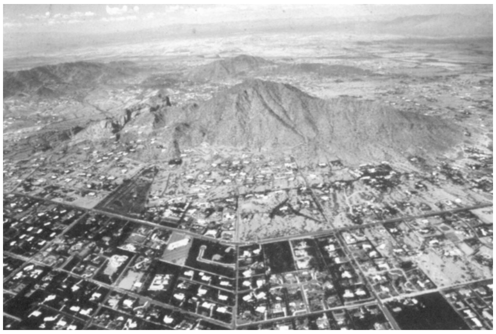

Figure 1. Urban development pressure on a mountain preserve in Phoenix, Arizona

This research aims to explore the patterns of edge changes around South Mountain Park, the largest mountain preserve in Phoenix, Arizona, which has experienced severe edge encroachment from the development side. Primary questions for this research are: 1) historically, which part of the edge of the South Mountain Park has been most disturbed? 2) how has the land around the preserve edge been encroached by urban development? and 3) what types of land use have caused the most severe disturbance? The analysis in this research was conducted in two steps. First, the change of land uses over time around the South Mountain Park has been examined to understand the overall disturbance patterns and to identify highly disturbed spots along the edge, using GIS(Geographic Information System). Second step focused on understanding the change patterns in sample sites of highly disturbed areas around the edge. In this step, utilizing 1:100 scale aerial photos, two particular locations in two different types of zoning were selected to understand the degree of disturbance by measuring impermeable and compacted land cover as well as introduced vegetation.

Ⅱ. The Concept of Edge and Impact of Disturbance

Edge has long been discussed as a topic of interest for research on fauna, but few studies have focused on edges with dense urban populations(Esbah, 2001; Hargrove, 2000). There are various definitions of the edge originating from different fields. Wildlife managers consider edges that game and other animals move along or across(Forman, 1995). Thus, when considering biodiversity and land transformation, the ratio of edge to interior habitat is significant. Those with aesthetic concerns see edges as elements that often dominate views. Foresters often characterize edges as sources of crooked trunks and blowdowns. In agriculture, edges can be the source of pests, as well as predators controlling pests. For those concerned with soil erosion control, boundaries change the wind speed and impact turbulence. In park and nature reserve management, edges may be barriers or sources of human overuse. Anthropologists see humans as edge species, and advocates of sustainable development argue against development of land that enormously increases edges, because key values of large patches are eliminated and landscapes are degraded(Forman, 1995).

In terms of architecture and urban planning, the theoretical concept of edge is suggested as one of the elements that make the city image(Lynch, 1960). According to Lynch (1960), the edge was classified as one of five elements- paths, edges, districts, nodes, and landmarks. Edges are defined as the linear elements not used or considered as paths by the observer, and also described as the boundaries between two phases, linear breaks in continuity: shores, railroad cuts, edges of development, and walls(Lynch, 1960). It was also asserted that such edges may be barriers, which close one region off from another; or they may be lines along which two regions are related and joined together(Lynch, 1960). More recent theories of edge related to urban ecology defined an edge as the outer portion of a patch where the environment differs significantly from the interior of the patch(Dale and Haeuber, 2000; Dramstad et al., 1996). The research focuses on this type of edge formulated around urban preserve patches as a result of land development pressure where very different characteristics of social and ecological components meet.

Ⅲ. The Edge of South Mountain Park

South Mountain Park is a regionally significant open space patch on the southern edge of City of Phoenix(Figure 2). It is bounded by the Gila River Indian Reservation on the southwest side,

