Developing Natural Hazards Mitigation Plan with ArcGIS

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Abstract

To promote sustainability as a strategy for disaster preparedness, the President of the United States signed the Disaster Mitigation Act of 2000. The Act encourages and rewards those local and state governments that develop and implement their mitigation plans for natural disasters. As a similar measure, the state of Ohio requires county governments to have a mitigation plan in order to obtain disaster relief funds. To assist several counties of northwest Ohio in developing their mitigation plans, the authors used ArcGIS to assess and analyze natural hazards potentially impacting their communities. After preprocessing spatial data from different sources, queries and overlays were performed to evaluate possible damages caused by floods and tornados, two major natural disasters in the area. GIS utilization provides a vital tool in mitigation planning. To that end, the results from GIS analysis become an essential part of a county's mitigation plan.

1. Introduction

To establish a national program for pre-disaster mitigation planning and to streamline the administration of disaster relief, the Disaster Mitigation Act (DMA), commonly known as the 2000 Stafford Act amendments, was approved by Congress and signed the President of the United States in October 2000 (FEMA, 2001). The Act encourages and rewards those county and state governments that develop and implement their community-specific mitigation plans. As an incentive, the State of Ohio requires county governments to develop and submit mitigation plans in order to obtain disaster relief funds (Ohio EMA).

As specified by the Federal Emergency management Agency (FEMA), the first step in producing a natural hazard mitigation plan is to identify the types of natural hazards that might affect the community and to estimate the possible financial losses that might result from those hazards (FEMA, 2001). To achieve this task, FEMA has recommended mitigation planners using the most cost-effective and efficient technology available. The choice of the technology, of course, is Geographic Information Systems (GIS). With GIS technology, maps that identify and analyze all applicable types of natural hazards can be produced. The maps can then be used by local governments to inform citizens within their communities of the potential risks from these hazards.

Figure 1. Location of Five Ohio Counties

In assisting five Ohio counties (Figure 1) to produce their mitigation plans, the authors produced a series of maps and performed hazard analysis with ArcGIS software. With spatial and attribute data from different sources, queries and overlays were performed to evaluate possible damages caused by floods and tornados, two major natural disasters potentially affecting these counties. The maps produced by GIS, served to assess and analyze natural hazards potentially impacting their communities. Although GIS has been utilized as an essential tool in the mitigation planning process, many technical issues remain. Using GIS more effectively and functionally becomes a challenge in the future of the mitigation planning process.

2. Hazard Analysis

An important component of mitigation plans is mapping hazardous areas, analyzing potential risks to the communities, and estimating possible losses resulting from the natural disasters. Up to this time, all five counties have finished map production and hazard analysis, and four of them, Wood (2003), Sandusky (2003), Huron (2004), and Preble (2004), have completed their natural hazard mitigation plans, with the author's assistance. All maps and hazard analysis were performed with ESRI's (Environmental System Research Institute) ArcGIS software.

The purpose of hazard analysis is to identify properties and populations within a county that are most at risk from natural disasters. The hazard analysis usually includes five components: hazard identification, profiles of hazard events, community profile, estimating losses, and vulnerability analysis.

The hazard identification is to recognize particular types of natural disasters that have the potential of occurring within a county. Recorded incidences of past natural disasters were used to make this determination. In all five counties, flood and tornado were identified as natural hazards that have, and will continue to adversely affect those communities. Profiles of hazards events identify past incidences of natural disasters within each county. The information and data presented in these profiles were obtained through review of historical data from news media sources, discussions with community residents, county officials, representatives from the Ohio Emergency Management Agency, Ohio Department of Natural Resources, and the National Weather Service. The community profile then compares overall county property statistics to those within the pertinent hazard area. Individual parcels and property asset data were used in the determination of estimated losses. Obviously, GIS is an ideal tool to fulfill these tasks.

