Quantification and Risk Assessment of the 2008 Ogoniland Oil Spill

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Summary

Persistent oil spills in the Niger Delta has led to severe environmental degradation with consequent human risk exposure. The 2008 Ogoniland oil spill remains a contentious issue because of the large volume of spilt over its spatial extent and impact. Here we derived Normalised Difference Vegetation Indices for Landsat images pre and post spill and correlate areas greatest change with UNEP's detailed measurement of pollutants in soil and water. Analysis revealed a significant spill footprint and high levels of correlation with pollutants measurements in surface water.

KEY WORDS: Oil Spills, NDVI, Spatial Impact, Risk Assessment, Exposure.

1. Introduction

The Niger Delta has witnessed significant oil spills with an estimated 50 million barrels having been spilled in the region over the last 50 years, leading to the destruction of the environment, lives and properties (Kadafa, 2012). Several factors have been identified as the root causes of oil spills in the region including sabotage, operational failures and other causes largely unknown (Obida et al., 2018). Due the number of oil spills in the region it has been described as one of the most polluted regions of the world. The oil spills have led to significant environmental degradation, which has greatly reduced ecosystems services (Opukri and Ibaba, 2008) including the fisheries and agriculture which constitute the major sources of livelihood of the region.

In November 2008, one particular spill caught regional and global attention, due the volume of oil released into the contiguous environment of Ogoniland from a 24-inch Trans Niger Delta pipeline (Fentiman and Zabbey, 2015). An estimated 250,000 barrels were spilled over a 72 day period before it was finally stopped (UNEP, 2014). This incident led to the complete destruction of the Ogoniland region and led to continuous litigation between the operators Shell and the local communities. A relatively recent landmark ruling by a British court in London in favour of the community led to a compensation payment of 55 million dollars (The Guardian, 2015). However, since the incident efforts to quantify the magnitude and extent of the impact have been largely limited. Both global and regional organizations such as UNEP and Amnesty International have conducted field-based studies to ascertain the extent of the pollution in terms of concentration of pollutants at certain locations (UNEP, 2011). However, the spatial extent and consequent health and environmental risk has not been investigated.

This study aims to quantify the spatial extent of the spill impact and examine its relationship with UNEP's detailed concentration measurements at selected locations. This will potentially provide inference on unmeasured locations. It will then use measured and inferred pollutant concentration values in a specialist environmental and human risk exposure model (RISC5) to determine the risk in the region as a whole. Therefore, the aims of this study are to a) determine the spatial extent of the 2008

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Ogoniland spills. b) examine the relationship between UNEP's measured concentration values and the spill footprint c) to quantify putative human and environmental risk using the RISC5 model.

2. Materials and Methods

Multi-temporal Landsat data was used to determine the potential spatial extent of the Ogoniland spill (Veloso et al., 2017). Images were selected to represent pre-spill (1986) and post-spill (2015) environmental conditions. Choice of imagery was restricted to some extent by persistent cloud cover and the scan line errors that affected Landsat 7 in 2003. Following atmospheric correction, Normalised Difference Vegetation Index (NDVI) were calculated for both time periods (Martínez and Gilabert, 2009). NDVI potentially shows the health and vigour of vegetation, thus can be used to infer the health of vegetation and potential spill impact in the delta region. Pre-spill NDVI (1986) and post-spill NDVI (2015) were manipulated to determine the oil spill footprint. Soil, water and sediment samples taken by UNEP in 2011 were then used with spill footprint as point of inference, since the measurements did not cover the entire Ogoniland

Spatial correlations were employed between delineated spill impacted areas and UNEPS's measurements of various pollutants concentration in soils and surface water of the study area (Álvarez-Cabria et al., 2016). Graduated symbols were used to visualize measured data with the footprint of Ogoniland spill. Risk assessment is currently being undertaken using RISC5 model to determine human and environmental exposure to key pollutants (PAHs, VOCs, BTEX).

3. Results

3.1. Mapping oil spill impact

Figures 1a and 1b show the pre and post-spill NDVI values in the study area. Figure 1b indicates a significant reduction in NDVI values in the area after spill. This could be considered an indication of the oil spill impact. The figure also shows spatial correlation between areas of NDVI reduction and the location of the pipeline break. Figure 2 presents a clearer spatial extent of oil spill impact. The figure, which shows the difference between the pre and post spill NDVI values, shows there is a significant reduction in NDVI downstream of the spill location. The greatest reduction in NDVI occurs close to the location of the spill.

