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Spatio-Temporal Analysis of Trends on Habitat Disturbance Between 1986 And 2021 In Protected Areas of, Zimbabwe

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ABSTRACT

The main aim of this research is to analyse spatio- temporal trends on habitat disturbance between 1986 and 2021 in protected areas of, Zimbabwe with a focus on anthropogenic activities such as mining which are leading to biodiversity loss, habitat and ecosystem services disturbances. This paper provides an overview of recent studies using Remote Sensing (RS and Geographic Information Systems (GIS) techniques to assess the extent of mining disturbance on plant habitats in protected areas of Zimbabwe. Through a systematic review, literature hotspot analysis was done as well as a trend analysis at regional specific level together with statistical tests in order to come up with an overview of the past studies which were done on habitat disturbance in protected areas of Zimbabwe over a thirty-five-year period. The paper highlights the complex nature of the impacts of mining as well as discuss spatial research methods, data sources and limitations. The results indicated an exponential growth of scientific literature on human-environment interactions in the mining environments at regional scale and a non- monotonic trend at country level. This has prompted a need to synthesize literature to guide future research. Conclusively there is limited research done on habitat disturbance in protected mining environments, hence the need for advanced geospatial scientific studies in the future on spatio-temporal analysis of trends on habitat disturbance.

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Introduction

The scale of human influence is driving the earth system towards a new unstable state which is characterised by extreme climate dynamics and biodiversity loss [1]. This is explained by the new geological epoch in which the earth has entered-the Anthropocene. Literature suggests that human activities (primarily mining) create dynamic complex coupled landscape signatures which alter processes regulating the stability and resilience of the earth`s system from which humans depend on, (interactions among the atmosphere, land/biosphere, and ocean) [2]. The world`s main source of living is mineral extraction and continued extraction of these minerals is expected to be among the prominent drivers of global environmental change [4]. The reason behind this is, mining transforms landscape with marked impacts on the natural ecosystems, since it replaces natural land surfaces with artificial surfaces for instance, asphalt surfaces that alter ecological processes, such as nutrient fluxes [4]. Although mining areas occupy <5% of the Global land surface area, its impacts on the natural ecology span over large spatial extents and even beyond the mining boundaries [5,6]. Consequently, assessing the spatial extent of disturbance in mining environments is an emergent trans-disciplinary scientific question for conservationists and natural resource managers [7].

The advent of mining as a main economic activity for many countries has resulted in the adverse consequences on the environment especially the ecological habitats [5,8]. These mines use some of the available resources to meet their needs, for example trees for timber and even for fuel, road construction and water for washing their machines. Such activities have diminishing effects on the habitat diversity [9,10]. Species are coming into direct contact with human beings and this is now having adverse effects on the human fraternity in that some of the diseases which were found within the original natural habitats are now transferred into human beings causing diseases. For instance, the outbreak of the recent Covid 19 pandemic is said to have emerged from habitat disturbance [11]. As humans alter the environment through habitat fragmentation, the microbes that live within will spill over into human communities leading to disease outbreaks. In Zimbabwe the mining industry has become a major threat to biodiversity as people clear land for different mining activities [12]. This has resulted in the extinction of some endangered species as well as key species within the ecosystem [13].

One challenge for natural resource managers is the maintenance of near natural ecosystem function in mining landscapes. The proposed solution to that challenge lies in understanding the extent of disturbance and landscape conditions which can make the ecological processes persist in mining areas [14]. Consequently, understanding and predicting the extent of habitat disturbance in a mining environment is very imperative [15]. In comparison to natural forested and agricultural landscapes, mining landscapes consist of mosaics of heterogeneous landscape elements varying widely in both structural and functional characteristics in very close proximity and are often juxtaposed [12,14]. Attempts to assess the complex-coupled spatiotemporal changes of habitat disturbance pre-dates the 1960s. Since then, in Zimbabwe the

interdisciplinary studies have processed theoretical perspectives to explain or predict the extent of habitat disturbance.

Given the recent attention on mining and its impacts on the environment, it is very imperative to have a constant synthesis on growing literature. The review of literature is of paramount importance since it helps us to identify hot topics (mostly pursued topics) and cold topics (receiving less attention) as well as to identify the direction of future research. This paper is a documentation of empirical literature on the use of geoinformation for habitat disturbance assessment in the field of mining. To date the comprehensive review of literature assessing habitat disturbance using geotechnology is minimal.

Herein we adopt a systematic review process after Roberts et al to quantify trends in habitat assessment in mining environment using geotechnology between 1986 and 2021 in different spatial environment journals [16]. The main objective of this paper is to systematically review literature on habitat disturbance assessment using geotechnology from 1986-2021.The first objective is to identify literature hotspots for key terms used in the use environment and biodiversity literature for 1986–2020. The second objective is to quantify trends in habitat loss in spatial literature in terms of study approaches and methods, and geographic region of study. This also contributes towards evidence for policy makers to make informed decisions on the best strategies and restoration measures for the habitats located in mining environments within the semi -arid savannah ecosystems.

Methods

The review was guided by the analytical framework figure 1 which emanated for the Unified theory of biodiversity and biogeography, which aims to provide a theoretical framework for explaining biodiversity patterns across all spatial temporal scales [17,18]. This neutral theory also assumes classically (i) that biotic communities are essentially governed by random population drift (thus, demographic stochasticity hypothesis), (ii) that all individuals irrespective of species share the same per capita birth, death, migration and speciation rates (neutral hypothesis) and (iii) that the number of individuals in the system is constant through time (zero-sum hypothesis) [17]. Additionally, several studies have shown that mining has adverse consequences on the environment for instance, direct impact on ecosystems and hence provision of goods and services from the same [14,19-21].

