Case Description

The Pennsylvania Department of Environmental Protection (DEP) is considering establishing a special fund to provide funds to local land conservancies to acquire important resources lands threatened by likely urban development.   Before looking at actual funding amounts, they ask you to assess the threat and opportunity with respect to future development. Your analysis will attempt to address two important and interrelated questions.

1.   What are the areas that may be environmentally 'sensitive' to development but where development may be infringing in the coming years? (Supply-side)

2.   What are the areas that are not environmentally sensitive to development where we would like to encourage development in the coming years? (Demand-side)

Analysis

I. First, we would like to know which areas or grid cells changed from non-urban in 1992 to urban in 2001, using the 1992 and 2001 USGS Urban land cover rasters.

Urban change map (1992 - 2001)

Pennsylvania
Urban-
Transformation
1992 - 2001

1992
Urban Cell Count: 10362

N

2001
Urban Cell Count: 18255

Legend

Non-Urban Area

Urban Area

Changed Area

Conversion
Non-Urban-to-Urban Count:
12418

0   20   40   80   120   160
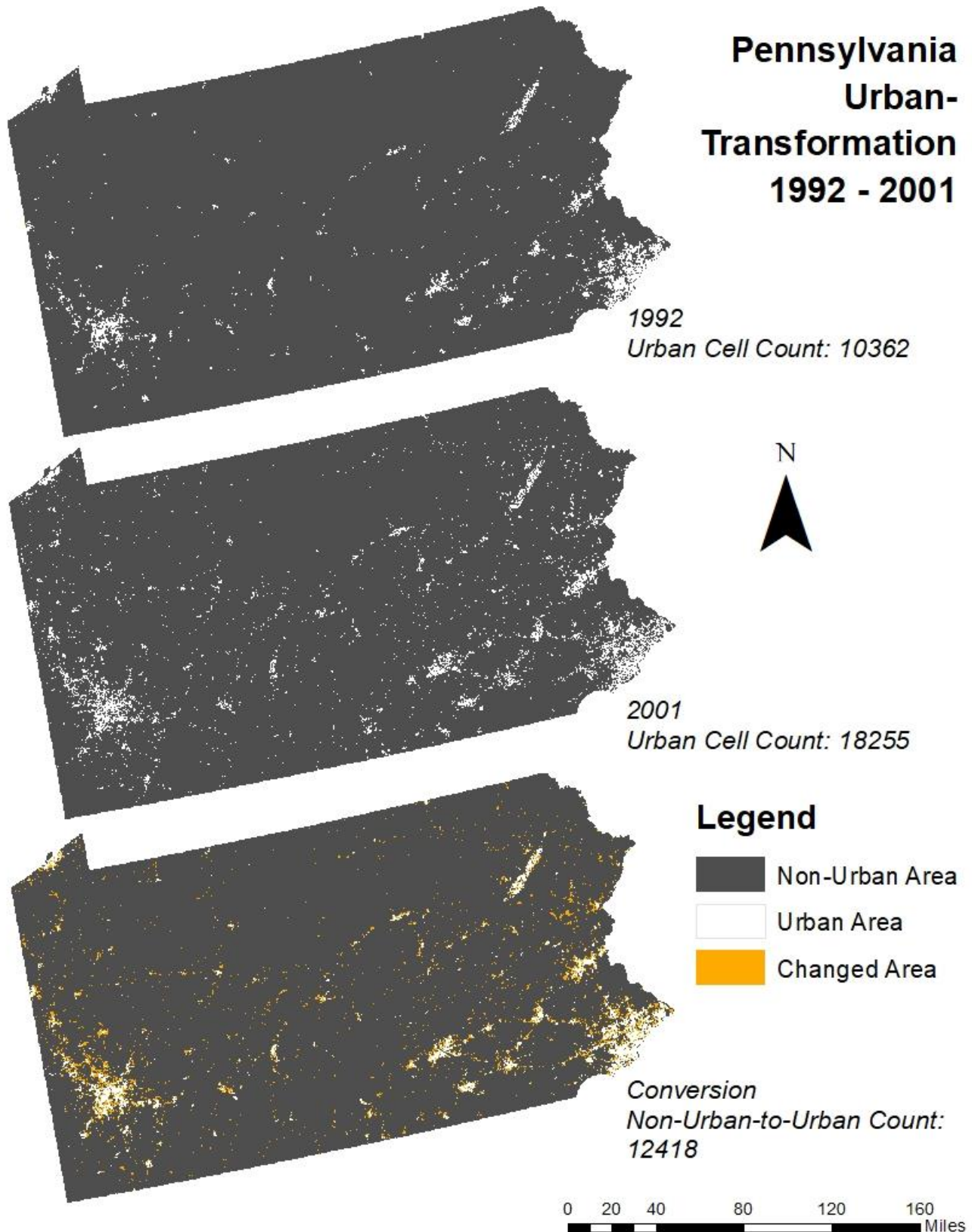   Miles

Fig. 1. 1. The map set describes the urban transformation of Pennsylvania cross 1992 to 2001. The white cells represent the urban area and dark gray cells represent the non-urban area. In the third map, the orange cells represent the cells that change from non-urban to urban between 1992 and 2001. For the cells represent the changed area, the method is using raster calculator to calculate the formula: ("Urban_Landcover_1992" == non-urban cells) & ("Urban_Landcover_2001 == urban cells).