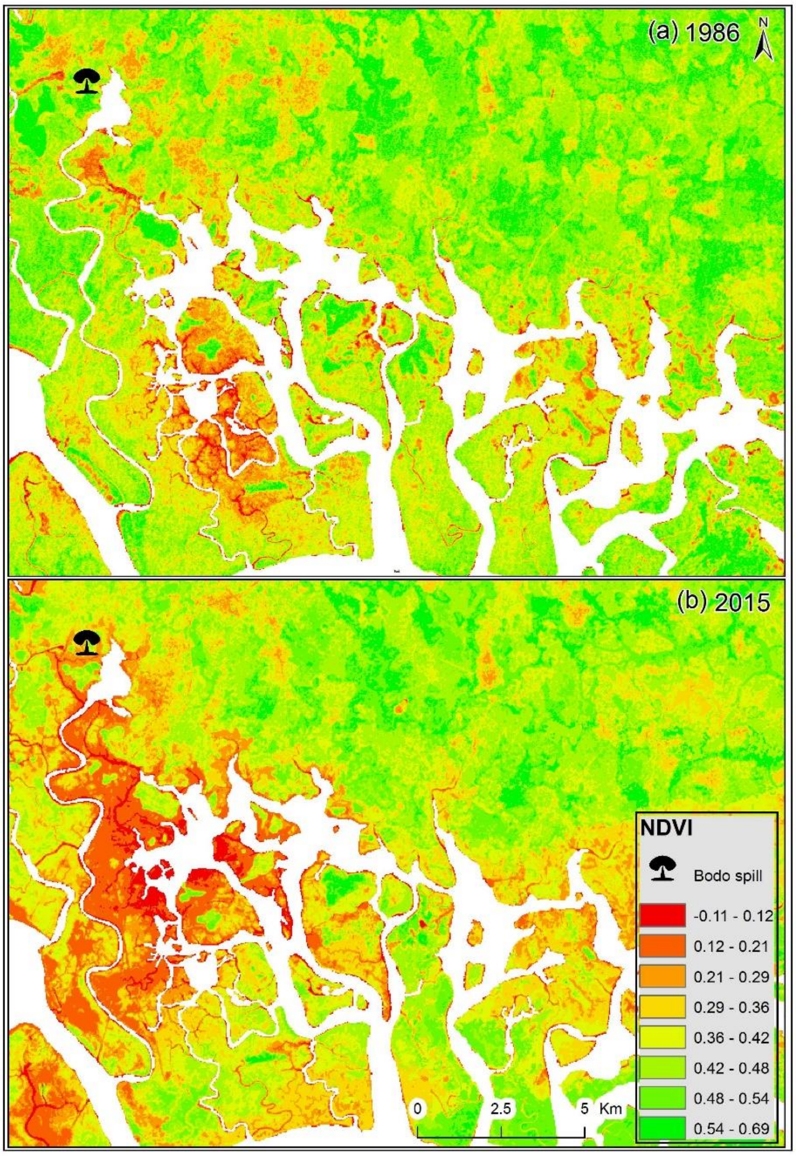

Figure 1(a) Pre-spill and (b) post-spill (2015) NDVI of spill location showing significant reduction in NDVI values and potential impact. Areas in white indicate the creek system in the deltaic environment.