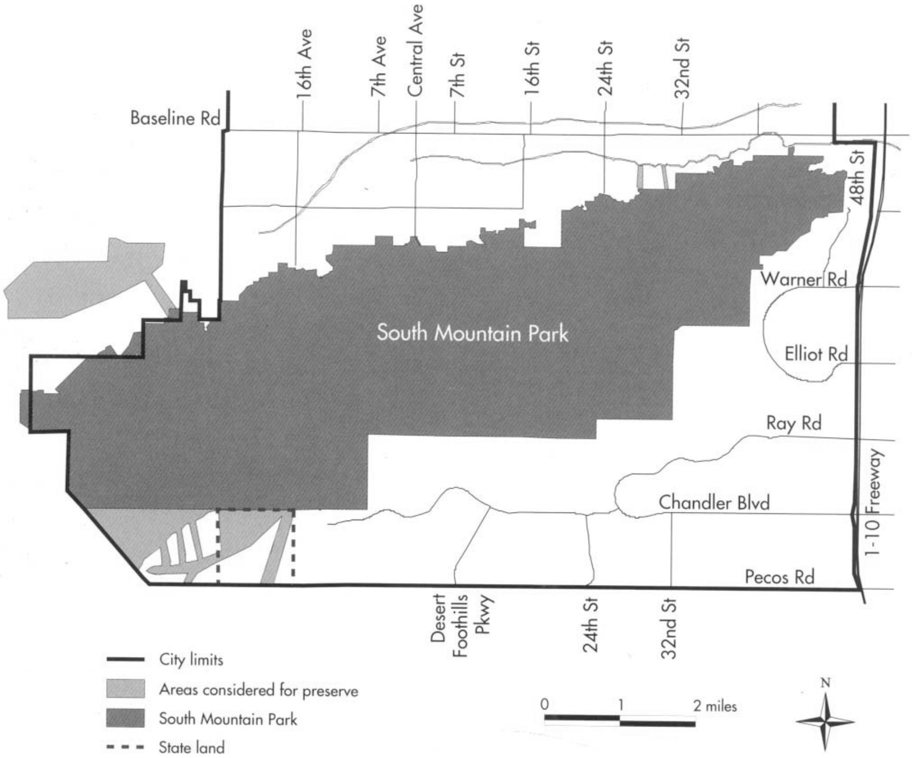

Figure 2. South Mountain Preserve in Phoenix, Arizona

and edges on all other sides are encroached by the urban development(Figure 3). The park includes 13,585 acres of a rugged mountainous area where native plant species and an exotic annual grass dominate. It has been heavily used for recreational activities such as hiking, bicycling, and horseback riding. Since the establishment of the park boundaries in the 1930's, urban development has continued to spread and finally reached park preserve boundary. Until the last 20 years, the park was primarily surrounded by native desert, and secondarily by some agricultural area and small amounts of urban development(Raja, 1999). However, as urban development has increased, an external buffer was lost and finally the edge effect has extended further into the park itself, negatively affecting the core habitat area of the park(Cook, 2000). The first urban residential development there, called Ahwatukee, had been zoned before it was annexed by City of Phoenix. It targeted at a retirement populations and developed as a very ordinary subdivision. Moreover, two huge master-planned communities, the Mountain Park Ranch and the Foothills, started to deteriorate the mountain ecology by wrapping the backside of South Mountain Park. The Foothills, the former proving ground for the International Harvester Corporation, had been scarred by testing with earth moving equipment (Gammage, 1999).

The level of disturbance by the development around the South Mountain Park has highly increased. The north side of the park has been severely disturbed by the heavy land uses and primary access locations. The southeast area is also encroached upon by urban development and is starting to realize a similar level of impacts. The least impacted area is the southwest portion, providing an extensive near natural habitat and important links to the Gila River Indian Reservation and the Estrella Mountains. Throughout the park an extensive natural habitat area exists, representing an important ecological resource, even though disturbance is more concentrated on the northern and eastern sides(Gammage, 1999).

Figure 3. South Mountain Park threatened by developments(photograph by author)

Ⅳ. Analysis of Land Cover Changes around the Edge

The study examined the change of disturbance around edge of the South Mountain Park by analyzing land cover using GIS. Urban land cover types and their spatial distributions are in wide use as fundamental data for wide range of studies in the physical and social science, as well as for land planning(William et al., 2001; Shaw et al., 1998). For the first step, land cover classification maps at the scale 1:100,000 were used to examine the changes of land cover at the edge of the park. These maps were produced by the Geological Remote Sensing Laboratory as part of the Land Cover/Land Use Change research effort of the CAP LTER(Central Arizona-Phoenix Long-Term Ecological Research). The land cover classifications for the Phoenix metropolitan were derived from Landsat Thematic Mapper(TM) data for 1985, 1990, 1993, 1998, and 2005, and have been useful for patch dynamics modeling and social science research. The data also include vegetation indices derived from Landsat Multispectral Scanner and TM imagery. Using expert system approach to improve surficial reflectance data obtained from the TM, the land cover was divided into twelve classes at 30 meters/pixel ground resolution. The data incorporated ancillary geospatial data such as water rights information, city boundaries, Native American reservation boundaries, and land use information to fix erroneous classification, resulting in an overall final classification accuracy of 85%(Stefanov, 2002). Despite increased accuracy with advanced remote sensing technology, the data are still subject to limitations such as uncertainties associated with the classification method, the sample size of evaluation data, and the inherent subjective characteristics of classification(Stefanov, 2002). All data were geo-referenced to UTM Zone 12, datum NAD27, and the classification maps have a pixel resolution of 28.5 meters/pixel. Five digitized land-cover maps were spatially layered using the ArcGIS, and the dramatic changes of land-cover around South Mountain Park were more clearly illuminated. Land-cover was roughly classified into disturbed and undisturbed area. The disturbed area includes asphalt, concrete, commercial/industrial land uses as well as mesic and xeric residential areas. The analysis of land-use illustrated a strong and growing pressure of land development from the southeastern side of the park(Figure 4).

