RAN XIN

[Urban Growth VS. Development Suitability]

INFORMATION

1. I reprojected all shapefiles and raster grids as the very first step for the assignment, and there is a change in cell size:

- Original cell size: 499.9973 meters
- Cell size after reprojection: 1640. 4079 feet (which I was using for calculation in this assignment)

2. Most of the base maps are clipped via PA county, and I also use PA county shapefile as the outline for each map.

3. To calculate areas, I chose "acre" as the unit. 1 acre = 43560 square feet

4. 1 km = 3280 ft, 6 km = 19685 ft, 10 km = 32808 ft

5. I assume "urbanized" is the same as "developed" in meanings, at least in the context of this assignment. So "undeveloped" is also the same as "non-urbanized".

COORDINATE SYSTEM OF MAPS

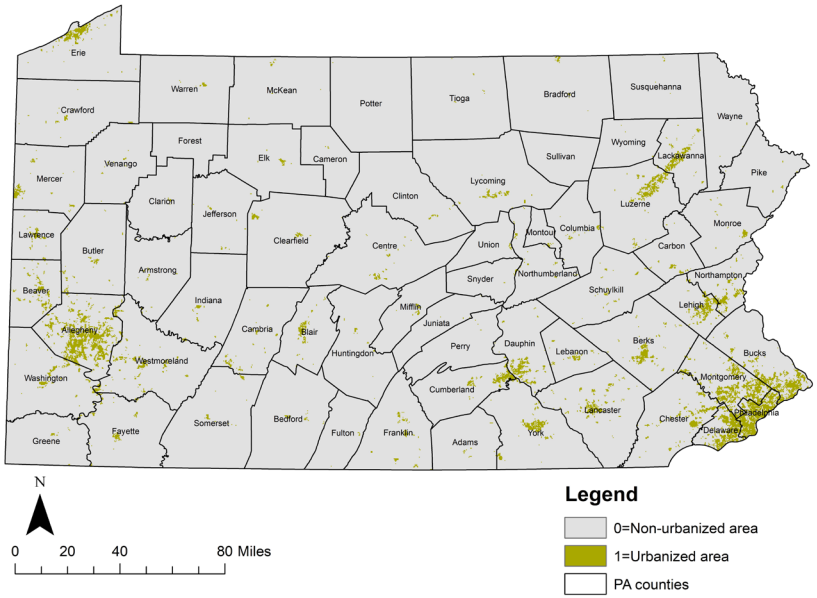
- Projected coordinate system: NAD_1983_StatePlane_Pennsylvania_South_FIPS_3702_Feet
- Geographic coordinate system: GCS_North_American_1983
- Linear unit: Foot_US

COVER PHOTOGRAPH

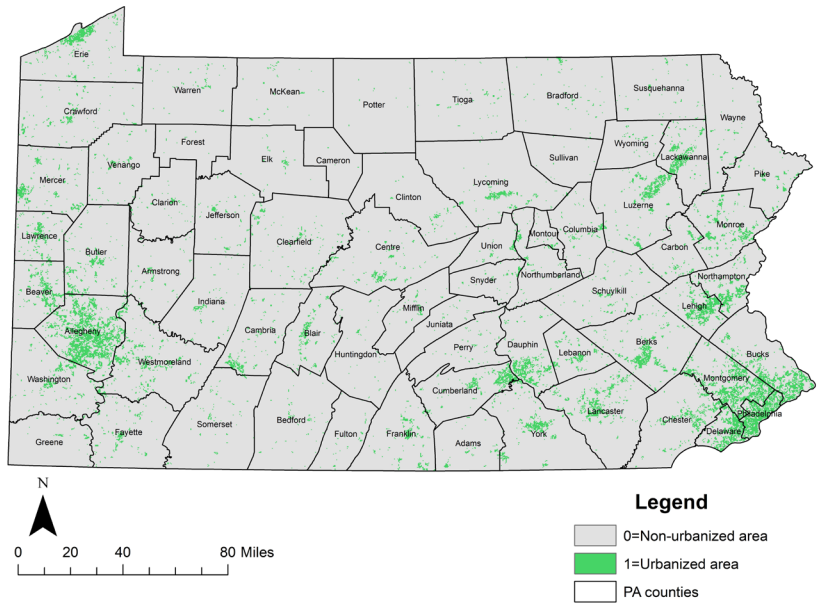
https://pixels.com/featured/center-city-philadelphia-eric-bowers-photo.html

1. URBAN GROWTH OF PENNSYLVANIA 1992-2001

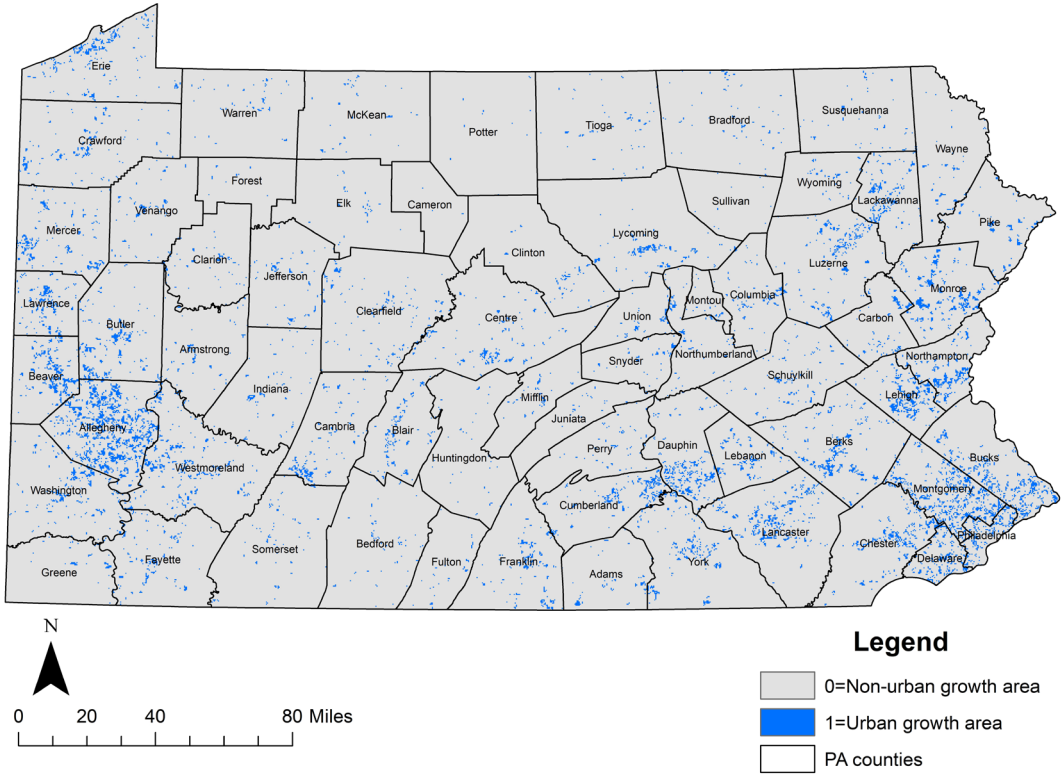
Urban location 1992



Urban location 2001



Urban growth location 1992-2001



According to current map projection and size, the number of grid cells that were newly converted to urban in 2001 is **14,060**.

