QUANTITATIVE AND QUALITATIVE DATA IN DISASTER RISK MANAGEMENT OF FIRES: A CASE STUDY FROM SOUTH AFRICA AT VARIOUS GEOGRAPHICAL LEVELS

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ABSTRACT. The current paper is aimed at investigating some quantitative and qualitative data, as well as their implications for the space/place/time perspective in terms of fire disaster management in Makana Local Municipality. The working hypothesis of the current article is that fire-fighting under drought conditions will post severe challenges on the disaster risk management system (DRM) in the study area. Methodology of the article includes a combination of document analysis, modelling using the Google-related tools to track and statistically analyse the public interest in fires, the legislation, and financial/practical implications of the drought on fire disaster management in Makana Local Municipality. Results of the study indicate that there has been a constant and increasing trend in terms of the South African public's in fires. That trend is driven by interest in fire-fighting equipment and possible also by the interest of the South African population in fire-fighting as a career. On causality front, the interest in fires is quantitatively driven by number of fires in South Africa between 2004 and 2017, as well as access to the internet by the South African population.

Key-words: *Fire, Risk, Quantitative data, Qualitative data, Disaster management, South Africa*

1. INTRODUCTION

Disasters are devastating events that lead to disruption of set ways in which humans are used to experience everyday life and situations in it. Between two disasters, the human society or a population at risk are in a stable condition or a steady state of their existence (Madondo et al., 2023). The population at risk exists as part of an open system, where the population members interact with each other, the society outside of the area at hazard interacts with the population at risk and the biosphere and the environment at large do as well. When no disaster has just happened, no response or recovery are unfolding, the population at risk exists by exchanging resources and information with the outside world and the surrounding environment (Madondo et al., 2023). The flow of the materials, energy, information and other everyday necessities of humans and socio-ecological systems lead to humans and the disaster-prone area to be part of a system and a location, where only the GPS coordinates are constant (Madondo et al., 2023). The remainder of the space, humans, the biosphere, and environment are in a constant state of flux. Humans can be stationary, but they can also move freely in and out of the area at hazard as part of an open geographical system. As the disaster hazards are omnipresent, and they continuously interact with the conditions of human existence at the GPS coordinates of a location at hazard. From an anthropocentric point of view, a steady-state population at risk will be experiencing a sense of place through the so-called 'life space', i.e. which is here understood as a combination of everyday activities and place that a human being exists in (Lawton, 1983). This overlaps with the life space of other people through interactions, which can be traced, monitored, and evaluated as a living and fluid structure of space over time (Gong et al., 2020).

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As a species, humanity has not only been living with disasters, but recent discourse and discoveries in the disaster risk science tend to indicate that humans have become triggering agents of disasters (Mizutori, 2020). Human actions, e.g. the building of settlements on marginal land, not in line with sound construction practices and in the proximity to disaster hazards (Chmutina et al., 2017), drive the occurrence and impact of disasters, they require that we stop using the term 'natural disasters' (Mizutori, 2020). All disasters could thus be seen as manmade and impacts of disasters, at least in part, are counteractive to ensuring human wellbeing (Padli et al., 2018). Based on the effects of climate change and other trans-boundary effects, it is the most plausible to say that disasters are manmade. At the same time, the impacts of such manmade disasters are often local based on the extent of human activity. A particular disaster always unfolds in space, affects particular people, and takes place in a given time frame (Meriläinen and Koro, 2021). In the accompanying paper, Madondo et al. (2023) described in detail that the Kant's definition of the space could be applied as way to interpret the experiences for the population(s), which is impacted by a disaster, or who live in a disaster-prone area, in a proximity to a disaster hazard (Lawton, 1983; Stanford Encyclopedia of Philosophy, 2009-2022). From a disaster risk management (DRM) point of view, a population of humans can be seen as a population at risk, i.e. population which lives or has lived in the vicinity of a disaster hazard for a short or a long period of time. In contrast, a population under disaster is a human population that finds itself existing in a disaster-impacted zone, geographical location at a particular time, in a place that has been impacted by a disaster. That disaster had been triggered by the proximity to a hazard by the population at risk (Madondo et al., 2023). Population at risk can transform into a population under disaster during such conditions, based on the space/place/time perspective (Madondo et al., 2023). Extent of the transformation into population under disaster unfolds and must be studied or understood in the same space across time frame of the disaster management cycle for a given disaster (Daly et al., 2020).