After examining land cover changes from 1985 to 2005 at the edge of South Mountain Park, residential land uses were identified as the one that generates highest disturbance among the range of land uses considered. Undisturbed areas had reduced in area for each period examined. Analysis of the land cover was based on four main classifications of disturbance defined by CAP LTER: 1) disturbed area by asphalt and concrete, 2) disturbed area by commercial/industrial, 3) disturbed area by mesic residential, and 4)

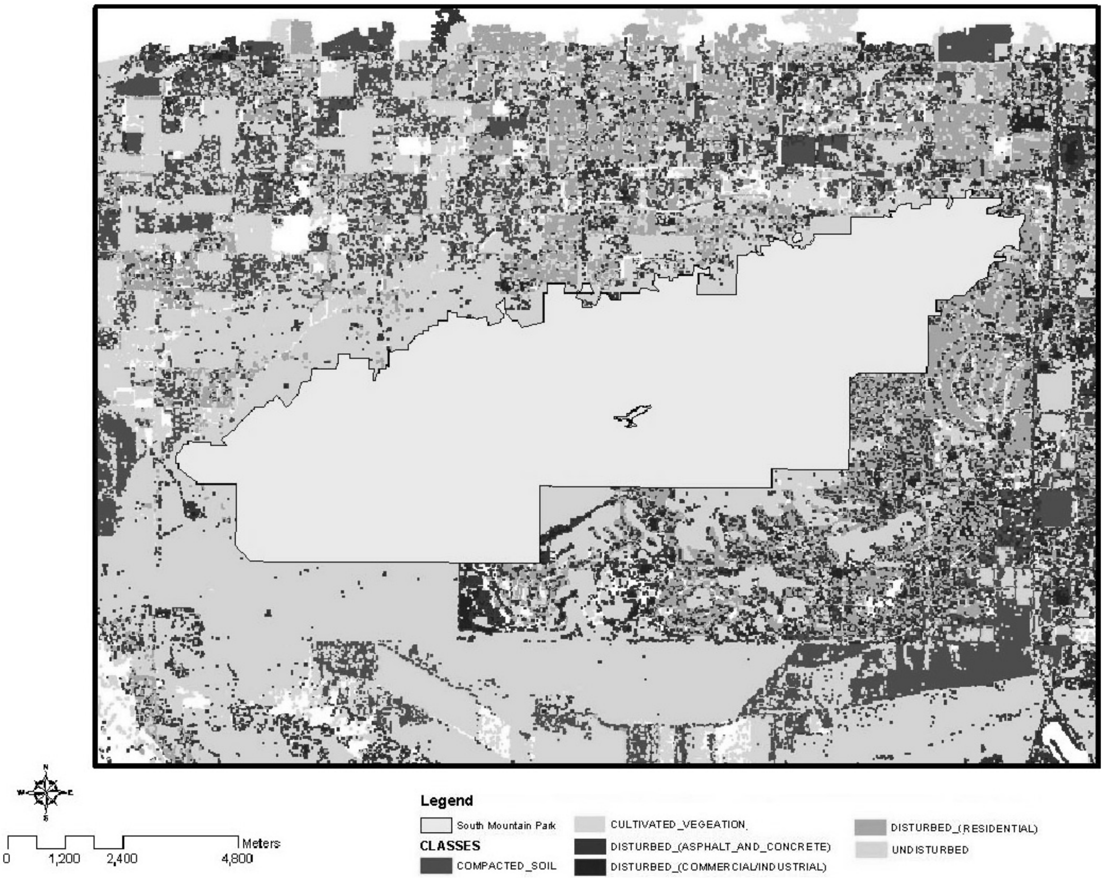

Figure 4. Edge disturbance in 1998 around the South Mountain Park

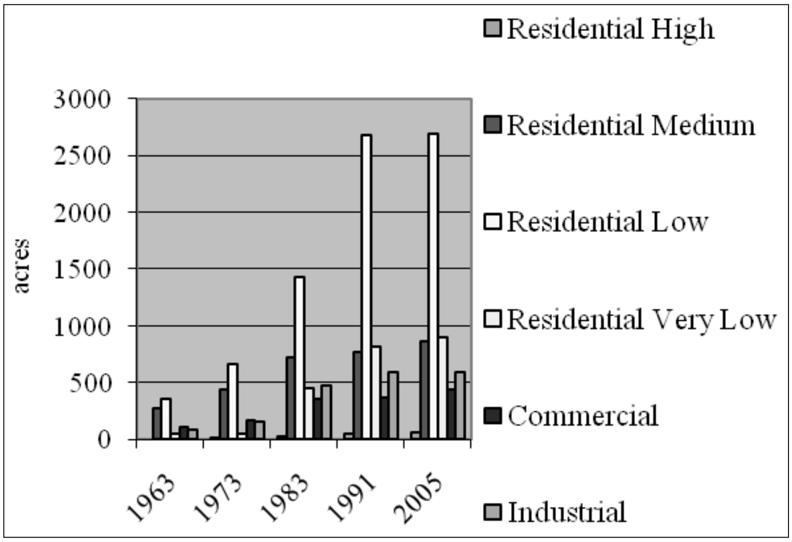

Figure 5. Land-use patterns within the disturbed area

disturbed area by xeric residential. To clearly understand the level of disturbance near the edge, a 100 meter-buffer was created along the edge by using GIS. The number of pixel resolution of 0.2 acre/pixel within the buffer was calculated to measure the disturbance for each classification. The analysis illustrated that the areas disturbed by residential land use have grown distinctively compared with the other indices(Figure 5). Most of the residential disturbances were generated between 1993 and 2005, indicating almost double the level of disturbance in 1993. The disturbances of two types of residential-xeric residential and mesic