From the maps, **Philadelphia** and **Allegheny** had already been highly urbanized since 1992 in the state. And from the urban growth locations, we could see that areas that are close to those existing urban areas tend to become urbanized as time goes by; the urban growth locations clusters around Philadelphia and Allegheny especially. There are also a considerable number of locations urbanized in the central area of the state.

2. URBAN LAND 1992-2001 & POPULATION CHANGE 1990-2000

County	Population change	Net urban land growth (acres)	Ratio of land conversion to population growth (acres/person)
Erie	5964	13035	2.19
Bradford	6691	4880	0.73
Tioga	1661	4201	2.53
Potter	1698	865	0.51
McKean	353	2718	7.70
Warren	5256	3459	0.66
Wayne	20068	5066	0.25
Susquehanna	7002	4448	0.64
Crawford	4786	11676	2.44
Wyoming	5434	3336	0.61
Lackawanna	59	8278	**140.30**
Elk	2086	1544	0.74
Forest	5016	927	0.18
Venango	1855	5745	3.10
Cameron	7270	0	**0.00**
Pike	30740	8401	0.27
Lycoming	11148	10069	0.90
Sullivan	4180	741	0.18
Mercer	4134	14394	3.48
Clinton	3883	3645	0.94
Clarion	-390	4942	-12.67
Luzerne	-9359	9081	-0.97
Jefferson	918	5498	5.99
Columbia	6574	5992	0.91
Clearfield	11549	10193	0.88
Centre	19168	12170	0.63
Monroe	50065	27058	0.54
Northumberland	299	5436	18.18
Butler	26479	18409	0.70
Montour	4257	1668	0.39
Armstrong	4132	4942	1.20
Union	8583	3892	0.45
Carbon	10812	5683	0.53

County	Population change	Net urban land growth (acres)	Ratio of land conversion to population growth (acres/person)
Lawrence	3585	11367	3.17
Northampton	26018	13035	0.50
Schuylkill	3280	5560	1.70
Indiana	-111	4324	-38.96
Snyder	4215	4324	1.03
Beaver	-5504	13405	-2.44
Mifflin	2307	2903	1.26
Lehigh	27850	18100	0.65
Huntingdon	9090	1853	0.20
Blair	2357	6734	2.86
Cambria	-12183	9884	-0.81
Juniata	4797	1668	0.35
Westmoreland	-4974	17668	-3.55
Berks	36913	18224	0.49
Allegheny	-55123	46702	-0.85
Dauphin	8754	14826	1.69
Perry	1743	3583	2.06
Bucks	38793	12355	0.32
Lebanon	2708	8710	3.22
Washington	-10436	9328	-0.89
Montgomery	24762	22795	0.92
Cumberland	26529	13838	0.52
Bedford	2264	3151	1.39
Lancaster	52055	19645	0.38
Franklin	10485	11490	1.10
Somerset	7903	3707	0.47
Chester	53626	9205	0.17
York	58042	9019	0.16
Fulton	933	2471	2.65
Fayette	4490	7166	1.60
Philadelphia	-68940	-2903	0.04
Adams	23189	4386	0.19
Delaware	697	-927	-1.33
Greene	1902	2780	1.46

County: lost population between 1990 and 2000

County: urban land conversion most EFFICIENT

County: urban land conversion most INEFFICIENT

2. URBAN LAND 1992-2001 & POPULATION CHANGE 1990-2000

Urban land change doesn't only refer to how much land is converted to urban areas, because I also noticed that there is a bunch of cell grids were converted from urban to non-urban areas (i.e. "**Disurbanize**"). Hence, to calculate the urban land conversion, I would like to use "**net urban growth**": **number of net urban growth cells = number of urbanized cells - number of disurbanized cells**. Therefore, **ratio of land conversion to population growth = net urban growth acres / population change**.

THE MOST EFFICIENT & INEFFICIENT COUNTIES FOR URBAN LAND CONVERSION

The most efficient county for urban land conversion is defined as: **the least population change leads to the greatest urban land conversion**. The greatest urban land conversion can either be urban land increase or decrease, so we are now looking at the net urban growth acres. For example, one person increase/decrease in population leads to a certain amount of land conversion increase/decrease. To determine which county is the most efficient and inefficient, we need to find out **the largest and the smallest ABSOLUTE VALUE of the ratio**. The ratio is very meaningful and important, because it can measure the degree of population growth for land conversion or even urbanization which people can make prediction by referring to this ratio.

By following such logic, **the most efficient county is Lackawanna** (one person increase will lead to 140.3 acres addition to urban growth), **the least efficient county is Cameron** (population increase brings no net urban land growth).

	COUNTY	RATIO OF LAND CONVERSION TO POPULATION GROWTH
MOST EFFICIENT COUNTY	Lackawanna	140.3
MOST INEFFICIENT COUNTY	Cameron	0.0

