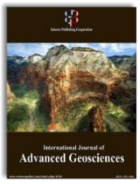
International Journal of Advanced Geosciences, 11 (1) (2023) 8-13

International Journal of Advanced Geosciences

Website: www.sciencepubco.com/index.php/IJAG

Research paper



Radar (sentinel 1 data)-based flood mapping in Rivers State, Nigeria

Emmanuel M. Menegbo [1] *, Ebele J. Emengini [1]

[1] *Department of Surveying and Geoinformatics, Nnamdi Azikiwe University, Awka, Nigeria*
**Corresponding author E-mail: em.menegbo@stu.unizik.edu.ng*

Abstract

The existence of floods in Nigeria, a notable environmental issue, is primarily linked to human-induced causes. These are largely linked to global warming causing shifts in climate patterns. Flooding is not always a direct result of preceding factors like heavy rain or dam overflow. Instead, it is frequently triggered by human actions such as overloading main rivers or inappropriate land use. The purpose of this study was to pinpoint areas prone to flooding in Rivers State. The main goals included the development of a spatial map depicting areas susceptible to floods. The research leverages multiple data sources, Shuttle Radar Topography Mission Digital Elevation and Rivers State Administrative Map, as well as Sentinel-1 SAR data. Assessment of potential surface runoff and identifying low probability flood-prone areas was conducted through Change Detection method on Google Earth Engine platform. ArcGIS and QGIS played a significant role in assessing the vulnerability to flood risks. The primary analyses conducted involved overlaps analysis. The study shows a vulnerability to flooding in Rivers State across a total area of 29,660 hectares, equating to 2.75% of the state's total size. This research provides important information that can aid decision-making processes in disaster preparedness, land use planning, and the implementation of effective risk reduction measures in Rivers State, and Nigeria at large. We strongly endorse the creation of Geospatial Information Systems to record the documentation of flood zones.

Keywords: *Flood Mapping; Google Engine; Land Extent Assessment; Radar, Rivers State.*

1. Introduction

Currently, the world is grappling with multiple environmental challenges, including fires, earthquakes, landslides, hurricanes, and floods. This scenario underscores the urgent need for an effective disaster response program that includes a geospatial approach (GAF, 1999). It's important to note, especially when discussing open climate risks, that floods are the most frequent disaster in the country. The sudden and deadly impact of these events can't be overlooked (Bhatta, 2011). Such catastrophes lead to substantial financial loss due to property destruction and infrastructure breakdown, not to mention the loss of lives (GAF, 1999). Drawing on GAF's research (1999), floods can result from sudden heavy rain, swift snowmelt or high tides, and they often coincide with severe weather patterns, like violent windstorms or tornadoes. The first step in managing these hazards should be to assess the risks they pose. This will inform the development of the most appropriate and effective response strategies (WHO, 2013). Understanding the potential risks is crucial in order to develop an effective plan. Like many other countries globally, Nigeria has experienced the destructive impacts of flooding disasters.

According to GAF (1999), the most devastating flood on record took place in Bangladesh in In 1988, a disaster occurred that had a direct effect on 25 million individuals. Furthermore, China underwent significant flooding twice, in the years 1991 and 1998, impacting an additional 200 million people (GAF, 1999). Such catastrophic flooding was not limited to China; several places around the world, including Nicaragua in Latin America, the Midwest region of the United States, Italy, and Germany in Europe, were also severely affected. In Nigeria, floods are a common occurrence, primarily due to River Niger and sudden heavy rainfalls. The probability of such events is amplified because of factors such as unsuitable land use, land erosion, deforestation, and deficient drainage configurations.

Recurring floods are a major issue in Nigeria, often resulting in catastrophic consequences for its residents. According to Oladokun and Proverbs (2016), it was reported that in 2001, floods caused the displacement of 5000 people in the states of Abia, Adamawa, and Akwa Ibom. In a similar fashion in 2005, flooding led to the displacement of 50,000 residents in the Taraba and Benue states. Furthermore, over 12,250 individuals were forced to evacuate their homes in 2008. Tragically, 2012 saw one of the most devastating floods in Nigerian history, causing the death of 39 individuals. Additionally, 200 homes were submerged and 3000 residents were displaced in all states along River Niger and Benue (Oladokun and Proverbs, 2016).