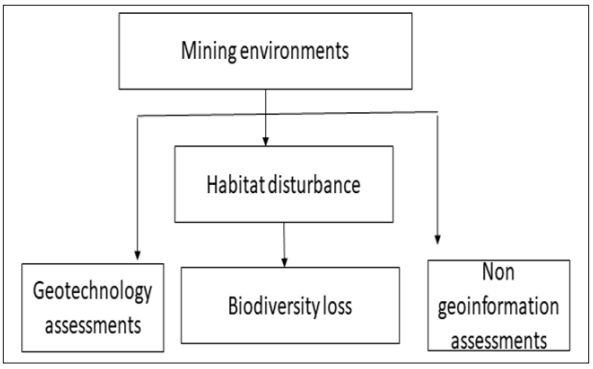

Figure 1: Analytical framework for habitat disturbance assessment.

Journal selection and identification

To identify journals on the assessment of habitat disturbance using geotechnology, the biodiversity and environmental section of the Institute for Scientific Information Journal Citation Reports was used to filter the leading journals, basing on impact factor sorting. All journals on environment which stated that they publish original research in time and space were included from the databases searched. Book chapters, journal articles, books, academic theses, and reports were all included in the search. Electronic databases including Web of science, Sci-Hub, Scorpus, Dimensions, Sage Elsevier Science Direct, PubMed, Scopus, PLOS-one and Google Scholar among others were searched for potential studies published in English between 1986 and 2021 reporting on Geoinformation advances on habitat disturbance in a mining environment [22].

Statistics on the number of publications per region per year were drawn from different databases to produce a spatial analysis map showing the spatio-temporal distribution of publications in the field of study. Some of the potentially relevant journals were excluded, because they were non-English. In this study a choice of journals was expected to influence the results, but the journals used for this study provided a widely read and authentic studies which are specific to the theme of habitat disturbance and geotechnology.

Collection and Categorization of data

The systematic review approach was adopted from the recommendation by Roberts et al. [16,23]. The approach is a rigorous and transparent methodology which enables a detailed exploration, critical evaluation, and interpretation of available evidence that is relevant to a particular subject based on a sample of original studies [16,24]. Credits behind the systematic reviews are their capacity in the limitation of bias and random error in quantitatively synthesizing independently conducted studies [25, 26]. The "traditional narrative review method" is mostly used by reviewers(Muderere et al. 2018). The "traditional narrative review method" quantitatively synthesize published results based on the subjective judgment as well as experience of the author (s) lacking clear methodological transparency, which is a main source of bias. Systematic reviews are both replicable and repeatable. This paper used a method based on electronic searches. The year 1986 in this study is regarded as the base year because it is the year when most of the journals began publishing online. The inclusion of a publication in this study was based on text search of listed keywords of titles and abstracts using the following search words: Geoinformation systems and conservation, habitat disturbance, mining and conservation, satellite imagery, spatial analysis. Specifically, a repetitive year on year filter was run using the search function in the online repositories of each database by filling in the key words. Query language was used facilitated by Boolean operators such as OR, AND, NOT among others and the following is one of the examples used, *(Geographic Information System AND conservation) AND (LIMIT-TO (AFFILCOUNTRY,"United States")) AND (LIMIT-TO (PUBYEAR,2021 PUBYEAR,1986)))*. From the larger pool 5,869 articles were included from the filtered search on geoinformation and habitat disturbance in the journals published from 1986-2021. Data for a specific region was also collected and some were analysed in Vos Viewer to come up with a text connection map.

The creation of a text file comprising of 358,659 words, including titles abstract and keywords of all the 5,869 open access articles on the theme of geoinformation assessment for habitat disturbance was created. Text data were cleaned at the same time eliminating publication details such as author name (s), publication dates, publication year, journal names, volume, page numbers. Each journal article was then examined using the following criteria a) spatial/non spatial and b) geographic region. After meeting each criterion, the article was given a score of 1.0 otherwise 0.0. Then the sums of the scores were used to infer trends in the literatures against time. All the data were recorded and processed in a Microsoft excel spread sheet for further analysis in R software.

Data Analysis

Hotspot Analysis of Literature

Literature hotspot analysis was done based on the text file with 358,659 words filtered from the 5,869 articles through the use of VOS viewer (http://www.vosviewer.com). VOS viewer is a machine learning open software tool for constructing and visualizing bibliometric and text networks maps which are scientific in nature [27]. It also offers text mining functionality which was used to construct and visualize co-occurrence networks of word clouds with heat signatures based on frequency of key words [27]. VOSViewer supports mapping citation data extracted from Web of Science, Scopus, Dimensions and PubMed among other databases.

Regional Trends Analysis

For spatially weighted regional trends analysis, spatial overlay analysis in Quantum GIS 3.18 was done on a desktop computer to assess the spatial distribution of the themes of geoinformation and habitat disturbance across the globe for the 5,869 articles. The shapefile on the frequencies of themes was created and integrated through the spatial join function with the world map. To visualize the trends in the regions, line graphs were created in R software for each region against time between 1986 and 2021.

A non- parametric Mann Kendall test was run in R software in order to statistically assess if there is a monotonic upward or downward trend of the publication data from 1986 to 2021. This is a rank non-parametric test developed by Mann and Kendall [28,29]. In this test, the null (H0) and alternative hypotheses (H1) are equal to the non-existence and existence of a trend in the time series of the observational data, respectively. Man Kendall was used to run the predictive statistical test in order to observe the monotonic trend behaviour in the publications for each region including Zimbabwe for the period of study.

Results and discussion

Trends and Geographical Distribution of habitat disturbance and geoinformation systems studies' between 1986 and 2021

The observation was that 5,869 out of 39,678 published papers from the extracted journals investigated habitat disturbance using geotechnology between 1986 and 2020. Most of the 5,869 were conducted in Asia (40.0%,2348/5,869 articles), followed by America (27%,1,585/5,869 articles) and South America, (17.0%,997/5,869 articles). The rest of the region had few published articles with Europe, (8.0%,470/5,869 articles), Africa (5.3%,311/5,869 articles) and Australia (4.6%,270/5,869 articles) as clearly illustrated in figure2.

