APPENDIX P

Applying GIS and landscape ecological principles
to evaluate land conservation alternatives,
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Applying GIS and landscape ecological principles to evaluate land conservation alternatives

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Abstract

Nowhere in the eastern United States is the conflict between the conservation of the rich biological diversity of existing forested landscapes vs. a continued expansion of suburban/exurban development more evident than in the case of Sterling Forest, a 7245 ha tract of land on the New York–New Jersey border. This paper reports on our application of geographic information systems (GIS)-based assessment and landscape ecological principles to assess the environmental sensitivity of Sterling Forest lands and to prioritize lands for conservation protection. This GIS assessment served as the basis of subsequent negotiations of a compromise conservation-development plan by a coalition of land conservation trusts and the land owner/developer. Sterling Forest represents a useful case study of the application of GIS technology by the non-profit environmental groups in successfully undertaking an independent analysis of a regionally important land use issue. © 1998 Elsevier Science B.V.

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1. Introduction

Recognizing that small-scale, piece-meal actions are inadequate to the task of conserving the overwhelming diversity of biological species, conservation biologists are increasingly advocating a broader landscape level approach (Noss, 1983; Franklin, 1993). While the loss of specific sites or habitats of threatened and endangered species is still considered important, concern is shifting to the larger issue of habitat fragmentation across the landscape. In the eastern United States, a recent decline in the breeding population of migratory passerine songbirds has been linked to the effects of fragmentation of their temperate forest breeding habitat (Robinson et al., 1995). Fragmentation leads to isolation and dimunition of interior (i.e., core as opposed to edge) forest habitat (Whitcomb, 1977) resulting in increased pressure by nest predators (Wilcove, 1985) and brood parasitism by cowbirds (Brittingham and Temple, 1983). As unfragmented forest habitat is becoming increasingly rare throughout the eastern United States primarily due to the impacts of expanding human development (Robbins et al., 1989), the preservation of large unbroken tracts of forest habitat for both migratory songbirds as well

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as other forest interior dependent wildlife has become a major biodiversity conservation issue.

Nowhere in the eastern United States is this conflict between the conservation of the rich biological diversity of existing forested landscapes vs. a continued expansion of suburban/exurban development more evident than the New York–New Jersey Highlands. An area of forested uplands of moderate relief, the New York–New Jersey Highlands serve as a natural geographic boundary serving to delimit the northern edge of the New York metropolitan region, the most densely populated region in the United States. Though comparatively close to New York City and associated New Jersey urban centers, the Highlands Region has been largely spared off the effects of 20th century suburban expansion. However, spurred by changing demographic patterns and the construction of several superhighways, suburban residential and commercial development has started to impact the Highlands. The distinct possibility that piece-meal development will overwhelm the Highlands has instigated intense concern and interest in trying to conserve the region's natural values as wildlife habitat, watershed and public open space (Michaels et al., 1992; Mitchell, 1992). Much of this concern has most recently focused on the fate of Sterling Forest, a 7245 ha tract of privately owned forest land on the New York–New Jersey border that was slated for a major development project

Based on our previous experience in assessing the potential forest fragmenting impacts of the proposed development of Sterling Forest (Lathrop, 1994), we were asked to formulate an alternative conservation plan. Our objectives were to: (1) preserve the essential characteristics of the Sterling Forest landscape which included its unfragmented forests, sweeping uncluttered views and rich native biological diversity; and (2) allow for limited development that minimized on- and off-site environmental impacts. In applying a landscape scale approach to biodiversity or nature conservation efforts, conservation planners are increasingly turning to geographic information systems (GIS) and remote sensing to provide a much needed spatial perspective (Bridgewater, 1993; Kupfer, 1995). This paper reports on our application of GIS-based analysis and landscape ecological principles to assess the environmental sensitivity of Sterling Forest lands and to prioritize lands for conservation protection. We discuss the role that GIS analysis played in subsequent negotiations of a compromise conservation-development plan by a coalition of land conservation trusts and the land owner/developer.

2. Case Study: Sterling Forest, New York–New Jersey, USA

Located approximately 60 km northwest of New York City, Sterling Forest at 7245 ha (17,900 acres) is among the largest remaining areas of unprotected open space in the New York metropolitan region (Fig. 1). Located in the New York–New Jersey Highlands physiographic province, Sterling Forest is of moderate relief with maximum elevations from 300 to 400 m. The geology consists of a complex series of folded and faulted metamorphic schist, granite and gneiss bedrock. Exposed rock outcrops are common and soils are generally rocky and shallow (Soil Conservation Service, 1981). Showing the influence of the southern Appalachian Oak-Hickory, the northern Appalachian Hemlock-Pine-Northern Hardwood, and the Atlantic Coastal Plain vegetation, Sterling Forest contains an excellent cross-section of the region's rich biological diversity. Upland deciduous forest forms an almost continuous matrix interspersed with patches of coniferous forest, forested swamps, shrub/emergent wetlands, ponds and lakes. As a result of past mining, timber harvesting, limited farming/pasturing, fire and disease/insect pests, the woods of Sterling Forest today are entirely of second growth (Keatinge, 1967). With few paved roads traversing the area, Sterling Forest represents the largest block of unbroken forest habitat in the NY–NJ Highlands region (Lathrop, 1996). With its pivotal central location, Sterling Forest serves to link large tracts of forested park and watershed lands in New York state with those in New Jersey. In addition to its value as wildlife habitat, Sterling Forest serves as high quality watershed for approximately 4.5 million New Jersey residents.

