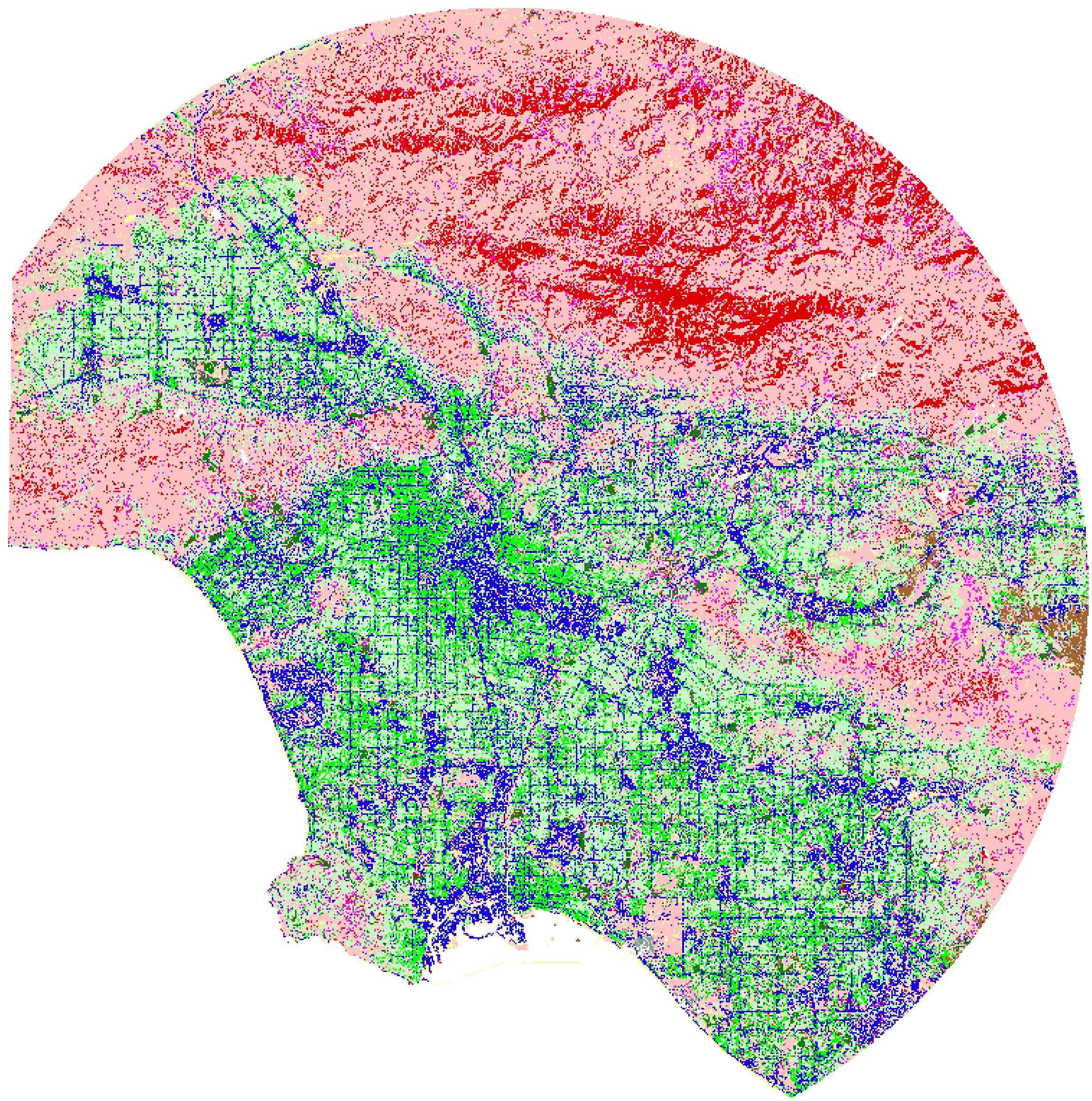
The Urbanization of America's Slopes



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Introduction

Proposal and Focus

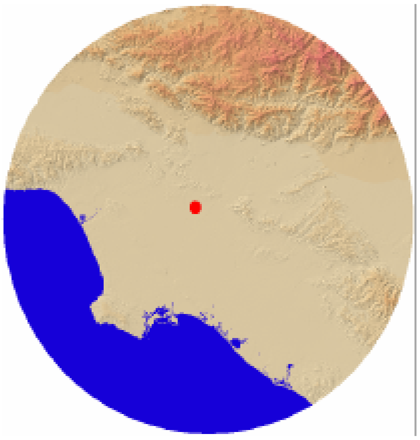
Our purpose is to design a plan that would use a digital elevation model and a land use grid to indicate the willingness of developers to build on land with a large slope value based on that parcels proximity to a major urban center. Los Angeles, CA will be our urban center used to depict this scheme in an area that is densely populated and has a large amount of slope variance. Chicago, IL will be our small slope variance “control city”” to contrast our Los Angeles results against. We will attempt to prove or disprove our following hypotheses:

1. Urban land is less likely to develop as the slope gradient increases
2. As the distance from the city center increases it is less likely that a cell with a greater slope value will become urbanized
3. Chicago will have a lower percentage of cells than Los Angeles that are urban across all slope values

Our contention is that we will see a large amount of urbanized cells near the city center on land that has a low slope value as well as a significant amount of land being developed with a slope value up to about 30%. As our area of study reaches farther from the downtown of the largest major city in the region, we will see a drop in the enthusiasm to build on a steeper terrain.

Sources of Data

All data collected will be from the National Elevation Dataset as provided by USGS. There was no 2001 land cover data provided for Los Angeles so 1992 data was used for both. The DEM and land cover was originally 1/3 arc second resolution before being projected to UTM zone 11 (Los Angeles) and zone 16 (Chicago) resulting in a cell resolution of approximately 28.283 meters.



Approx. city center, LA

Approx. city center, Chicago

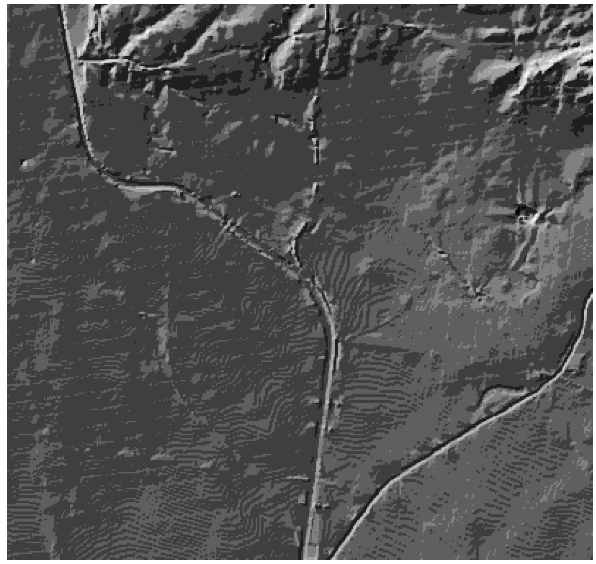
The city center coordinates were determined by manually placing the mouse over an ariel photo of downtown on NED’s website which gave us coordinance that could later be entered in to a text file to be implemented using various functions in GRID (See the “methods” section for more details).

Cover: A Land Cover map of Los Angeles, CA. Shades of green represent residential, blue are commercial, industrial and transportation. Brown is agricultural, Reds simulate an infrared view with lighter pinks being grasslands, red being deciduous .forest, dark red being coniferous forest.

Identifying Data Issues

Los Angeles

A number of unexpected problems occurred that may or may not have resulted in skewing some of our results. Artifacts such as a “waffle iron” artifact occurred near downtown Los Angeles that may have resulted from being re-projected. All of the graphs generated show that this probably did not affect our conclusion in any significant way, but is worth noting. There were also obvious contour line artifacts in the flat areas south of downtown.

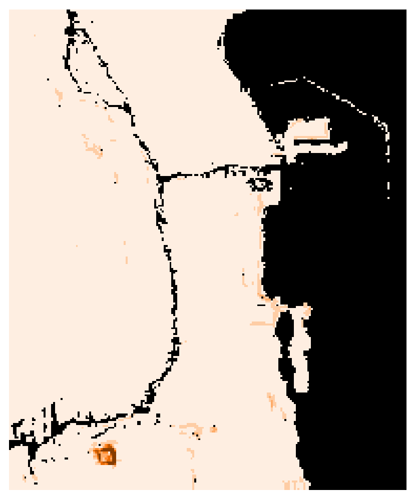


Example of the “waffle iron” and contour artifacts

Chicago

Since the DEM for Chicago and all of the surrounding suburbs falls in an area that spans Wisconsin, Illinois, and Indiana, there is a slight disagreement between the three states as to what the exact elevation of Lake Michigan is. Wisconsin believes it is about 178 meters while Illinois seems to place it around 175 meters. To reduce the chance for any issues that this could cause, the water was clipped out of both DEMs before any other operations were run on them.