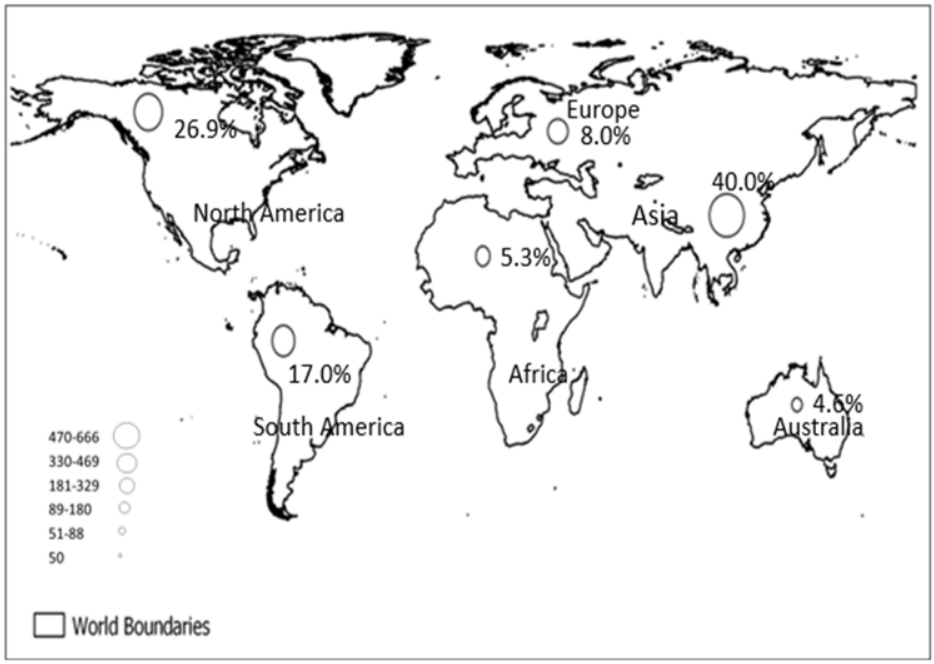

Figure 2: Spatiotemporal distribution of the foci on habitat disturbance and geoinformation articles found using a search of 'habitat disturbance' AND 'biodiversity' OR 'geoinformation' AND 'conservation' spanning between 1986 and 2021

Another observation is illustrated on figure 3 where there is a diagrammatic representation of trends of articles published between 1986 and 2021. Asia has the largest number of articles published but from 1986 to 1990 it is showing a delay in online publication. North America is a little bit advanced in terms of technology because its online publication started from way before 1986, the same applies to Europe, South America and Africa.

Trend analysis

The results followed two hypotheses, the null hypothesis, H0, there is no monotonic trends over the years in publications and the H1, which states that there is a monotonic trend in the data on publications from 1986 to 2021. A monotonic upward (downward) trend means that the variable consistently increases (decreases) through time, but the trend may or may not be linear [28-30]. The results for Man Kendall test run in R are found in table 1.

Region	Z	p-value	s	tau
North America	-4.9347	8.027e-07	348.0000000	0.5903565
Asia	-7.3101	2.67e-13	513.0000000	0.8832169
South America	-6.76	1.38e-11	476.0000000	0.8116794
Europe	-5.7388	9.534e-09	4931.3333333	0.6913006
Africa	-6.7728	1.263e-11	464.0000000	0.8473137
Australia	-4.3024	1.689e-05	404.0000000	0.6913006
Zimbabwe	1.971	0.04872	117.0000000	0.2723214

ManKendall results show that there is a monotonic trend over the years as signified by the p-values which range from 0.0008, 0.0002,0.0001,0.0009,0.00016 for North America, Asia, South America, Europe, Africa and Australia respectively. Zimbabwe has 0.048 which shows that there is not any monotonic trend in the publications that were done in Zimbabwe for the period study thus between 1986 and 2021. This helps much in strengthening the gap in knowledge for Zimbabwe. There is a lot that need to be done in research since its lagging behind. This is also well explained by the trend lines shown in figure 3. There is a pattern which is exponential for the regions, but at country level there tends to suffer a lot of criticism. Zimbabwe was computed among the regions a study area, and the results are reflecting that more needs to be desired. There is no trend or specific pattern that can be pointed at. The number of publications is very few and this shows that less work has been done on the area of study in Zimbabwe.

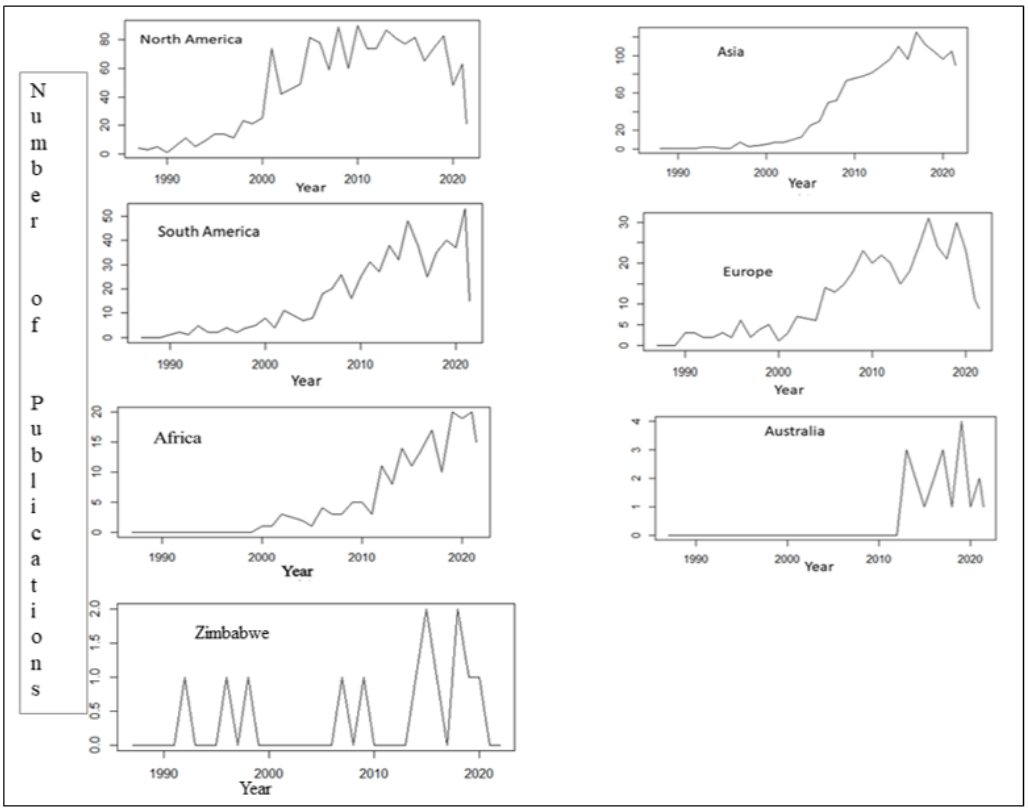

Figure 3: Trend analysis of literature at a global scale for a period between 1986 and 2021