II. Next we'd like to understand which counties have been the most efficient with their urban land conversion with respect to population increase. The table below provides the population change information and comparison.

Table from land conversion and population change

| NAME	COUNT	Pop_Change	Change per resident	NAME	COUNT	Pop_Change	Change per resident
Lackawanna	223	59	3.7797	Bucks	459	38793	0.0118
Delaware	234	697	0.3357	Butler	312	26479	0.0118
Northumberland	99	299	0.3311	Northampton	284	26018	0.0109
McKean	53	353	0.1501	Somerset	86	7903	0.0109
Jefferson	91	918	0.0991	Carbon	117	10812	0.0108
Blair	170	2357	0.0721	Centre	202	19168	0.0105
Mercer	258	4134	0.0624	Cumberland	268	26529	0.0101
Lawrence	217	3585	0.0605	Susquehanna	68	7002	0.0097
Venango	102	1855	0.0550	Berks	340	36913	0.0092
Lebanon	145	2708	0.0535	Wyoming	48	5434	0.0088
Erie	291	5964	0.0488	Monroe	416	50065	0.0083
Fulton	39	933	0.0418	Potter	13	1698	0.0077
Tioga	68	1661	0.0409	Lancaster	398	52055	0.0076
Crawford	194	4786	0.0405	Union	64	8583	0.0075
Fayette	168	4490	0.0374	Montour	27	4257	0.0063
Schuylkill	122	3280	0.0372	Chester	333	53626	0.0062
Dauphin	324	8754	0.0370	Juniata	24	4797	0.0050
Perry	57	1743	0.0327	Huntingdon	44	9090	0.0048
Bedford	66	2264	0.0292	York	256	58042	0.0044
Greene	55	1902	0.0289	Pike	130	30740	0.0042
Montgomery	713	24762	0.0288	Wayne	79	20068	0.0039
Mifflin	59	2307	0.0256	Adams	79	23189	0.0034
Armstrong	99	4132	0.0240	Sullivan	11	4180	0.0026
Franklin	213	10485	0.0203	Forest	13	5016	0.0026
Elk	40	2086	0.0192	Cameron	3	7270	0.0004
Lycoming	188	11148	0.0169	Philadelphia	209	-68940	0.0030
Clinton	65	3883	0.0167	Cambria	185	-12183	0.0152
Clearfield	191	11549	0.0165	Allegheny	1250	-55123	0.0227
Columbia	103	6574	0.0157	Washington	279	-10436	0.0267
Snyder	63	4215	0.0149	Luzerne	296	-9359	0.0316
Bradford	90	6691	0.0135	Beaver	333	-5504	0.0605
Lehigh	350	27850	0.0126	Westmoreland	403	-4974	0.0810
Warren	63	5256	0.0120	Clarion	76	-390	0.1949
				Indiana	88	-111	0.7928

Table 1. The table describes the amount of urban land conversion by county in Pennsylvania state. The county names in red means those counties experienced negative population growth in this period. The table is sorted by the conversion rate per residents.

Based on the table, Cameron County has the most efficient land conversion rate, and the most inefficient conversion rate is in the Indiana county. The statistic assigns the urban conversion area to each resident, so that it reflects whether the urban conversion attract more new residents. For the most efficient county, a small amount of urban conversion still attracts a large amount of population, so each urban cell eventually contains the densest population. In contrast, at the most inefficient state, urbanization does not increase population, and the population per cell keeps decreasing. This ratio is important, because it helps to determine whether it worth to urbanize this county and find out the most attractive county to invest more money on urbanization.

III. To make better decision, it will use a series of raster layers (water, farm, pasture & forest) to derive a new map or grid of 'sensitive' land areas in Pennsylvania.

Sensitive land map

Pennsylvania Sensitive Land Area (1992)