Sterling Forest is privately owned and managed by the Sterling Forest Corporation (SFC) which is in turn owned by Zurich Insurance Corporation, a Swiss international holding company. Under existing policies, the forest land has been managed for multiple

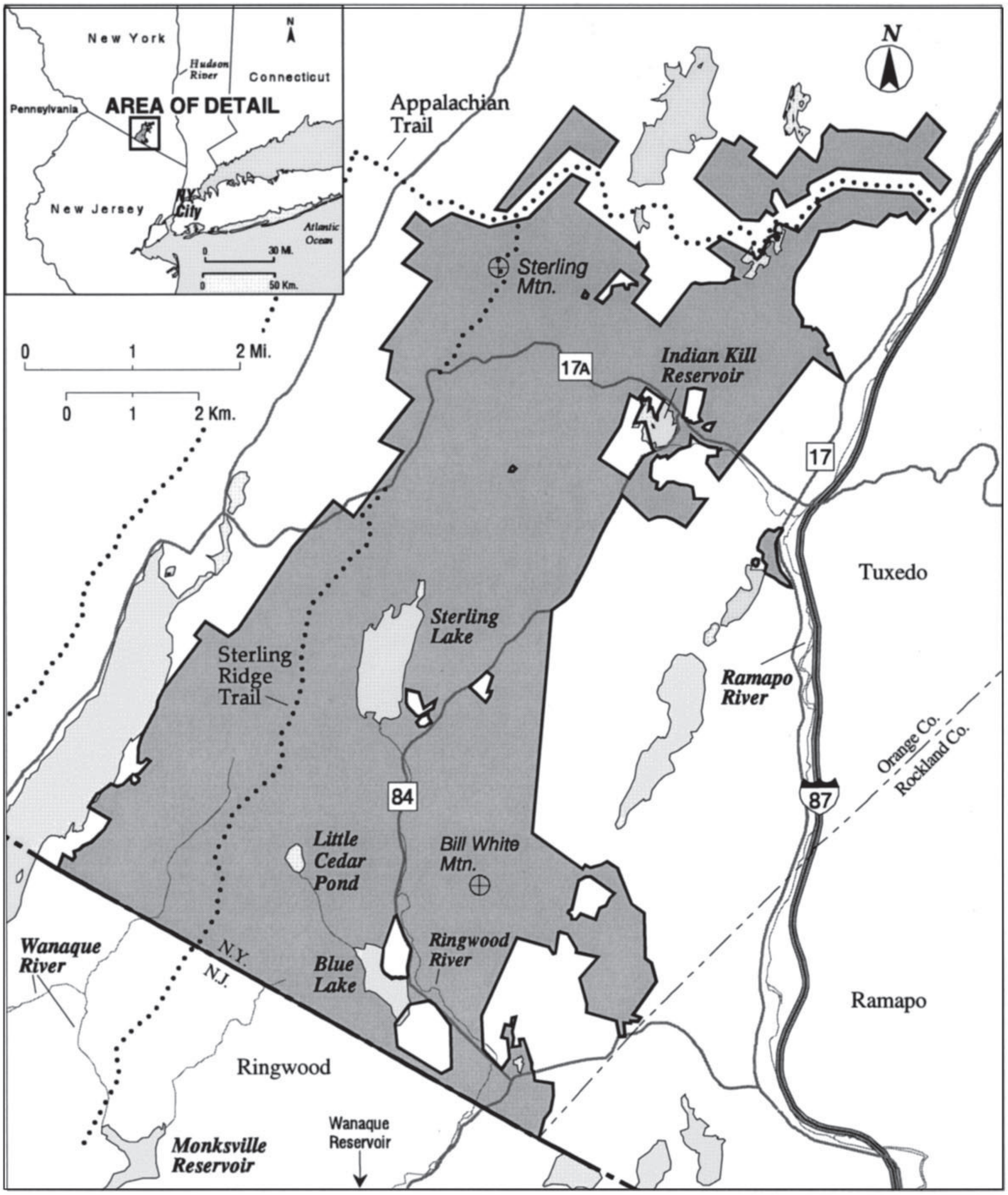

Fig. 1. Location of Sterling Forest.

uses including recreation, hunting/fishing and timber. While there has been limited commercial and residential development on Sterling Forest lands since the 1960s, at present the area remains largely intact forest land. However, in the early 1990s an ambitious commercial and residential development project (called the Sterling Forest Community) was proposed that would have dramatically altered the present situation. Approximately 13,000 housing units, 500,000 m^2 of commercial and light industry development and 200,000 m^2 of retail and service development were planned at project buildout (Lathrop, 1994). While the proposed Sterling Forest Project, as envisioned in the Draft Generic Environmental Impact Statement (DGEIS) (Lathrop, 1994), was designed with some sensitivity to environmental concerns, the size and intensity of planned development ensured that a significant environmental impact both locally and regionally was inevitable.

Due to the inherent natural values of Sterling Forest as wildlife habitat, open space and protected watershed, there was a concerted effort on the part of local, state and national government agencies and non-governmental environmental advocacy groups to limit, if not stop, the proposed development. Two non-profit land conservation trusts, the Trust for Public Land (TPL) and the Open Space Institute (OSI), have led a joint effort to purchase a significant portion of Sterling Forest and turn it over to the Palisades Interstate Parks Commission to manage as public open space. Due to the real estate value of the land and reluctance on the part of the Sterling Forest Corporation to completely abandon their development plans, TPL and OSI realized prior to the negotiation process that a full purchase of the Sterling Forest property was infeasible. Before entering into negotiations with the SFC, TPL and OSI determined that 6350 ha (out 7245 ha) was realistic target for a partial buyout. At an appraised value of $8650 per ha ($3500 per acre), this meant a purchase price of $55 million. The question then became, which acres should be purchased? TPL and OSI requested our assistance in prioritizing lands for acquisition vs. development and evaluating alternative conservation strategies.

The following sections discuss the environmental constraints assessment, the land prioritization/allocation and compromise negotiations.