Networks of word clouds with heat signatures based on frequency of key words

The observation was that most of the article's connections range from 0 to -1 using standard deviation, showing how the search words were deviating from the mean. From the field of study, the observation was the range from -0.5 to 5 and that is the category where most of the search words on geoinformation and habitat disturbance fall in. (figure 4). This is also well described by the heat map on figure 6. These results concur with some other studies that did systematic review analysis using the networks of word clouds with heat signatures and they found out that there is less frequency on the search words that are specific to the focus of their study [31].

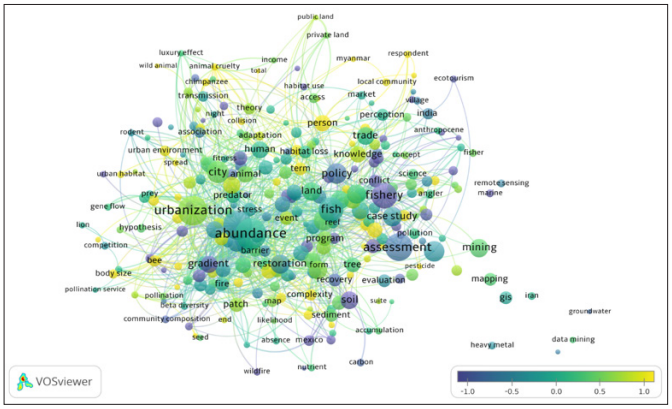

Figure 4: Co-occurrence networks of word clouds with heat signatures based on frequency of key words

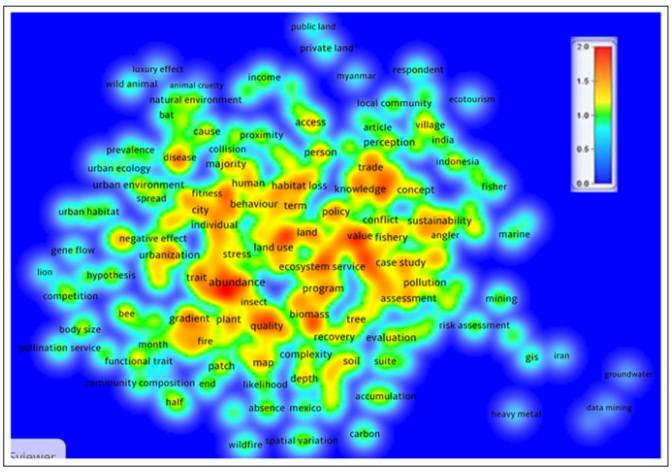

Figure 5: Heat map showing frequency of key terms based on a text corpus of all the titles, keywords, and abstracts of articles of the geoinformation and habitat disturbance journals between 1986 and 2020 on a scale of 0 to 2 where 0 represents low frequency and 2 represents high frequency

Another observation was that, a total of 3944 non-Geographic Information Systems (GIS) and or Remote Sensing (RS) based studies and a total of 1925 were Geographic Information Systems (GIS) and or Remote Sensing (RS) based studies (figure 6)

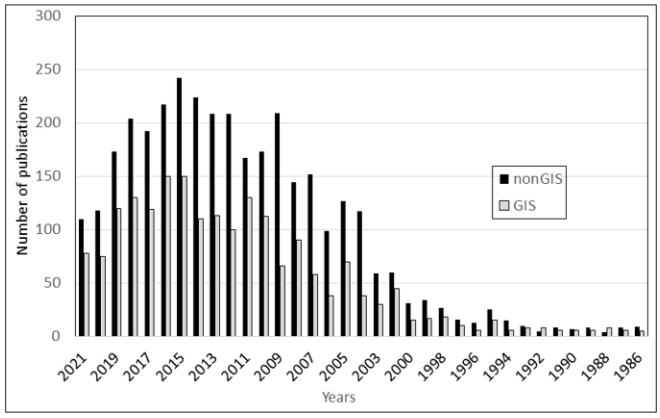

Figure 6: Number of articles found each year on Habitat disturbance and geoinformation found using the search 'Remote sensing' AND 'Geographic information System' between 1986 and 2020

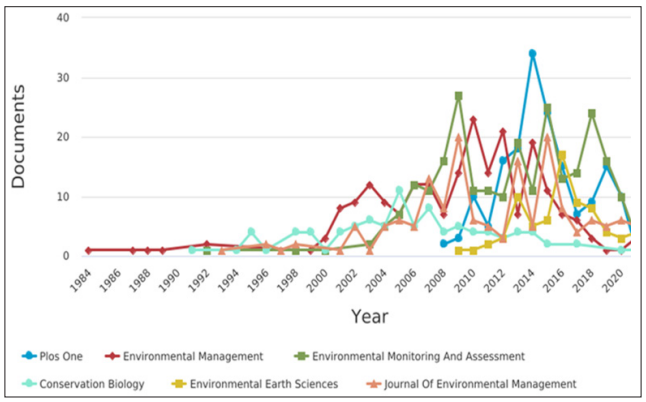

Figure 7: Journals with documents counts of up to ten sources by Elsevier in Scorpus.

The above is a line graph showing the number of documents published around the study for the period of study. Journal of environmental management and environmental management journal are leading journals when it comes to publications in study since they have been publishing for long as compared to PLOS-one and conservation biology.