Another problem with Chicago is that small amounts of urbanized slopes exist near the city center that is actually freeways and the very edge of the Chicago River. Almost all of these cells retained an urban value though there are not many of them. The charts listed later in this report help clarify and support this statement.



Above - Dark orange cells are areas of high slope. The I-94 freeway enters from the bottom of this graphic and is one of the contributing factors to error for the Chicago area

Left - Different tones of grey indicate a variation in height values over water in the yellow area.

Methods

The methods we employed to manipulate the DEM and Land Cover data were very complex and resulted in the creation of over 60 separate GRIDs, all filled with relevant and useful data to support out hypotheses. There are two main sets of operations we executed simultaneously that are both linked together throughout. One set, which deals with manipulating the DEM and LC GRIDs to produce urban land cover statistics for slope intervals, is relatively easy to follow. After eliminating water land cover and cropping the data to include only the inner 50,000 meters of cells (the distance grid is created in the other set), we altered the data to produce useful results. The DEM data yields seven individual sets of data divided up into 7 slope intervals. These intervals are: 0-5%, 5-10%, 10-15%, 15-20%, 20-25%, 25-30%, and 30-90%. The land cover grid yields one GRID covering our study area with two values: 1 for urban land cover (including low and high residential, commercial, industrial, and transportation) and 0 for non-urban land cover. By multiplying these two GRIDs together, we created 7 GRIDs that each have data for only the cells in a given interval. Within these cells, a 1 is urban land and a 0 is non-urban land. The second set of operations is slightly simpler, and involves the creation of a coverage showing the center point of each metro area's development. We chopped up the distance data into 5 10,000 meter radius/distance incremental areas to create 5 GRIDs similar in function to the 7 slope interval grids. In order to have the most comparison data, we multiplied these two grids together to form 35 combinations of intervals, each with data for only the cells that are in both intervals specified showing the urban and non-urban land cover cells. All the figures from this data can be seen in the Appendix.

Methods – Flow Diagrams

DEM

Project GRID

Projected DEM

Calculate Percent Slope

Percent Slope GRID

Crop all cells: ctr_dist > 50000

Crop all cells: LC < 20 (water)

Cropped Slope GRID

Using CON, create 7 GRIDs where value = 1 means it is in given interval (5% inc. up to 30%), with all other cells = NODATA

Slope Interval GRIDs (7)

Land Cover

Project GRID

Projected LC

Crop all cells: ctr_dist > 50000

Crop all cells: LC < 20 (water)

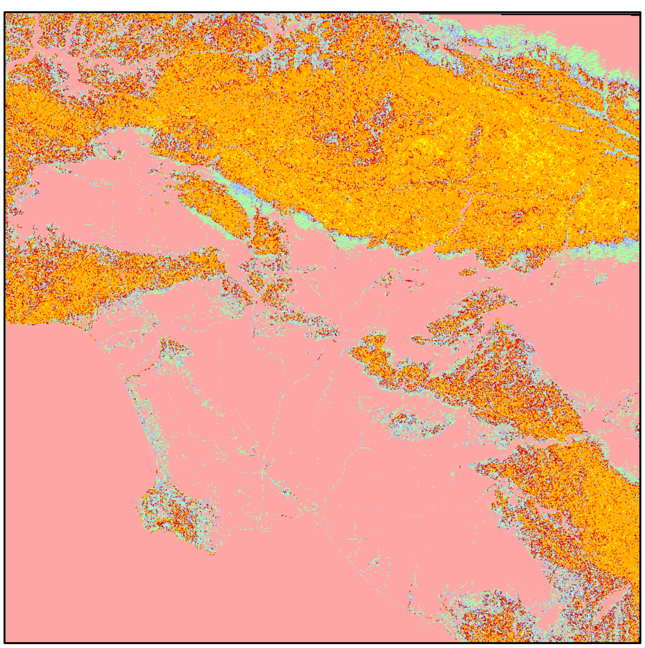
Cropped LC GRID

Using CON, assign value = 1 for all cells of "Urban" LC (Residential, Commercial, Ind, Transportation) with all other cells = 0

Urban LC GRID

Multiply each of the 7 slope interval GRIDs by the Urban LC grid: `Urban_(interval#)=urbanLC*slope_int` to get values = 1 for all Urban LC within given interval, values = 0 for all non-urban LC in given interval, and values of NODATA for all cells outside of given interval

Urban LC per slope interval GRID (7)



Above – This map illustrates the results of making 7 separate interval slope grids. Each color on the map represents a different slope interval.