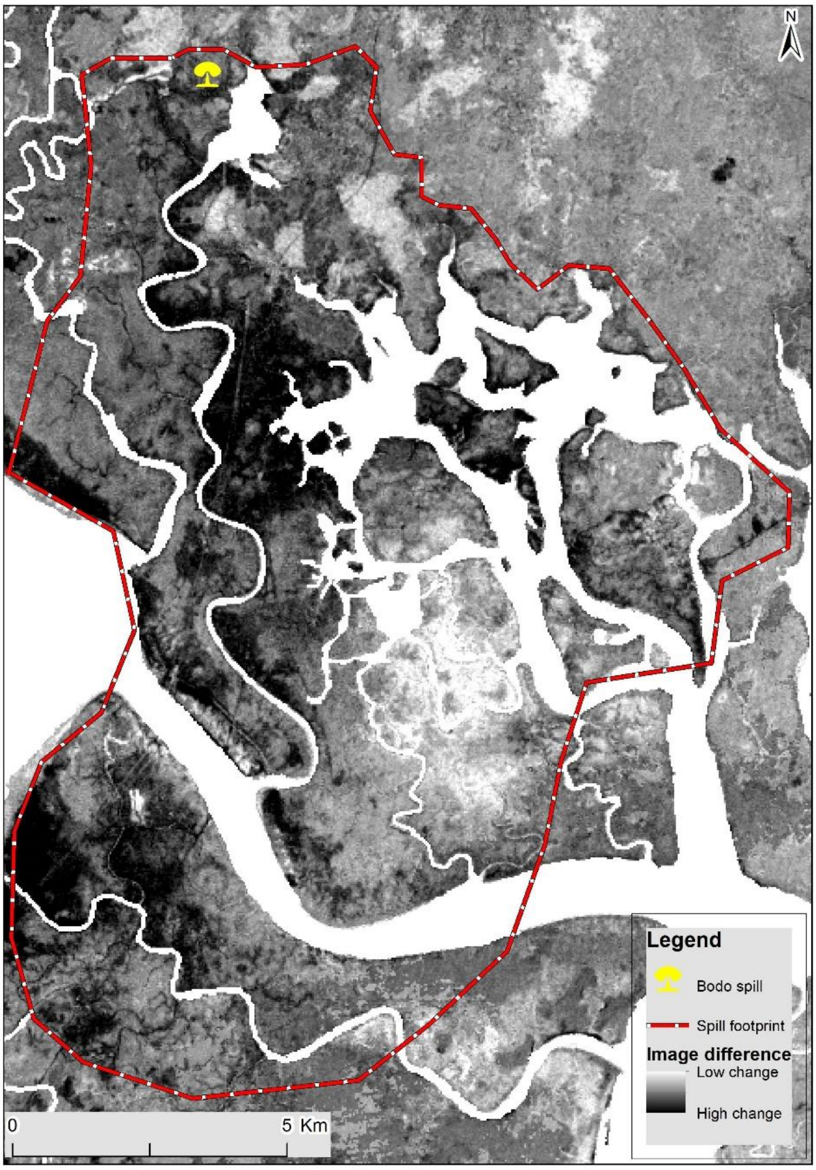

Figure 2 NDVI image difference between pre-spill image (1986) and post spill image (2015) with darker areas indicating areas of significant NDVI reduction.

3.2. Spatial relationship between oil spill footprint and measured pollutant concentration in soils and surface water

Figure 3 shows the spatial correlation between the oil spill impact footprint and measured concentrations of total petroleum hydrocarbon (TPH) in the soil. The figure indicates that areas of high TPH concentrations occur closer to the spill location, however, the figure also reaveals that the correlation is not perfect as there are areas north of the spill location with relatively high TPH values, possibly indicating the impact of other spills before or after the 2008 Ogoni spill disaster.

Figure 4 shows the concentrations of total aromatic hydrocarbons in surface water relative to the location of the spill. Areas of high concentration do show the expected spatial pattern downstream of the location of the spill. This pattern can be explained by the hydrophobic nature of oil which has travelled downstream, stciking to mangroves and sediments thus increasing concentrations in water.