Discussion

Trends and Geographical Distribution of habitat disturbance and geoinformation systems studies between 1986 and 2020

From the analysis, there is a relatively exponential growth rate in the publication of scientific articles on the theme of geotechnology and habitat disturbance in a mining environment. For instance, in 1986, the studies constituted 0.11% of scientific articles on theme of Geotechnology, habitat disturbance and mining in 1990 they were 0.27%, 2.03 in 2000, 4.83 in 2010 and 5.44 in 2020. This is consistent with previous results reviews which observed in some other fields like urban landscape ecology where there was an increase in the number of studies that applied the concepts and techniques of the ecology of landscape in disturbed areas [32,33]. This reflects the filling of a important gap in spatial ecosystems such as the need to advance in geotechnology. The findings on the geographical distribution of studies were also consistent with some other studies although they are not well connected to the main focus of this study. Under the focus of this study little has been done so far and more attention is desired [34].

Approaches and Methods in Geotechnology and habitat disturbance in mining environment

Two major approaches were observed thus, GIS and Remote Sensing based studies and the Non-GIS and Remote Sensing based approaches. There is a growing number of studies who are not integrating GIS and habitat disturbance studies in mining environments, and this indicates a limited but growing attention on the spatial aspect on habitat disturbance over the study period. This finding tally well with some other reviews on landscape ecology that found out that most of the studies of ecology have rarely used Geo technological approaches. On the other hand, it can be noted that while there is a small proportion of GIS based research, there cannot be a conclusion that the Application of GIS in habitat assessment in mining environments is limited. Some of the studies may have deliberately failed to mention GIS terms yet they did some GIS based mapping. While GIS can be regarded as an important tool for assessing habitats in mining environments, but it is not the only approach. Some other approaches such as experimental approach which does not requires GIS or complex spatial analysis.

Remote sensing is the art and science of acquiring information about some property of an object, area or phenomena which is not in physical contact with the objects or area under investigation [35-37]. On the other hand, GIS is computerized software that stores, retrieves, manipulates, analyses and displays geographically referenced data sets, which can be used for different applications [37-40]. GIS can manage two basic types of data known as geospatial data that define the location of a feature or object on the ground and attribute data that describe the characteristics of these features. GIS has an analytical ability which can result in the generation of new information as patterns and spatial relationships are revealed. Remote sensing data are being used to manage various types of natural resources and monitoring the dynamics of land-use/land-cover, which is a basic pre-requisite for planning and implementing various developmental activities [41].

Geoinformation science and remote sensing provide landcover information and landscape characterization statistics on the assessment of habitat disturbance in a mining landscape. Intermediate disturbance enhances diversity although the species will be vulnerable to change [42]. This was well confirmed at a study undertaken in Schlabendorf which confirmed the explicit disturbance and fragmentation due to landcover changes are related to processes with strong relationships that affect habitat diversity in a mining environment [43]. Mining operations generate range of ecological and environmental impacts that can be measured spatially using geographic information system and remote sensing methods. A study done on the Spatial evaluation of land-use dynamics in gold mining area using remote sensing and GIS technology revealed that areas with low index values are susceptible to the impact of mining and other anthropogenic activities, whereas high-index areas connote little or no impact [44]. Another study also reflected that a strong linear relationship ($r2>0.86$) was found between NDVI and NDMI.

The combination of various geo-technologies can be used to build very crucial systems which are currently being applied in the determination of priority areas for ecosystem conservation and restoration [45]. The use of geo-technology is also important in the diagnosing of the sites which have a minimum resilience but high restoration potential, thus maintaining ecological processes and services as well as favouring biodiversity increase. Upon this background the technology will facilitate the implementation of restoration projects, increase environmental gains and decreasing costs and potentiating the regeneration of the natural environment. As of today, nothing has been done in Mashonaland West Province, Zimbabwe, pertaining the geo-technological approaches in the assessment of habitat disturbance. From the results, (Figure 6) GIS is a tool which is yet to gain a ground and people must use it in order to move away from the empirical methods of biodiversity and conservation management in mining environments.

Geotechnological tools are very important for the assessment of Net Primary production. Normalised Difference Vegetation Index (NDVI) is used for tracking the history of any place's vegetation dynamics [46]. NDVI is derived from reflectance data registered by 'National Ocean and Atmospheric Administration and Advanced Very High Resolution Radiometer (NOAA AVHRR), which act as a surrogate measure of NPP [47,48]. NDVI can also be used to parametrise models that may also accurately reflect actual changes in NPP and as well as quantifying its absolute amount [49]. Net Primary Production represents the net flow of carbon to plants from the atmosphere and defines a balance between gross photosynthesis and autotrophic respiration [50-52]. Upon this background, it is of paramount importance to apply geo-technological tools for assessment of primary productivity for the better management of ecosystems in mining environments

Literature have suggested that advancements in geospatial approaches have opened up the possibilities for understanding the spatial pattern of landscapes and the associated ecosystem patterns. Some of the scholars have asserted that Geotchnology have made it possible for researchers to analyze patterns and coexistence thereby strengthening the methodological rigor of studies. The final assertion would be, Geotechnological based assessment of habitat disturbance in mining literature would beneficial if there is the incorporation of geospatial analysis in its approaches [53].

Networks of word clouds with heat signatures based on frequency of key words

The observation was that most of the articles connections range from 0 to -1 using standard deviation, showing how the search words were deviating from the mean. From the field of study the observation was the range from -0.5 to 5 and that is the category where most of the search words on geoinformation and habitat disturbance fall in. (figure 4). This is also well described by the heat map on figure 6. These results concur with some other studies that did systematic review analysis using the networks of word clouds with heat signatures and they found out that there is less frequency on the search words that are specific to the focus of their study [31].