The research aims to assess the potential of Radar Technology in detecting flood occurrences in areas traditionally known as dry lands. This is made feasible through the collection and interpretation of Synthetic Aperture Radar (SAR) satellite images, including land cover data. A remarkable characteristic of SAR data is its weather and time-independence, an essential attribute for effective flood monitoring. The efficiency of SAR is further evidenced by its ability to detect linear water bodies. Such surfaces might act as 'blank slates' as they fail to reflect any signals back to the antenna within the microwave spectrum, leading to a profound black representation in SAR imagery. However, despite the noted effectiveness of SAR data, its precision could be compromised in heavily populated regions due to an increased volume of 'pingbacks' from man-made structures and various objects. Consequently, this might have implications on its accuracy.

By making use of the data obtained through remote sensing, we can obtain vital insights that are essential for precise assessment of flood risk and the potential for damage. Risk evaluation studies hinge on tools which model data derived from various sources. These include meteorology, topography, soil type, land cover, terrain, and catchment areas. Notably, the assessment of flood damage relies chiefly on merging images from different time periods with maps classified by land use, digital elevation models, and historical maps. The employment of remote sensing technologies enhances the precise tracking and measuring of flooded regions. This paves the way for efficient strategizing of relief operations and gives dependable estimates of the land area and infrastructure affected (Bhatta, 2011). The integration of data remotely sensed into a Geographic Information System (GIS) facilitates swift calculations of damage to urban and rural structures. Further, it supplies crucial knowledge about the impacted areas.

This research uses a machine-learning approach for raster analysis of Sentinel-1 SAR images on the Google Cloud Platform. The goal is to recognize flooded areas. To realize this, a method for detecting changes (between two specific dates) is carried out to create a 'flood magnitude' map. The entire process is conducted within a GIS data visualization environment.

1.1. Flooding in rivers state

The persistence of floods as a natural disaster is often experienced across a vast majority of regions in Nigeria, especially in Rivers State. It experiences significant impact during the rainy season. Research has highlighted the correlation between this increasing occurrence and changes in climate. However, the severity of floods due to rainfall can be mitigated through proper urban planning and enacting appropriate legislations. Presently, these measures are not being employed comprehensively in either Rivers State or Nigeria at large. The most devastating flood incident in Rivers State occurred in 2012, largely as a result of poorly managing dam outflows. Given its low-lying terrain and abundance of rivers, Rivers State is typically hit hardest by severe flooding.

In 2019, River State experienced severe rainfall that caused the River Niger to overflow, resulting in widespread flooding. The local economy, homes, and crops suffered substantial damage. The unmanaged risks of flooding have profound negative effects on socio-economic stability, health, and environmental sustainability. These issues obstruct the path toward achieving sustainable development goals. The leading culprits of flooding in River States include: Poor Drainage Systems: Drainage networks inadequately divert water to natural channels. Rapid Urbanization: The increase in constructed areas decreases the water absorption rate, leading to increased runoff. Unmanaged Waste Disposal: Improper waste disposal and management also contribute to the problem. Shoddy attitudes towards waste disposal among citizens can block drains, resulting in floods. Inappropriate Land Use: Constructing buildings on waterways in urban areas also compound the flooding situation.

SAR technology significantly benefits from its ability to penetrate dense cloud formations, thereby ensuring the delivery of current and relevant information even during harsh weather conditions. The procurement of accurate data helps decision-makers and communities affected by these disasters to meticulously plan for upcoming flooding incidents.

1.2. Nigeria disaster management

The United Nations International Strategy for Disaster Reduction (UNISDR, 2009) has classified a disaster as a severe disruption causing substantial damage to a community or society. It results in extensive loss and impacts which surpass the capability of the affected community to mitigate using its own resources, affecting the human, material, or environmental elements. In the context of Nigeria, the coordination of Disaster Management is not in isolation. It involves multiple stakeholders, primarily the Nigerian Military Agencies which constitute the police, army, among others. Also in the fray is the National Emergency Management Agency (NEMA), established first in 1976 under the name National Emergency Relief Agency (NERA). It underwent amendments in Decree No. 12 of 1999 & Act No. 50 of 1999. NEMA plays a crucial role in managing and coordinating emergency and disaster-related operations, working in consonance with other concerned stakeholder

In 2019, an executive order by the President led to the establishment of the Federal Ministry of Humanitarian Affairs, Disaster Management and Social Development. This entity has been tasked with various responsibilities, such as the design and implementation of humanitarian policies, overseeing national and international humanitarian efforts, implementing disaster prevention strategies, executing appropriate disaster response, and creating and rolling out targeted social protection and inclusion programs across Nigeria. However, the ability of NEMA to adequately respond during crises has fallen below expectations.