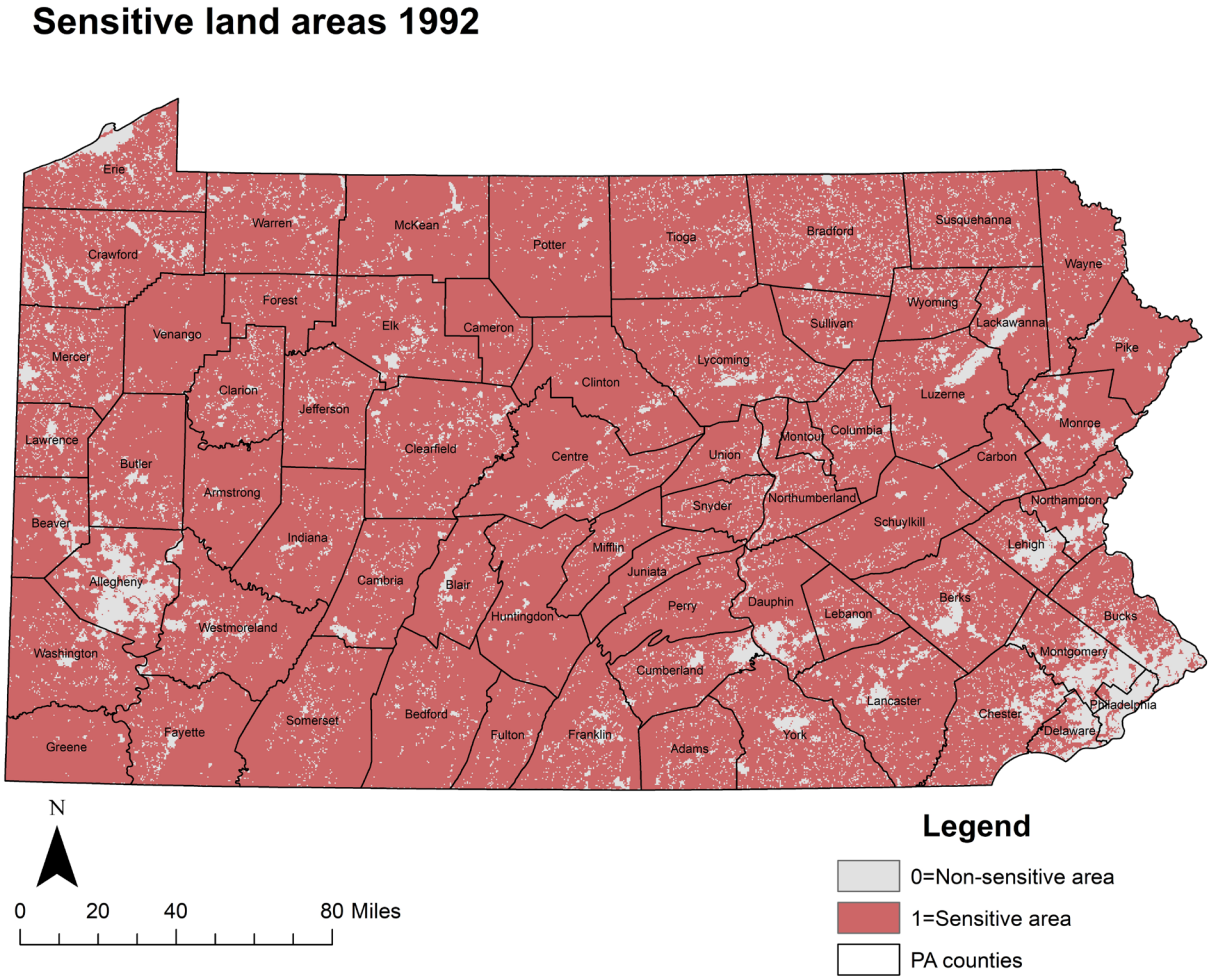
OTHER FINDINGS

For net urban land growth acres, the maximum is **Allegheny** and the minimum is **Philadelphia** which was even "disurbanizing". Coincidently, the two counties are the most urbanized from 1992 to 2001, but both of them were experiencing population loss as well.

- In addition, there were 9 counties in total which experienced population loss between 1990 and 2000 in Pennsylvania.

NET URBAN LAND GROWTH	COUNTY	ACRES
MAX	Allegheny	46,902
MIN	Philadelphia	-2,903

3. SENSITIVE LAND 1992



Sensitive areas include **land with water/farm/pasture/forest, or the overlapped areas among the four land types if there are**. From the map, we can see most land in Pennsylvania is categorized as sensitive. But from the map or compared with urban location map, counties that are highly urbanized tend to have less sensitive areas, Allegheny and Philadelphia are two very evident examples.

According to the table, **Lycoming has the largest sensitive areas**, and **Philadelphia has the smallest sensitve areas**, which might reflect the high urbanization in Philadelphia. In the county level, the average area of sensitive areas is **385,448 acres**.

County: with SMALLEST sensitive areas

County: with LARGEST sensitive areas

County	Number of sensitive cells	Sensitive area (acre)
Erie	6711	414575
Bradford	10488	647901
Tioga	10782	666063
Potter	10801	667237
McKean	9691	598666
Warren	8419	520087
Wayne	7301	451022
Susquehanna	7622	470852
Crawford	9201	568396
Wyoming	3635	224554
Lackawanna	4050	250191
Elk	7856	485308
Forest	4248	262422
Venango	6911	426930
Cameron	4004	247349
Pike	5560	343471
Lycoming	11647	**719499**
Sullivan	4308	266129
Mercer	6012	371394
Clinton	8933	551840
Clarion	5723	353541
Luzerne	8236	508783
Jefferson	6420	396598
Columbia	4423	273233
Clearfield	10975	677985
Centre	10803	667360
Monroe	5507	340197
Northumberland	4363	269526
Butler	7536	465540
Montour	1205	74439
Armstrong	6648	410683
Union	3019	186500
Carbon	3761	232337
Lawrence	3200	197681
Northampton	3081	190330
Schuylkill	7683	474621
Indiana	8267	510698
Snyder	3061	189095
Beaver	4008	247596
Mifflin	4050	250191
Lehigh	2567	158578
Huntingdon	8872	548072
Blair	5054	312213
Cambria	6594	407347
Juniata	3831	236662
Westmoreland	9681	598048
Berks	7664	473447
Allegheny	4638	286515
Dauphin	4703	290530
Perry	5476	338282
Bucks	4320	266870
Lebanon	3277	202438
Washington	8195	506250
Montgomery	2729	168585
Cumberland	4696	290097
Bedford	10133	625971
Lancaster	8976	554496
Franklin	7137	440891
Somerset	10659	658464
Chester	6450	398452
York	7956	491485
Fulton	4340	268105
Fayette	7784	480860
Philadelphia	321	**19830**
Adams	4941	305232
Delaware	1010	62393
Greene	5894	364104

4. DEVELOPED BUT SENSITIVE LAND (urban growth 1992-2001 in sensitive land 1992)

*** Instead of looking at net urban growth (urbanized - disurbanized), here we are only looking at **urban growth (urbanized)** cells.*

The more sensitive land converted to be urbanized, the more threatening to the sensitive land from urban growth.

According to the table, **Allegheny has the largest developed sensitve land**, therefore, Allegheny is the county that urban growth was most threatening to local sensitive land of 1992. Conversely, Cameron is the county that urban growth was least threatening to local sensitive land, as **Cameron has the smallest developed but sensitve area**.

- Although Allegheny is highly urbanized with the biggest net urban land growth, however, it doesn't have a very large amount of sensitve land compared to other counties, which reflects that the development largely took place on sensitive land in Allegheny.