The theoretical perspective, which the authors have compiled as an accompanying paper to this article, provides an outline about the nature and types of data that are used in DRM (Madondo et al., 2023). Data were argued in that paper to be critical in the description of the 'life space' of individual humans and communities they are part of. Careful evaluation of quantitative and qualitative data facilitates allocation of the resources along the lines of principles of humanitarian ethics, humanity, impartiality, independence, and neutrality (NRC, 20023). Resources, their types and quantities; and their allocation to the population at risk or under disaster at particular GPS coordinates must be carefully tailored to the needs of the local population (Madondo et al., 2023). Diversity of the DRM practices can be seen at the theoretical and practical levels of engagement of diverse DRM stakeholders in phases of the disaster management cycle. They reflect the local conditions that set the overall scene for the disaster unfolding, the legislative settings in which the phases of the disaster management cycle are carried out, and the interaction among the private citizens, the government, the insurance companies, and the non-governmental/third sector that assists with specific tasks in the DRM landscape (Lee et al., 2014).

Localisation of approaches to DRM manifests in relevant differences between the low-income and middle-income settings (Lee et al., 2014). Data from the local settings, whether quantitative or qualitative in nature, are important as they provide for an ethical, a locally-tailored, and the most efficient foundation for unit operations in the individual stages of the disaster management cycle. It is a foundation to protect the steady state of human 'life space' by the country's DRM system, or to minimise the extent of changes between the steady state of existence at risk and the '(un)steady state' under disaster. In the next section, data sources for DRM in South Africa are outlined here and linked to the theoretical concepts of Madondo et al. (2023).

1.1. Data and the DRM landscape in South Africa

Life space of South Africans and the localisation of the data about it can be demonstrated by outlining the disaster profile of the country (e.g. Vhiriri et al., 2021). As a snapshot of the last 12 months, South Africa has experienced floods and landslides in the Province of KwaZulu-Natal which

led to 448 fatalities and the displacement of 40000 (OCHA/Reliefweb, 2022). Some communications about disaster response and recovery were unclear tracking the source(s) of the issues identified (Linyana, 2022). Drought is another disaster type that has plagued South Africa in recent years (Iheanetu and Tandlich, 2022). Other examples of recent disasters include the riots and widespread civil unrest, looting, blockages of highways and the destruction of economic assets across the Gauteng and the KwaZulu-Natal Provinces in July 2021 (Daily Maverick, 2021). The 2017 Knysna fire destroyed extensive parts of the Southern Cape and the DRM data were collected, e.g. the smoke extent over the impacted area via aerial photography to assess the size of burnt assets and forests (VWFM, 2017-present, page 7). Widespread inefficiencies in the delivery of stable electricity supply by the national electricity company of South Africa has also created conditions that precipitate or amplify disaster hazards, e.g. interruption of potable water supply and economic damage to mining and manufacturing (Winter, 2011; City of Johannesburg, 2018). In South Africa, lack of safe and sustainable potable water supply can be the result of a complicated socio-economic, political, and technical/infrastructure challenges (Calverley and Walther, 2022). The above-mentioned is just a snapshot of the South African disaster profile, and not an exhaustive list. It does, however, illustrate complex nature of the DRM landscape in the country and the type of quantitative/qualitative data that need to be collected and analysed by the DRM system in South Africa. As outlined by Madondo et al. (2023), data used in such evaluations are a combination of peer-reviewed and non-peer-reviewed types.

Data on disaster impacts are collected in various ways, in various databases and by various institutions (Jones et al., 2022). The collected data reflect the historical and current factors, contribute to the DRM landscape complexity, e.g. the well-documented and commonly known unequal distribution and access to resources in South Africa during apartheid and the resulting vulnerability in informal settlements (Mntambo and Adebayo, 2022). The National Disaster Management Centre, the central organ of state responsible for the coordination of the DRM system in South Africa, runs the historical database for declared disasters (NDMC, 2006-2023). The same institution also allows for the ongoing collection of data, e.g. on the municipal disaster management centres, hazards, and early warning (NDMC, 2023). At the same time, data are collected and released by other institutions, such as the South African Weather Service on drought (SAWS, 2022). At the same time, there has been tracking of the COVID19 pandemic information by various international stakeholders that South Africa collaborates with, e.g. the World Health Organisation (WHO, 2019-2023). South Africa' population at risk also carries a trauma and 'qualitative record of apartheid atrocities', a struggle for an inclusive society, the record of the manmade disaster. This is a legacy disaster and apartheid atrocities have made South African population under constant disaster and significant decrease in human wellbeing for a large part of the country's population (Motlhoki, 2017).