Furthermore, it has been conveyed by the National Emergency Management Authority (NEMA) that 22 Nigerian states have setup their respective State Emergency Management Agencies (SEMAs). This creation aims to streamline the management of local emergencies. However, it is worthy of note that Rivers State does not fall within this group. NEMA brings together the efforts of federal agencies, military personnel, international and local bodies, and Non-Governmental Organizations (NGOs), fostering a synergy aimed at creating well-structured emergency procedures nationwide. SEMAs on the other hand, are tasked with organizing the management of urgent incidents within their states. The provision of forecasts for weather, seasonal and annual rainfall, as well as surface water information in space-time, is primarily handled by the Nigerian Meteorological Agency (NIMET) and Nigeria Hydrological Services Agency (NIHSA). These agencies, through proactive risk monitoring, can notify the National Agency for Emergency Management and other pertinent stakeholders about possible crises in their early stages.

2. Study area

Rivers State, established on 27th May 1967 under the regime of General Gowon, has Port Harcourt as its administrative center and spans.

Fig. 1: Map of Africa with location of Nigeria

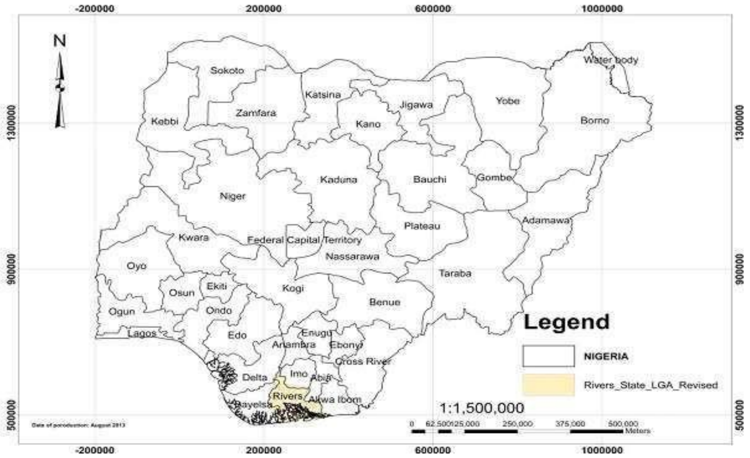


Fig. 2: Map of Nigeria with Location of Rivers State.

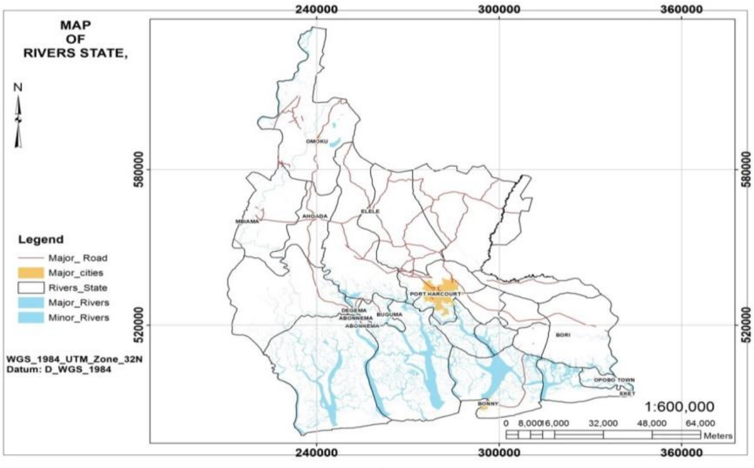


Fig. 3: Map of Rivers State.

Over 23 Local Government Areas. Its geographical coordinates range from 210590.00m to 344490.00m on the northings, and 477432.00m to 634925.00m on the eastings, relative to UTM Zone 32N origin (Refer Figure 3). Geographically, Rivers State shares its perimeters with the Atlantic Ocean towards the south, Imo, Abia, and Anambra states to the north, Akwa Ibom state to the east, and Bayelsa and Delta states to the west. The state is noted for its diverse ethnicities, which include the Abua, Andoni, Ekpeye, Engenni, Etche, Ibali, IKwerre, Kalabari, Ogba/Egbema/Ndoni, Okrika, and Ogoni. The landscape undergoes a noticeable shift towards the coastal regions, characterized by the prevalent mangrove swamps, a distinctive feature of the Niger Delta.