Legend

- Non-Sensitive Land
- Sensitive Land
- County Boundaries
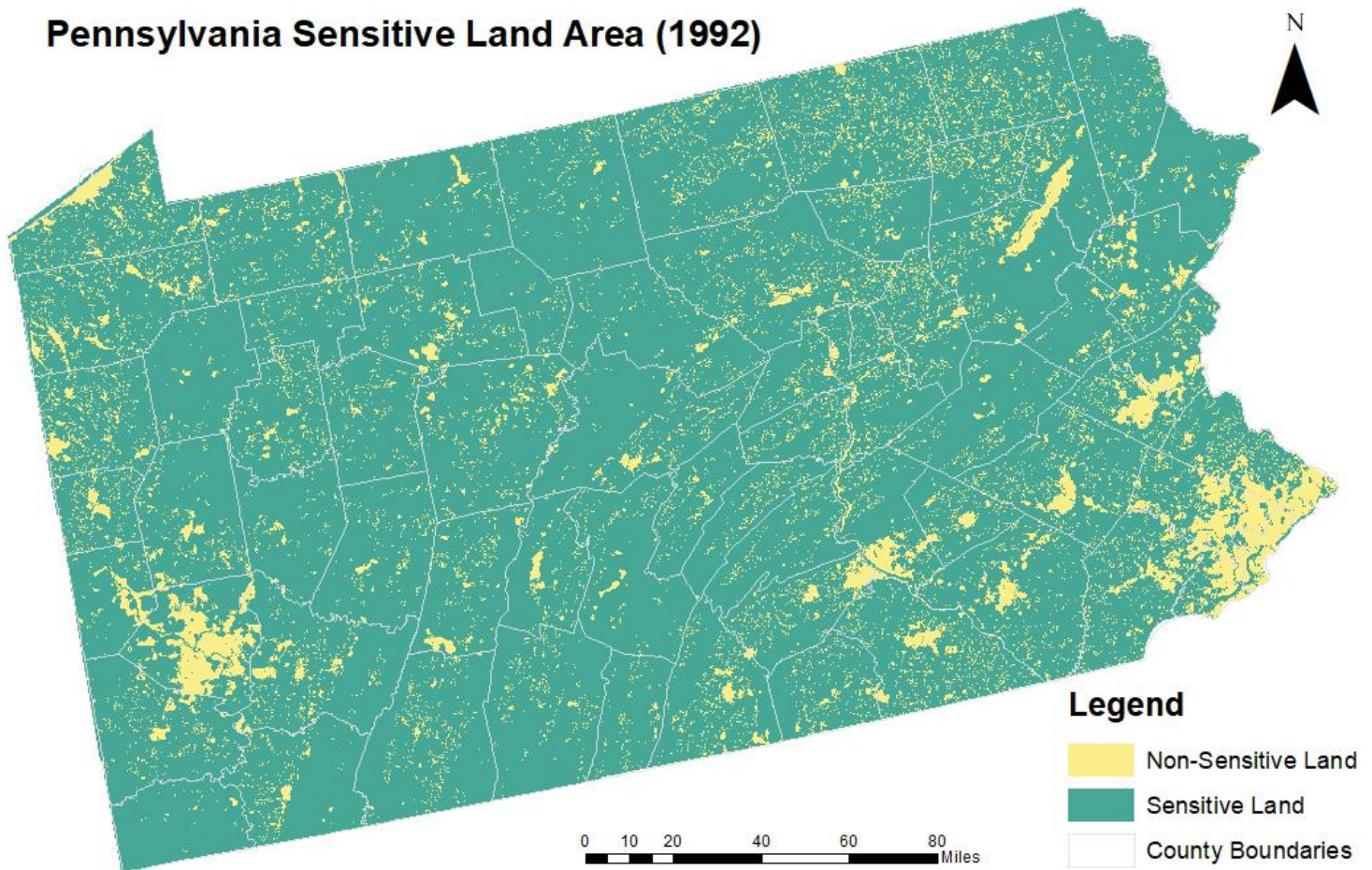
Environmental Sensitive Land in Each County (1992)

NAME	COUNT	AREA	NAME	COUNT	AREA	NAME	COUNT	AREA
Erie	5949	1487234120	Columbia	3887	971739624.4	Westmoreland	8523	2130727250
Bradford	9263	2315725274	Clearfield	9720	2429974054	Berks	6760	1689981956
Tioga	9535	2383724548	Centre	9525	2381224575	Allegheny	4104	1025989045
Potter	9533	2383224554	Monroe	4872	1217986995	Dauphin	4146	1036488933
McKean	8560	2139977151	Northumberland	3862	965489691.2	Perry	4831	1207737105
Warren	7443	1860730132	Butler	6636	1658982287	Bucks	3788	946989888.7
Wayne	6412	1602982884	Montour	1067	266747151.9	Lebanon	2901	725242256.4
Susquehanna	6726	1681482046	Armstrong	5864	1465984347	Washington	7210	1802480754
Crawford	8124	2030978315	Union	2668	666992878.3	Montgomery	2393	598243612.4
Wyoming	3215	803741418.2	Carbon	3315	828741151.3	Cumberland	4139	1034738952
Lackawanna	3566	891490481.3	Lawrence	2816	703992483.2	Bedford	8926	2231476174
Elk	6931	1732731499	Northampton	2709	677242768.9	Lancaster	7905	1976228899
Forest	3742	935490011.5	Schuylkill	6798	1699481854	Franklin	6259	1564733293
Venango	6085	1521233757	Indiana	7303	1825730506	Somerset	9405	2351224895
Cameron	3538	884490556	Snyder	2698	674492798.2	Chester	5659	1414734894
Pike	4889	1222236950	Beaver	3532	882990572	York	7020	1754981261
Lycoming	10261	2565222610	Mifflin	3577	894240451.9	Fulton	3818	954489808.6
Sullivan	3795	948739870	Lehigh	2256	563993978.1	Fayette	6877	1719231643
Mercer	5301	1325235850	Huntingdon	7828	1956979105	Philadelphia	286	71499236.58
Clinton	7863	1965729011	Blair	4464	1115988084	Adams	4333	1083238434
Clarion	5055	1263736507	Cambria	5814	1453484481	Delaware	870	217497677.7
Luzerne	7266	1816480605	Juniata	3391	847740948.4	Greene	5200	1299986120
Jefferson	5655	1413734905						

Fig. 2 & Table 2. The map demonstrates environmental sensitive land of counties in Pennsylvania. The sensitive land incudes land cover types of water, farm, pasture and forest. The table summarizes the count of sensitive cells and the total area of sensitive land in each county.