2.1. Environmental constraints assessment

A GIS data base of basic environmental characteristics of the Sterling Forest area was created containing the following data layers: land cover type, hydrography, roads, elevation, soils. Arc/Info (6.1), Geographic Resources Analysis Support System (GRASS version 4.1) and ERDAS Imagine (8.0) software packages were used to support the GIS analysis. A land cover type map of the Sterling Forest region was developed based on the digital analysis and interpretation of Landsat Thematic Mapper (TM) imagery (March 17, 1991 and August 15, 1988) and high altitude color infrared aerial photography (1:40,000 March 1991) in combination with other mapped environmental data sets and field visits. The wetland and water types were determined from the existing U.S. Fish and Wildlife Service National Wetlands Inventory (NWI) digital maps. Roads and elevation from the U.S. Geological Survey 1:24,000 topographic maps and soil type from recompiled County Soil Survey maps were manually digitized. These various data layers were all rectified to a Universal Transverse Mercator coordinate system and resampled to a grid cell resolution of 30 m (i.e., the minimum mapping unit was a cell 30×30 m).

A GIS based 'cartographic modeling' analysis was undertaken of the environmental costs or constraints that development posed. In trying to incorporate a suite of critical environmental characteristics and landscape ecological principles in a limited set of variables, we used the following five parameters as input for the assessment: (1) development limitations due to soil conditions/steep slopes/flooding; (2) non-point source pollution potential due to proximity to water/wetlands; (3) habitat fragmentation potential due to distance from existing roads and development; (4) sensitive wildlife habitat areas; and, (5) visibility from the Appalachian and Sterling Ridge Trails. The environmental cost/development constraints for each parameter (at every grid-cell) were classified and ranked into 5 categories: (1) Very slight; (2) Slight; (3) Moderate; (4) Severe; and (5) Very severe. The criteria used to determine the environmental cost/constraint rankings for the 5 various input parameters are outlined below.

2.1.1. Limitations to development due to soils and terrain

Soil and terrain conditions represent a well-recognized constraint to development due to both on- and off-site impacts. Based on the Orange County Soils Survey (Soil Conservation Service, 1981) and recommendations therein, the soil types were grouped into suitability for urban/residential development with respect to engineering limitations to development and to potential environmental impact due to increased runoff, erosion and associated non-point source (NPS) pollution. The SCS development suitability rating takes into account: steepness of slope, soil permeability/drainage/stability, depth to bedrock, stoniness, droughtiness, and frequency of flooding. This grouping was done assuming that any development would be serviced by sewers and not in-place septic systems. By SCS standards less than 1% of the Sterling Forest is considered suited or well suited for development (Table 1) (Fig. 2(a)).

2.1.2. Non-point source pollution potential

Commercial and residential development have a number of well-documented impacts on water quality and adjacent aquatic ecosystems (Novotny and Chesters, 1981). Due to Sterling Forest's importance as watershed for 4.5 million New Jersey residents, the impact of the proposed development on downstream water quality was a critical factor for consideration. Furthermore, many of Sterling Forest's lake, river and wetland habitats are in comparatively pristine conditions, and as such are of regionally important conservation value. We employed a simple spatial distance or buffer model approach to account for the potential transport of impacts off-site to adjacent wetland and aquatic ecosystems. We reasoned that there is an inverse relationship between distance to a wetland/water body and potential impact on water quality. In other words, the closer a development is to a water body/wetland (i.e., the narrower the buffer), the higher the impacts due to erosion, increased runoff and associated non-point source (NPS) pollution of surface runoff and groundwater flow. However, the translation of this general principle into an appropriate buffer weighting scheme (e.g., the expected impact of development with specific buffer distance) is highly problematic (Muscutt et al., 1993; Zampella et al., 1994). Further, depending on their design and implementation, storm water management systems can either enhance the role of riparian buffers or greatly negate their effectiveness by short-circuiting the natural flow of storm runoff. The site-specific field studies coupled with appropriate hydrological modeling needed to more conclusively define appropriate buffer zones was beyond the scope of this study.

Based on 1:24,000 USGS digital hydrology and USF and WS NWI digital wetland maps, a buffer distance analysis was undertaken. The NPS pollution potential ratings given to each spatial buffer distance are based on our own subjective interpretation from readings in the relevant scientific literature. By New York state law, development is generally excluded from existing water bodies and mapped wetlands. The resulting buffer analysis (Fig. 2(b)) shows a majority (greater than 50%) of the Sterling Forest property within 150 m of water/wetlands and thus having moderate to very severe NPS pollution potential or completely off-limits to development if mapped as water or wetlands (Table 1).

2.1.3. Habitat fragmentation potential

Human development has the direct impact of removing existing natural habitat as well as fragmenting the habitat that remains into smaller pieces. Paved roads, residential and commercial development often serve as barrier or hazard to wildlife movement and native plant dispersal. Human development also has 'indirect' impact by creating a number of different kinds of intrusions with varying depth of impact into adjacent natural habitat. These intrusions include increased air, water and noise pollution; changes in microclimatic conditions due to higher sunlight and wind levels; increased populations of invasive 'weed' species; and increased frequency of disturbance due to direct contact with humans, human pets and associated 'rural/suburban pest' species. The border area affected by these disturbances is labelled 'edge', as compared to the undisturbed 'interior' habitat (Zipperer, 1993). A number of passerine songbirds such as warblers and vireos, so-called area-sensitive species, depend on large tracts of undisturbed interior habitat to maintain viable populations. Due to the negative impacts on area-sensitive species, the effect of the proposed Sterling Forest development on habitat fragmentation was included in the suitability assessment.