In 2006, the National Population Commission (NPC, 2006) estimated Rivers State's population to be 5,198,716. This figure accounted for 3.7% of Nigeria's entire population, with a density of 468 people per square kilometer. The state, predominantly covered by tropical rainforest, is one of Nigeria's most populous regions. Significantly, the majority of Rivers State's populace resides in the city of Port Harcourt. Urban planners often refer to it as a 'one-city state'. The remaining population is scattered across various Local Government Areas (LGAs), suburbs, towns, and villages, influenced by specific ecological and physical conditions. The 2006 census data indicate that the population is dense in urban areas and sparse, especially in the riverine villages of Rivers State.Rivers State experiences a rainy season that typically lasts from March to October, reaching its peak in June and July. Despite a relatively short dry season from November to April, rainfall is common throughout this period. The state's climate is inherently warm with average temperatures ranging from 25°C

(77°F) to 28°C (82°F). High levels of relative humidity are a characteristic feature of the wet season, which slightly drop during the dry months (Eludoyin et al, 2011). The state is characterized by a predominantly tropical rainforest and mangrove landscape, particularly in the coastal zones. Meanwhile, the upland zones are largely populated with oil palm trees, giving them the term 'oil palm forest'. The riverine zones showcase diverse hydro-vegetation such as palms and low shrubs among beach ridge areas and sandy low ridges. The region between the beach ridge and saltwater areas is particularly known for its mangrove vegetation, which tends to cover most of the saltwater areas.All paragraphs must be justified alignment. With justified alignment, both sides of the paragraph are straight.

3. Methodology

3.1. Basic principles

The Electromagnetic Spectrum: Optical Sensors: These sensors function by measuring reflected solar light. However, their functioning is restricted to daylight conditions. In conditions like cloud cover, visible or infrared sensors fail to image the Earth's surface. Microwaves: Microwaves, on the other hand, have the ability to penetrate through clouds and vegetation. These sensors are versatile as they have the capability to operate in both day and night conditions. Active Sensors: Active sensors have a unique feature where they create an artificial radiant energy source for illuminating radar, synthetic aperture radar (SAR), and Radar. These sensors offer nearly all-weather capability. They have minimal atmospheric effects and can penetrate through the vegetation canopy and soil. Other important characteristics of active sensors include the sensitivity to dielectric properties like liquid vs. frozen water and structure sensitivity. Radar Measurements: Radars function by measuring the amplitude, which refers to the strength of the reflected echo, and the phase, which is a term for the position of a point in time on a waveform cycle. It's important to note that radars can only measure the portion of the echo that is reflected back towards the antenna, a feature that is also referred to as "backscatter".

The propagation rate of radar pulses is equivalent to the speed of light. The backscattering coefficient, also known as sigma naught, denotes the potency of the reflected echo, quantified in decibels (dB). Key RADAR components factored into this analysis comprise: Wavelength - Pointing towards the wavelengths predominantly utilized in Synthetic Aperture Radar (SAR). Polarization - This discriminates the polarized condition of the radar signal, the polarizations are usually controlled between H and V:

- HH: Horizontal Transmit, Horizontal Receive
- HV: Horizontal Transmit, Vertical Receive
- VH: Vertical Transmit, Horizontal Receive
- VV: Vertical Transmit, Vertical Receive

Quad-Pol Mode: This mode is activated when all four polarization levels are measured. This aids in identifying the physical properties of the observed object by using various polarizations. Local Incidence Angle: This refers to the angle formed between the direction of the radar's illumination and the plane of the Earth's surface. The brightness of an image is influenced by this angle which depends on the sensor's altitude and the image's geometric aspects. It is crucial to note that this angle varies across different points in the range direction. The reflection of the radar signal off the Earth's surface encapsulates vital data about the observed surface. This reflected information is also known as radar backscatter.

3.2. Geospatial concepts

This process is responsible for determining the area and percentage of coverage whereby the features of a certain input layer are overlapped by features from a couple of selected overlap layers. With the use of this algorithm, fresh attributes are incorporated into the resulting layer stating the aggregate area of overlap and percentage of the input feature being overlapped by every individual overlay layer chosen.