IV. Then, summarize the amount of sensitive lands by county in 1992.
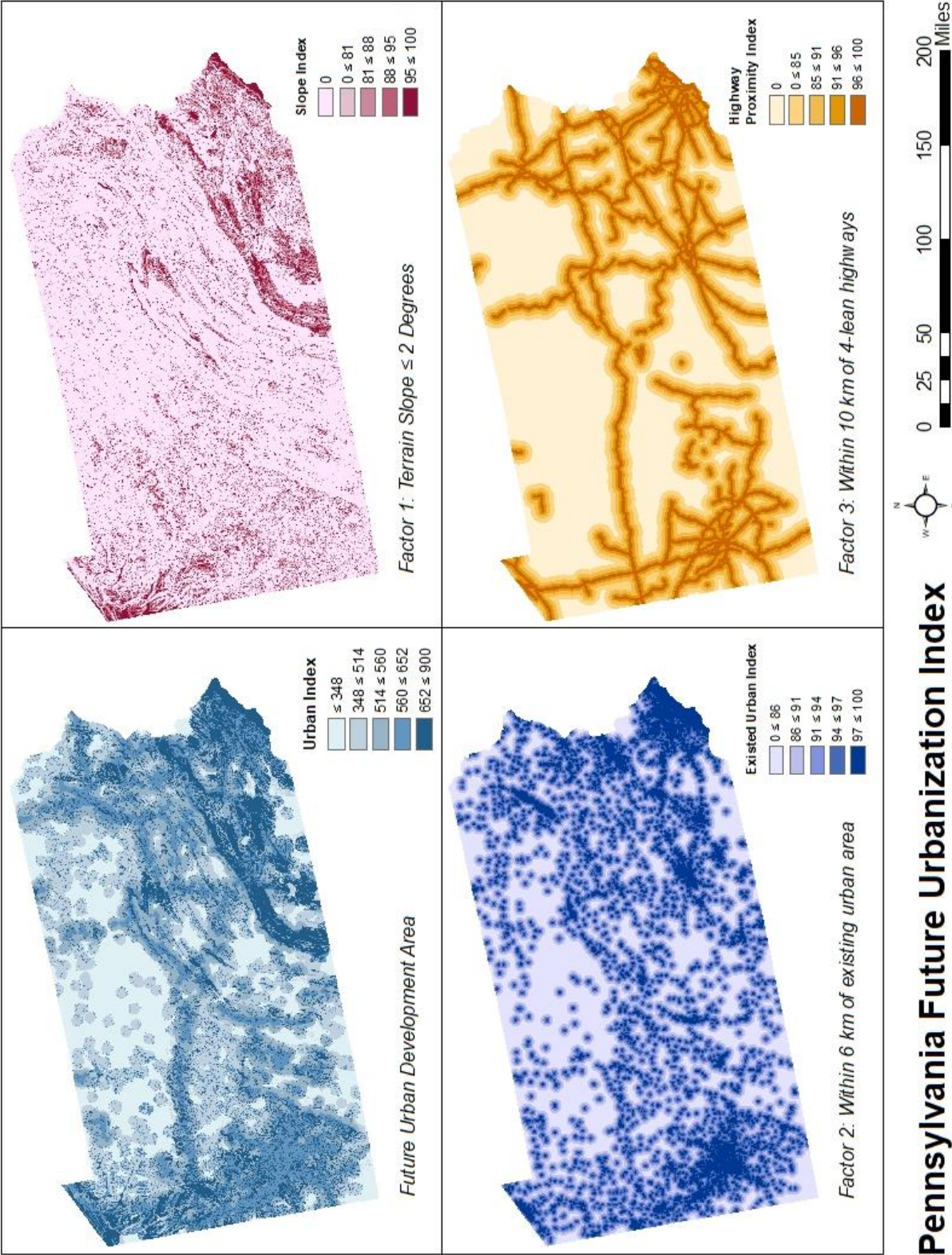
Table for developed sensitive land

NAME	COUNT	NAME	COUNT
Allegheny	286	Jefferson	62
Westmoreland	173	Carbon	61
Lancaster	149	Lebanon	59
Monroe	142	Lycoming	58
Washington	134	Bradford	57
Montgomery	131	Armstrong	56
Butler	125	Bedford	52
Clearfield	123	Wayne	51
Beaver	118	Indiana	51
Berks	113	Perry	50
Lawrence	101	Tioga	46
Centre	99	Clarion	46
Luzerne	97	Columbia	46
Dauphin	95	Warren	44
Mercer	94	Northumberland	41
Bucks	93	Philadelphia	41
Chester	93	Susquehanna	37
Erie	92	Huntingdon	37
York	91	Clinton	36
Crawford	90	Snyder	35
Schuylkill	90	Greene	35
Fayette	88	McKean	34
Cambria	87	Mifflin	33
Blair	81	Adams	32
Delaware	81	Fulton	28
Lehigh	75	Union	27
Cumberland	72	Wyoming	23
Franklin	71	Elk	23
Somerset	67	Montour	18
Northampton	65	Juniata	15
Lackawanna	63	Potter	12
Venango	62	Sullivan	9
Pike	62	Forest	8
		Cameron	3

Table 3. The table include all environmental sensitive cell that has been urbanized in the 9-year period between 1992 to 2001. The counties in red contain the largest number of threatened sensitive land. In contrast, the counties in green experience the least threatening.

v. Based on the 2001 urban land use, it will use the *urban index* to decide which areas are likely to be urbanized going forward and then which areas are worth preserving.

