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Land Subsidence Monitoring Using Geographic Information System (GIS) Techniques in Akwa Ibom State, Nigeria.

JOSEPH C. UDOH and EMMANUEL P. UDOFIA

Department of Geography and Regional Planning, University of Uyo,
Uyo, Akwa Ibom State, Nigeria.

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ABSTRACT

Akwa Ibom state of Nigeria is susceptible to subsidence as a result of complex interaction between anthropogenic activities and natural processes. As an area of subterranean fluid extraction, the study arose because of the need for subsidence monitoring so as to minimize the anticipated resultant risk. The study utilized water extraction data that was linked to an existing data base of the study area. To obtain the subsidence susceptibility index, the total water extraction data for each LGA was normalized and the data converted into grids and interpolated with Inverse Distance Weighted (IDW) tool of ARCMAP spatial analyst extension to create an isoline map. IDW is used to create a continuous surface from sampled point values. The resultant map showed the spatial distribution of the subsidence zones of High and Very High zones are found in emerging urban areas of Uyo, Ikot Ekpene and Ikot Abasi. This emphasizes the need for the population growth and the water supply needs of our urban centers to be monitored. It is recommended that an agency should be established to monitor land subsidence in the vulnerable areas identified by the study.

Key words: Land subsidence, Geographic Information system, Akwa Ibom State, Nigeria.

INTRODUCTION

Increasing population and anthropogenic activities have brought about many environmental problems globally. One of such problems is land subsidence described as the gradual differential settling or sudden sinking of the ground surface due to the movement of ground materials [1,2]. Land subsidence is generally caused by human activities, alterations to the earth's surface and underground geologic processes. Specific causes include: Underground mining of solid minerals, and the collapse of such mines; withdrawal of groundwater and petroleum; dewatering or drainage of organic soils; sink holes, wetting of dry low density soil; and, natural sediment compaction.

The growth of world population and the increasing need for water has led to this geological hazard that has affected all continents of the world except Antarctica[3]. Land subsidence has received the attention of researchers in different parts of the world. Land subsidence problems that has resulted from the overuse of ground water in Bangkok in Thailand has been investigated[4]. According to the study, subsidence occurred at rates up to 10cm/year in critical areas. The crises worsened flood conditions and caused damages to buildings and infrastructure. Hence since 1983, government agencies have monitored subsidence and ground water levels and implemented general measures to mitigate the problem. Also, the effect of ground water on rural housing in USA was equally studied leading to the conclusion that land subsidence occurred where large amounts of ground water was withdrawn from a thick layer of saturated fine gravel sediment that is susceptible to compaction. Remote sensing and Geographic Information System (GIS) techniques were used to detect and quantify land subsidence caused by aquifer compaction in Antelope Valley, California[6] . The resultant maps with high spatial detail and resolution allowed a comprehensive comparison between recent subsidence patterns and those detected historically by traditional methods.

A 24 year data was used to analyze establish trends and causes of land deformations in Yangtze River delta, China[7]. This area is characterized by the occurrence of land subsidence due to the exploitation of ground water resources that serve as a major water supply for industrial and municipal purposes. An assessment of land subsidence in the Karst region of Rongkop, Indonesia was carried out with the purpose of delineating the areas that are at risk. A land subsidence risk map was developed based on 5 parameters – slope degree, lithology, relative relief, distance to lineaments and land use. The result revealed that the highest risk zones coincided with sink hole locations.

As part of mitigation strategies, the government of New South Wales, Ausrtalia established the Mine Subsidence Board (MSB) as a service organization operating for the community responsible for the administering the Mine Subsidence Compensation Act. This provided the basis for compensation or repair services where subsidence induced damages occur in this coal mining area[8]. The Board is responsible for reducing the risk of more subsidence damage to properties by assessing and controlling the type of buildings that can be erected in subsidence prone districts. It is worthy of note that although subsidence damages were reported in New Castle from late 19th century, comprehensive subsidence monitoring programs were not initiated until 1970s.

The study area, Akwa Ibom State of Nigeria is susceptible to subsidence as a result of complex interaction between anthropogenic activities and natural processes. It is located between latitude $4^{0} 32^{I}$ and $5^{0} 33^{I}$ North and Longitude $7^{0} 25^{I}$ and $8^{0} 25^{I}$ East. To the East of the state is Cross River State, to the West Rivers and Abia and to the South Atlantic ocean. The geology of the study area consists of four recognizable distinct stratigraphical units[9]. The shale – limestone unit is the oldest geological fancy in the state belongs to the late Cretaceous (Nsukka formation) and the early Eocene (Imo clay shale group) periods. They are found in the north and north east parts of the state. The coastal plain sand also found in the north and north east part of the state belong to the Oligocene – Pleistocene period, the younger Benin formation Coastal plains sand and the beach ridge complex and alluvial deposits cover the remaining parts of the state.