3.3. Methods

This process presents an automated method for identifying variations using Sentinel-1 Ground Range Detected (GRD) data in Google Engine. It employs a Deep Convolutional Neural Network (CNN) model to amalgamate Synthetic Aperture Radar (SAR) intensity and Interferometric Synthetic Aperture Radar (InSAR) coherence, with the goal of examining settlement flood mapping.

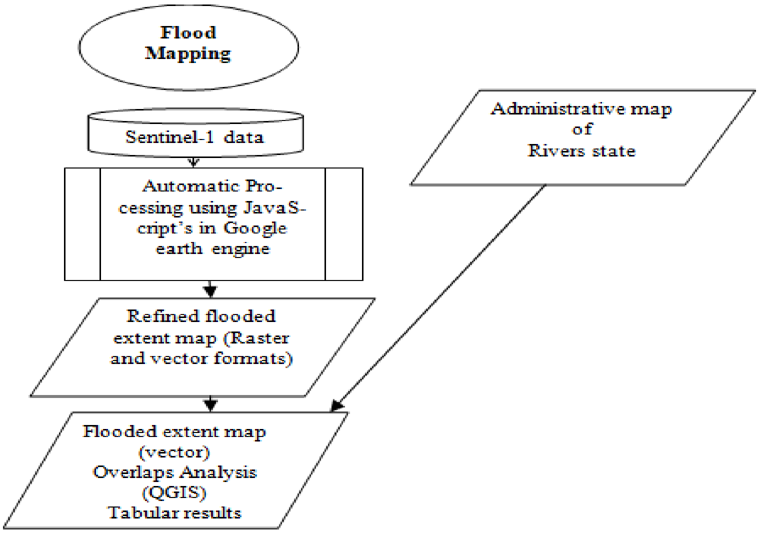


Fig. 4: Methodology Workflo.

A comprehensive framework utilizing Advanced Self-Learning Deep Convolutional Neural Network (A-SL CNN) was implemented. This framework incorporated multi-temporal intensity and coherence to accurately categorize exposed floodwater spaces and inundated built-up areas in urban locations. Tools like Quantum GIS and ArcGIS were employed to scrutinize a disaster map data. This integration was crucial in gaining a comprehensive understanding of the situation. Leveraging on the interoperability function of ArcGIS 10.3, from the Ministry of Lands and Surveys' digital dwg files, which included current roads, and administrative information, were transformed into an ESRI shape file format. This transformation allowed the data to align with the study area. The digital roads dataset that stemmed from this process was later converted into a network dataset. Next, a code editor script was utilized to access Google Earth Engine, guaranteeing precision and dependability. Following this, a Shapefile (.shp) was created to showing the exact spatial extents, which facilitated achieving the highest level of accuracy.

4. Results and findings

Several research initiatives have leveraged the power of geo-informatics to collect essential data on flood vulnerability. This information is inclusive of the flood's range and the geographic distribution of the impacted populace.

Upon an exhaustive analysis and diverse investigations, the studies yielded substantial findings. According to the study' outcomes, a total of 29,660 hectares (see Figure 5), or a representation of 2.75 percent of Rivers State's total area, felt the effects of flooding. Among all the local government regions, Ogba/Egbema/Ndoni LGA was the most impacted, with the flood covering an area of 5,958 hectares (see Table 1). This makes up 6.02 percent of the total size of the LGA. Conversely, Gokana Local Government Area marked the lowest influence, only being flooded across 1.075 hectares, which amounts to just 0.01 percent of the LGA's spatial extent.

Table 1: Flooded Area and Percentage of Lgas

Name of LGA	flooded Extent(m^2)	flooded__Percentage
AHOADA WEST	39858889.71	6.94
EMOHUA	6384052.42	0.75
IKWERRE	21655222.21	3.11
ABUA/ ODUAL	2260386.56	0.25
AHOADA EAST	10430789.21	3.27
OMUMA	668217.33	0.40
AKUKU-TORU	16728171.11	1.33
DEGEMA	53875274.98	5.12
ASARI-TORU	4217008.29	3.71
BONNY	1843269.46	0.28
OKRIKA	616873.38	0.33
OBIO/AKPOR	23943507.80	8.61
PORT HARCOURT	10115076.74	9.27
ELEME	1720347.07	1.15
KHANA	4661977.26	0.77
TAI	2799235.66	1.90
GOKANA	10753.91	0.01
ANDONI	289091.70	0.11
OPOBO/ NKORO	170761.30	0.20
OGBA/ EGBEMA/ NDONI	59582435.20	6.20
ETCHE	32576637.66	3.73
OYIGBO	2051351.60	0.83
OGU/ BOLO	465116.98	0.41