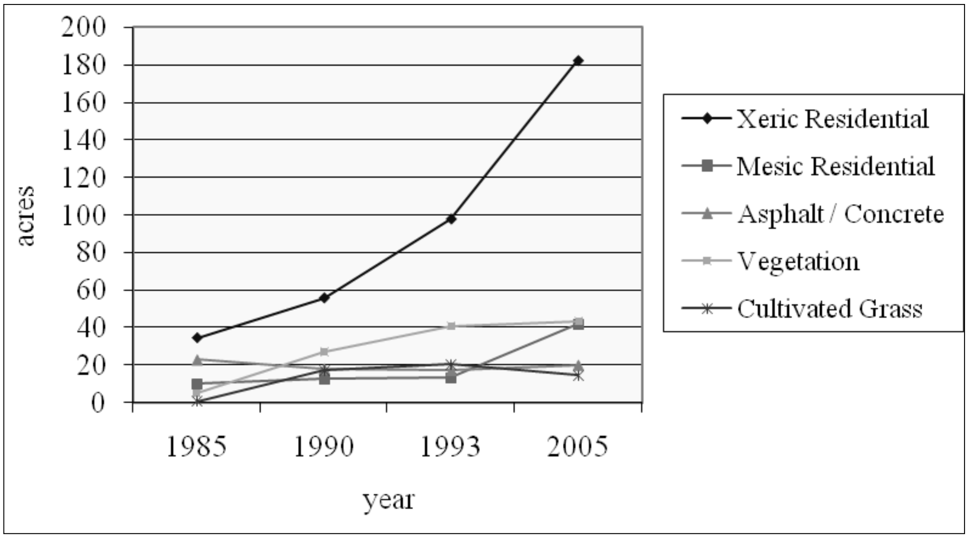

Figure 6. The change of land cover within the buffer

residential were also examined. Xeric residential is defined as a residential area in environmental conditions that require less water, while mesic residential areas require medium water use. The analysis of the change of land-cover inside the buffer demonstrated that xeric residential is the predominate disturbance along the edges (Figure 6). It also illuminated that despite the increase of disturbance, vegetation had increased on the edge. This implies that man-made vegetation, which is different from natural desert vegetation, had increased in developed areas.

Based on the observation, the analysis of land cover changes can be summarized as follows. First, the change in disturbance due to residential land development between 1993 and 2005 indicates that the edge of South Mountain Park experienced severe disturbance for that period of time. Second, the vegetation in the buffer has increased over time. This can be explained as a result of increased care and water for introduced trees in residential areas, while the natural vegetation decreased over time. Finally, the disturbance caused by xeric residential land uses increased more significantly compared to mesic residential land uses. This result demonstrates that xeric landscapes, which mean arid landscapes, are the dominant landscape around edge of the preserve.

Ⅴ. Analysis of Edge Disturbance Process

To understand the process of disturbance of the edge around South Mountain Park, a land of 7,256 acres in Ahwatukee area was selected for its highest disturbance pattern in the edge as was identified from the previous analysis(Figure 7). Ahwatukee, which had been zoned in the county before being annexed by the City of Phoenix, was firstly developed as a significant subdivision targeted at a retirement population. Subsequently, two huge master- planned communities, the Mountain Park Ranch and the Foothills were developed, and started to encroach on the southeast side of the South Mountain Park(Gammage, 1999). For the analysis of disturbance process, black and white aerial photographs of highly disturbed areas in larger scales were examined. Observation of aerial photos and survey of related literature are commonly applied methods to identify causes and patterns of land transformation(Forman, 1995; Cousins, 2001). For the analysis, six aerial photos of 1:3200 scales from 1963, 1973, 1983, 1991, 2000 and 2005 that present distinctive land changes were obtained from *Landiscor co*, Phoenix, and scanned to rectify into available forms of data in ArcGIS. By using the editor function, disturbed areas were digitized and layered on the same frame to calculate the exact areas of the disturbance.

A result illustrated that the disturbance by urban development in the study area had occurred consistently since 1963. 63% of disturbance in 2000 was generated from 1963 to 1983 and 90% of disturbance in 2000 was occurred until 1991. This implies that most of