Historical and current human actions are dual in anthropogenic duality impact. This is because cumulative impact of human actions on the biosphere and environment might have short-term benefits to humanity, but they do negatively influence the human wellbeing in the long run (Iheanetu et al., 2023). This is long run across space, place and time…creating the necessary perspective that space/place/time will have ethical, qualitative, and quantitative dimensions in the DRM context (Leinfelder, 2020). The historical, cumulative, and current actions will also impact resilience, vulnerability, and the temporality of the transformation of population at risk into a population under disaster (Iheanetu et al., 2023). Human wellbeing is negatively impacted by those factors and actions, as these lead to hazard enhancement for a given population at risk, e.g. the population of South Africa. Current factors, which influence the DRM landscape and impacts on a population at risk or population under disaster, can be studied at various levels of complexity (Leinfelder, 2020; Madondo et al., 2023). Those levels can include the individual level, the level of a community…e.g. a town, city or village, a country or at the global level. It is possible to make the argument that whichever level one chooses, a human being, a population at risk, or under disaster can be considered part of a geographical system, e.g. an open system (Chick and Dow, 2005). South African population will be exposed to elimination of access to information, access to resources, transport in and out of an area at hazard, and to work during a disaster (Madondo et al., 2023). Thus, transformation of the population at risk in South Africa to a

population under disaster will be linked to closing off or shrinking of the open system. This is the system that an individual, a community, or the country's population was part of prior to the disaster onset. Disasters can thus be seen as a human-driven and impacts/unfolding of disaster takes place in open geographical systems. Therefore, the geographical space, place and time will be transformed as well, and this will in turn change the DRM landscape in the disaster-impacted area of South Africa (Madondo et al., 2023). In the next section, the DRR/DRM and its relationship to various types of geographical systems are described.

1.2. Context of the current paper

Disasters in South Africa, e.g. the 2022 floods, occurred and unfold in a discontinuous set of 'life space' objects which are in turn governed by factors which have been developing over time (Madondo et al., 2023). Floods occur in South Africa annually and the country is also prone to drought (see below). Both types of disasters have been increasing in frequency in last several years, due to climate change and their impacts are also increased due to the location of impacted settlements. Balance of current and historical factors which have played a role in shaping the relevant 'life space' as a concurrent DRM space in South Africa, are not simple but rather the cumulative result of the historically-driven shaping of the space and place at the time of life for and by the population at risk in South Africa (Iheanetu et al., 2023; Lawton, 1983; Stanford Encyclopedia of Philosophy, 2009-2022). In addition, the disaster for a given South African community will unfold at a place of their existence and against the history of the objects' organisation in that space and place of existence. Interactions of these factors will then precipitate a particular disaster, occurring at a given point in time and impacting a given South African community. Localisation of data from that community will play a critical role in the DRM of the disaster in question. Historical factors will overlap with the parameters of the current situation/current human actions in the disaster niche and the population at risk will transform into the particular population under disaster (Iheanetu et al., 2023). Indicators of disaster impacts, that are lagging and quantitative, provide a depersonalised perspective about the particular disaster impacts. Stripping away the information about, who individually is at risk or under disaster…who is the 'source of the data', allows the DRM practitioners to evaluate the general trends in data at the community level. This is then the foundation for dealing with the impacts of a particular disaster or hazard on a particular population at risk or under disaster. Correlation of such data, with other variables to establish DRM causality in the general sense (Madondo et al., 2023), will mainly be effective in the preparedness and mitigation phases of the disaster management cycle. Quantitative and real-time/near-real-time data will allow for tracking of the interest of the public in DRM information campaigns, to conduct triage of patients and resources in the disaster-impacted zone. This type of quantitative data is partially overlapping with qualitative data, e.g. medical history of a patient will be important to establish how a patient might have been injured and then diagnosis can provide an indication about the severity/frequency of impact of disaster on the population or individual under it. Personal identifiers are attached to data, which are related to a particular person, i.e. a human being under disaster with a name or biometric identification (IASC, 2021). It is necessary to assist the patients with the targeted medical care and other assistance in line with unit operations in the response and recovery phase of the disaster management cycle. The real-time or near-real-time qualitative data can be social media posts (Madondo et al., 2023). These are personal information-linked, e.g. the Twitter handle can be known for the message originator. Personal stories of the victims of human trafficking or refugees can be known but identifying marks can also be stripped away. Balancing the use of quantitative and qualitative data, which can be anonymised and personalised, provide a complete picture of the transformation of a population at risk into a population under disaster (IASC, 2021). It allows the DRM practitioners to gain understanding about the equality of presence and inequality of path for the members of the population under disaster from the space/place/time perspective.