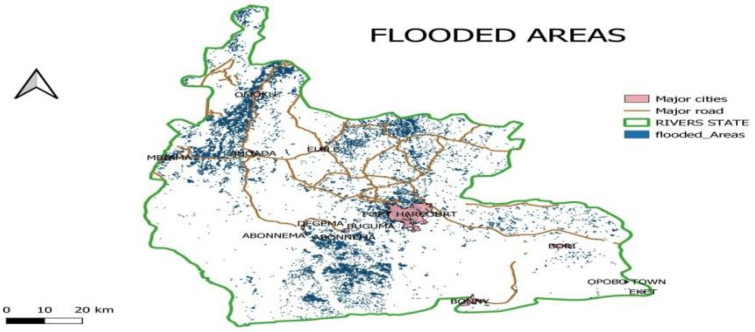


Fig. 5: Map of Rivers State with Flooded Areas.

5. Conclusion

This study centered on an exhaustive examination of regions vulnerable to flooding, and carried out a meticulous evaluation of their susceptibility in Rivers State, Nigeria. During this inquiry, various significant subjects came to light. Understanding the parameters of floods is vital for damage appraisal and risk management. It aids in constructing scenarios which underscore populations, economic endeavors, and environmental components at risk of potential flood-related dangers. The conclusions derived from the analyses completed in this study emphasize the extraordinary potential of Geospatial technology. They illustrate its effectiveness in accurately mapping flood vulnerability in Rivers State, and by extension, Nigeria.

Acknowledgement

Special words of thanks go to Engr. Edward K. Menegbo for his invaluable support. My supervisor, Prof. E. J. Emengini, deserves a distinctive acknowledgement. Her wealth of knowledge has enormously enhanced the quality of this dissertation.

References

[1] Bhatta B. (2011). Remote sensing and GIS (Second Edition ed.). New delhi: Oxford University Press.

[2] Eludoyin O.S. Wokocha C.C. and Ayolagha G. (2011). GIS Assessment of Land Use and Land Cover Changes in Obio/Akpor L.G.A., Rivers State, Nigeria. Research Journal of Environmental and Earth Sciences, 3(4), 307-313. Retrieved May 21, 2021, from http://maxwellsci.com/print/rjees/v3-307- 313.pdf.

[3] GAF (1999). ENVIRONMENTAL PLANNING. Earth Observations Education and Training GAF for decision makers.

[4] Guo, H., Cao, K., & Wang, P. (2017). Population estimation in singapore based on remote sensing and open data. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XLII-2/W7, 1181–1187. https://doi.org/10.5194/isprs-archives-XLII-2-W7-1181-2017.

[5] Mossoux, S., Kervyn, M., Soulé, H., & Canters, F. (2018). Mapping population distribution from high resolution remotely sensed imagery in a data poor setting. Remote Sensing, 10(9), 1409. https://doi.org/10.3390/rs10091409.

[6] Oladokun V.O. and Proverbs D. (2016). flood risk management in Nigeria: A Review of the challenges and opportunities. Int. J. of Safety and Security Eng., Vol. 6, No. 3 (2016) 485–497. https://doi.org/10.2495/SAFE-V6-N3-485-497.

[7] WHO (2013): Floods in the WHO European Region: health effects and their prevention. WHO Regional Office for Europe, Copenhagen. Pp. 6-38

[8] Wu, C., & Murray, A. T. (2007). Population estimation using landsat enhanced thematic mapper imagery. Geographical Analysis, 39(1), 26–43. https://doi.org/10.1111/j.1538-4632.2006.00694.x.

[9] UN (2021). 68% of the world population projected to live in urban areas by 2050, says UN | UN DESA | United Nations Department of Economic and Social Affairs. (n.d.). Retrieved November 23, 2021, from https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html

[10] UNISDR (2009). UNISDR terminology on disaster risk reduction. Geneva: UNISDR. 30,http://www.preventionweb.net/files/7817_UNISDRTerminologyEnglish.pdf Date of access: 8 Sep. 2021.

[11] Zhan, F. B., Tapia Silva, F. O., & Santillana, M. (2010). Estimating small-area population growth using geographic-knowledge-guided cellular automata. International Journal of Remote Sensing, 31(21), 5689–5707. https://doi.org/10.1080/01431161.2010.496802.