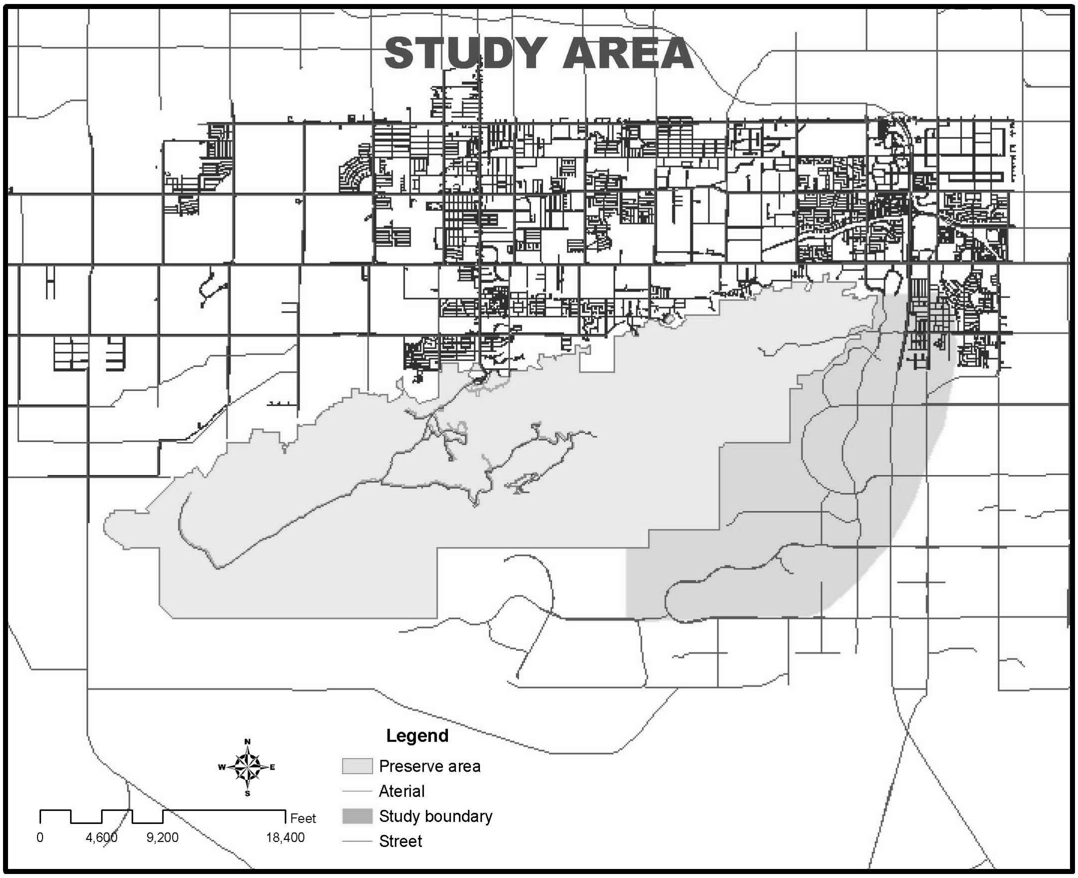

Figure 7. Ahwatukee area for the analysis of land transformation around edge

disturbance occurred between 1963 and 1991. The zoning codes in the disturbed area each year were also examined. For this analysis, the densities of residential land uses were classified into four categories; very low density residential, low density residential, medium density residential, and high density residential. Very low density was defined as 5 dwelling/acre or below, and low density as 5.3 dwelling/acre. Medium density includes from 10 dwelling/acre to 22 dwelling/acre, and high density includes 29 dwelling/acre or above. This classification of residential zonings was based on reorganization of the following zoning codes system of the City of Phoenix.

- High density: R-4(multi-family residential, 29.0 dwelling/acre base density), R-4A (multi-family residential, 43.5 dwelling/acre base density), R-5(multi-family residential, 43.5 dwelling/acre base density)
- Medium density: R-2(multi-family residential, 10.0 dwelling/acre base density), R-3 (multi-family residential, 14.5 dwelling/acre base density), R-3A(multifamily residential, 22.0 dwelling/acre density)
- Low density: R1-6(single family residence,

Table 1. Changes in disturbed area by different land uses in Ahwatukee area

(unit: acre)

Year	Residential				Commercial	Industrial
	High	Medium	Low	Very Low		
1963	0	272 (31.48%)	353 (40.86%)	46 (5.32%)	111 (12.85%)	82 (9.49%)
1973	17 (1.14%)	440 (29.53%)	666 (44.70%)	50 (3.36%)	162 (10.87%)	155 (10.40%)
1983	20 (0.58%)	724 (21.05%)	1,425 (41.42%)	446 (12.97%)	357 (10.38%)	468 (13.60%)
1991	49 (0.93%)	771 (14.64%)	2,678 (50.85%)	819 (15.55%)	364 (6.91%)	585 (11.11%)
2000	55 (0.99%)	865 (15.59%)	2,697 (48.61%)	901 (16.24%)	438 (7.89%)	592 (10.67%)
2005	67 (1.16%)	890 (15.42%)	2,780 (48.18%)	930 (16.12%)	498 (8.63%)	605 (10.49%)

5.30 dwelling/acre base density)

- Very low density: S-1(ranch or farm residence), S-2(ranch or farm commercial), RE-43(single family residence, 43,560 sq. ft. lots minimum), RE-35(single family residence, 1.10 dwelling/acre base density), RE-24 (single family residence, 24,000 sq. ft. lots minimum), R1-18(single family residence, 1.95 dwelling/acre base density), R1-14(single family residence, 14,000 sq. ft. lots minimum), R1-10(single family residence, 3.50 dwelling/acre density), R1-8(single family residence, 4.30 dwelling/acre density)