Left – This DEM GRID is the result of cropping all the cells beyond the 50,000m distance from the center while also eliminating all cells with water land covers.

City Center Text File of Coordinates Manually Determined

Use GENERATE to create a points coverage with above coordinates

City Center Point Coverage

Use POINTGRID w/ window and cell set to the extent of the DEM

Center Cell GRID

Use EUCDISTANCE to calculate distance from center point

City Center Projected GRID

Use PROJECT to translate the decimal degree coordinates into x and y meters

Center Distance GRID

Using CON, create 5 separate GRIDs at 10,000m increments, where value = 1 means it is in given interval, all cells outside are NODATA

Distance Buffer GRIDS (5)

Multiply each Distance Buffer GRID by each slope interval GRID and the urban LC GRID; buf(buf#)_(int#) = dbg# * intg# * urbanLC Values = 1 means it is urban land in given distance and slope interval; value = 0 means non-urban land in given intervals, all cells outside intervals are NODATA

Urban LC GRIDs for each buffer/slope interval combination (35 total GRIDs)

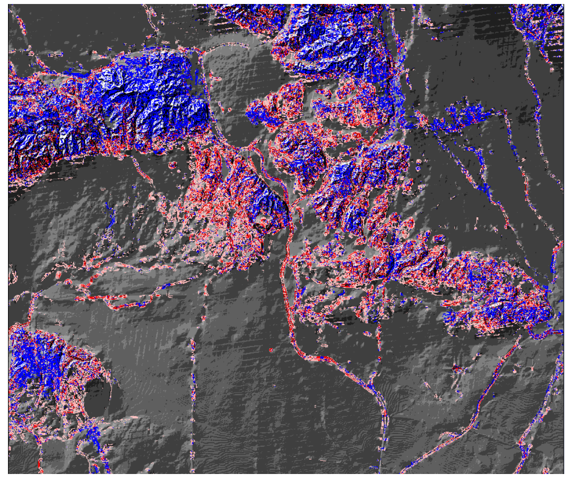
Multiply the distance buffer GRIDs by the Urban LC Grid; value = 1 is urban cell in buffer, 0 Is non-urban, NODATA is outside buffer

Urban LC GRIDs for each buffer interval

Individual Results

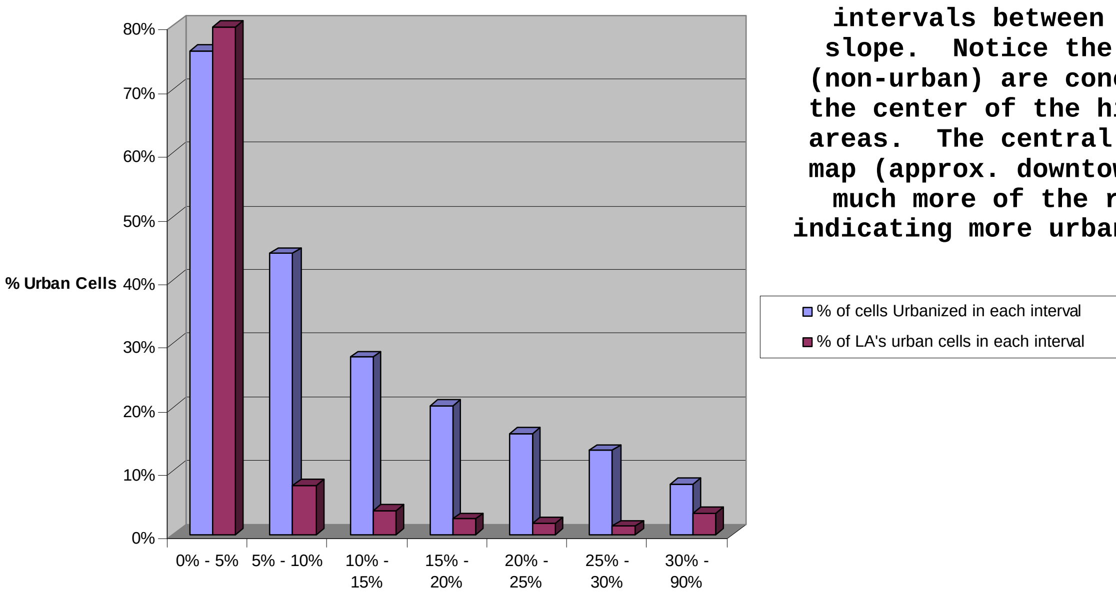
Los Angeles

The results for the Los Angeles area were exceptional and proved our theory to be correct. Almost all of the flat land near the city center was developed while there was a gradual decrease in development as the slop increased. Moving farther away from the designated city center there was significantly less urban development as slopes increased while flatter surfaces were apparently "more desirable" areas to build on.