Habitat disturbance

Habitat disturbance occurs when there is a change in conditions which interferes with the normal functioning of a biological system [54]. A 'disturbed habitat' is an ecological concept which indicate a temporal change in the conditions of the environment, which has pronounced changes in the ecosystem [55,56]. Disturbances are classified into two, human caused or natural. Disturbances which are anthropogenic related include cultivation, weeding, land clearing, digging, mining, burning among others. Natural disturbances include natural fires, lightning strikes and fires; temperature changes storms, strong winds among others [57-59]. The relationships that exist between the changes in the environment and health is well known. This has been documented by several scientific studies conducted in the past for both animal species and humans and vegetation, although little is known on

the extent of habitat damage and the associated consequences in a mining landscape [56, 60-63]. A study conducted in Matebeleland South Province, Zimbabwe on assessing the efficiency of mining frameworks and highlights how institutions affect the management of other natural resources/ecosystem goods and services found that formal institutions have become a major catalyst in converting common property into an open access regime that is susceptible to the Tragedy of the Commons. The study also showed that the reigning status quo had negative effects on other rangeland-inclined ecosystem services and compromised the ability to effectively manage them [64].

Mining as a factor that affect habitat loss

Mining has a massive influence on the natural environment in Africa [65,66]. Impacts of mining on habitats are both direct and indirect. Direct impacts occur within the immediate confines of the mining enterprise [59]. Indirect effects are a consequence of external infrastructure, pollution among others.Mining activities can lead to the destruction of environmental habitats in the surrounding areas [67]. Clearing of land is the first process where the land above the mine is cleared of all obstructions in order to allow free space for the activity and its clear that most mines are willing to destroy the entire forest to get access to mineral wealth [68]. The process of clearing land yields several effects to the environment and among them are, birds, animals, and creatures that depend on trees and plants for food or shelter lose their homes or starve to death. Any remaining survivors are forced to relocate and find a new dwelling [67]. The removal of trees can also significantly affect the plants that rely on them for shade from the harsh sun. Upon this background there is need to effectively assess the extent of habitat disturbance in a mining environment using geotechnology.

Conclusions

The study revealed important gaps in literature. The theme of habitat disturbance and geotechnologies has limited citations which highlight it as an emergent theme in literature. Despite the limited number of citations, the available citations from the highlighted leading spatial journals showed that there shall be an exponential increase in publishing in the long run at regional level. Considering the current trends in mining and its impacts on the habitats, there is need to improve the focus on its spatial literature. The conclusion is that spatial temporal habitat disturbance is receiving very limited but growing focus. Another important point noted was that most of the research did not integrate geospatial approaches in their studies. Hence the conclusion that habitat disturbance studies in protected areas could benefit from considering GIS approaches. Landscape scale areas are the most frequently studied spatial extents, like the patch size of a habitat. There is need for multiple spatial scales to allow for comparison of findings across scales. There is also need for longer temporal scales studies that span decades to observe and account for lags in ecosystems responses to patterns of ecosystems regeneration. Similarly, majority of studies were done over short time spans, so there is need for multiple spatial scales to allow for comparison of findings across scales. Built up areas and forest fragments are the most studied ecosystems and fewer studies are on grassland, freshwater, wetland, wasteland, and austral ecosystems. Hence, there is need for research to focus on cross ecosystem studies and the neglected ecosystems. Studies that will focus on these ecologically vulnerable areas would help in providing crucial insights for the conservation of biodiversity. From the analysis done there was a disproportionate number of studies from Europe and North America, and fewer studies were from Africa, Australia, Asia, and North America even though Africa, South America and Asia are the leading continents in supporting much of the Earth's biodiversity [69]. The trends highlighted are an important representation of very important gaps in knowledge that need to be addressed through the funding of research and cross regional collaborations. Therefore, this research emphasises that the habitat disturbance and geoinformation theme my grow into a central theme in biodiversity management research and that knowledge will have tremendous importance in the global management of ecosystems.

Author contributions

Kunedzimwe F. Thematic development, data collection, data analysis, compiling of results and discussion and reference management.

Taru P. Data collection, thematic conceptualisation, methods development, data analysis, proofread and discussion.

Muposhi V. Outline development, methods development and Statistical analysis of data, compiling of results and development of the discussion.

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Conflict of Interest

"The authors declare that there are no conflicts of interest regarding the publication of this manuscript".

References

1. Pickett, Steward TA, and Mary L Cadenasso (1995) "Landscape ecology: Spatial heterogeneity in ecological systems." Science 269: 331-334.
2. Vitousek Sean and Charles H Fletcher (2008) "Maximum Annually Recurring Wave Heights in Hawai 'i1." Pacific Science 62: 541-553.
3. McLaren Duncan (2012) "Environmental space, equity and the ecological debt." In Just sustainabilities 36-54.
4. Pathirana Assela, Hailu B Denekew, William Veerbeek, Chris Zevenbergen, and Allan T Banda (2014) "Impact of urban growth-driven landuse change on microclimate and extreme precipitation-A sensitivity study." Atmospheric Research 138: 59-72.
5. Richards PJ, and RP Hoxey (1993) "Appropriate boundary conditions for computational wind engineering models using the k-ϵ turbulence model." Journal of wind engineering and industrial aerodynamics 46:145-153.
6. Riitters Kurt, James Wickham, Robert O'Neill, Bruce Jones and Elizabeth Smith (2000) "Global-scale patterns of forest fragmentation." Conservation ecology 4.
7. Saunders, Denis A, Richard J Hobbs, Chris R Margules, and Richard J Hobbs (1991) "Biological consequences of ecosystem fragmentation: a review." Conservation biology 5:18-32.
8. Amankwa OPJ (2003) Ghana: A human geography for secondary schools, St. Francis Press, Ghana.
9. Mberengwa Ignatius (2010) "Humanenvironment relations in Zimbabwe: the case of land–pre colonial, colonial, and post-independence periods."Journal of Business and Administrative Studies 2: 73-100.
10. Murwendo Talent, Amon Murwira, Mhosisi Masocha, Amon Murwira (2021) "Vegetation phenology dynamics as an indicator of energy and productivity functions in semi-

arid savannah protected areas: a case study of Gonarezhou National Park in south-eastern Zimbabwe." Transactions of the Royal Society of South Africa 1-9.

