Estimation of the Probability of Human Disturbance Using GIS - 14446

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ABSTRACT

In order to understand the potential for future human intrusion into low-level radioactive waste disposal sites an estimate was made of the extent and depth to which humans have disturbed the land in the U.S. to date. NRC's commercial low-level waste disposal regulations require protection of inadvertent intruders. Some stakeholders have expressed the belief that the probability of future inadvertent intrusion is very low such that NRC does not need regulatory requirements for protection of this class of receptors. This research provides a snapshot using Geographic Information Systems (GIS) software to estimate past human disturbance probabilities as a proxy for future human disturbance of a waste disposal site.

In the absence of a nationwide dataset specifically designed to quantify depth of human disturbance, land use/land cover data was used as a surrogate. The process of producing a nationwide "depth of human disturbance" dataset involved taking nationwide land use/land cover (LULC) datasets from various time periods and converting the land use/land cover classes of each dataset into "depth of disturbance" classes. Nationwide land use/land cover datasets available for the past three decades were employed. Each land use/land cover class in the datasets used was assigned to a depth of disturbance class. GIS software was used to convert the land use/land cover data into depth of disturbance data and visualize the results.

The following datasets were used: 1992, 2001, & 2006 National Land Cover Database (NLCD) data, and 1970's-80's Geographic Information Retrieval and Analysis System (GIRAS) data. Both the NLCD and GIRAS data were produced by the USGS. The GIRAS data underwent a series of revisions by the EPA and USGS. There is no nationwide data available prior to the GIRAS data. The classification systems of both the NLCD and GIRAS data are based on the Anderson Level II classification. The GIRAS data adheres to this scheme more closely. The major differences between the GIRAS scheme and the NLCD are in the urban/developed classes. There are more developed classes in the GIRAS data. Also, the NLCD classes are less related to land use and more related to land cover.

The overall disturbance probabilities estimated are in general agreement with NRC's regulatory requirements for low-level waste disposal. The existing NRC regulations were developed based on the assumption that future human intrusion is unlikely albeit possible. Therefore waste classification tables and other requirements were developed with an implied radiological dose of 0.5 mSv/yr (500 mrem/yr) for an intruder compared to 0.025 mSv/yr (25 mrem/yr) for an offsite member of the public. Based on the

differences in dose limits, the implied likelihood of the intruder scenario compared to the offsite member of the public is approximately 5%. In this analysis it was estimated in the past three decades that the land area disturbed to a depth greater than one meter is approximately 2.5%.

INTRODUCTION

In order to understand the potential for future human intrusion into low-level radioactive waste disposal sites an estimate was made of the extent and depth to which humans have disturbed the land in the U.S. to date. NRC's commercial low-level waste disposal regulations require protection of inadvertent intruders. Some stakeholders have expressed the belief that the probability of future inadvertent intrusion is very low such that NRC does not need regulatory requirements for protection of this class of receptors. This research provides a snapshot using modern software to estimate past human disturbance probabilities as a proxy for future human disturbance of a waste disposal site.

DISCUSSION

Data

In the absence of a nationwide dataset specifically designed to quantify depth of human disturbance, land use/land cover (LULC) data was used as a surrogate. Nationwide land use/land cover datasets available for the past three decades were employed. Each land use/land cover class in the datasets used was assigned to a depth of disturbance class. GIS software was used to convert the land use/land cover data into depth of disturbance data and visualize the results.

The following datasets were used:

- 1992, 2001, & 2006 National Land Cover Database (NLCD) data
- 1970's-80's Geographic Information Retrieval and Analysis System (GIRAS) data

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The NLCD data are based on automated classification of Landsat Thematic Mapper (TM) 30-meter resolution satellite imagery. The older GIRAS data was based on interpretation of NASA high-altitude aerial photographs (NAAP) and National High-Altitude Photography (NHAP) program photographs.

The GIRAS data were originally created in vector format with polygons representing areas of similar land use. The average minimum mapping unit was 1 hectare or 2 ½ acres. This data was later converted to raster format (a grid or pixel data). The NLCD was created as raster data with a 30 meter pixel size.

The classification systems of both the NLCD and GIRAS data are based on the Anderson Level II classification system shown in Table I.