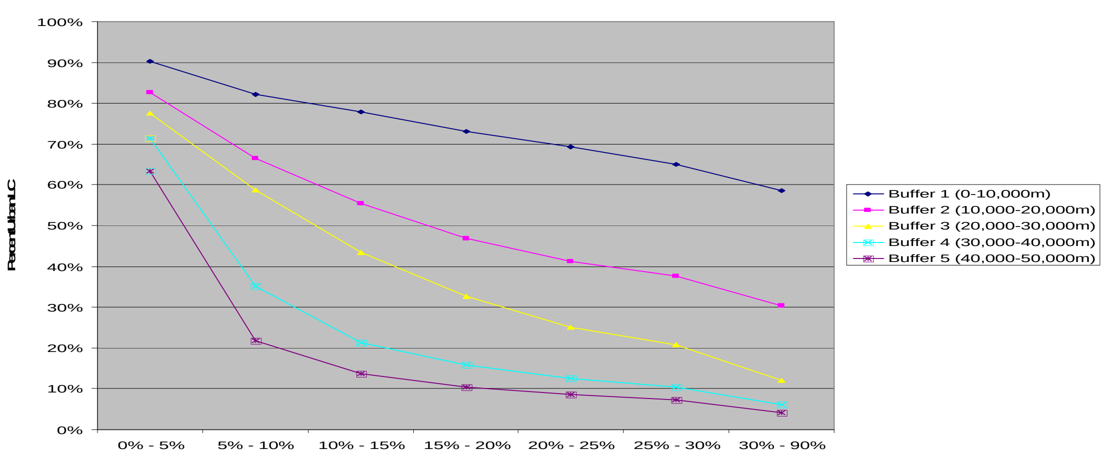


Above – This map shows the Urban and non-urban cells for the slope intervals between 5% and 30% slope. Notice the blue cells (non-urban) are concentrated to the center of the higher sloped areas. The central area of the map (approx. downtown L.A.) has much more of the red shades, indicating more urbanized slopes.