As an area of subterranean fluid extraction, there is the need for subsidence monitoring so as to minimize the resultant risk. Considering the sensitivity of the Niger Delta ecosystem of which the State is a part, the need for utilization of GIS so as to quantify spatial changes in this dynamic environment cannot be over emphasised[10].

METHODOLOGY

Data on Subsidence Susceptibility Index of the study was used to produce subsidence surface map which was divided into 4 subsidence zones using a Reclass tool of Arcmap's Spatial Analyst extension. Figures 1& 2 show the spatial distribution of the subsidence while Table 2 shows the areal distribution of the zones, From the table it can be seen that Very High zone covers 0.59% while the Marginal zone covers 75.71%. The analysis using water extraction is a good estimate of land subsidence hence serves as a good tool for policy makers to monitor environmental hazards. Areas of special interests could also be monitored. For example, the map shows that areas of High and Very High zones are found in established urban areas of Uyo, Ikot Ekpene and Ikot Abasi. This emphasizes the need for the population growth and the water supply needs of our urban centers to be monitored.

The study utilized water extraction data obtained from Akwa Ibom Water Campany Ltd, and Ministry of Rural Development, to model the subsidence susceptibility surface of the study area. Total quantity of water extracted in the study area was calculated by combining extraction figures that include the annual discharge for all the hand pump boreholes per LGA; annual discharge for all the mini water schemes in the LGA; and, the annual discharge of all the Akwa Ibom Water Company

Ltd head works in each of our urban LGAs. Although Akwa Ibom State is a petroleum oil producing state in the Niger Delta of Nigeria, most of the extraction is done offshore. For this reason, petroleum oil could not be used as the basis to estimate the areas' susceptibility to subsidence. Since the data required for the study have spatial components that can change over time. GIS proved useful in the storage, integration and display of the data.

The data on water extraction was linked to an existing data base of the base map of the study area. To obtain the subsidence susceptibility index, the total water extraction data for each LGA was normalized using the formulae:

$$Dimension\ index = \frac{Actual\ value - \max.value}{Max\ value - \min\ value}$$

The data was then converted into grid using ArcMap 9.1 GIS software with Spatial Analyst

Table 1: Akwa Ibom State Showing Annual Water Discharge Rates

S/N	LGAs	TotalPop.	Total Q(m^3/yr)	SubsidenceIndex
1	Abak	191,752	1,859,675	0.3836
2	Eastern Obolo	24,509	25,550	0.0001
3	Eket	145,549	1,939,975	0.4004
4	Esit Eket	71,267	59,312.5	0.0071
5	Essien Udim	229,423	142,350	0.0244
6	Etim Ekpo	123,590	848,077.5	0.1720
7	Etinan	158,720	1,237,350	0.2534
8	Ibeno	72,880	103,112.5	0.0162
9	Ibesikpo Asutan	152,208	96,725	0.0149
10	Ibiono Ibom	182,264	120,450	0.0198
11	Ika	79,294	66612.5	0.0086
12	Ikono	162,012	229,767.5	0.4334
13	Ikot Abasi	116,543	1,856,025	0.3828
14	Ikot Ekpene	171,433	1,860587.5	0.3838
15	Ini	125,608	73,000	0.0099
16	Itu	140,916	2,606,107.5	0.5397
17	Mbo	118,578	29,252.5	0.007
18	Mkpat Enin	183,459	114,975	0.0187
19	Nsit Atai	78,965	44,803.75	0.0004
20	Nsit Ibom	112,002	802,087.5	0.1624
21	Nsit Ubium	130,071	107,675	0.0172
22	Obot Akara	114,155	97,637.5	0.0151
23	Okobo	122,332	77,562.5	0.0109
24	Onna	199,178	187,062.5	0.0338
25	Oron	98,183	1,795,800	0.3702
26	Oruk Anam	223,276	563,012.5	0.1124
27	Udung Uko	40,813	50,187.5	0.0051
28	Ukanafun	38,622	118,625	0.0195
29	Uruan	140,789	1,513,837.5	0.3113
30	Urueoffong/Oruko	54,150	389,637.5	0.0762
31	Uyo	222,841	4,807,050	0.9999

Source: Compiled from data Supplied by AK-RUWATSAN, Akwa Ibom Water Campany Ltd, Ministry of Rural Development; and, Cross River Basin Development Authority (CRBDA).