TABLE I. Anderson Level II Classification System

1. Urban or Built-up Land	**2. Agricultural Land**	**3. Rangeland**	**4. Forest Land**	**5. Water**	**6. Wetland**	**7. Barren Land**	**8. Tundra**	**9. Perennial Snow or Ice**
11. Residential	21. Cropland and Pasture	31. Herbaceous Rangeland	41. Deciduous Forest Land	51. Streams and Canals	61. Forested Wetland	71. Dry Salt Flats	81. Shrub and Brush Tundra	91. Perennial Snowfields
12. Commercial and Services	22. Orchards, Groves, Vineyards, Nurseries, and Ornamental Horticultural Areas	32. Shrub and Brush Land	42. Evergreen Forest Land	52. Lakes	62. Nonforested Wetland	72. Beaches	82. Herbaceous Tundra	92. Glaciers
13. Industrial	23. Confined Feeding Operations	33. Mixed Rangeland	43. Mixed Forest Land	53. Reservoirs		73. Sandy Areas other than Beaches	83. Bare Ground Tundra	
14. Transportation, Communications, and Utilities	24. Other Agricultural Land			54. Bays and Estuaries		74. Bare Exposed Rock	84. Wet Tundra	
15. Industrial and Commercial Complexes						75. Strip Mines, Quarries, and Gravel Pits	85. Mixed Tundra	
16. Mixed Urban or Built-up Land						76. Transitional Areas		
17. Other Urban or Built-up Land						77. Mixed Barren Land		

The GIRAS data adheres to this scheme more closely. The 1992 NLCD data is a mix between the GIRAS classification system and that used later by the 2001 and 2006 NLCD data. The major differences between the GIRAS scheme and the NLCD are in the urban/developed classes. There are more developed classes in the GIRAS data. Although the 1992 NLCD data and 2001/2006 NLCD data have very similar LULC classes they were derived using different techniques and therefore are not directly comparable on a pixel by pixel basis. Also, the NLCD classes are less related to land use and more related to land cover.

Methods

The depth of disturbance class was assigned based on the estimated depth of foundation needed for buildings for developed areas, depth of plowing or clearing land for agricultural areas, etc. The developed/urban LULC classes fell into the 1 – 3 meters and > 3 meters disturbance classes. The agricultural and other vegetation related LULC classes fell into the < 1 meter class.

The open water, perennial ice or snow, and wetland classes were not assigned depth of disturbance classes. All other LULC classes were assigned to one of the following depth of disturbance classes: < 1 meter, 1- 3 meters, and > 3 meters.

The original intention was to also map a no disturbance class and a > 5 meters class, but this was not possible with the Level II classification scheme.

Table II shows the percentage of land area that was assigned to each depth of disturbance class for each dataset.

TABLE II. Depth of Disturbance by Dataset

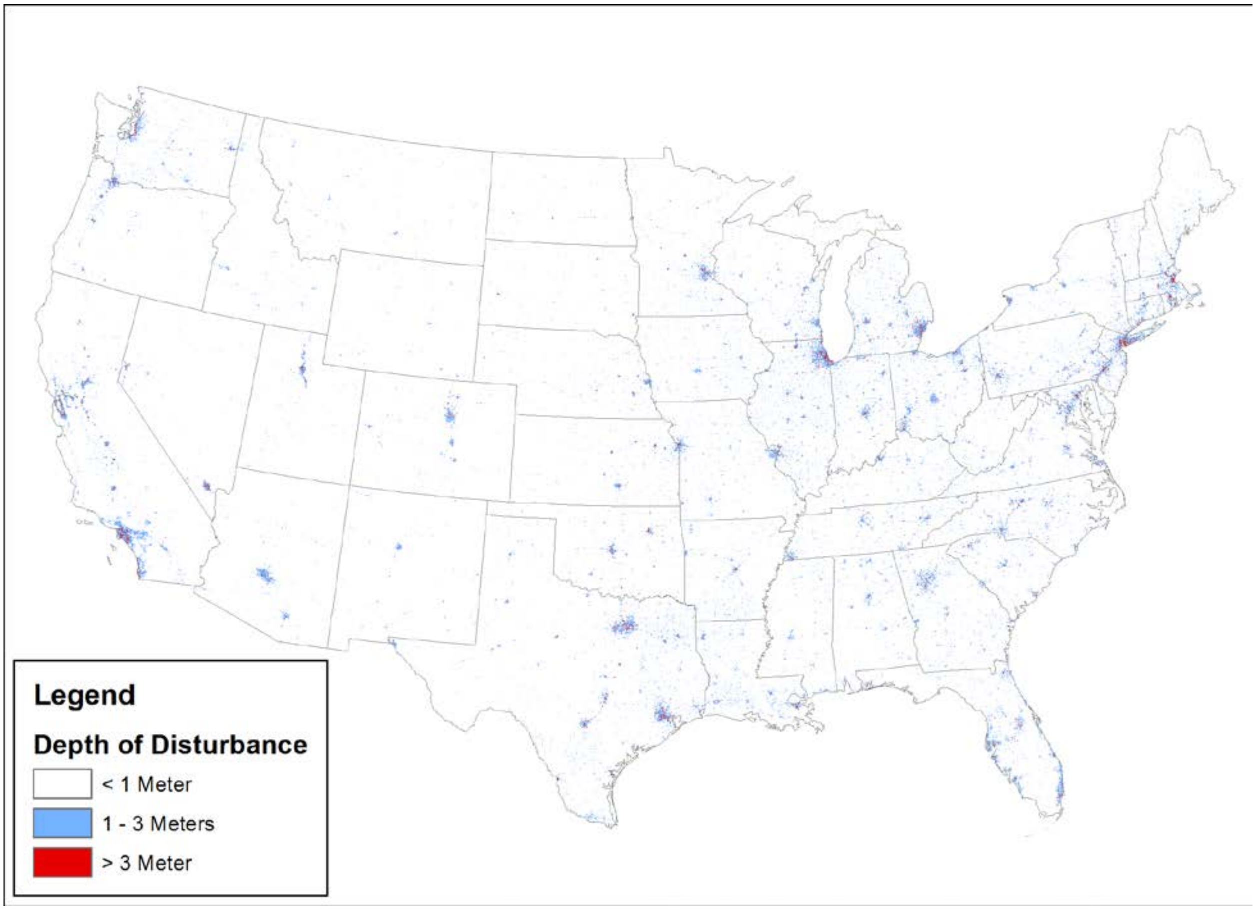
Depth of Disturbance	**1983 GIRAS Data**	**1992 Enhanced NLCD Data**	**2001 NLCD Data**	**2006 NLCD Data**	**2006 NLCD Utah Only**
< 1 Meter	97.4%	97.3%	97.6%	97.5%	99.1%
1 – 3 Meters	1.5%	1.7%	2.2%	2.3%	0.8%
> 3 Meters	1.1%	1.0%	0.2%	0.2%	0.1%