Table 1
Area of Sterling Forest by Environmental Limitation Categories for the 5 input parameters

Soil/terrain limitations to development				
Class #	SCS development suitability	Environmental limitation ranking	Area (ha)	Area (%)
1	Well suited	Very slight	7	<1
2	Suited	Slight	3	<1
3	Less suited	Moderate	3595	50
4	Poorly suited	Severe	2500	34
5	Very poorly suited	Very severe	907	14
6	Water	Not applicable	232	3
Non-point source pollution potential				
Class #	Distance from water & wetlands	Environmental limitation ranking	Area (ha)	Area (%)
1	>200 m	Very slight	2547	35
2	150–200 m	Slight	820	11
3	100–150 m	Moderate	1000	14
4	50–100 m	Severe	1002	14
5	0–50 m	Very severe	1883	26
Habitat fragmentation potential				
Class #	Distance from roads & development	Environmental limitation ranking	Area (ha)	Area (%)
1	0–250 m	Very slight	2200	30
2	250–500 m	Slight	1560	22
3	500–750 m	Moderate	1258	17
4	750–1000 m	Severe	881	12
5	>1000 m	Very severe	1343	19
Visibility from hiking trails				
Class #	Visibility ranking	Environmental limitation ranking	Area (ha)	Area (%)
0	No visibility	No impact	2514	35
1	Very low	Very slight	1719	24
2	Low	Slight	1176	16
3	Moderate	Moderate	481	6
4	High	Severe	344	5
5	Very High	Very severe	1009	14
Sensitive wildlife habitat areas				
Class #	Sensitive Wildlife habitat	Environmental limitation ranking	Area (ha)	Area (%)
1	Unconfirmed habitat	Unknown	5085	70
5	Confirmed habitat	Very severe	2159	30

Based on the land cover type map, a buffer distance analysis was undertaken to incorporate the fragmenting nature of development. Existing roads and development were extracted and then buffered into zones at 250 m intervals. The habitat fragmentation potential ratings are based on our own subjective interpretation of the relevant scientific literature. Development placed on the edges of existing development (e.g., <250 m from an existing edge) will have a lesser impact than development that is placed deep in the

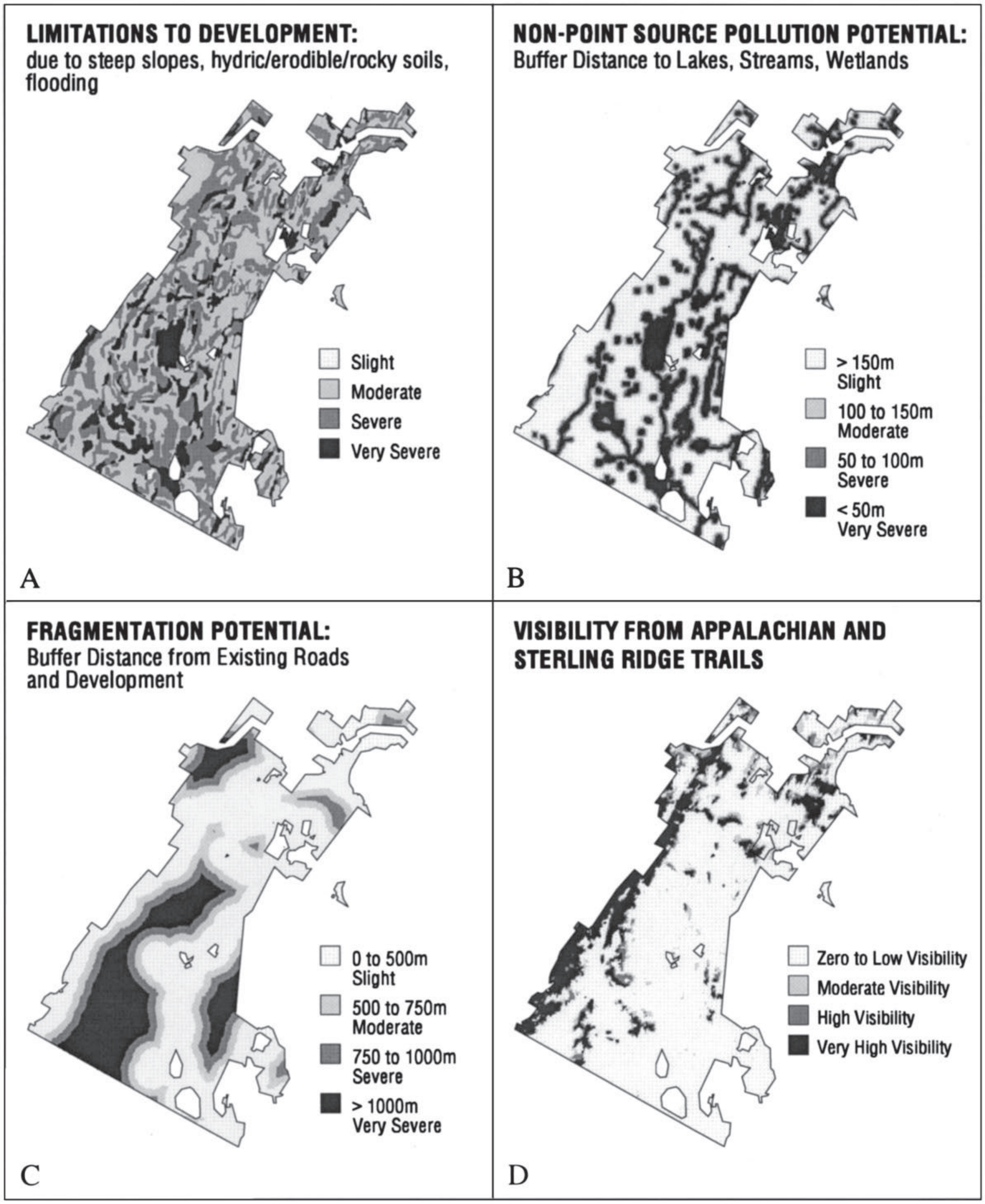

Fig. 2. Map of environmental constraints to development. (a) Limitations to development due to terrain conditions. (b) Non-point source pollution potential. (c) Fragmentation potential. (d) Visibility from hiking trails.

forest interior (e.g., >1000 m from an existing edge). The resulting buffer analysis (Fig. 2(c)) shows nearly 50% of the forest as consisting of 'interior' habitat (>500 m from existing edge) (Table 1).