Table 2: Akwa Ibom State Showing coverage of subsidence zones

S/N	Subsident Zone	Area (Km²)	%
1.	Very High	40.52	0.59
2.	High	117.65	1.72
3.	Moderate	1501.55	21.97
3.	Marginal	5174.13	75.71
	Total	6833.85	100

Extension. The grid was interpolated with Inverse Distance Weighted (IDW) tool to create an isoline map. IDW is used to create a continuous surface from sampled point values. The method is a deterministic interpolation that assigns values to locations based on the surrounding and on a specified mathematical formulae that determines the smoothness of the resulting surface.. Isoline map that resulted, based on the assumption that the phenomena represented has a continuous distribution and smoothly changes in value in all direction of the plain; was used to show the spatial distribution of water extraction in the study area

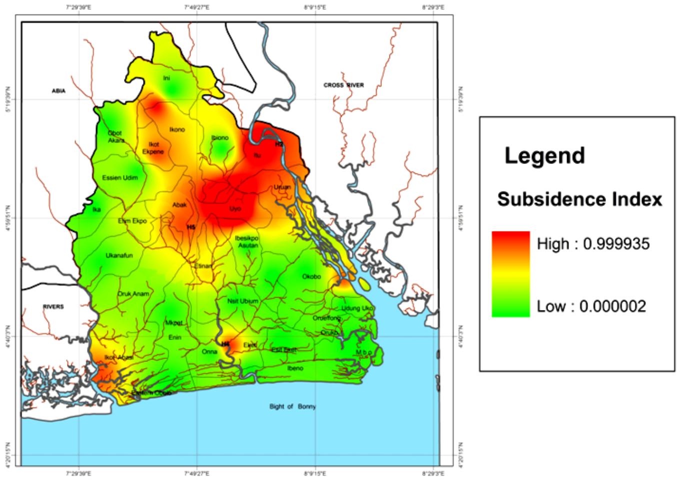

Fig.1 : Subsidence index map of the study area

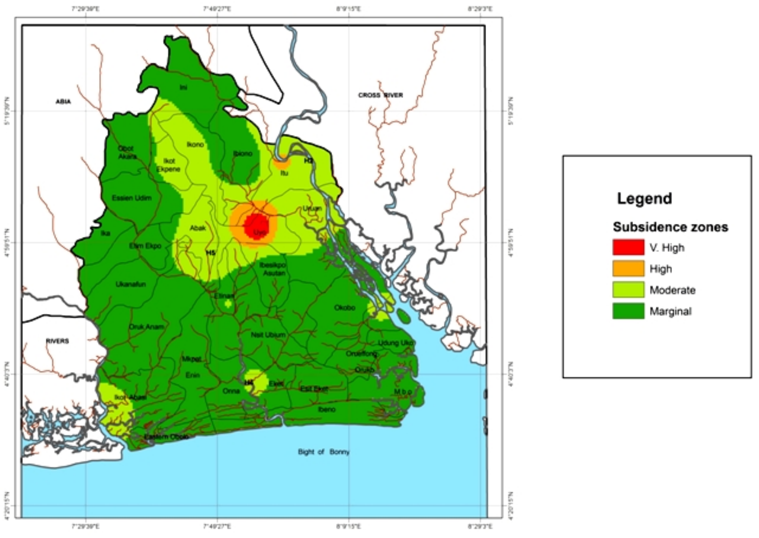

Fig. 2 : Subsidence zones map of the study area

urban areas of Uyo, Ikot Ekpene and Ikot Abasi. This emphasizes the need for the population growth and the water supply needs of our urban centers to be monitored.

DISCUSSION

Data on Subsidence Susceptibility Index of the study was used to produce subsidence surface map which was divided into 4 subsidence zones using a Reclass tool of Arcmap's Spatial Analyst extension. Figures 1& 2 show the spatial distribution of the subsidence while Table 2 shows the areal distribution of the zones, From the table it can be seen that Very High zone covers 0.59% while the Marginal zone covers 75.71%. The analysis using water extraction is a good estimate of land subsidence hence serves as a good tool for policy makers to monitor environmental hazards. Areas of special interests could also be monitored. For example, the map shows that areas of High and Very High zones are found in established urban areas of Uyo, Ikot Ekpene and Ikot Abasi. This emphasizes the need for the population growth and the water supply needs of our urban centers to be monitored.