The result from this analysis of residential areas yielded the following two conclusions. First, by the year of 2005, 70% of developed area had been developed as residential(Table 1). Out of the residential developments, R1-6(5.30 dwelling/acre base density) occupies dominant portion of the study area(Figure 8). This 5.30 dwelling/acre, according to Shaw(1998), is classified as a low vegetative characteristic among several types of urban land covers. Second, low density developments generate new awkward edge lines, affecting negatively the interior core of the preserve. The lack of open space in the study area is thought to be the one

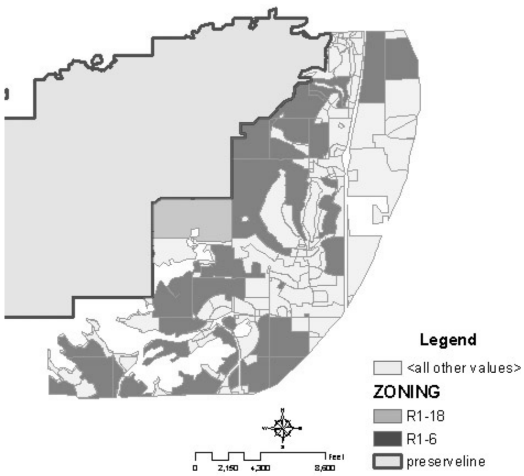

Figure 8. Dominant portion of R1-6 in the Ahwatukee area

of the reasons of increased disturbance on the edge. However, this type of developed area can offer another possibility for the future habitat. Cook(2000) and Arendt(1994, 2004) asserted that modification in the development pattern could make adjacent development areas more useful for habitat, yielding a more effective external buffer, rather than sacrificing critical core habitat of the park.

Ⅵ. Analysis of Disturbance at the Residential Areas

As a result of prior analysis, two different sites from highly disturbed edges were chosen and examined using aerial photos in 1:100 scale. This level of analysis focused on the intensity of disturbance in residential areas. Following Cook's approach(2002) to define disturbance, this study employed two key indicators: the presence of exotic species and soil compaction or extent of paving. According to Cook(2002), compacted soils and pavement or areas of soil erosion cause considerable secondary ecological problems, such as increased runoff, loss of nutrients and minerals, as well as increased sediment in streams, reducing water quality. Exotic vegetation also causes the decline of naturalness(Smith and Theberge, 1986). Krieg(1999) defined the exotic vegetation as "technically, any plant that is introduced into any area that would not have the ability to naturalize in that area if left to its own devices." The area chronically disturbed by humans has a high proportion of non-native species, and these locations are suitable sources for potential invaders into surrounding native ecosystems(Soule, 1991). Forman(1995) also advocated that the human disturbance provides exotic species with resources, such as light and mineral nutrient availability, and especially space without competitors.

Based on the prior observation that the low density residential and the very low density residential are the two most dominant residential patterns with high disturbance in the study area, two representative zonings: R1-6 as a low density residential and R1-18 as a very low density residential, were selected for further examination. For this analysis, aerial maps of the R1-6 zoning from 1975, 1978, 1982, 1999, and 2005 as well as the R1-18 zoning from 1982, 1986, 1991, 1999, and 2005 were obtained from City of Phoenix. The selection of years was limited by the availability, and the distinctiveness in change was considered in choosing the years of maps. These aerial photos representing 2.67 acre of prototypical residential area were transferred to editable forms of data to use GIS. To evaluate the intensity of disturbance with naked eyes, four categories were predefined; impermeable area, introduced vegetation, permeable area with no vegetation, and native or undisturbed area. Each of definitions was given as follows: 1) impermeable area: the area occupied by impermeable materials, including buildings, roads, concrete, and cement, 2) introduced vegetation area: the area re-vegetated by the humans, 3) permeable area with no vegetation:

Table 2. Disturbed areas in a low density residential area

(unit: acre)

	1975	1978	1982	1999	2005
Impermeable area	0.00	0.17 (6.39%)	1.40 (52.43%)	1.47 (55.13%)	1.52 (57.05%)
Introduced vegetation	0.00	0.00	0.31 (11.48%)	0.73 (27.42%)	0.79 (29.50%)
Native vegetation	1.47 (54.92%)	0.00	0.00	0.00	0.00
Permeable with no vegetation	1.20 (45.08%)	2.50 (93.61%)	0.96 (36.09%)	0.47 (17.45%)	0.36 (13.45%)

Table 3. Disturbed areas in very low density residential

(unit: acre)

	1982	1986	1991	1999	2005
Impermeable area	0.00	0.34 (12.67%)	0.92 (34.27%)	1.08 (40.50%)	1.22 (45.55%)
Introduced vegetation	0.00	0.00	0.14 (5.15%)	0.67 (25.01%)	0.90 (33.55%)
Native vegetation	2.45 (91.61%)	0.66 (24.74%)	0.40 (14.83%)	0.09 (3.26%)	0.08 (2.95%)
Permeable with no vegetation	0.22 (8.39%)	1.67 (62.59%)	1.22 (45.75%)	0.83 (31.23%)	0.48 (17.95%)

the area including disturbed soil by human activities, or graded area for the urban development, and 4) native or undisturbed: the area undisturbed or occupied by native vegetation. To measure the area of each kind of disturbance, the relative amount of disturbance was calculated, based on the total study area. Distinction of native or non-native vegetation in the aerial photos was made through naked eyes by comparing the shape, color, and texture of tree crown with the ones in South Mountain Park. Most of non-native vegetation is lawn widely spread throughout low and very low density residential areas. After examination of changes in disturbance intensity in the low density and the very low density residential through the analysis of aerial photos, a field trip was conducted to confirm the characteristics of vegetation for each residential site.