3. Data Sources

Spatial and attribute data used for these mitigation plans came from four major sources. The first one was local governments. In most Ohio counties, GIS data have been created and maintained in each county's Auditor's offices. The data were usually geo-registered to the Ohio State Plan Coordinate System. Some counties have had established GIS divisions for many years. These counties can provide relatively high-quality GIS data ready for use. For other counties, GIS technologies are fairly new to them and their geo-databases are still in the infant stage. In this case, all five counties were able to provide parcel data (in either ArcGIS shapefile format or AutoCAD exchange file format) as well as digitized aerial photos (either in color or in black and white).

In general, GIS data generated by local governments have limited number of layers. For those existing layers, attributes may also in the status of incomplete. These problems can be supplemented by using the US Census Bureau's TIGER GIS database. TIGER data can be obtained from the Census Bureau's website (www.census.gov). The ESRI's website (www.esri.com), however, provides TIGER data in shapefile format, which can be used immediately in ArcGIS. All TIGER data are geo-registered in latitude and longitude form. County-based TIGER data provides various layers which can serve in either direct analysis or as reference.

In all five counties, two major natural hazards, flood and tornado, were identified. The data of floods and tornadoes, therefore, were extremely important to have. The flood data were obtained from the Ohio Department of Natural Resources' GIS warehouse website http://www.dnr.state.oh.us/gismain/. The dataset was derived initially from FEMA's NFIP (National Flood Insurance Program) maps with 100-year floodplain boundary. The NFIP maps were scanned into TIFF file and then transferred to the Ohio Department of Transportation's road centerline network vector files, which were digitized from 1:24,000 scale maps. The flood data was downloaded as ArcInfo exchange files and it was converted to ArcGIS shapefiles. Another potential flood hazards component in mitigation planning is the locations of Class 1 dams within the county. The Class I dam information was also obtained from the Ohio Department of Natural Resources' GIS warehouse website.

Digitized tornado path maps were not available for all five counties. However, historical tornado data, including each tornado's occurring date and time, magnitude in F-scale, and beginning and ending locations (both in latitude/longitude), can be found in NOAA's (National Oceanic and Atmospheric Administration) website http://www.noaa.gov/. Based on this information, those historically significant tornadoes were digitized with ArcGIS.

4. Hazard Analysis with ArcGIS

With available spatial and tribute data, ArcGIS software was used to make maps and perform hazard analysis for all five counties. To make the mitigation plan more readable for wider variety of audiences, reference maps were first produced. These reference maps allow the readers understand distribution of each county's general geographic elements and their relationships. Examples of such maps include townships and cities, roads, streams, water bodies, and 100-year floodplains. Figure 2 is a reference map showing distribution of streams and 100-year floodplain in Preble County, Ohio