2.1.4. Aesthetic impact

The forested landscape of the NY–NJ Highlands region is an important aesthetic and recreational resource for the citizens of the New York metropolitan region. The Appalachian Trail, a recreational corridor of national significance, traverses the northern portion of Sterling Forest. There are a number of scenic overlooks from the Appalachian Trail and local off-shoots (e.g., Sterling Ridge Trail) that at present provide unencumbered views of a comparatively undeveloped forested landscape. The potential impact of development on this aesthetic resource was also considered in the analysis.

A digital viewshed map rating the visibility of individual locations from the Appalachian and Sterling Ridge Trails was provided by the Appalachian Trail Conference. This map was created by J. Fels (North Carolina State University) from a 3D intervisibility (line-of-sight) analysis based on the digital elevation model produced from digitized 1:24,000 scale USGS topographic quadrangle maps (Fels, 1992). The visibility from the Appalachian Trail was determined from a series of points spread systematically along the extent of the trail during a leaf-off condition (i.e., screening by intervening vegetation was not considered). Visibility from the Sterling Ridge Trail was determined from several selected viewpoints (e.g., the Sterling Ridge Fire Tower). These two maps were then combined to produce a composite visibility map (Fig. 2(d)). The visibility rating for any particular grid cell was determined by compositing the number of times this cell was visible from the various viewpoints analyzed. This assessment was relatively simplistic, a more sophisticated analysis (e.g., Burrough and DeVeer, 1984) that incorporated the actual location and height of the proposed development and the screening of the development by existing or planted vegetation was not feasible at this stage of project planning. The visibility rating was used as a surrogate for visual aesthetic impact assuming that development in areas of high visibility would create more severe aesthetic impacts by greatly marring the view from these scenic hiking trails. Approximately 25% of the Forest has moderate to very high visibility and thus has potential for aesthetic impacts (Table 1).

2.1.5. Sensitive wildlife habitat areas

In addition to forest interior nesting songbirds, there are a number of other species that are particularly sensitive to human disturbance that presently inhabit Sterling Forest. The DGEIS (LMS, 1995) identifies several 'indicator' species that are also New York State Threatened and Endangered species: the northern cricket frog (Acris crepitans), the timber rattlesnake (Crotalus horridus), and the red-shouldered hawk (Buteo lineatus). Northern cricket frogs are generally limited to relatively undisturbed wetland locations that have suitable upland buffer. Timber rattlesnakes are considered a restricted range species because they rely on communal winter denning sites (hibernacula). During the periods immediately before and after hibernation the snakes congregate around these sites, making them particularly susceptible to human disturbance (Brown, 1993). The red-shouldered hawk is an area-sensitive species that requires large blocks of mature forested wetlands and adjacent upland forest (Galli and Forman, 1976; Robbins et al., 1989). In addition, the Little Cedar Bog wetland complex which includes a low shrub (glacial) bog with a Sphagnum mat and an extensive white cedar swamp was included as sensitive wildlife habitat due to the rarity of these vegetation communities in the NY–NJ Highlands region (Keatinge, 1967; Lynn, 1984).

A map of known habitat areas for these three indicator species was produced based on information supplied by the New York chapter of the Nature Conservancy, however due to the sensitive nature of this data the map must remain confidential. The wetland area and adjacent upland fringe (out to approx. 100 m) that contained known cricket frog populations was mapped as sensitive habitat. All areas within a 1.6 km (1 mile) buffer radius of confirmed timber rattlesnake denning sites were classified as sensitive habitat. The specific wetland areas that contained confirmed nesting sites the red-shouldered hawk were mapped as sensitive habitat. The Little Cedar Bog wetland complex and its upland watershed were mapped as sensitive habitat. The confirmed habitat areas for the three above species and the Little Cedar Bog wetland complex (when combined) represent approximately 30% of the Forest (Table 1).

2.1.6. Composite model of environmental constraints

The five parameters outlined above were combined using overlay analysis to provide a composite picture of the potential environmental costs or constraints posed by/to development. Due to the limited spatial resolution of the underlying data, this analysis was not designed to assess specific site suitability (i.e., for individual building placement) but to provide a general overview of potential sensitivity and conversely, suitability of areas for development. The input maps were overlaid and then composited by taking the maximum value of any of the 5 input parameters for any particular grid cell. While there are several different ways to derive land suitability maps using map overlays (for a review see Hopkins, 1977), we examined two general approaches: (1) a local mean method that averages the scores of these various input data layers; and (2) a local maximum approach that takes the most constraining value and assigns that value to the composite cell (Tomlin, 1990). For example, four of the five parameters may have class values of 2 (i.e., low environmental constraints), if the fifth parameter has a class value of 5, then the composite value for the mean method will be 2.6 (rounded to 3 or moderate) compare to a composite value of 5 (very severe) for the local maximum method. We chose the local maximum approach as this might be considered the most conservative approach with the most constraining parameter taking precedence (i.e., all parameters were weighted equally and any parameter can have 'veto' power).