The equality of presence means that all people impacted by a disaster are present in the disaster-impacted zone during the response and recovery phases of the disaster management cycle. All of such humans are equal and must be provided with assistance according to the principles of humanitarian

ethics (NRC, 2023). On the other hand, quantitative and qualitative data provide the basis for understanding the pathway of the population at risk into an unsteady state of the population under disaster. Highly personalised or de-personalised data provide a description of that path from a steady state of existence, from the multi-loci and discontinuous place of normalcy, towards the time of disaster (Madondo et al., 2023). Understanding of equality of presence is matched by data to investigate the inequality of path. Data collection should reflect this by keeping information flowing openly between the population at risk and the DRM practitioners. Analogical open system and human geography should apply in the conditions under disaster. Openness of the data and transparency of its evaluation/modelling is a necessity as the path from 'at risk' to 'under disaster' is linked to the DRM system. This will practically mean that data must be collected, about the changes to human life space at risk and under disaster. Such data must be evaluated and used continuously to test/evaluate, update, and improve the DRM system in a country. Results of that process are then applied as a foundation for protecting the wellbeing of the population at risk and under disaster. Data in DRM are thus part of an open system, and it depicts a geography of human wellbeing from a space/place/time perspective (Madondo et al., 2023). In this way, data about human impacts of a disaster can be seen as an embodiment of the civil protection in the DRM. Therefore data are part of a system aimed at decreasing human injuries and fatalities, so the data will be linked to the DRM policies and the whole DRM system in a country, e.g. South Africa.

Quantitative data and qualitative data being available, the South African DRM system does conduct unit operations in the individual phases in the disaster management cycle which are informed by data (based on the above). However, the extent varies greatly between the national, provincial, and local government. In an ideal situation, the multi-stakeholder platforms are involved in the use and analysis of data and making decisions based on them and to It is very redundant; reformulation needed increase resilience of systems (Ngqwala et al., 2017; Dormady et al., 2021). Ongoing evaluation of data on risk, hazards, and vulnerability analysis is part of continuous minimisation or likelihood reduction of the impacts of disasters on human wellbeing. Therefore DRM in the country is a combination of observations, data collection and evaluation; and targeted minimisation of disaster risk through specifically-tailored interventions to local conditions. This points to the fact that DRM has features of a natural experiment (Messer, 2016) and/or a quasi-experiment (Béné et al., 2020). A disaster will be classified by a type, e.g., a tornado, cyclone, flood or drought. Using the natural experiment/quasi-experiment analogy, the disaster onset can be seen as an intervention which targets a population at risk and its members are affected by disaster impacts. Based on the combination of the historical and current human actions influencing the life space of the population at risk, that population is not randomly split into sub-groups that are impacted by the disaster type to varying extents. However, human actions, at least in part, drive the disaster type as an intervention that transforms the population at risk into one under disaster. So the group selection for the degree and severity of the disaster impact does not take place intentionally, but disaster can be studied as being partly human-driven and intervention-like human actions lead to data production. The produced data are then evaluated to study the disaster impacts in order to speed up the return of population under disaster to the population at risk. In addition, evaluation of the natural experiment-like situation of disaster allows the DRM system to mitigate future transformation of the population at risk to a population under a type of disaster. Thus disaster can be looked as having properties of natural experiments through considering their utility (Crane et al., 2020, Box 1).

Interventions in natural experiments are targeted to impact everyday activities, e.g. changes to labelling of foodstuffs to fight obesity (Crane et a., 2020). Disasters are similar in the sense that they disrupt and change the everyday activities in the discontinuous and multi-loci life space of a single human or population at risk. Those impacts affect a particular population at risk, a population who are located in a specific life space(s). The onset of a disaster is followed by interventions, and wellbeing of the population at risk/under disaster can be protected or improved. The data collected at specific GPS coordinates and actions taken from them are based on and take into account the equality of presence and the inequality of path to the particular situation by the population under disaster. Mitigation and preparedness phases of DRM contain dedicated/intentional activities along the lines