11. Ahmad Tauseef, Muhammad Khan, Taha Hussein Musa Haroon, Saima Nasir, Jin Hui, et al. (2020) "COVID-19: Zoonotic aspects." Travel Medicine and Infectious Disease.
12. Zwane Nonhlanhla, David Love, Zvikomborero Hoko, Dennis Shoko (2006) "Managing the impact of gold panning activities within the context of integrated water resources management planning in the Lower Manyame Sub-Catchment, Zambezi Basin, Zimbabwe." Physics and Chemistry of the Earth, Parts A/B/C 31: 848-856.
13. Spiegel Samuel J (2009) "Socioeconomic dimensions of mercury pollution abatement: Engaging artisanal mining communities in Sub-Saharan Africa."Ecological Economics 68: 3072-3083.
14. Maponga Oliver, Clay F Ngorima (2003) "Overcoming environmental problems in the gold panning sector through legislation and education: the Zimbabwean experience." Journal of Cleaner Production 11: 147-157.
15. Kennedy Robert E, Zhiqiang Yang, Justin Braaten, Catharine Copass (2015) "Attribution of disturbance change agent from Landsat time-series in support of habitat monitoring in the Puget Sound region, USA." Remote Sensing of Environment 166: 271-285.
16. Roberts Marion E, Kate Tchanturia, Daniel Stahl, Laura Southgate (2007) "A systematic review and meta-analysis of set-shifting ability in eating disorders." Psychological medicine 37:1075-1084.
17. Chave Jerôme (2004) "Neutral theory and community ecology." Ecology letters 7: 241-253.
18. Hubbel SP (2001) "The unified neutral theory of biodiversity and biogeography". Princeton 390.
19. Boldy Robyn, Talitha Santini, Mark Annandale, Peter D Erskine, Laura J Sonter, et al. (2021) " Understanding the impacts of mining on ecosystem services through a systematic review." The Extractive Industries and Society.
20. Larondelle Neele, Dagmar Haase (2012) "Valuing post-mining landscapes using an ecosystem services approach-An example from Germany." Ecological Indicators 18: 567-574.
21. Xiao Wu, Yanhua Fu, Tao Wang, Xuejiao Lv (2018) "Effects of land use transitions due to underground coal mining on ecosystem services in high groundwater table areas: A case study in the Yanzhou coalfield." Land Use Policy 71: 213-221.
22. Chuvieco Emilio (2020) Fundamentals of satellite remote sensing: An environmental approach: CRC press.
23. Munn Zachary, Micah DJ Peters, Cindy Stern, Catalin Tufanaru, Alexa McArthur, et al. (2018) "Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach." BMC medical research methodology 18: 1-7.
24. Khan KS, G Ter Riet, J Glanville, AJ Sowden, J Kleijnen (2001) " Undertaking systematic reviews of research on effectiveness: CRD's guidance for carrying out or commissioning reviews " NHS Centre for Reviews and Dissemination 4.
25. Gates Simon (2002) "Review of methodology of quantitative reviews using meta-analysis in ecology." Journal of Animal Ecology 71: 547-557.
26. Mulrow Cynthia D (1994) "Systematic reviews: rationale for systematic reviews." Bmj 309: 597-599.
27. Van Eck N, Waltman L (2009) "Software survey: VOSviewer, a computer program for bibliometric mapping." Scientometrics 84: 523538.
28. Kendall James M (1975) "Wind tunnel experiments relating to supersonic and hypersonic boundary-layer transition." Aiaa Journal 13: 290-299.
29. Mann Henry B (1945) "Nonparametric tests against trend." Econometrica: Journal of the econometric society: 245-259.
30. Gilber Richard O (1987) Statistical methods for environmental pollution monitoring: John Wiley & Sons.
31. Muderere Trymore, Amon Murwira, Paradzayi Tagwireyi, Amon Murwira (2018) "An analysis of trends in urban landscape ecology research in spatial ecological literature between 1986 and 2016." Current Landscape Ecology Reports 3: 43-56.
32. Francis Alexandra L, Chris Procter, Gerald Kuzyk, Jason T Fisher (2021) "Female Moose Prioritize Forage Over Mortality Risk in Harvested Landscapes."The Journal of Wildlife Management 85:156-168.
33. Wheeler Nick, David Neale (2013) "Landscape genomics: An emerging discipline that can aid forest land managers with planting stock decisions."Mountain Views: Cirmount 7:10-14.
34. Turner John, Marcia Lambert (2005) "Soil and nutrient processes related to eucalypt forest dieback." Australian Forestry 68: 251-256.
35. Ejigu Dessalegn (2016) "Application of Remote Sensing and Geographic Information System in Ecology."
36. Janssen MA, MD Hofstadter, S Gulkis, AP Ingersoll, M Allison, et al. (2005) "Microwave remote sensing of Jupiter's atmosphere from an orbiting spacecraft." Icarus 173: 447-453.
37. Mironga JM (2004) "Geographic information systems(GIS) and remote sensing in the management of shallow tropical lakes." Applied Ecology and Environmental Research 2: 83-103.
38. Kanga Shruti, LK Sharma, Prem Chandra Pandey, Mahendra Singh Nathawat (2014) "GIS Modelling approach for forest fire risk assessment and management." International Journal of Advancement in Remote Sensing, GIS and Geography 2: 30-44.
39. Kangas Annika, Rasmus Astrup, Johannes Breidenbach, Jonas Fridman, Terje Gobakken, et al. (2018) "Remote sensing and forest inventories in Nordic countries–roadmap for the future." Scandinavian Journal of Forest Research 33: 397-412.
40. Roy PS, Shirish A Ravan (1996) "Biomass estimation using satellite remote sensing data—an investigation on possible approaches for natural forest." Journal of biosciences 21: 535-561.
41. Murthy CS, PV Raju, KVS Badrinath, PV Raju (2003) "Classification of wheat crop with multi-temporal images: Performance of maximum likelihood and artificial neural networks." International Journal of Remote Sensing 24: 4871-4890.
42. White Peter S (1979) "Pattern, process, and natural disturbance in vegetation." The botanical review 45: 229-299.
43. Odum Eugene P (1985) "Trends expected in stressed ecosystems." Bioscience 35: 419-422.
44. Salem Aliasger K, Peter C Searson, Kam W Leong, Peter C Searson (2003) "Multifunctional nanorods for gene delivery." Nature materials 2: 668-671.
45. Kohnen Stephan L, Ange A Mouithys-Mickalad, Ginette P Deby-Dupont, Carol MT Deby, Maurice L Lamy, et al. (2001) "Oxidation of tetrahydrobiopterin by peroxynitrite or oxoferryl species occurs by a radical pathway." Free radical research 35: 709-721.
46. Goetz SJ, Stephen D Prince (1999) "Modelling terrestrial