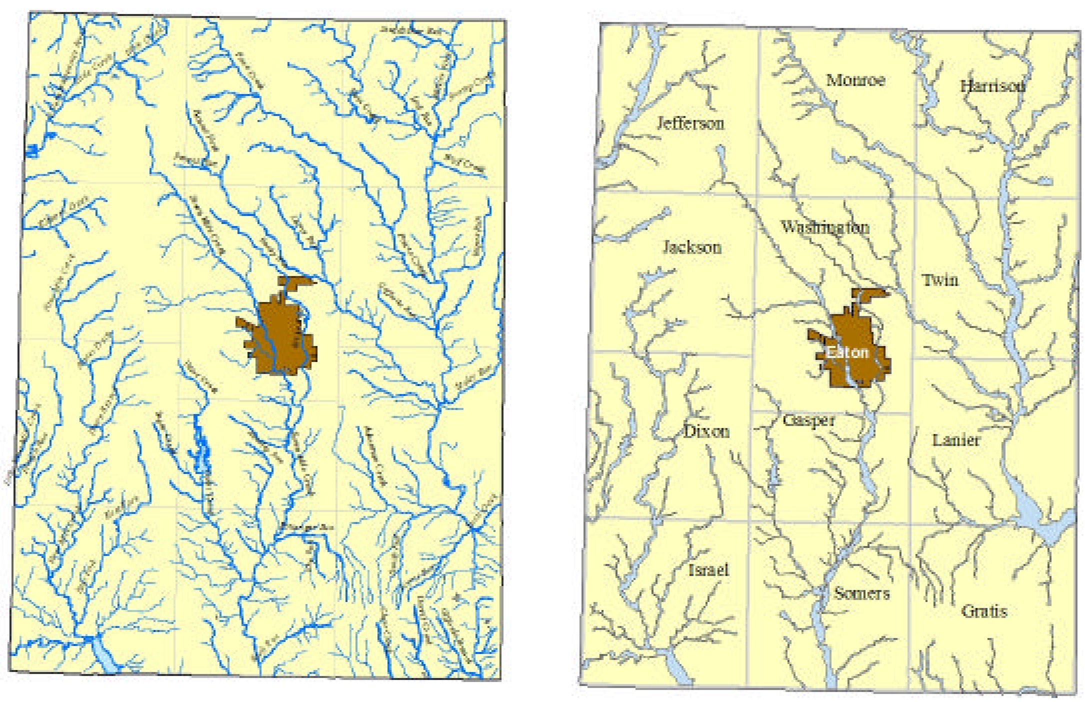

Figure 2. Example of Reference Map: Streams and 100-Year Floodplain in Preble County

To identify natural hazards and estimate possible losses, basic GIS analysis was performed. In the GIS analysis process, the parcel layer from each county's GIS database played a significant role. In this layer, each parcel's property value and land use type were used to estimating damages. By overlaying natural hazard occurrence (e.g., 100-

year flood) with the parcel layer, a map showing the parcels within the hazard area was generated. An attribute query was then performed to assess the possible damages caused by the hazard. Since the parcel layer included the attribute of land use code, the damage for each land use was also calculated. Table 1, for example, lists total number of parcels and parcel values within 100-year flood zone in Preble County. Parcels are categorized by types of land use.

Table 1. Impacts of 100-Year Flood on Preble County

Land Use Types	**Number of Parcels**			**Value of Parcels**		
	# in County	# in Hazard Area	% in Hazard Area	$ in County	$ in Hazard Area	% in Hazard Area
Residential	21,110	2,520	12%	1,598,458,740	193,951,260	12%
Commercial	1,500	315	21%	184,943,410	33,137,550	18%
Industrial	211	44	21%	127,694,450	21,921,480	17%
Agricultural	9,668	3,380	35%	739,563,220	278,241,120	38%
Religious	334	53	16%	44,408,600	4,873,700	11%
Government	696	220	32%	208,514,200	74,315,700	35%
Education	78	9	12%	97,436,600	688,700	1%
Total	**37,085**	**7,227**	**19%**	**3,001,027,820**	**607,198,110**	**20%**