of natural/quasi-experiments to minimise disaster risk impacts on human wellbeing based on data (Béné et al., 2020). Such a feedback loops into improvements of the DRM system from the space/place/time perspective (Lawton, 1983). Risk assessment and DRM are localised in nature, and they often target systemic issues and impacts of disaster in a highly localised settings of space/place and at a given time. In addition, this is the cyclic process of risk assessment (risk identification, risk analysis, risk evaluation) and risk treatment (ISO, 2018). This view of DRM places humans at the centre of the impacts and also at the need for conscious activities to decrease the disaster risk and disaster impacts on wellbeing of *Homo sapiens*. The current article builds on the theoretical perspective of Madondo et al. (2023) and it uses the disaster settings in a municipality in the Eastern Cape Province of South Africa to demonstrate the localisation of data for drought and fires, their evaluation and DRM implications.

1.3. Study settings and the working hypothesis

Localisation of the data will be examined in this paper for parts of the Sarah Baartman District Municipality (SBDMuni), where the profile of disaster risk management and relevant policies have been studied and analysed by Madikizela et al. (2019). Drought and its impact on the agricultural production were specifically seen as affected (Madikizela et al., 2019). The development costs and their investment mitigate possible disaster impacts in the future (Oosthuizen, 2018). Population of the SBDMuni has been impacted heavily by ongoing drought in the Eastern Cape Province of South Africa (Iheanetu and Tandlich, 2022).

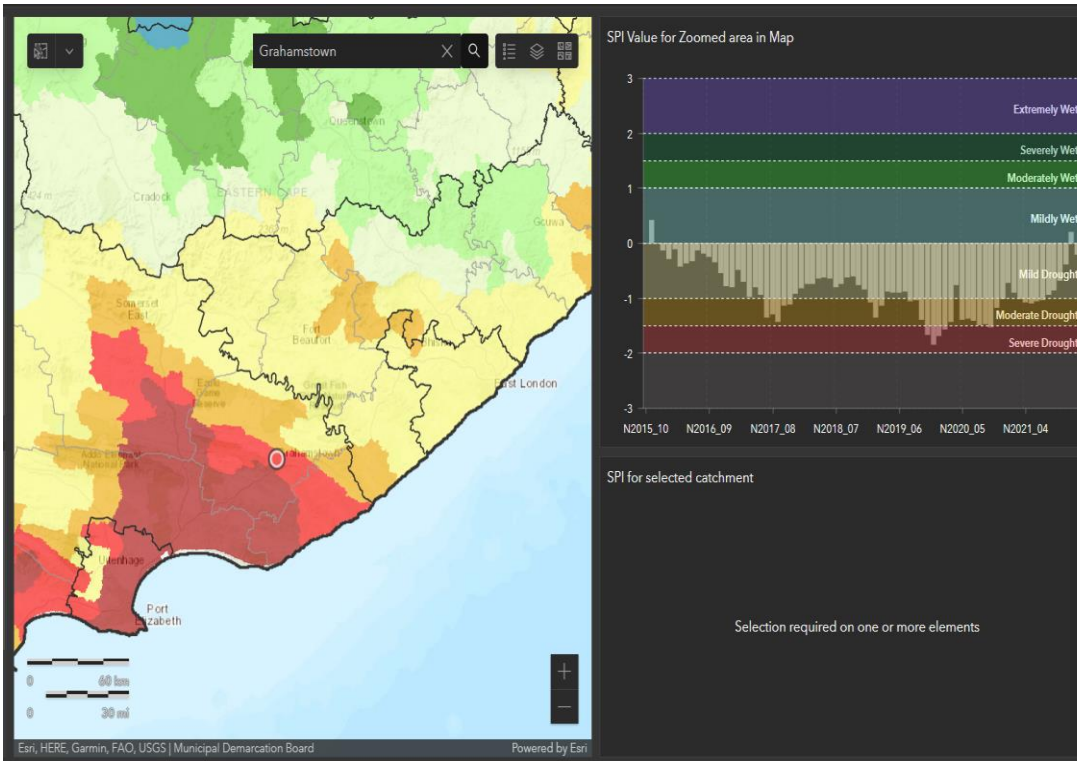

Fig. 1. The GIS presentation of the SPI index in Grahamstown/Makhanda, South Africa (NDMC, 2022).

South Africa is a water scarce country, and many citizens still lack access to sufficient quantities and quality of drinking water, e.g., in Makana Local Municipality, the Eastern Cape Province of South Africa (Iheanetu and Tandlich, 2022). Consequently, consumption of contaminated water has

potential health risks, and this requires regular water quality monitoring. Since 2015, Makana Local Municipality and the Sarah Baartman District have been in a state of drought disaster (NDMC, 2022). Drought is evaluated and classified using the SPI index, which is calculated using precipitation data in a given area (Karabulut, 2015).