Fig. 3 graphically displays the mapped results of the composite environmental cost/suitability assessment. Roughly 86% of the property (excluding water) was classified as having severe (1473 ha) or very severe (4080 ha) environmental constraints (Table 2). Only 12.5% of the Property had a moderate (890 ha) or slight/very slight (4 ha) environmental constraints. The overlay analysis shows that a vast majority of Sterling Forest is not suitable for development. As noted above, this analysis was conservative (i.e. from a conservation point of view) and somewhat different results could be obtained using different rules of combination. Regardless, it is clear that the proposed development has the potential to significantly increase non-point source pollution and erosion, increase habitat fragmentation, negatively impact sensitive wildlife habitat and visual aesthetics.

Table 2
Area of Sterling Forest by Composite Environmental Constraint Categories

Composite environmental constraints			
Class #	Environmental constraint	Area (ha)	Area (%)
1	Very slight	1	<1
2	Slight	3	<1
3	Moderate	898	12
4	Severe	1473	20
5	Very severe	4638	64
6	Water	232	3

2.2. Prioritizing land acquisition

The prioritizing of land area for conservation purchase vs. development was based on a number of factors. The results of the environmental suitability assessment (described above) provided an initial starting point to allocate lands to conservation vs. development. A computerized optimal land allocation model was not employed but decisions were made on reasoned judgement. Many of these additional factors have a locational component and could have been potentially included in the environmental suitability assessment (e.g., a weighting given to priority watersheds). This was purposefully not done so as to initially rank all areas equally going into the negotiation process. The general rule was to allocate areas with lower environmental cost/constraints to development and allocate areas with higher environmental cost/constraints to conservation. The initial target to begin negotiations was to identify approximately 1100 ha (approx. 2800 acres) for development, this resulted in a focus on areas classified as having moderate environmental impacts (see Fig. 3), as only a tiny portion of the property was classed as having slight to very slight impacts (Table 2). In then delineating potential development parcels a number of additional factors were taken into consideration:

- maintain a buffer around the Appalachian Trail corridor;
- minimize fragmentation of largest contiguous forest blocks (i.e. the core Sterling Ridge, and adjacent Bill White and Sterling Mountain tracts);

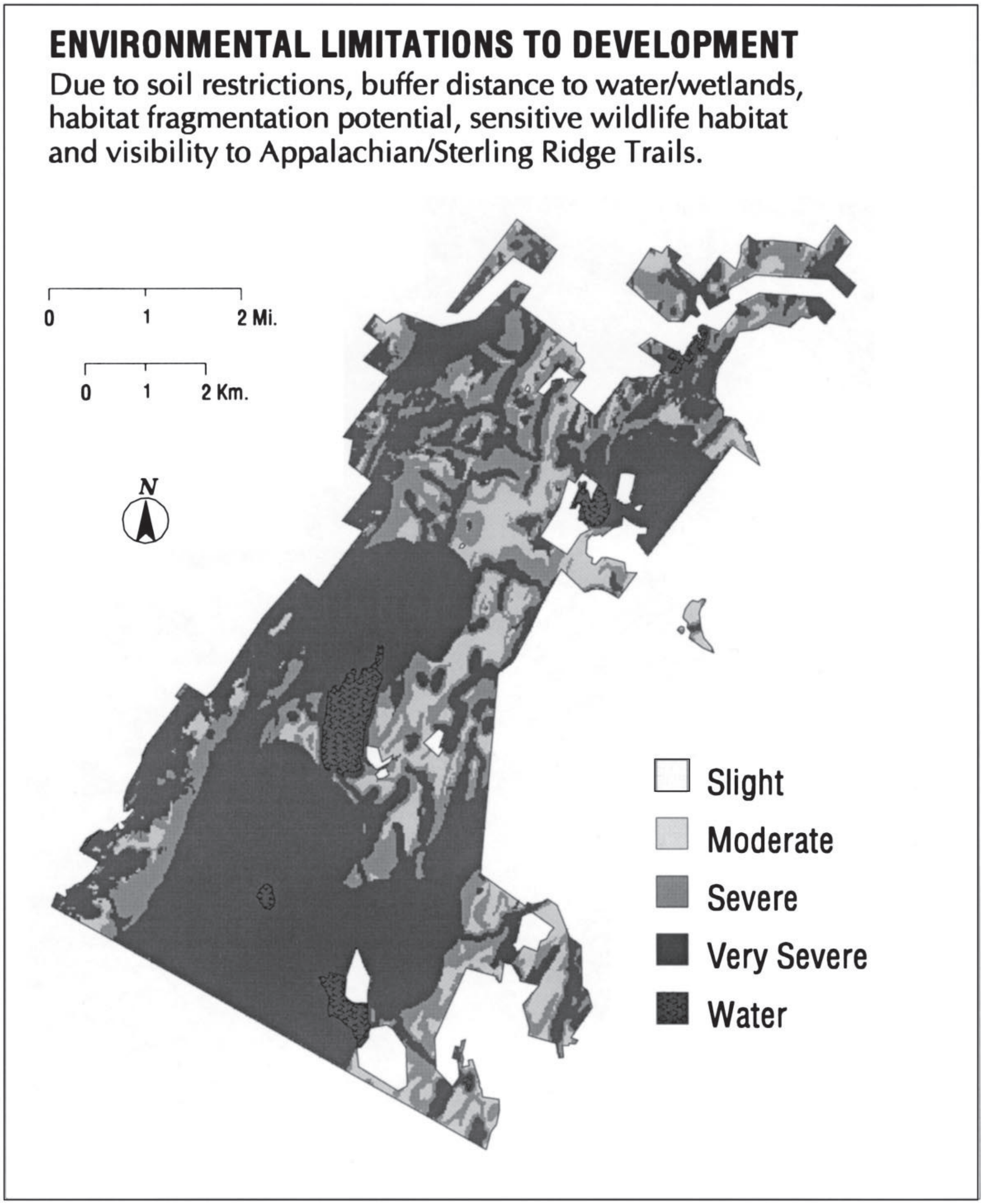

Fig. 3. Map of composite model of environmental constraints.