Los Angeles Urban LC Statistics

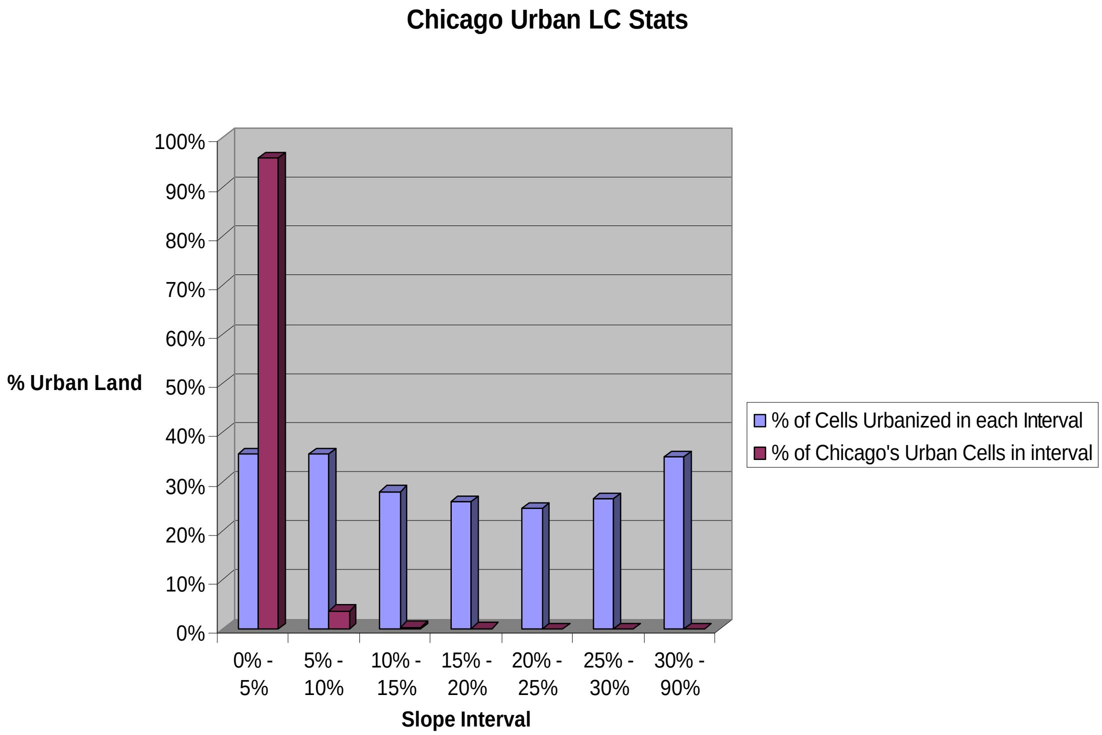


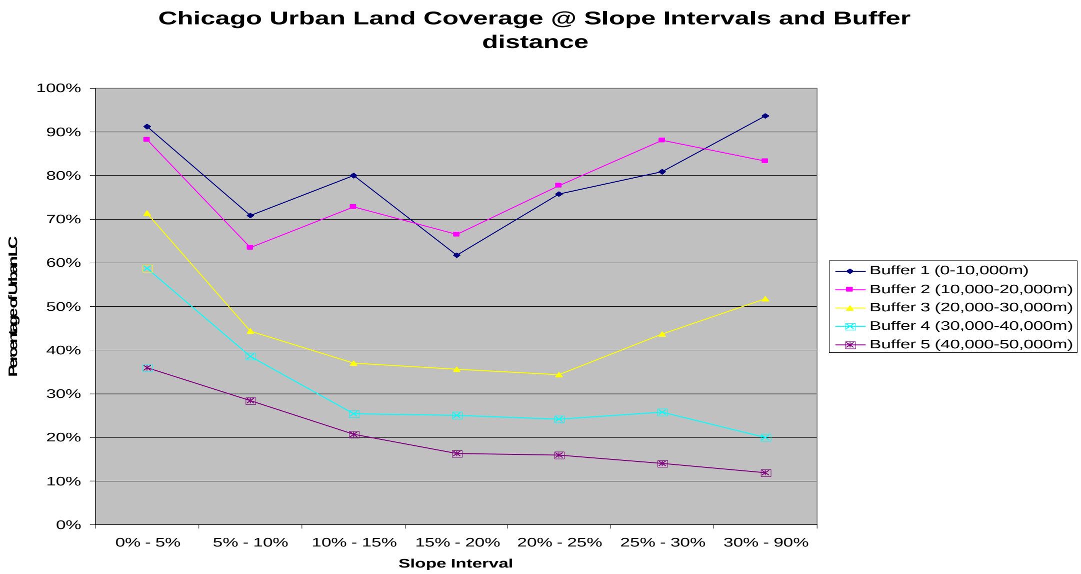
Los Angeles Urban LC @ slope interval and buffer distance



Chicago

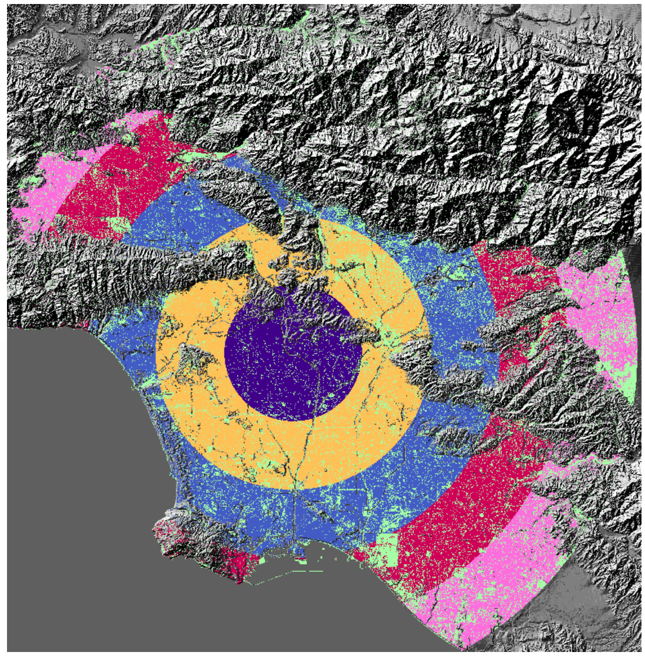
As noted earlier, the highways and rivers cutting through highly urbanized areas on the Chicago DEM contributed to the misleading data for the inner most buffer zones on the chart at the bottom of the page. Other than this, the results prove other criteria for our hypothesis correct. About 96% of Chicago's urbanized land falls within the 0-5 percent slope range. Developers will continue to consume flat or relatively flat as distance from the city center increases when there are no slope or related inhibiting factors.