As it can be seen from **figure 1**, the SPI values for the Makhanda/Grahamstown area have been equal to 0 or it has had negative values down to -2 since 2015 until present (NDMC, 2022). As a result, the area has experienced mild to severe drought in that time period (see below). This has led to cascading effects on the provision of drinking water to the population in Makana Local Municipality, part of the SBDMuni (Malema et al., 2019; Iheanetu and Tandlich, 2022). The decreased drinking water supply is further compounded by the fact that Makhanda/Grahamstown has long suffered from infrastructure problems and supply interruptions/water quality issues (Makana Local Municipality, 2020-2021). Drought and problems with the water reticulation infrastructure can contribute to the increased risk of fires and compromised firefighting if a fire had broken out.

Under conditions like these, it might be challenging to get the sufficient volumes of water to operate the fire hydrants to fight any ensuing fires (Martin, 2016). The situation in the SBDMuni is also complicated by loadshedding or controlled power cuts in South Africa, which can compromise water pumping and water availability (Winter, 2011). The DRM system in the SBDMuni and the Eastern Cape Disaster Management Centre put in place prohibition of open fires, with threat of prosecution for violators in 2020 and 2021 (SBDMuni, 2022). Exceptions had only been allowed under strict conditions, e.g. with the approval of the Chief Fire Officer for Makana Local Municipality (SBDMuni, 2022). The municipal website contained information about the details of the fire disaster management, but that might be outdated as no updates appear to have been done in the past 10 years (Makana, 2013). However, the DRM system worked in conjunction with the community, e.g. as documented with the coordinated efforts between the fire fighter and the community (Grocott's Mail, 2018). Business and government from SBDMuni have collaborated on boosting the capabilities of the Makana fire services, e.g. Santam donated personal protective equipment, foam cans and other materials to the worth of 220000 ZAR in 2016 (1 USD equal approximately to 16.0-17.5 ZAR; Creamer Media – Engineering News, 2016).

There are thus grey-literature sources and newspaper articles that indicate fire disaster management is actively pursued in Makana and SBDMuni. However, there has been no systematic and academic assessment of the fire disaster management in Makana Local Municipality as a model part of SBDMuni. This should urgently be addressed based on the policy dimension, conditions of drought and the resulting compounding factors for fire disaster management in the municipality. Therefore, the current paper is aimed at investigating some quantitative and some qualitative data, as well as their implications for the space/place/time perspective in Makana Local Municipality and SBDMuni, in terms of fire disaster management. The working hypothesis of the current article is that firefighting under drought conditions will pose challenges on the DRM system in SBDMuni and Makana Local Municipality. These challenges will be practical, ethical and adaptation will be required from the DRM system of the municipality. Understanding stakeholder involvement and gaps in the unit operations in the disaster management cycle can be identified using these tools and improvements can be proposed.

2. METHODOLOGY

2.1. Public interest as an open-system and quantitative data example for South Africa fires

An open system will require the free exchange of information between the SBDMuni/Makana population, the South African population and the global information/DRM landscape. Information about fires will be sought by the population on a continuous basis and thus there should be data sources to evaluate this interest. Some commonly known tools are questionnaires (Bird, 2009) and focus group discussions (Rivera, 2019). Excellent qualitative and quantitative data for DRM can be obtained through them if they are run or administered through openness of interaction and by following research ethics principles (Francioli, 2020). Results from the use of these tools can be

valuable for the DRM planning in the preparedness and mitigation phase of the disaster management cycle. This is mostly the case, as questionnaires and focus groups provide mostly lagging indicator data. In real time or near-real time, a different set of tools is necessary. One that allows for the evaluation of the public interest in a particular disaster type, i.e. fires in South Africa, over extended periods of time but without the delay of lagging indicators. Such a tool should be providing data within days or hours of the data being produced. Madikizela et al. (2022) tested the use of the Keywordseverywhere.com plugin to retrieve the WASH monthly search volumes from Google for the 2004-present time period. In the next article, Tandlich et al. (2023), who used a similar methodology to test the reliability of the plugin for real-time application in emergency management. Analogical methodology was used here with the focus on fires in South Africa. Therefore analysing these data can lead to the examination of the fluctuation and temporal variability in the public interest in disaster information, e.g. the fire-related search terms.