- Cameron is county that has the least efficieny in urban land conversion with 0 net urban growth from 1992 to 2001, therefore, it is reasonable for Cameron to have the least developed but sensitive land.

- In the county level, the average area of developed but sensitve land is **4,874 acres**.

County	Developed but sensitive cells #	Developed but sensitive area (acre)
Erie	101	6239
Bradford	63	3892
Tioga	54	3336
Potter	14	865
McKean	38	2347
Warren	51	3151
Wayne	58	3583
Susquehanna	43	2656
Crawford	101	6239
Wyoming	29	1791
Lackawanna	75	4633
Elk	25	1544
Forest	10	618
Venango	75	4633
Cameron	4	**247**
Pike	66	4077
Lycoming	67	4139
Sullivan	9	556
Mercer	107	6610
Clinton	40	2471
Clarion	47	2903
Luzerne	109	6734
Jefferson	67	4139
Columbia	52	3212
Clearfield	131	8093
Centre	114	7042
Monroe	162	10008
Northumberland	49	3027
Butler	142	8772
Montour	20	1236
Armstrong	63	3892
Union	25	1544
Carbon	70	4324

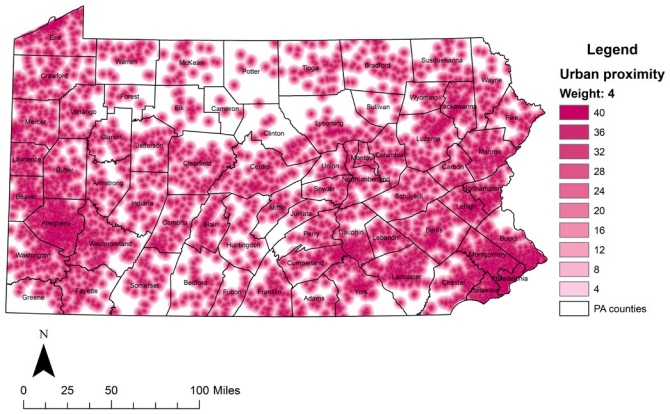
County	Developed but sensitive cells #	Developed but sensitive area (acre)
Lawrence	112	6919
Northampton	70	4324
Schuylkill	103	6363
Indiana	54	3336
Snyder	38	2347
Beaver	137	8463
Mifflin	35	2162
Lehigh	85	5251
Huntingdon	37	2286
Blair	91	5622
Cambria	99	6116
Juniata	21	1297
Westmoreland	216	13343
Berks	128	7907
Allegheny	328	**20262**
Dauphin	111	6857
Perry	59	3645
Bucks	108	6672
Lebanon	72	4448
Washington	150	9266
Montgomery	153	9452
Cumberland	84	5189
Bedford	52	3212
Lancaster	170	10502
Franklin	80	4942
Somerset	72	4448
Chester	100	6178
York	94	5807
Fulton	31	1915
Fayette	103	6363
Philadelphia	44	2718
Adams	35	2162
Delaware	93	5745
Greene	40	2471

County: with SMALLEST developed but sensitive areas

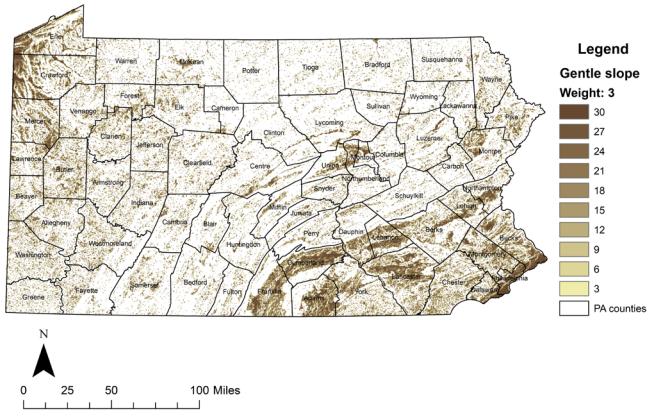
County: with LARGEST developed but sensitive areas

5. FURTURE URBANIZATION DECISION FACTORS & INDEX (FUI)

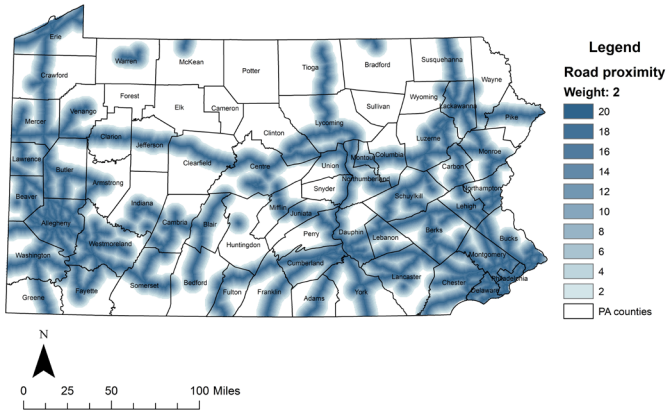
Weighted factor value:
Distance to existing urban development in 2001 (within 6 km)



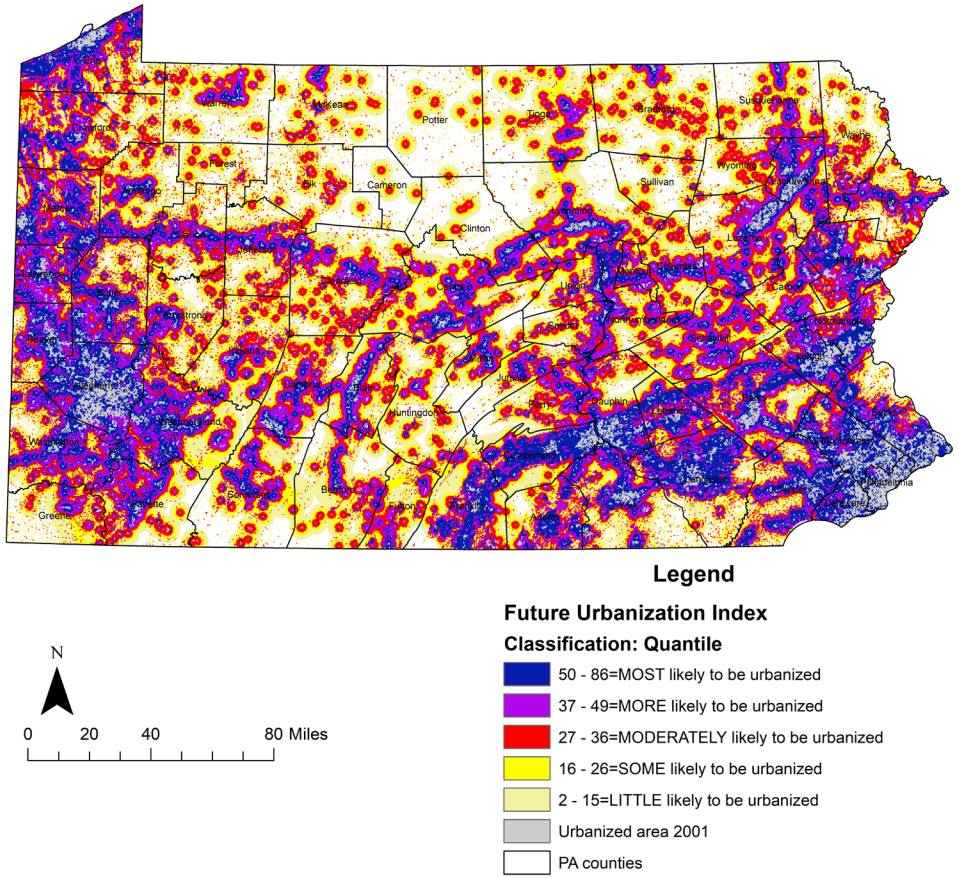
Weighted factor value:
Sites having slopes of less than 2 degrees