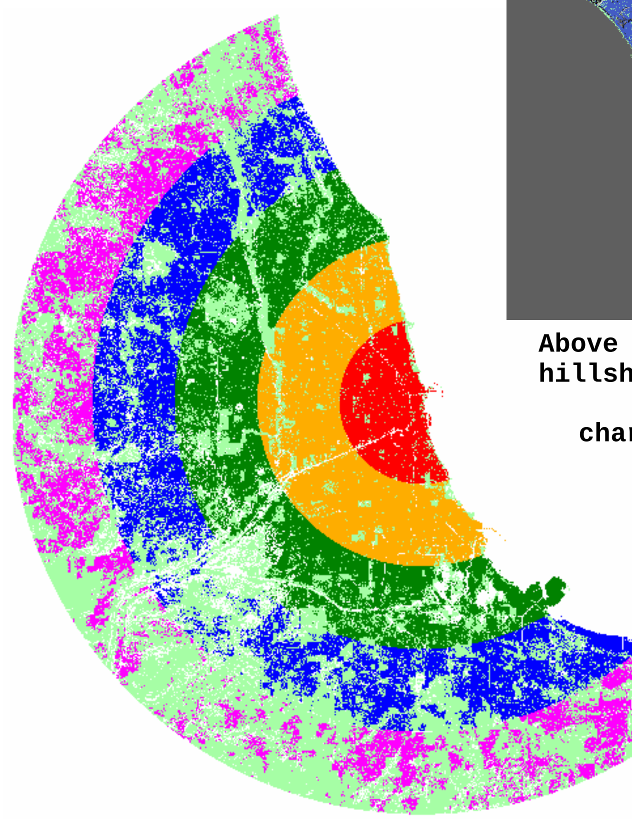


Comparing Results

Both of the "bull's-eye" graphics on this page display non-urban land cover as light green and all other colors are urban land at their respective distances away from the urban center. All data displayed is for the 0-5% slope interval.

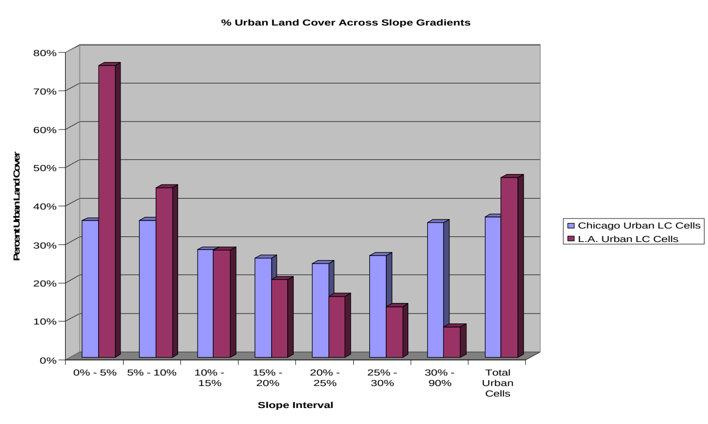


Above – the Los Angeles area with a hillshaded DEM in the background to help give identifying characteristics to the region.



Left – the Chicago area shows substantially less urban land cover in the outer rings since developers can build in any direction without the interference from mountainous terrain. There is no hillshade behind the Chicago land cover since it does not show through well.

The chart to the right represents the % of cells in each slope interval that are Urbanized. While L.A.'s show a decrease in urbanization as slope increases, the scarcity of higher slope land in Chicago skews the data to show a generally lower urbanized % of cells. Notice that even with the large bank of extreme slopes in the north 1/3, L.A. still has a higher overall urbanization figure.