In the current article, the plugin was downloaded and installed on their PC by the authors and the online search credits were procured from the plugin developer (as shown on https://keywordseverywhere.com/credits.html; website accessed on 23rd January 2023), a four-prong strategy for public interest assessment and the data accuracy/validity provided by Keywordseverywhere. Firstly, the monthly search volumes for fire on Google in South Africa were obtained from the first month of 2004 until the sixth month of 2022. The monthly search volumes were extracted from Google (Y_i) on three separate occasions between June and November 2022. The extracted data for fire were averaged for the given month, and the standard deviation of the month search volumes from three data extractions was calculated using the Microsoft Excel 2022 software (Microsoft Inc., Johannesburg, South Africa). Any trends in those volumes were assessed for increase or decrease with time using the Mann-Kendall test at 5 % level of significance (Past 3.0, Hammer et al., 2001). Secondly, the Y_i values in each year were summed up to obtain the yearly volumes of fire searches in South Africa between 2004 and 2017. As shown in Equation (1), *TFSSA* is the yearly volume of the Google searches for fire in South Africa in a given year between 2004 and 2017.

$$TFSSA = \sum_1^{12} Y_i \quad (1)$$

Those yearly volumes were investigated for statistically significant correlation with the total number of fire callouts/fires in South Africa between 2004 and 2017 (as summarised by Madondo et al., 2022 and designated as *TFBC* in further text of the article). At the same time, the total financial losses from fires were correlated with the total yearly searches for fire in South Africa (see **Table 1** for value details and the summary by Madondo et al., 2022). That was done using the using the Spearman coefficient at 5 % level of significance (see https://www.socscistatistics.com/tests/spearman/default2.aspx for details; website accessed on 23rd January 2023). If the public interest followed the significance of fires as disasters in South Africa, then the number of yearly searches for fires on Google should correlate positively with the number of fires as disasters in South Africa. Fires in South Africa can be considered disasters, in terms of the fire brigade call outs, as the largest portion of the fire brigade call outs were to the domestic fires between 2004 and 2017. Such fires would have devastating consequences on the human wellbeing of the South African population, given unequal to distribution of income and other resources (IMF, 2020). Therefore, they are disasters from the viewpoint of civil protection and DRM.

Thirdly, a search was conducted for veld fire or veldfire, i.e. a term from South Africa which is not widely used outside of the country. Searches for this term were run for South Africa and for the global Google data. Veld fire/veldfire was chosen as a test term to assess the accuracy of the search results from the Keywordseverywhere.com plugin. If the plugin extracts reliable data from Google, then the search volumes for veld fire/veldfire from South Africa should accounts for the majority of the search volumes in the world. In other words, the monthly/yearly search volumes for veld fire/veldfire from South Africa should account for 100 % or close to 100 % of all global searches for the term. In the current study, veld fire/veldfire will be considered as a synonym of the wildfire.

Finally, the accuracy of the plugin will be Boksburg truck explosion/fire of December 2022. On Christmas Day 2022, a truck carrying liquefied natural gas got stuck under a bridge in the City of Ekurhuleni in the Gauteng Province (Pijoos, 2022). After about 60 minutes, there was a massive explosion and fire, which caused 37 immediate deaths and damage to a major regional hospital (Pijoos, 2022). The truck explosion and the ensuing fire was a major event which got national and international coverage (Banda and O'Reagan, 2022). It should therefore lead to the highest daily search volumes on Google Boksburg fire/explosion in the days right after the explosion and decline thereafter, i.e. about the end of next month.

The daily volumes were extracted fort the time period from 26th October 2022 until 22nd January 2023. The term Boksburg explosion was chosen as a fire ensued after the truck exploded, and also because the reporting on the disasters was run under titles that contained the phrases Boksburg explosion. There was a concurrent fire and destruction due to the blast and fire, i.e. the term Boksburg explosion was deemed suitable in the context of the current article. There should be zero searches for Boksburg explosion from 26th October 2022 until 23rd December 2022. This should then be followed by sudden spikes in the search volumes and a maximum should be reached on 24th December 2022. After that, the search volumes should decrease from 25th December 2022 until 22nd January 2023.