- minimize development in high priority watersheds (i.e. those watersheds draining directly into New Jersey drinking water reservoirs);
- maintain corridors appropriate for wildlife movement;
- locate development near existing development;
- clump development into contiguous blocks.

The goal of these additional factors was to maintain the essential open space characteristics of the Sterling Forest landscape and minimize the off-site impacts of any development.

The first iteration of this land allocation process is displayed in Fig. 4(a). To reach the target figure of 1100 ha, not all the allocation principles outlined above could be simultaneously satisfied requiring various tradeoffs. Development was allocated to form two primary parcels, one centered around the Routes 17A and 84 corridor (Parcel A, 625 ha) and one located in the southeastern section of Sterling Forest (Parcel B, 510 ha), where there was a large concentration of areas classed with only moderate environmental limitations. This scenario maintains buffer land around the Appalachian Trail and sites development near existing development and road corridors on the eastern boundary of the Property. To limit development in the Appalachian Trail corridor, Parcels A and B were of necessity placed in the Sterling Ridge and Bill White Mountain tracts but located towards the eastern periphery to minimize impacts on the core interior habitat and maintain a wildlife corridor that spans the north–south axis of the property. Maintaining this existing corridor along Sterling Ridge was deemed especially important in linking large forest blocks in New Jersey with the Appalachian Trail Corridor and other forested areas to the north and east in New York state. The primary development parcel, Parcel A, is sited in the Ramapo River watershed which is not considered a high priority watershed, though Parcel B is sited in the Wanaque and Ringwood River watershed which are deemed high priority. In addition, development was excluded from the Sterling Lake watershed, another high priority water body.

2.3. Negotiated compromise plan

TPL and OSI then used the initial land conservation/development scenario outlined above in their negotiations with SFC. After each round of negotiation, the conservation/development plan was modified by us at the Rutgers University Center for Remote Sensing and Spatial Analysis (CRSSA) based on TPL/OSI comments to formulate an alternative scenario to bring back to the table. While the negotiators at TPL/OSI did not have real-time hands-on access to GIS technology, by using CRSSA facilities we were able to provide quick turn-around of GIS-based assessments to meet their needs. In addition to developing alternative land allocation scenarios, this included producing hard-copy reports (e.g., various acreage figures) and maps.

After a protracted series of negotiations spanning many months and numerous iterations of the land allocation exercise, a compromise plan was reached with 6345 ha (15,680 acres) targeted for the conservation buyout leaving 900 ha (2220 acres) for development (Fig. 4(b)). Comparison of Fig. 4(a) and (b) shows that original Parcel B has been eliminated with most of the acreage reallocated to an expanded Parcel A. At the insistence of SFC, two smaller commercially-oriented development parcels (next to existing development within the Ringwood River watershed) were added. This compromise trades off increased development toward the central core of the property with the advantage of shifting most development out of the high priority Ringwood River watershed and without jeopardizing sensitive wildlife habitat. This plan, while no means perfect from a conservation perspective, where feasible concentrates development on the lands with more moderate environmental constraints. The ratio of moderate constraint area to total area is approximately 33% (300 ha/900 ha=33%) for the proposed development area as compared to only 12% for the total SFC property area (890 ha/7245 ha=12%). It is anticipated that the actual siting of development will be on the moderate, and to a lesser extent severe, environmental constraint areas with much of the very severe constraint areas (e.g., steep slopes, wetlands, immediate riparian zones) serving as open space buffer. The compromise plan satisfies most of the initial priorities outlined in the section above, resulting in publicly-protected open space and conservation lands that preserve the essential characteristics of the Sterling Forest landscape while still allowing for significant development.