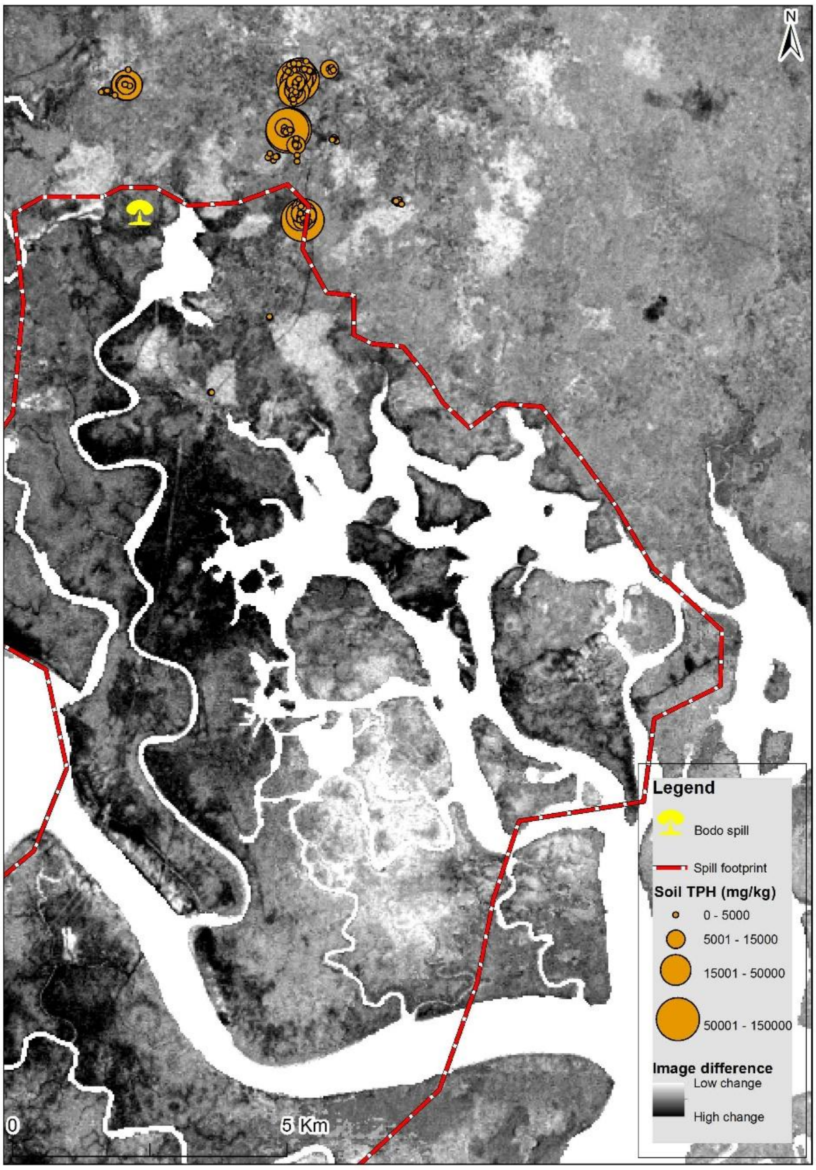

Figure 3 Total Petroleum Hydrocarbon pollutant concentration measurements and spatial relationship with NDVI difference image.