Weighted factor value:
Distance to 4-lane highways (within 10 km)



Future Urbanization Index (for non-urban sites)



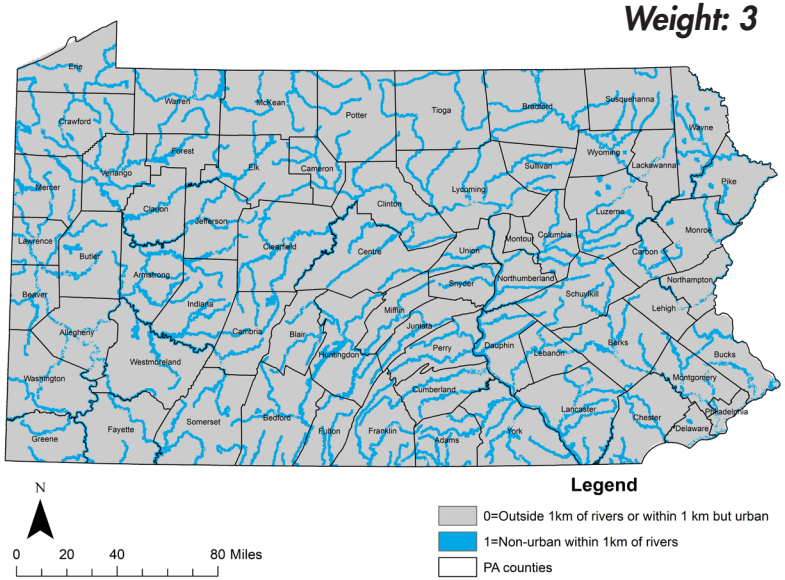
For undeveloped (non-urban) area in 2001, the 3 decision factors for are: 1) within 6 km of existing urban area, 2) within 10 km of 4-lane highways, 3) slopes of less than 2 degrees. For the deliverable of each factor, I cut the extent into the above qualified values, and classified the qualified values into **10 quantiles**, then I reclassified the values into 10 scores by referring to the 10 qunantiles and taking the weights (urban-4, slope-3, road-2). Thus, all three maps on the left have the same scale. **For road and urban proximity, a site will be scored higher if it is closer to highways and urban areas. For slope, a site will be scored higher when the slope is smaller (i.e. closer to flat land)**.

Future urbanization primarily targets to non-urban area, in future urban index map, **index value area excludes urbanized area 2001**. Still using Philadelphia and Allegheny as evident examples, we can clearly see areas that are close to existing urban areas tend to have higher index, which means they are more likely to be urbanized going forward.

6. ENVIRONMENTAL SENSITIVITY DECISION FACTORS

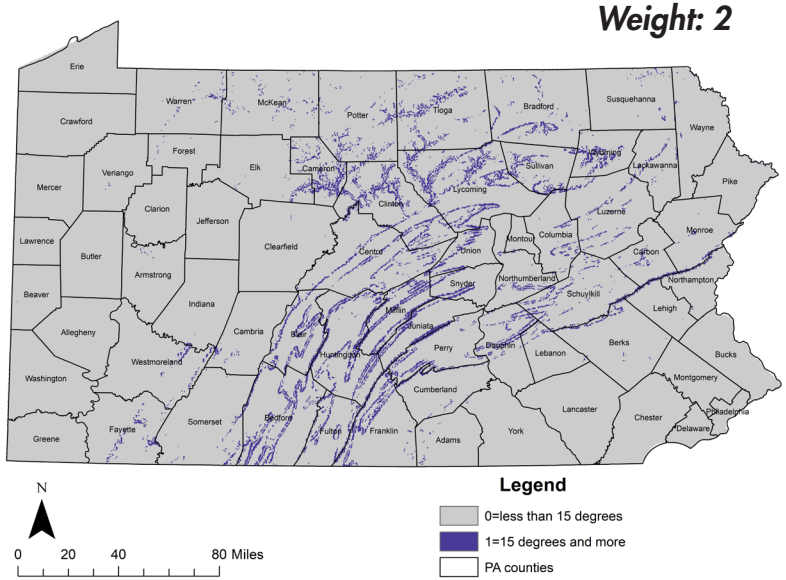
Distance to rivers (within 1 km for UNDEVELOPED sites)

Weight: 3



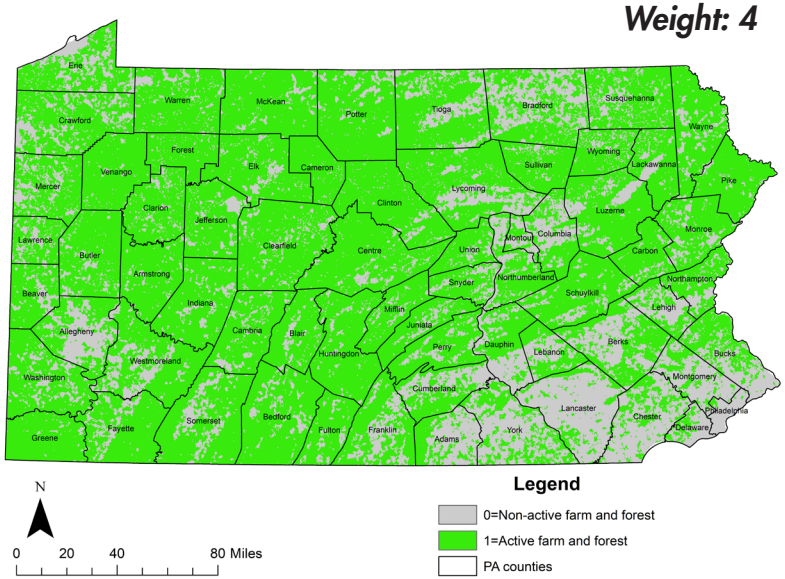
Hillside slopes (at least 15 degrees)

Weight: 2



Active farm and forest (farm or forest in 2001 non-urban areas)

Weight: 4



I gave "active farm and forest" a weight of 4, because learning from future urbanization factors, active farm and forest has the largest area covered, and those areas are significant to the environment and climate. **The weight of "distance to rivers" is 3, of "hillside slope" is only 2**, because I think they are important but not the most influential, especially for slope factor, people might not be interested to live in areas with steep slopes.