The analysis in this stage indicates that the low density and the very low density residential showed different process and characteristics in disturbance(Table 2 and 3). In the low density residential, the percentage of native vegetation declined considerably between 1975 and 1978. This implies that the disturbance by mass grading in the low density residential swept throughout the natural desert during a short period of time. Impermeable area in the low density residential intensively increased between

1978 and 1982. On the other hand, the impermeable area in the very low density residential increases at much slower rate than in the low density residential. The land transformation pattern in very low density residential leaves more rooms to save native vegetation. Introduced vegetation area increases more rapidly in the very low density residential. Especially between 1991 and 1999, introduced vegetation increased the most. This reflects people's higher preferences for artificial vegetation in the very low density residential(Figure 9). In the low density residential, the increase of introduced vegetation is slower than in the very low density residential. With regard to permeable area with no vegetation, the low density residential indicates the highest disturbance in 1978, and decreased intensively by 1982. This implies that a higher ratio of given land in low density residential, was graded and replaced with other types of disturbance, such as impermeable area and introduced vegetation. Based on the analysis of disturbance intensity, the change patterns of disturbance in both the low density residential and the very low density residential are not significantly different. However, it is notable that the time to reach the similar level of disturbance is quite different. It took only five years in low density residential to reach to its highest level of disturbance. On the other hand, it took 17 years in the very low density residential to reach to its highest level of disturbance. This result indicates that the disturbance by development in the very low density residential increases less rapidly than in the low density residential. Thus, the low density residential causes more rapid deterioration of native land than very low density residential.

Figure 9. Introduced vegetation in the very low density residential(R1-18) (photograph by author)

Ⅶ. Conclusion

This study was conducted to understand how the edge of the South Mountain Park has been encroached upon and what types of land use affected the edge the most. Based on systematic analysis of aerial photos in conjunction with GIS, it is observed first that the edge of the north and the southeast side of the South Mountain Park has been greatly disturbed by residential development. Although both R-1(very low density) and R1-18(very low density) zonings occupy considerable portion of the edge of southeast side of South Mountain Park, R1-6(low density) occupies the most dominant proportion. Second, disturbance caused by impermeable area occurs more rapidly in low density residential area(R1-6) than in very low residential area(R1-18). Measurements of the level of disturbance at 1:100 scale maps yielded that the R1-6 zone quickly changes land cover with impermeable area by mass grading. Third, disturbance caused by introduced vegetation is faster in very low density residential than in low density residential. The landscape characteristics of these two selected areas have dominant exotic vegetation, with little native vegetation. The rates of disturbance caused by exotic and introduced vegetation are similarly high in both areas of low and very low density residential. This reflects people's preference for more exotic, tropical vegetation, rather than native vegetation in their backyards in the desert environment. As Gammage(1999) pointed out, the gap between people's preference and the natural characteristics of the desert is one of significant barriers in sustainable landscape management.

An observation from a larger spatial scale focusing on the most disturbed edge in the southeast portion of the South Mountain Park illuminated that considerable portion of the edge was impacted by the R1-6 zoning(5.30 dwelling/acre base density), which was classified into low density residential in this study. The disturbance process in the R1-6 residential showed more destructive land transformations compared to the very low density residential. In addition, the development pattern of R1-6 showed rapid and sweeping land changes, leaving little native vegetation. Examination of the changes of exotic vegetation in low residential and very low residential concluded that the rates of exotic vegetation in both areas are high. Most native vegetation was substituted with exotic or introduced vegetation, which has an ecologically negative impact on the edge. In short, current land use patterns in low residential and very low residential zonings are not ecologically sound for sustainable management of the edges of the South Mountain Park. Based on this observation, I suggest the following recommendations to improve local land use policies for effective management of the Mountain Preserve.

First, the zoning codes around the South Mountain Park need to be revised. Inadequate zoning adjacent to the edge of the South Mountain Park has contributed to rapidly disturbing the edge, and destroying native vegetation. In particular, the R1-6 zoning that dominates the edge needs to be changed to a lower density with improved design. A previous plan, "Peripheral Area C and D Design Guidelines," proposed design guidelines for developments in Phoenix for zoning of R1-10 and below, and R1-18 and above. These ranges of zoning should be considered to respond to this problem. Second, to promote native vegetation cover, it is also recommended that following land uses be considered for the edge of the preserve, as was advocated by Shaw et al.(1998): 10 acres/house or less, 4-10 acres/house, 1-3 houses/acre, school, pond, and neighborhood park. Third, guidelines for vegetation to reflect regional desert characteristics need to be provided for the residential area adjacent to the edge. As Gammage(1999) noted, people want to make their gardens in their own ways without regard to the native characteristics. Especially for the residential areas around the edge of the preserve, it is critical for the local government to provide appropriate education and guidelines for the residents to maintain native vegetation.