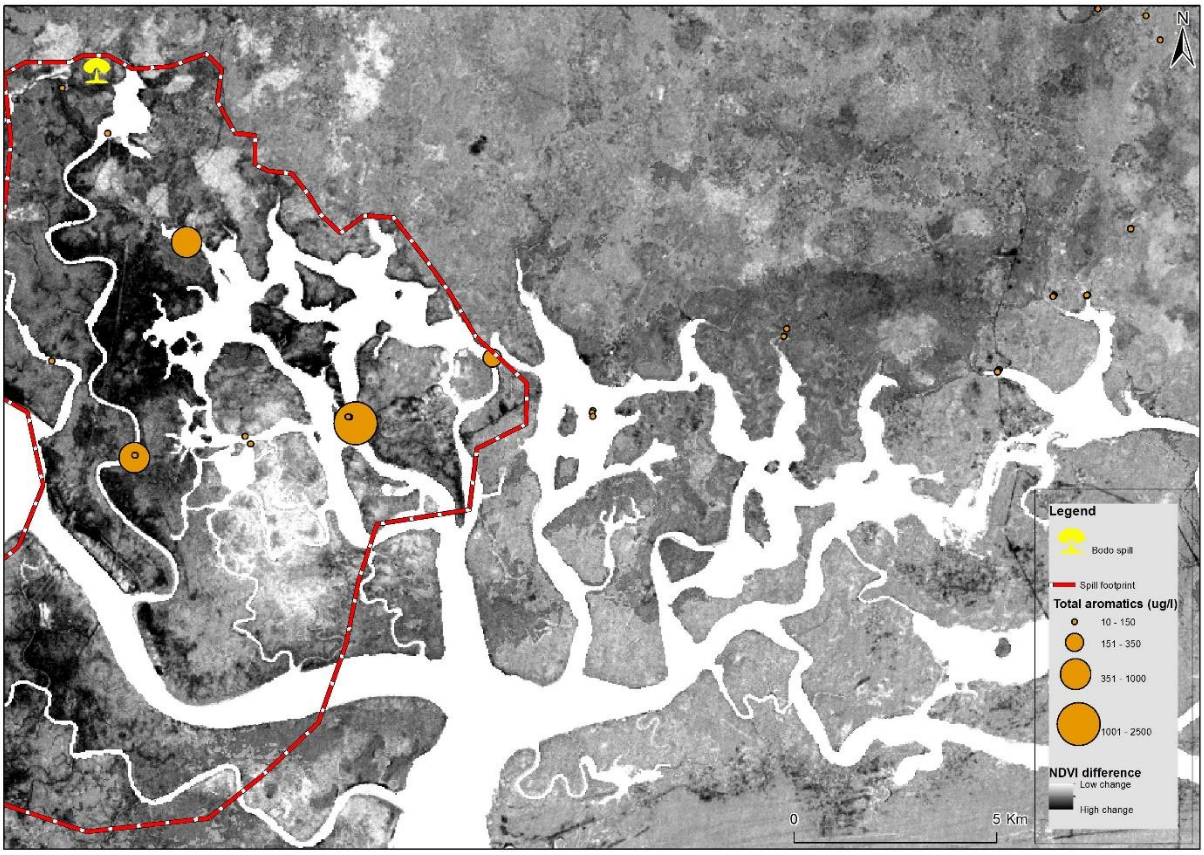

Figure 4 Total Aromatic pollutant concentrations in surface water and spatial relationship with NDVI image difference.

4. Conclusion

This study has substantiated the claims that the 2008 Ogoniland spill had a devastating impact on the environment. Pre and post-spill Landsat images were used to delineate and map the potential impact of the spill. The comparison revealed that the oil spill potentially had strong impact, especially on the contiguous creek systems along the river channels, smothering vegetation, potentially affecting the biotic components, and potentially exposing the population to toxic food (fish) and polluted drinking water.

The study shows that while the pollutant concentration in soils does not correlate strongly to spill location, concentrations in surface waters do give an indication of pollutant transportation and deposition in the creek systems. Inference from delineated spill footprint and measured concentration of pollutants will be used in RISC5 model for precise human and environmental risk exposure analysis. This is due to not sufficient and biased sampling caused by problems of accessibility in the UNEP data. Remote sensing and spatial correlation therefore serves as a good alternative in the absence of data to be fed into RISC5 model.

Biography

Christopher Obida is an early career researcher, and a final year Ph.D. student at Lancaster University with research interest in geospatial data applications in decision support.

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References

Álvarez-Cabria, M., Barquín, J. and Peñas, F.J. (2016), "Modelling the spatial and seasonal variability of water quality for entire river networks: Relationships with natural and anthropogenic factors", *Science of the Total Environment*, Elsevier B.V., Vol. 545–546, pp. 152–162.

Fentiman, A. and Zabbey, N. (2015), "Environmental degradation and cultural erosion in Ogoniland: A case study of the oil spills in Bodo", *The Extractive Industries and Society*, Vol. 2 No. 4, pp. 615–624.

Kadafa, A.A. (2012), "Oil Exploration and Spillage in the Niger Delta of Nigeria", Vol. 2 No. 2, pp. 2222–2863.

Martínez, B. and Gilabert, M. (2009), "Vegetation dynamics from NDVI time series analysis using the wavelet transform", *Remote Sensing of Environment*, available at: http://www.sciencedirect.com/science/article/pii/S0034425709001254 (accessed 8 Dec 2018).

Obida, C.B., Alan Blackburn, G., Duncan Whyatt, J. and Semple, K.T. (2018), "Quantifying the exposure of humans and the environment to oil pollution in the Niger Delta using advanced geostatistical techniques", *Environment International*, Elsevier, Vol. 111 No. October 2017, pp. 32–42.

Opukri, C.O. and Ibaba, I.S. (2008), "Oil Induced Environmental Degradation and Internal Population Displacement in the Nigeria'S Niger Delta", *Journal of Sustainable Development in Africa*, Vol. 10 No. 1, pp. 173–193.

The Guardian. (2015), "Shell announces £55m payout for Nigeria oil spills | Environment | The Guardian", available at: https://www.theguardian.com/environment/2015/jan/07/shell-announces-55m-payout-for-nigeria-oil-spills (accessed 21 December 2018).

UNEP. (2011), *Environmental Assessment of Ogoniland*, available at: http://postconflict.unep.ch/publications/OEA/UNEP_OEA.pdf (accessed 21 March 2017).

UNEP. (2014), *An Evaluation of the Implementation of Unep's Environmental Assessment of Ogoniland, Three Years On*, available at: https://www.amnesty.org/download/Documents/4000/afr440132014en.pdf.

Veloso, A., Mermoz, S., Bouvet, A., Le Toan, T., Planells, M., Dejoux, J.-F. and Ceschia, E. (2017), "Understanding the temporal behavior of crops using Sentinel-1 and Sentinel-2-like data for agricultural applications", available at:https://doi.org/10.1016/j.rse.2017.07.015.