An analysis of the pattern of population growth, age distribution of the population and trend of urbanization will enable one to understand the implications of the study. The spatial distribution of the population density of the state shows that the state is located in the high population zone of the country. It has an average density of 541 persons/ km^2 based on the 2006 population census. Oron has the most highest density of 2128 persons per km^2 followed by Uyo (1986), Ikot Ekpene (1116), Eket (983), Nsit Ibom (998) and Etinan (928). All other LGAs have densities that are lower than 300 except Uruan (280). The age characteristics of the population to the state show that 60.75 % of the population are below 20 years[11].

This shows that the area has a youthful, dynamic and growing population. It has been observed that urban areas in the state have grown significantly in the last 100 years with Uyo the State capital being the most populous with 118,250 people[12]. The generally high population growth result in the spilling over of urban residents into unplanned urban suburbs . The pressure on urban services and facilities has exceeded the coping capacity resulting in acute shortages of essential services like water, electricity, health, transportation and education.

The analysis of population characteristics, pattern of growth and urbanization show a long term pressure in the underground water reserves, hence land subsidence is a real threat in the study area. The study has demonstrated the use of GIS to visualize the subsidence of the study area. This environment allows for ease of data editing, integration, analysis, and storage. The resultant product will help to identify, and locate sensitive areas that can be impacted by subsidence so that emergency managers can customize disaster relief efforts. Using a GIS for the modeling has enabled a data base to be created hence could be updated as new facts emerge. It is recommended that a subsidence unit should be established within the Akwa Ibom State Water Corporation so that the rate land subsidence could be monitored especially in the vulnerable areas identified in the study.

CONCLUSION

The study has used water discharge figures to model the susceptibility of the study to land subsidence IN A GIS environment. The map produced shows that the Very High and High Subsidence Susceptibility zones are found in the Uyo, Ikot Ekpene Itu and Ikot Abasi and the surrounding areas. Using a GIS for the modeling has enabled a data base to be created which could be updated as new facts emerged.

REFERENCES

1. Putra, D. P. E.. Setianto, A Keokhampui K. and Fukuoka, H., Land Subsidence Risk Assessment Case Study: Rongkop, Gunung Kidul, Yogyakarta – Indonesia, *The 4th AUN/ SEED Net Regional Conference on Geo Disaster Mitigation in ASEAN*, The Royal Paradise Hotel & Spa, Phuket, Thailand, October 25 26, (2011).
2. Devin, G. Jones, D and Ingebritsen, S. E., Land Subsidence in the United States , *U.S.*

Geological Survey Circular 1182, (1999).

3. Prokopovich, N. P. Detection of Aquifers Susceptibility to Land Subsidence, *Land Subsidence* (Proceedings of the Fourth International Symposium on Land Subsidence). IAHS Publ.: 200; 3333 Braeburn Street, Sacramento, CA 95821, U.S.A, (1991).
4. UNEP , *T*he *Bangkok* City *State of the Environment*, Thailand, (2001)*.*
5. Waller, R. M., Ground Water and the Rural Homeowner, U.S. Department of the Interior / U.S. Geological Survey, (1994).
6. Galloway, D. L., K. W. Hudnut, S. E. Ingebritsen, S. P. Phillips, G. Peltzer, F. Rogez and P. A. Rosen, Detection of Aquifer System Compaction and Land Subsidence Using Interferometric Synthetic Aperture Radar, Antelope Valley, Mojave Desert, California, *Water Resources Research*, **34**(10), 2573-2585 (1998). http://dx.doi.org/10.1029/98WR01285
7. Balogun , W. O. B., M. A. Anifowose, M. A. Shogo, F. A. Salaudeen, Trends And Mechanisms Of Land Subsidence Of A Coastal Plain In The Delta Of Yangtze River-China, *Researcher,* (3), 76-81, (2011) .
8. Mine Subsidence Board, Graduated Guidelines for Residential Construction (New South Wales),**1**: Historical and Technical Background, NSW, Australia, (2000).
9. Usoro, E. J., Geology, In: P Akpan and Usoro E Ed., *Akwa Ibom State: Geographical Perspective*, Department of Geography Publications, Uyo, 23-34, (2010).
10. Ogba, C. O. and B. P. Utang, Geospatial Evaluation of Niger Delta Coastal Susceptibility to Climate Change, FIG Congress Sydney, Australia, 11-16 April 2010. PMid:20453883 PMCid:PMC2892028
11. Inyang, I. B., Population and Settlement, In: P. Akpan and E. Usoro, Ed., *Akwa Ibom State: Geographical Perspective*, Department of Geography Publications, *Uyo,* 179 -190, (2010)**.**
12. Akpan, P. A., Urban Settlement, In: P. Akpan and E. Usoro, Ed., *Akwa Ibom State: Geographical Perspective*, Department of Geography Publications, *Uyo*, 191-202, (2010).