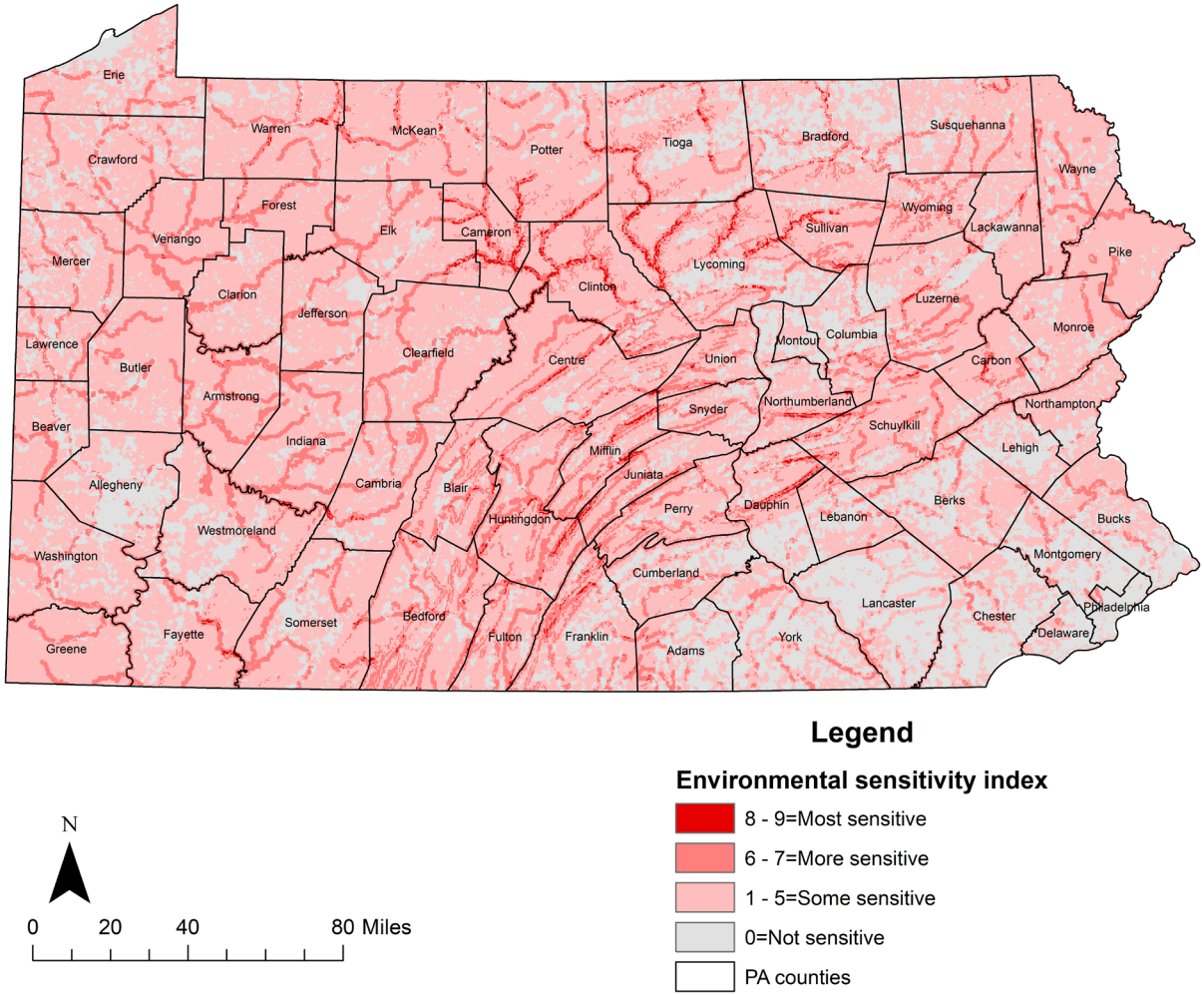
For "distance to rivers" and "active farm and forest", I **limited the extent of qualified area (i.e. value "1") to 2001 non-urban areas**, because we are focusing on undeveloped sites. So for instance, I figured out the urban area within 1km of rivers and moved it into value "0"; also, I defined "active farm and forest" area as: **farm in non-urban area OR forest in non-urban area**.

HOW TO GET THE FINAL "ENVIRONMENTAL SENSITIVITY INDEX"?

After I made each factor binary in result (0 and 1), I used "Raster Calculator" to re-calculate the value by the corresponding weight, and used "Cell Statistics" to add those weighted factor deliverables together to get the environmental sensitivity index map with values ranging from 0 to 9. *(Continuing to next page)*

6. ENVIRONMENTAL SENSITIVITY INDEX (ESI)

Environmental Sensitivity Index



Legend

Environmental sensitivity index

- 8 - 9=Most sensitive
- 6 - 7=More sensitive
- 1 - 5=Some sensitive
- 0=Not sensitive
- PA counties