Prior research has identified that urbanization tends to favor undeveloped sites that are (i) within 6 kilometers of existing urban development in 2001; (ii) sites having slopes of less than 2 degrees grade; and (iii) sites within 10 kilometers of 4-lane highways.

Future urbanization index

Factor 1: Terrain Slope ≤ 2 Degrees

Factor 3: Within 10 km of 4-lean highways

Future Urban Development Area

Factor 2: Within 6 km of existing urban area

Pennsylvania Future Urbanization Index

Fig. 3. The map set for future urbanization area of Pennsylvania. To determine the most appropriate undeveloped site, the study trends to favor sites that are within 6 kilometers of 2001 existing urban area, having slops less than 2 degrees grade, and within 10 kilometers of 4-lane highway. The three maps demonstrate the sites that fulfill each factor. Then, by weighting all possible sites (urban area: 4 points; slope: 3 points; road proximity: 2 points), all area is scored and mapped. In the future urbanization area map, higher score represents the site is more appropriate to receive new urbanization.

Decisive Factors for Environmental Sensitive Area

N

0   25   50   100 Miles

Land Use

Farm & Forest Land Use
Other Land Use

Factor 1: Acrive farm & forest land use

Riverside Area

River & Distance to River ≤ 1 km
Distance to River > 1 km

(White blank cells are developed area)

Factor 2: Undeveloped land within 1 km of rivers

Terrain Slope Index

0
0 ≤ 97
97 ≤ 98
98 ≤ 99
99 ≤ 100

(Higher Index = Sharper Slope)

Factor 3: Terrain slope is more than 15 degrees
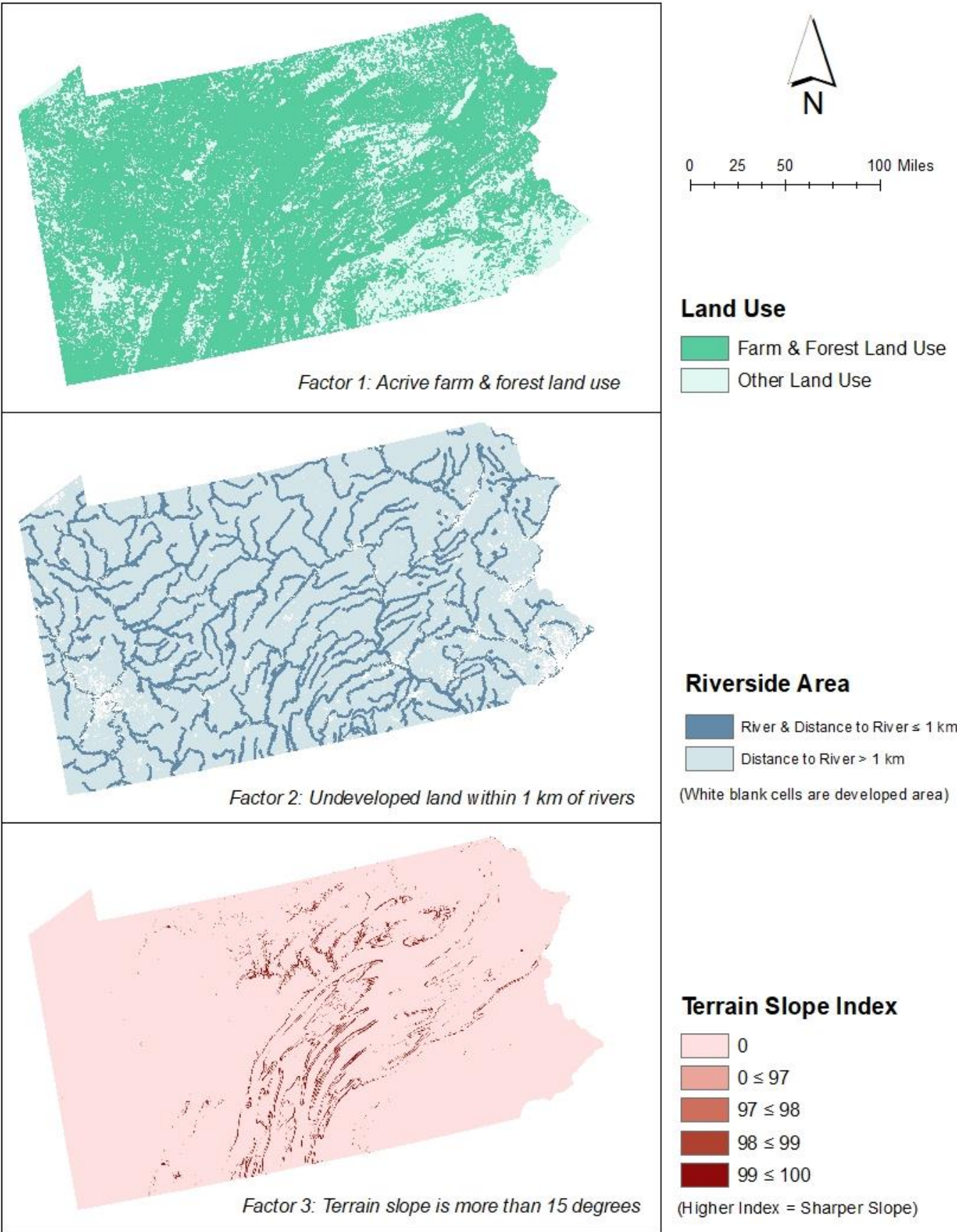
Fig. 4. The decisive factors for choosing the preserved environmental area from new urbanization includes the original farm and forest land use, high river proximity and high terrain slope. The map set describe the appropriate cells for each factor in Pennsylvania. By comparing the urban transformation pattern of 1992 and 2001, the map #1 picks the active farm and forest land use cells in 2001. Those cells are farm or forest land uses in 1992, and in 2001 they are still non-urban area. For factor 2, the map draw river and the 1 km area around river. The third map is about the terrain slope. The slope is classified into 100 quantile ranges and then the steeper area was picked and assign score. Eventually, the highest score represents the steepest slope.