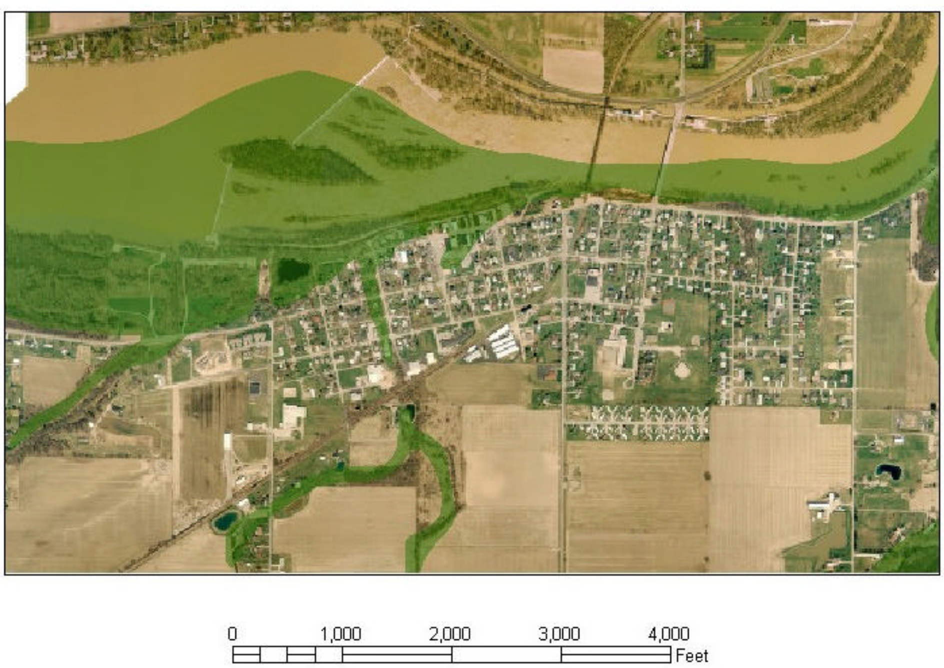

Figure 3. Impacts of Maumee River 100-Year Flood on Grand Rapids, Wood County

For potential flood hazards, the hazard analysis was also performed on each individual floodplain (e.g., 100-year flood for a specific stream). Figure 3, for example, is a map showing the impacts of a 100-year flood (in dark green) of Maumee River on Grand Rapids of Wood County. Using attribute query, possible damages caused by the flood were calculated according to types of land use (see Table 2).

Table 2. Impacts of 100-Year Flood of Maumee River on Wood County

Land Use Types	Number of Parcels in Hazard Area	Value of Parcels in Hazard Area
Residential	1,240	$200,862,460
Commercial	106	$18,998,110
Industrial	2	$401,640
Agricultural	179	$10,392,390
Religious	9	$7,510,400
Government	113	$10,225,100
Education	15	$42,888,000
Total	**1,664**	**$291,278,100**

Figure 4 presents a similar example. In this case, the path of a 1953 Wood County tornado, which caused eight human deaths and 24 injures, was mapped. The impacts of this tornado, based on both 1953 and current property value, were summarized and compared in Table 3.

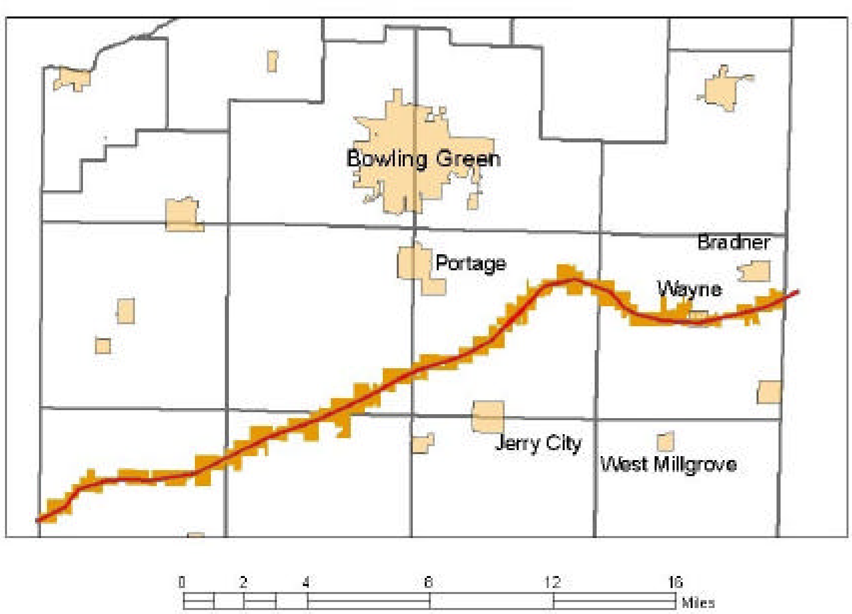

Figure 4. Parcels Affected by the 1953 Tornado in Wood County

Table 3. Impacts of the 1953 Tornado on Wood County

Number of Parcels		**Value of Parcels**	
Year: 1953	Year: 2003	Year: 1953	Year: 2003
60	403	$1,500,000	$18,108,700

For townships and/or cities affected by a natural hazard, a community profile was created. This community profile identified number of parcels and their values impacted by the natural hazard. Table 4, for example, shows the total number of parcels and estimated losses of four incorporated areas that would potentially be affected by a 100-year flood of Maumee River.