carbon exchange and storage: evidence and implications of functional convergence in light-use efficiency." Advances in ecological research 28: 57-92.
47. Wang Quan, Jian Ni, John Tenhunen (2005) "Application of a geographically-weighted regression analysis to estimate net primary production of Chinese forest ecosystems." Global ecology and biogeography 14: 379-393.
48. Waring RH, JJ Landsberg, M Williams, JJ Landsberg (1998) "Net primary production of forests: a constant fraction of gross primary production?" Tree physiology 18:129-134.
49. Reeves Raymond (2001) "Molecular biology of HMGA proteins: hubs of nuclear function." Gene 277: 63-81.
50. Field Christopher B, James T Randerson, Carolyn M Malmström James T Randerson (1995) "Global net primary production: combining ecology and remote sensing." Remote sensing of Environment 51: 74-88.
51. Gowe Stith T, Chris J Kucharik, John M Norman, Chris J Kucharik (1999) "Direct and indirect estimation of leaf area index, fAPAR, and net primary production of terrestrial ecosystems." Remote sensing of environment 70: 29-51.
52. Maisongrande P, A Ruimy, G Dedieu, B Saugier (1995) "Monitoring seasonal and interannual variations of gross primary productivity, net primary productivity and net ecosystem productivity using a diagnostic model and remotely-sensed data." Tellus B 47: 178-190.
53. Legendre Pierre, Mark RT Dale, Marie-Josée Fortin, Jessica Gurevitch, Michael Hohn, et al. (2002) "The consequences of spatial structure for the design and analysis of ecological field surveys." Ecography 25: 601-615.
54. Johns Andrew D, Joseph P Skorupa (1987) "Responses of rain-forest primates to habitat disturbance: a review." International journal of primatology 8: 157.
55. Seltmann Anne, Gábor Á Czirják, Alexandre Courtiol, Henry Bernard, Matthew J Struebig, et al. (2017) "Habitat disturbance results in chronic stress and impaired health status in forest-dwelling paleotropical bats." Conservation physiology 5.
56. Young Hillary, Randi H Griffin, Chelsea L Wood, Charles L Nunn (2013) "Does habitat disturbance increase infectious disease risk for primates?" Ecology letters 16: 656-663.
57. De Chazal Jacqueline, Mark DA Rounsevell (2009) "Land-use and climate change within assessments of biodiversity change: a review." Global Environmental Change 19: 306-315.
58. Jewitt Debbie, Peter S Goodman, Barend FN Erasmus, Timothy G O'Connor, Ed TF Witkowski (2015) "Systematic land-cover change in KwaZulu-Natal, South Africa: Implications for biodiversity." South African Journal of Science 111: 01-09.
59. Kamdem Colince, Billy Tene Fossog, Frederic Simard, Joachim Etouna, Cyrille Ndo, et al. (2012 "Anthropogenic habitat disturbance and ecological divergence between incipient species of the malaria mosquito Anopheles gambiae." PloS one 7.
60. Dobson Andrew, David Lodge, Jackie Alder, Graeme S Cumming, Juan Keymer, et al. (2006) "Habitat loss, trophic collapse, and the decline of ecosystem services." Ecology 87:1915-1924.
61. Mantyka-Pringle, Chrystal S, Piero Visconti, Moreno Di Marco, Tara G Martin, et al. (2015) "Climate change modifies risk of global biodiversity loss due to land-cover change." Biological Conservation 187: 103-111.
62. Nagendra Harini, Belinda Reyers, Sandra Lavorel (2013) "Impacts of land change on biodiversity: making the link to ecosystem services." Current Opinion in Environmental Sustainability 5: 503-508.
63. Dube Timothy, Cletah Shoko, Mbulisi Sibanda, Paschaline Madileng, Xivutiso G Maluleke, et al. (2020) "Remote sensing of invasive lantana camara (verbenaceae) in semiarid savanna rangeland ecosystems of south africa." Rangeland Ecology & Management 73: 411-419.
64. Blum Moshe, Itamar M Lensky, Polychronis Rempoulakis, and David Nestel. 2015. "Modeling insect population fluctuations with satellite land surface temperature." Ecological Modelling 311: 39-47.
65. Pourret Olivier, Bastien Lange, Jessica Bonhoure, Gilles Colinet, Sophie Decrée, et al. (2016) "Assessment of soil metal distribution and environmental impact of mining in Katanga (Democratic Republic of Congo)." Applied Geochemistry 64: 43-55.
66. Bernhardt-Römermann Markus, Lander Baeten, Dylan Craven, Pieter De Frenne, Radim Hédl, et al. (2015) "Drivers of temporal changes in temperate forest plant diversity vary across spatial scales." Global change biology 21: 3726-3737.
67. Olson David M, Eric Dinerstein (1998) "The Global 200: a representation approach to conserving the Earth's most biologically valuable ecoregions." Conservation biology 12: 502-515.
68. Bolnick Daniel I, Michael Doebeli (2003) "Sexual dimorphism and adaptive speciation: two sides of the same ecological coin." Evolution 57: 2433-2449.
69. GowerStith T, Chris J Kucharik, John M Norman, Chris J Kucharik (1999) "Direct and indirect estimation of leaf area index, fAPAR, and net primary production of terrestrial ecosystems." Remote sensing of environment 70: 29-51.