Environmental sensitivity index
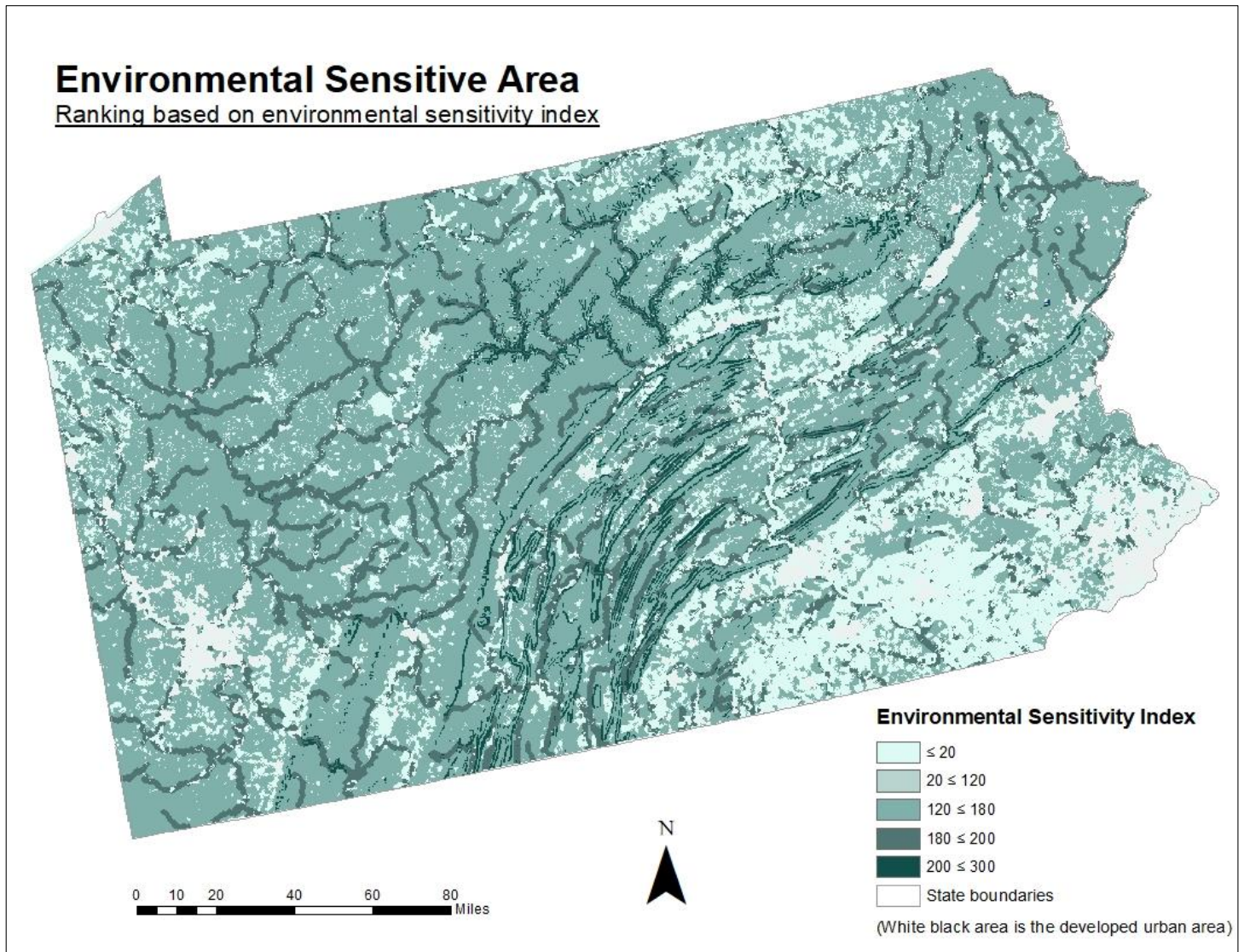
Fig 5. The environmental sensitivity index assigns each cell a score to show whether it is the most environmental sensitive area and needs to be protected from new urbanization. Each factor from the Fig. 4 are weighted to for the final index: the weight of slope is 1, the weight of river and 1-km area along the river is 20, and the weight of active farm & forest land use is 180. Due to the previous method on classification, the highest original weight of slope factor is 100. Thus, to balance the weights of two binary factors, riverside area and active farm & forest land use have higher weights than slope does. In terms of weight, it believes that the very steep area is not a good choice for urban constructions. The original farm & forest land use should be protected, since it would take a