N

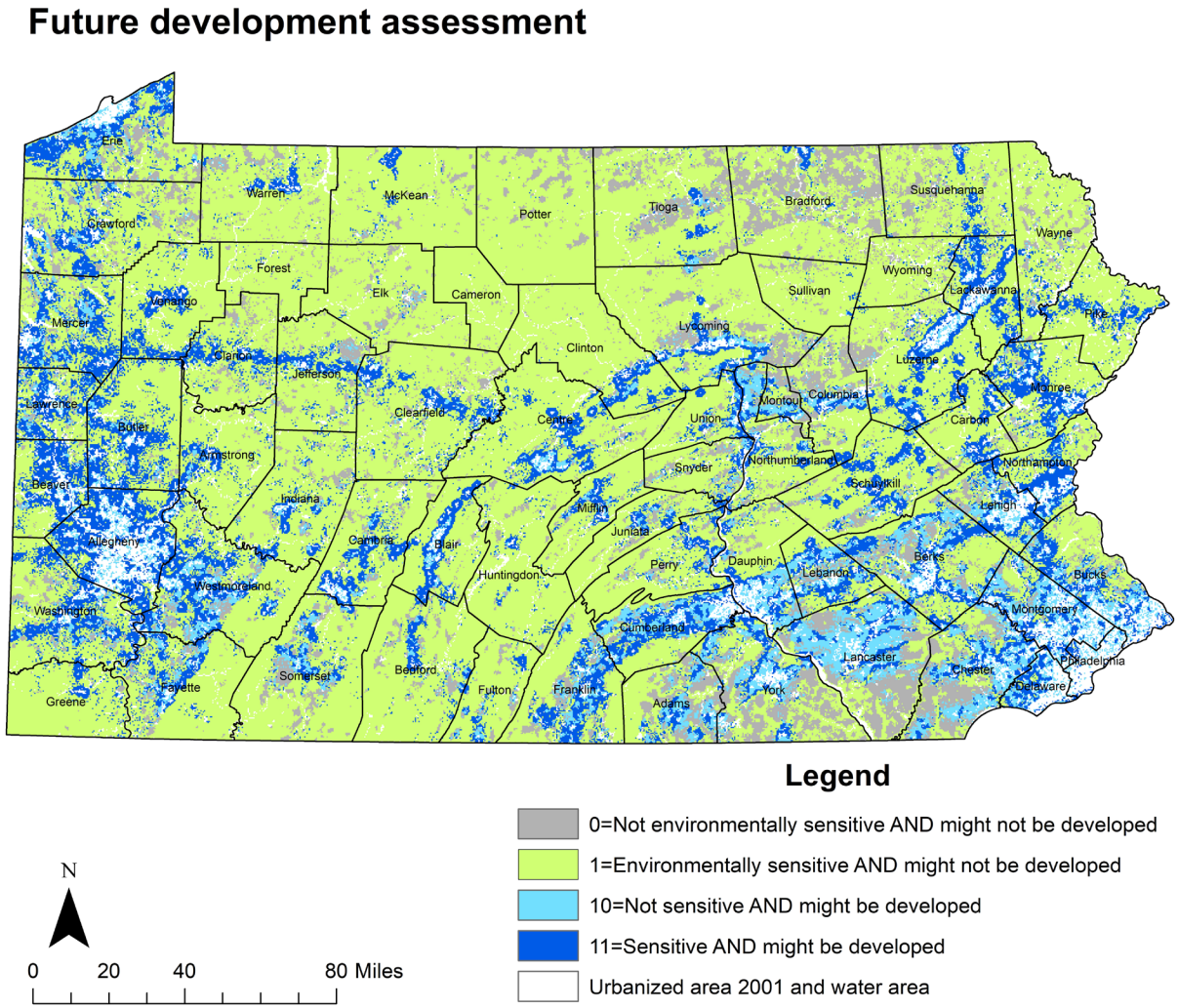
0 20 40 80 Miles

The final environmental sensitivity index ranges from **2 to 9**, and I categorized it into 4 levels via **Natural Breaks** classification method. This individually displays the 0 value which indicates non-sensitive area .

From the display of value symbols, the map shows that **areas that are closer to rivers or have slope greater than 15 degrees tend to be more or most environmentally sensitive**. Not sensitive area includes some urban areas as well.

- If we zoom into Philadelphia County, some areas clustered in northwest part are more environmentally sensitive. There are also several small portions of land in north and south of Philadelphia County being classified to be more environmentally sensitive.

7. FURTURE DEVELOPMENT ASSESSMENT



HOW DID I RECLASSIFY "FUI" INTO BINARY?

The furture urban index ranges from 2 to 86, and as I did in the early step, I classified the all index values into **10 quantiles**. Here I picked the **TOP 3 (or statistically the last 3) quantiles** and classified them into 1, indicating "most likely to be urbanized", and the values in remaining quantiles to 0.

HOW DID I RECLASSIFY "ESI" INTO BINARY?

I think no matter how much the degree of sensitivity classified in ESI, **as long as there is sensitivity, the area is sensitive**. So I just reclassified all non-zero values into 1, and kept "0" values as 0.

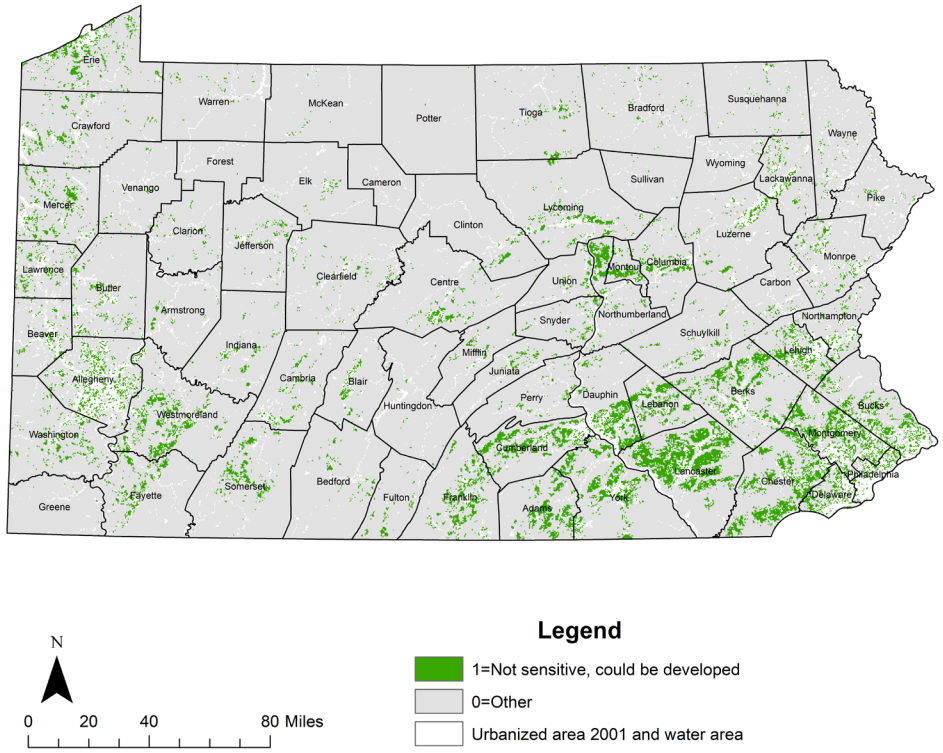
For both reformatted/reclassified ESI and FUI maps, I also **excluded urban area 2001** which indicates existing development) **and water area**, and then added together to have the **future development assessment** map with 4 categories. The final values of future development assessment does not cover existing urban area 2001 and water area.