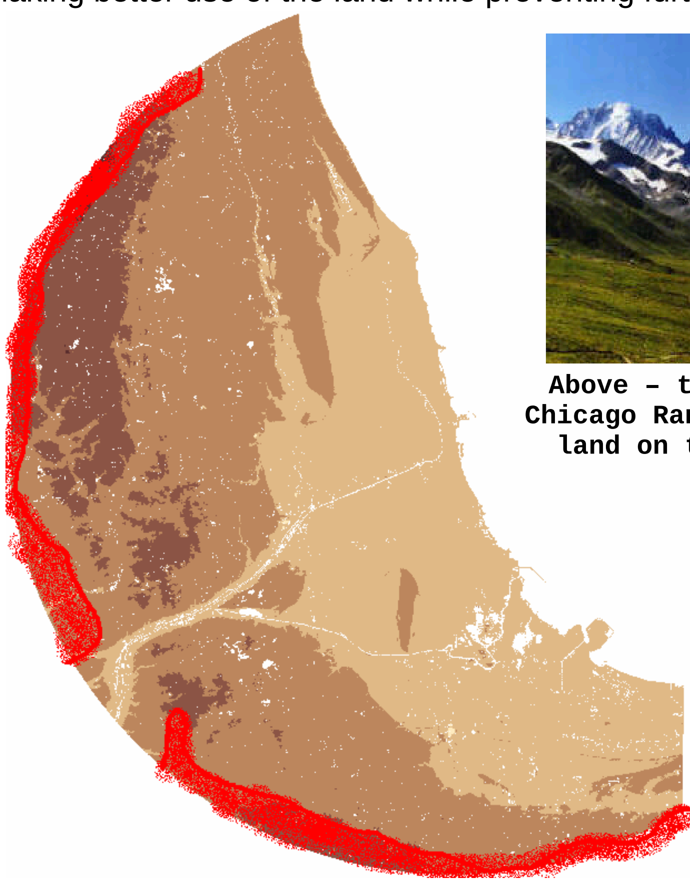


Implications

Most of our results are consistent with what we expected despite the few errors we came across along the way. Some implications are as follows:

1. Cities with more diverse distribution of land across slope intervals will develop lower slopes more densely than a city with little slope variation (LA is more dense than Chicago).
2. Urban Land Cover is less likely to occur on areas as the slope gradient increases.
3. Areas lacking a slope differential have the tendency to develop a lower percentage of land in all slope intervals.
4. As the distance from the city centroid of a metro are with high slope variation increases, the percentage of urban land cover decreases across all slope intervals.

Considering that this uncontrolled development in all directions is a problem, we have developed an idea that may be some kind of solution in the years to come. Build giant high-slope mound around perimeter of current development to turn all new growth towards the center, increasing density and making better use of the land while preventing further sprawl!



Above – there, now that the West Chicago Range is in place, the flat land on the other side is safe!

Left - The red indicates areas of high slope 50,000 meters away from Chicago's city center. Construction of a huge, high sloped wall may be the ultimate solution to preventing further development of low density urban land not only in Chicago, but all over the world!

Appendix

*** All data is in Cells**

Chicago Slope Interval - Urban Land Cover Data

Slope Interval	Urban	Non-Urban	Total Cells	% of Cells Urbanized	% of Chicago's Urban Cells in interval
Interval 1: 0% - 5% Slope	3,086,637	5,586,342	8,672,979	36%	96%
Interval 2: 5% - 10% Slope	119,436	215,327	334,763	36%	4%
Interval 3: 10% - 15% Slope	11,581	29,781	41,362	28%	0%
Interval 4: 15% - 20% Slope	2,481	7,116	9,597	26%	0%
Interval 5: 20% - 25% Slope	910	2,806	3,716	24%	0%
Interval 6: 25% - 30% Slope	500	1,381	1,881	27%	0%
Interval 7: 30% - 90% Slope	611	1,131	1,742	35%	0%
Total Urban Cells	3,221,388				
Total Non-Urban Cells	5,586,342				

Los Angeles Slope Interval - Urban Land Cover Data					
Slope Interval	**Urban**	**Non-Urban**	**Total Cells**	**% of Cells Urbanized**	**% of L.A.'s Urban Cells in interval**
Interval 1: 0% - 5% Slope	2,801,865	883,961	3,685,826	76%	87%
Interval 2: 5% - 10% Slope	269,778	341,051	610,829	44%	8%
Interval 3: 10% - 15% Slope	133,570	345,078	478,648	28%	4%
Interval 4: 15% - 20% Slope	86,677	341,709	428,386	20%	3%
Interval 5: 20% - 25% Slope	60,576	321,803	382,379	16%	2%
Interval 6: 25% - 30% Slope	44,085	290,155	334,240	13%	1%
Interval 7: 30% - 90% Slope	117,617	1,372,889	1,490,506	8%	4%
Total Urban Cells	3,507,959				
Total Non-Urban Cells	3,974,963				