Since few studies have been conducted to understand how different types of land uses affect the edges of mountain parks, it is important to focus on examining diverse characteristics of edge disturbance and understanding how different land use patterns are associated with a particular type of the disturbance. This will provide a useful guideline for the city to establish or revise zonings around the edges of mountain preserves that are very vulnerable to inconsiderate patterns of urban land development.

References

Arendt, R., 1994, *Rural by design*, Chicago: American Planning Association Press.

______, 2004, "Creating Greenway Corridors through Conservation Subdivision Design Strategies in the Northeastern and Central United States", *Landscape and Urban Planning*, 68(2): 241~269.

Noss, R., and Harris, L., 1986, "Nodes, Networks, and MUMs: Preserving diversity at all scales", *Environmental Management*, 10(3): 299~309.

Cook, E., 2000, *Ecological networks in urban landscapes*, Wageningen: Wageningen University.

______, 2002, "Landscape structure indices for assessing urban ecological networks", *Journal of Landscape and Urban Planning*, 58: 269~280.

Cousins, S., 2001, "Analysis of land-cover transitions based on 17th and 18th century cadastral maps and aerial photographs", *Landscape Ecology*, 16: 41~54.

Dale, V., and Haeuber, R., 2000, *Applying ecological principles to land management*, New York: Springer-Verlag.

Dramstad, W., Olson, J., and Forman, R., 1996, *Landscape ecology principles in landscape architecture and land-use planning*, Cambridge: Harvard University.

Esbah, H., 2001, *Using landscape structure indices to understand the possible impacts of landscape change: Case of the mountain preserves in the city of Phoenix, Arizona*, Tempe, Arizona: Doctoral dissertation, Arizona State University.

Forman, R., 1995, *Land Mosaics: The ecology of landscapes and regions*, Cambridge: University Press.

Gammage, G., 1999, *Phoenix in perspective: Reflections on developing the desert*, The Herberger Center for Design Excellence, College of Architecture and Environmental Design, Arizona State University.

______, 2007, *Proposition 207, Land Use Challenges and Choices for the 21th Century*, Arizona Town Hall.

Hargrove, A., 2000, *The thin green line: Balancing development and the ecology of the Phoenix Sonoran preserve*, Tempe, Arizona: Master's thesis, Arizona State University.

Hope, D., Gries, C., Casagrande, D., Redman, C., Grim, N., and Martin, C., 2006, "Drivers of Spatial Variation in Plant Diversity Across the Central Arizona-Phoenix Ecosystem", *Society and Natural Resources*, 19: 101~116.

Krieg, J., 1999, *Desert landscape architecture*, CRC Press LLD.

Lang, R., and Dhavale, D., 2005, *Beyond Megalopolis: Exploring America's New 'Megapolitan' Geography*, Metropolitan Institute Census Report Series.

Lynch, K., 1960, *The image of the city*, Cambridge, Massachusetts: MIT Press.

Morrison Institute for Public Policy, 2000, *Hits and Misses: Fast Growth in Metropolitan Phoenix*, 18-19, Arizona State University, Tempe, Arizona.

_______, 2008, *Megapolitan: Arizona's Sun Corridor*, Tempe, Arizona: Arizona State University.

Pack, J., 2005, *Sunbelt / Frostbelt: Public Policies and Market Forces in Metropolitan Development*, Washington DC: The Brookings Institution.

Parks Recreation and Library Department(PRLD), 1988, *South Mountain Park preliminary analysis*, City of Phoenix, Arizona.

______, 1998, *Sonoran Preserve Master Plan: An Open Space Plan for the Phoenix Sonoran Desert*, City of Phoenix, Arizona.

Raja, R., 1999, *An evaluation of ecological sustainability in residential neighborhood design*, Thesis, Arizona State University.

Shaw, W., Harris, L., and Livingston, M., 1998, "Vegetative characteristics of urban land covers in metropolitan Tucson", *Urban Ecosystems*, 2: 65~73.

Smith, P., and Theberge, P., 1986, "A Review of criteria for evaluating natural areas", *Environmental Management*, 10(6): 715~734.

Soule, M., 1991, "Land use planning and wildlife maintenance", *Journal of the American Planning Association*, 57(3): 313~323.

Stefanov, W., 2002, "Remote sensing of urban ecology at the Central Arizona-Phoenix Long Term Ecological Research Site", *ARIDLANDS newsletter*, 51. (http://ag.arizona.edu/oals/ALN/aln51/stefano.html).

William, S., Michael, R., and Philip C., 2001, "Monitoring urban land cover change: An expert system approach to land cover classification of semiarid to arid urban centers", *Remote Sensing of Environment*, 77(2): 173~185.

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