The maps and tables generated by GIS are the centerpiece of each county's natural hazard mitigation plan. After the mitigation plan is completed, it will be submitted to the Ohio Emergency Management Agency (OEMA) and then on to the Federal Emergency Management Agency (FEMA) for peer review. Once a plan is approved by OEMA and FEMA, a certificate will be awarded to the county and the county is now compliance with the federal Disaster Mitigation Act of 2000. Up to this point, three of the five counties have submitted their final mitigation plans to OEMA/FEMA and have received certificates. The remaining two counties are still working in progress.

Table 4. Community Profile: Incorporated Areas Affected by Maumee River Flood, Wood County

Affected Incorporated Area	**Number of Parcels**			**Value of Parcels**		
	# in Comm-unity	# in Hazard Area	% in Hazard Area	$ (mil.) in Comm-unity	$ (mil.) in Hazard Area	% in Hazard Area
Grand Rapids	722	146	20%	$44	$7	17%
Perrysburg	8,014	465	6%	$1,345	$66	5%
Rossford	3,648	296	8%	$428	$71	16%
Northwood	3,948	29	1%	$357	$4	1%

5. Problems and Challenges

GIS, as experienced from the five Ohio counties, is an essential tool in making natural hazard mitigation plans. Hazard analysis, powered by GIS operations, forms the core of each county's mitigation plan. In the process of using GIS in hazard analysis, however, a number of problems are notable.

First and foremost was the problem of data availability. A successful hazard analysis relies on the quality of spatial and attribute data. While some counties provided relatively high-quality data, some had minimal or otherwise inadequate data, probably because of short GIS program history and lack of human resources and funding. One county, for example, only had parcel map of each individual township in AutoCAD format. For those AutoCAD files, no spatial coordinate systems were defined. The AutoCAD data, therefore, had to be converted to ArcGIS shapefiles and individual township maps had to be merged into a county map. Then, the newly created county map had to be transformed to the Ohio State Plan Coordinate system, which is standard for all counties in Ohio. This was a very time consuming and very tedious process.

Several counties provided parcel layers without any attribute data. To perform hazard analysis, the parcel map had to join with related attribute table. In many cases, however, the table could not be joined correctly to the parcel map simply because the parcel ID were not standardized. In such cases, data had to be reformatted so that the tables could be joined properly.

Data standardization was also generally lacking in county-level geo-databases. A typical example was land use classification. While some counties used USGS (U. S. Geological Survey) land cover/land use classification system, some used unknown classification schemes. This caused extreme difficulties in analyzing the impact of particular hazards in a community.

Data accuracy was also a big problem. This problem was apparent for both spatial and attribute data. In the case of spatial data, many parcels were not correctly digitized. This was very evident in road-related polygons. In some counties, the parcel property values were not updated so the financial data generated from the queries were not current.

The hazard analysis process used in the development of the mitigation plans was purely parcel-based. In reality, the parcel-based operation caused significant problems. If, for instance, a parcel was located in 100-year flood zone, the assessment was based only on the value of the parcel. The damages caused by a flood in that parcel and flood damage to the building within the parcel should be different. Data from the five counties, however, did not have a separate building layer. Losses estimated by parcel values, therefore, were not accurate. Financial looses caused by the flood, therefore, was normally overestimated.

These problems pose challenges in the future of natural hazard mitigation planning. The first challenge is the standardization of the county-level GIS database. A county GIS database should use a consistent land use classification system so the results are comparable. The database should also standardize the attributes.

In current mitigation planning, only a few basic GIS functions (e.g., overlay and query) have been used. The power of GIS spatial analysis has not been fully utilized. For example, risk modeling can be used in natural hazard loss assessment. Natural disaster evacuation plan, an important procedure, was entirely missing in the current mitigation planning. It should be included in the future for plan development.

6. References

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