long time to form a forest, and the needs to ensure the area of cultivated land. 180 is able to ensure the highly sensitive level for farm and forest use, because it balances the possible bias from the highly sensitive index from the overlapped part between farm & forest and river. The riverside area weight 20 because of the certain needs from water transportation and tourism. Eventually, the highest index 300 represent the most environmental sensitive area, and they should be protected from urban conversion.
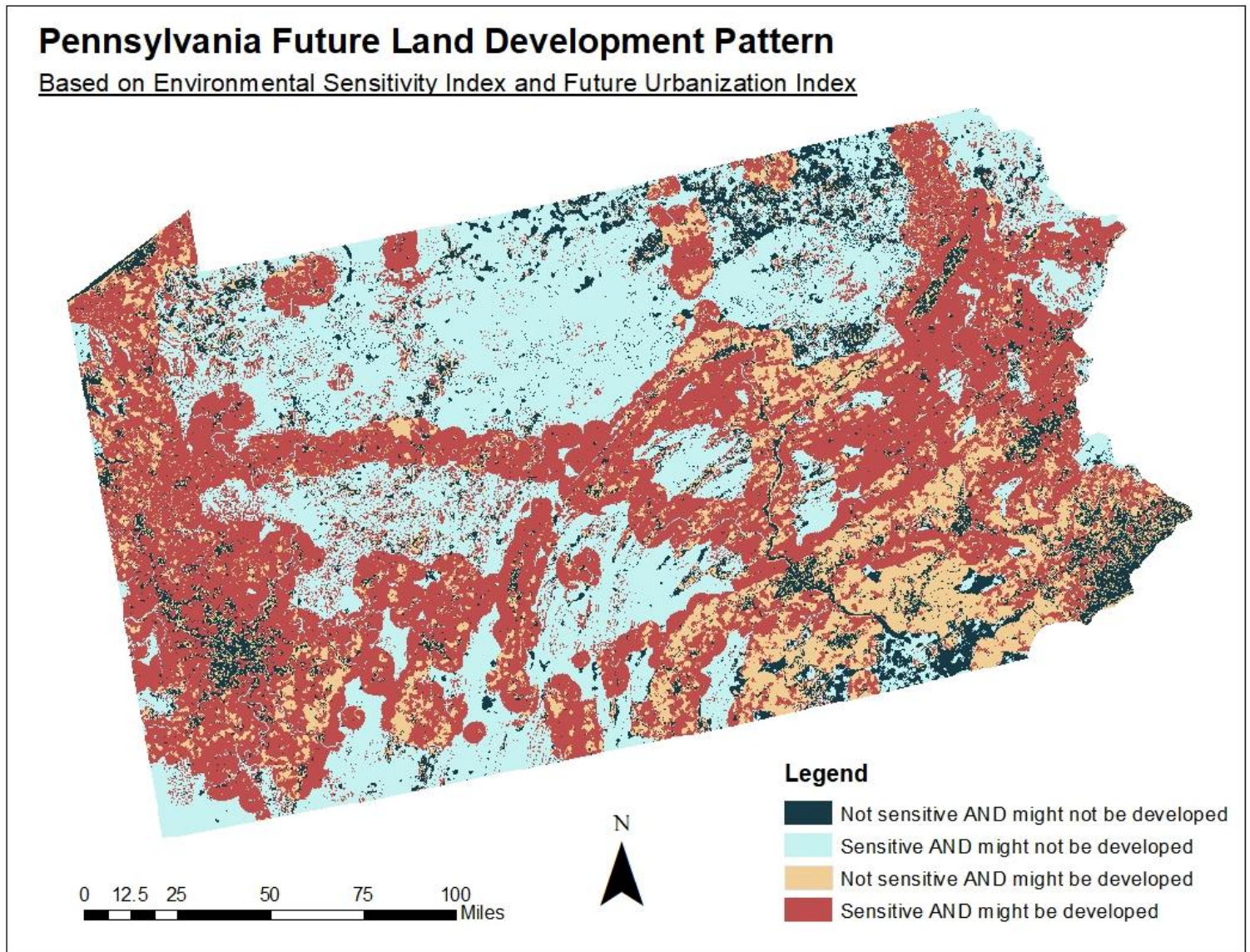
Map with four categories

Fig. 6. The map is the result for the combination of environmental sensitivity index ad future urbanization index. As the legend describes, each cell is assigned an index and classified to one of the categories. The red area (environmental sensitive and might be developed) are the key part for future urbanization. Those sites have great environmental conditions and also close to human activities, so it is crucial to keep the balance of environmental preservation and urban construction at those sites.