Results

The results of this analysis were fairly consistent for each generation of land use/land cover data used. There is a decrease in the > 3 meters class and increase in the 1 – 3 meters class for the 2001 and 2006 datasets versus the 1983 and 1992 datasets. This change is due largely to the change in classification schemes for 2001 and 2006 which resulted in the loss of the LULC classes that could be identified as being disturbed to a depth of greater than 3 meters.

As of 2006 only 2.5% of all land in the country has been disturbed to a depth greater than 1 meter. This may seem counter intuitive given the extensive urban and suburban development in the eastern states. However, the much larger western states are dominated by agricultural and forestry development which typically only disturb the top 1 meter of the surface. For example, less than 1% of all land in the state of Utah has been disturbed to a depth greater than 1 meter. Figure I shows the distribution of the depth of disturbance across the U.S. produced from the 2006 NLCD dataset.

FIGURE I. Depth of Disturbance Map (2006 NLCD)



CONCLUSIONS

There are several problems with this approach:

- the developed classes include structures, driveways, parking areas, and land that would be disturbed to different depths
- building practices vary greatly across the country and even within small geographic areas
- techniques used to map land use/land cover do not account for underground utilities
- agricultural land includes structures as well as the cultivated land
- automated techniques used to map land cover, and the classes they are mapped to, do not account for building heights which would correspond to different foundation depths

- recreational land use classes include a wide range of uses from park land to stadiums
- large military operations often are mapped to the vegetation related land cover class they are found in, which makes it difficult to identify the true depth of disturbance found at these locations
- transportation features are often lumped in with the land cover class they are near
- recent NLCD data do not include the separate strip mines/quarries/gravel pits class which account for a significant amount of the land disturbed to a depth of > 3 meters
- recent NLCD data do not distinguish between industrial and commercial facilities which may have deeper foundation requirements
- data used in this project only represent a relatively brief period of time and do not account for land that may have previously been disturbed to a greater depth than its more recent land use/land cover state would indicate.

Potential Refinements

Land use mapped to Level III of the Anderson classification system would be more useful for determining the deeper levels of disturbance. Unfortunately, so far there has been no effort to create a nationwide Level III dataset. Some statewide Level III data is available for eastern states. Vegetation classes have been mapped to the Level III and even Level IV level for many of the western states, but unfortunately these datasets do not map the agricultural and developed classes beyond Level II.

Methods to improve the Level II classification of the nationwide data would include:

- using GIS data of transportation features to create a separate transportation class
- using impervious surface data to separate the structures included in the agriculture and residential classes, which would have a greater depth of disturbance, from the land included in those classes
- using maps of large military installations which often show up in the LULC data as the vegetative class found in the area but which are often highly disturbed by the activities conducted there
- including a separate class for strip mines, gravel pits, and quarries as done in the earlier datasets, rather than lumping then in with other barren land which is often disturbed to a shallower depth
- using Census Bureau or tax parcel data to distinguish between high density, single family home residential areas from apartment complexes and taller commercial and industrial buildings which would have deeper foundations

- using LIDAR data, where available, to determine building height to identify taller buildings and corresponding deeper foundations
- using maps of virgin areas of vegetation (forests, grasslands, shrub land, etc.) to create an undisturbed class
- using maps of utilities, especially underground utilities if/where available.

Unfortunately, most of the data mentioned above is currently only available for limited portions of the country. Also, many of these attempts to refine this analysis would be labor intensive and therefore only practical for small geographic areas.

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