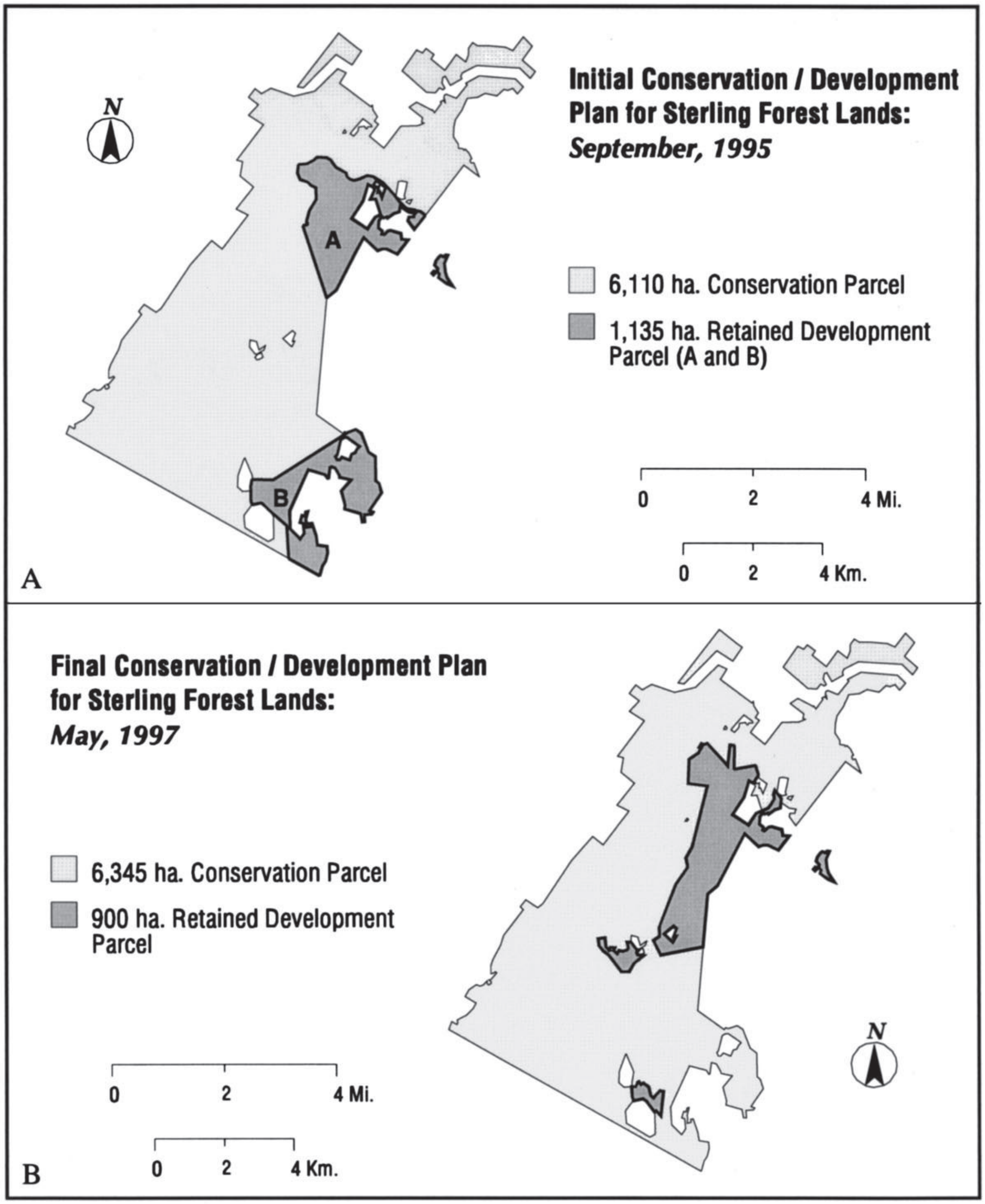

Fig. 4. Sterling Forest conservation purchase plan. (a) Initial conservation/development plan. (b) Final compromise conservation/development plan.

The negotiated settlement was deemed a suitable compromise between conservation and development and received overwhelming support by many of the involved parties including local and national conservation/environmental groups, the local municipal governments and their citizens, the state governments of New York and New Jersey and the U.S. federal government (Fisher, 1996). The funding scheme devised by TPL/OSI to raise the $55 million needed to purchase the 6345 ha for open space conservation includes $17.5 million from the federal government, $16 million from New York, $10 million from New Jersey, $5 million from a private foundation and an additional $6.5 million to be raised from private sources. Once purchased the land will be managed by the Palisades Interstate Parks Commission, a bi-state (NY–NJ) agency already responsible for managing nearby Palisades Interstate and Harriman State Parks.

3. Concluding remarks

It must be noted that the final negotiated settlement was a compromise. As demonstrated in the environmental suitability assessment, the rugged forest-covered landscape of Sterling Forest is not eminently suited for development. While attempting to minimize the overall environmental cost, the proposed development will still entail significant on-site and off-site environmental impacts. The issue comes down to a question of scale; within the 7245 ha of Sterling Forest, the proposed 900 ha are among those best suited for development. However, looking across the larger New York metropolitan region, the proposed development targeted for Sterling Forest could surely be accommodated elsewhere with much lower overall environmental impacts. Consequently, while still supporting the proposed conservation buyout of Sterling Forest, there are a number of people in the conservation/environmental community that would prefer to co-opt any development and purchase the remaining 900 ha if sufficient funding became available.

We believe that the case of the Sterling Forest conservation buy-out plan is a good illustration of Calkins' (1991) model for the effective use of GIS in the public policy arena. Calkins (1991) proposed that the ability to use a GIS effectively to assist in the public policy area requires two conditions to be met: (1) a rational or at least partially rational process for the formulation of the public policies; and (2) the quantification of the significant attributes of the policy. In the Sterling Forest case, many of the significant decision criteria could be quantified and mapped for inclusion in the GIS-based land suitability assessment. The results of the environmental constraints assessment, along with other pertinent information, then provided a rational basis with which to evaluate alternative land allocation scenarios and negotiate the purchase of public conservation lands. Equally important to the effective of use GIS in this case was our ability to meet Calkins' (1991) additional objective of 'presenting as much high quality information to the decision maker as is needed, to be able to describe important relationships within the information, to predict the impacts of selected decisions, and to follow up by evaluating the results of decisions'.

For many years, the utilization of GIS in environmental planning and natural resource management was largely the domain of centralized governmental authorities at the federal and state level (Tomlinson, 1991). With the widespread adoption of GIS technology by various government agencies as well as well-financed development interests, some have expressed concern that the flow of information to the public will be highly controlled and that the activities of citizen 'watch dog' groups in monitoring government or corporate activities will be severely handicapped (Pickles, 1995). However, more recently with decreasing hardware costs, more user-friendly GIS software, and increasing availability of digital spatial data, there has been an increasing spin-off of GIS technology to more local 'grassroots' levels. The Sterling Forest conservation buy-out plan provides a good example of this trend and demonstrates the effective use of GIS technology by the non-profit environmental community (with assistance from the academic community). The ready availability of GIS technology, especially the availability of public domain non-proprietary spatial data, greatly facilitated the two non-profit land trusts, TPL and OSI, in undertaking an independent (i.e., independent of information supplied by SFC) land suitability assessment at comparatively low cost and short time frame. The ready access to timely information and high-quality graphics greatly strengthened the land trusts' position at the negotiating table with their well-financed opponent (R. Harvey, pers. comm.) and contributed to their ultimate success. In this case, GIS technology helped to balance the 'information as power' equation.

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