After comparing all factors, it found that areas that are not environmental sensitive AND might be developed & Areas that are environmental sensitive AND might be developed
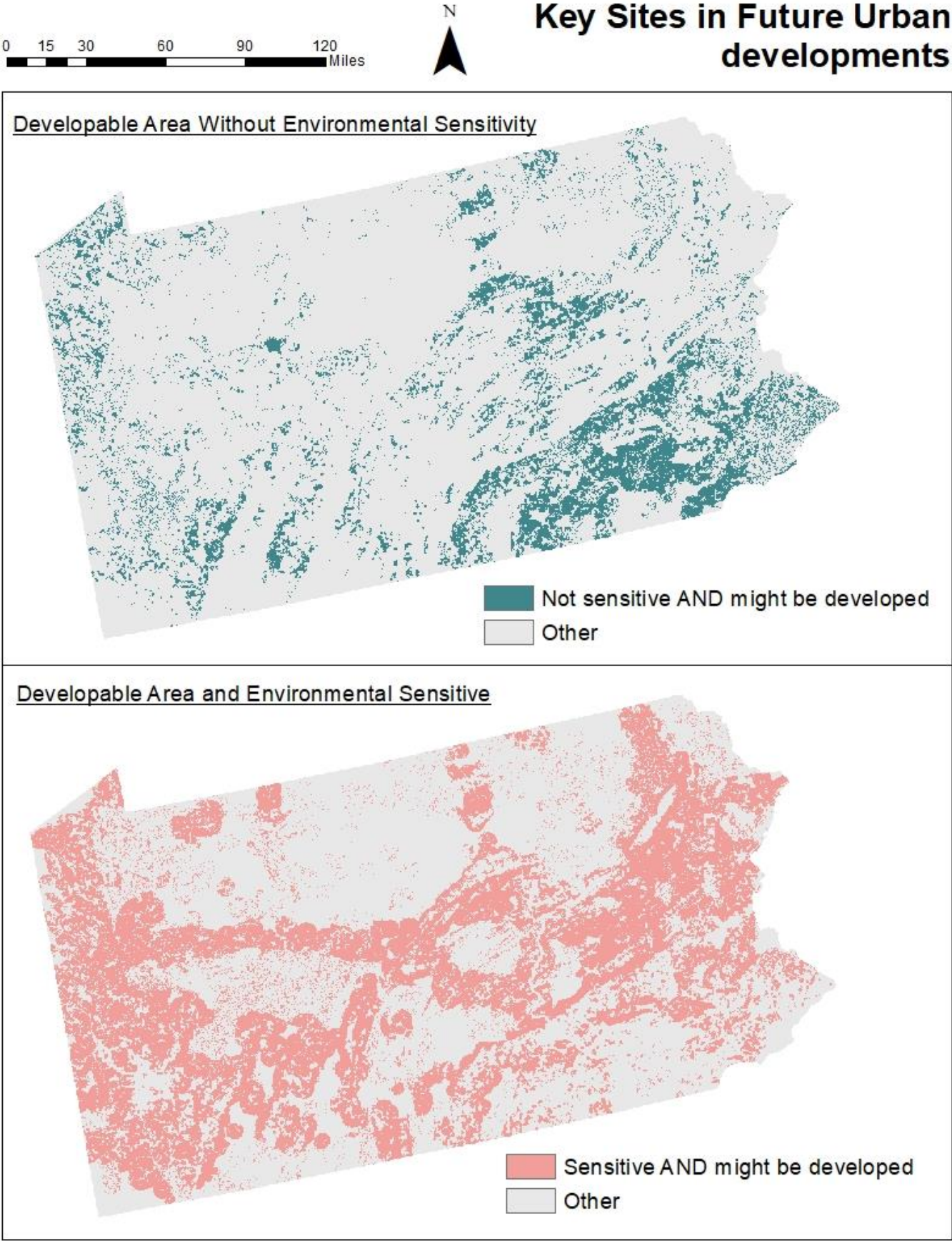
Fig. 7. The map set include two key factors for the future urbanization in Pennsylvania: Non environmental sensitive & developable area, and environmental sensitive & developable area. The first kinds of site would be the main focus on future urban planning, and the second kind of site should be noticed, and find out the way to balance environmental protection and developments.

Comments on Philadelphia county

Philadelphia county is one the of most developed areas in Pennsylvania. It has already become the metropolitan area in 2001, so in the "Pennsylvania future land development pattern", most area in Philadelphia county is classified as "Not sensitive and might not be developed". However, there are still a small number of cells have potentials for new developments, and only a few cells at the northwestern Philadelphia are environmental sensitive. Thus, Philadelphia county has received relatively mature developments, and for the future planning, it has low developed potential and there is less conflict between environmental protection and developments.