- It is clear to see the majority part is **"Environmentally sensitive AND might not be developed"** with value of 1 in Pennsylvania, which means the land is **not ideal** for development at all, as we need to protect those environmentally sensitive land.

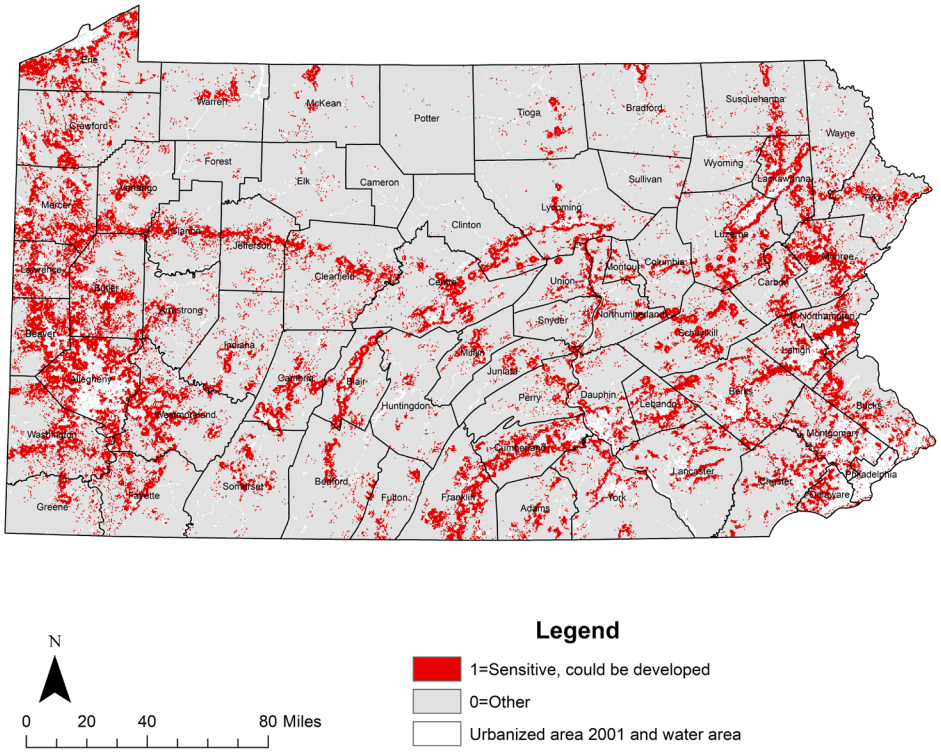
- **"Not sensitive AND might be developed"** with value of 10 indicates **ideal** areas for development, because there is no sensitive area for us to protect. I found most of them concentrate around urbanized area in the southeast part of Pennsylvania.

7. TWO KINDS OF "MIGHT BE DEVELOPED"

Non-environmentally sensitive future development area



Environmentally sensitive future development area



The RED environmentally sensitive future development area (#cells:66,346) is **much more** than the GREEN non-environmentally sensitive one (#cells:28,015). From previous analysis, if a site is not environmentally sensitive and might be developed, it is ideal for development, therefore, the green area indicates the **ideal** sites for development, and conversely, the red area indicates the **non-ideal** sites for development due to its environmentally sensitve area. There are two times more non-ideal sites than ideal sites in Pennsylvania.

-The distribution shows that, ideal sites cluster in **southwest** of the state more, such as Lancaster and counties around Philadelphia. While non-ideal sites are almost **evenly distributed** across the state from east to west with more nature. There are some non-ideal sites around existing urban areas as well, such as Philadelphia and Allegheny.

PHILADELPHIA COUNTY

With little sensitive land and having already been highly urbanized (low ESI and high FUI), Philadelphia only has very small portions of non-ideal sites (red) clustered in north, south and west. It makes sense, because Philadelphia doesn't have much nature including forests, farms, etc.

Ideal sites (green) scattered almost evenly from south to north inside Philadelphia, which gives Philadelphia an opportunity for **urban redevelopment/urban renewal** as an example. In addition, just outside Philadelphia, ideal sites are almost evenly distributed along the border adjacent to Delaware, Montegomery, Chester and Bucks, which provides Philadelphia oppotunities to further urbanize in a **radiant** form to neighboring non-urban area.

APPENDIX: GRID CELLS FOR NET URBAN GROWTH (1992-2001)

County	Urbanized cells #	Disurbanized cells #	Net cell change
Erie	321	110	211
Bradford	96	17	79
Tioga	77	9	68
Potter	15	1	14
McKean	59	15	44
Warren	71	15	56
Wayne	87	5	82
Susquehanna	76	4	72
Crawford	218	29	189
Wyoming	58	4	54
Lackawanna	255	121	134
Elk	42	17	25
Forest	15	0	15
Venango	115	22	93
Cameron	4	4	0
Pike	148	12	136
Lycoming	209	46	163
Sullivan	12	0	12
Mercer	295	62	233
Clinton	74	15	59
Clarion	86	6	80
Luzerne	331	184	147
Jefferson	101	12	89
Columbia	117	20	97
Clearfield	212	47	165
Centre	232	35	197
Monroe	472	34	438
Northumberland	115	27	88
Butler	348	50	298
Montour	30	3	27
Armstrong	110	30	80
Union	66	3	63
Carbon	134	42	92

County	Urbanized cells #	Disurbanized cells #	Net cell change
Lawrence	242	58	184
Northampton	323	112	211
Schuylkill	138	48	90
Indiana	98	28	70
Snyder	72	2	70
Beaver	374	157	217
Mifflin	65	18	47
Lehigh	395	102	293
Huntingdon	45	15	30
Blair	185	76	109
Cambria	212	52	160
Juniata	30	3	27
Westmoreland	477	191	286
Berks	389	94	295
Allegheny	1438	682	756
Dauphin	363	123	240
Perry	68	10	58
Bucks	533	333	200
Lebanon	172	31	141
Washington	308	157	151
Montgomery	802	433	369
Cumberland	310	86	224
Bedford	71	20	51
Lancaster	459	141	318
Franklin	235	49	186
Somerset	95	35	60
Chester	373	224	149
York	290	144	146
Fulton	46	6	40
Fayette	197	81	116
Philadelphia	244	291	-47
Adams	86	15	71
Delaware	262	277	-15
Greene	62	17	45

County: decreasing urban area (i.e. more disurbanized)