The need to confirm data for the same time period, which had been extracted using the plugin on different occasions, are necessary as the indexing issues have been raised in relation to some Google data and the sliding time scale can cause shifts in the monthly volumes (Kovalenko et al., 2021; Madikizela et al., 2022; Tandlich et al., 2023). If the proposed pattern in the daily search volumes for the Boksburg explosion is observed, it would indicate that the Keywordseverywhere.com plugin extracts reliable search volume estimates from Google. Qualitative drivers of the South Africans' interest in fire were also analysed from the Keywordseverywhere.com plugin, to see and confirm that the disaster implications of fire drove the level of public interest in them.

2.2. Makana public interest and the DRM planning for fires at the local municipality level

Results from the previous section will indicate the level of public interest in fires and whether an online-Google linked tool can provide useful data tools for assessing the public interest in DRM. That section also states a bigger picture for the open system of South African DRM geography. It is important to use data available to assess the public interest in fires at the smaller geographical scales. Madondo et al. (2022) summarised the Makana fire callout numbers from 2004 until 2017. The data on fire brigade call outs in Makana can be used to estimate the probability of a fire on any day in a given calendar year in the municipality. That parameter was designated as *PFMM* in further text of the article and was calculated using Equation (2).

$$PFMM = 100 \times \frac{NFCM}{365.29} \quad (2)$$

In Equation (2), the number 100 allows for the reporting of probability as percentages. The numerator represents the number of the fire brigade callouts in Makana in a given calendar year, i.e. *NFCM*. The denominator represents the average days in a calendar year, namely 365.29 days, between 2004 and 2017. The calculated *PFMM* values indicate that fire hazard in Makana Local Municipality is significantly high to influence everyday lives of the population at risk there. The probability levels could be one of the drivers for the public's interest in fires. This interest was compared with other geographical scales in South Africa, as shown below.

To investigate how fires are addressed in the planning at the local government level in Makana Local Municipality, the integrated development plans from Makana Local Municipality were downloaded from the respective website for 2014 until present (Makana, 2013-present, a). Then the documents were searched for the word frequency of disaster and fire, using the Adobe Reader search function (Adobe Inc., USA) or Microsoft Word (Microsoft Inc., Johannesburg, South Africa). Then the words, notions or sentences that were associated with both terms were also analysed in each document (Fries, 2019). The ability to deal with fires the Makana DRM system was assessed by

extracting the description and/or quantity of capacity available, the resource allocation and the availability of quantitative and qualitative data on the fire disaster management, or the unit operations conducted in phases of the disaster management cycle.

The Keywordseverywhere.com plugin does not allow one to obtain a breakdown of the search volumes to smaller geographical resolution than the country level. Therefore, Google trends were used to investigate the differences in the open geographical system and the level of public interest in the fires as disasters. The monthly Google trends scores were extracted on one occasion for the 2004-2017 periods for South Africa and the Eastern Cape. The Google trends indicate the relative significance of the interest in fires in the specified geographical area, when compared to the other search term interest on Google by users in that area (see https://support.google.com/trends/answer/4365533?hl=en for details; website accessed on 29th January 2023). Any statistically significant difference between the two sets of scores would indicate whether there is a statistically significant difference in the relative interest of the public in fires in South Africa and the Eastern Cape population (tested using the Mann-Whitney test at 5% level of significance; Past 3.0; Hammer et al., 2001). For some towns in SBDMuni it was also possible to extract single scores, i.e. those were made part of the semi-qualitative evaluation of the fire interest in the district.

2.3. Financial estimates of the fire DRM burden on Makana population and system

Selected pieces of relevant South African legislation which governs firefighting at municipal level were assessed. One such element of legislation gives municipalities the possibility to charge tariffs for firefighting. Makana Local Municipality charges these based on an annual list of municipal charges and those were analysed in the context of the potential vulnerability implications of the Makana population (see Results and Discussion for details of relevant legislation). The costs structure of the fire tariffs will be changed on an annual basis and will likely be guided by two specific ethical considerations. Firstly, the emergency and humanitarian aspects of the fire DRM roles played by the fire departments must be taken into account. In other words, there will be activities that a fire brigade will conduct to protect and save human lives in the context of fires, in line with the principles of humanitarian ethics (NRC, 2023). Such call outs will likely not attract any charges, as the right to life is being protected (South African Constitution, 1996-present). Then there will be fires that require the protection of the assets, such as houses or infrastructure, which are like to attract some cost recovery by the municipal fire services.

The circumstances of such call outs will likely require case-by-case approach in the cost recovery, or tariff invoicing for firefighting. Equality of presence will play a significant role here. The second invoicing consideration will be the financial status of the recipient of fire brigade call outs, or activities. If a person is destitute by the impact of the fires and/or indigent prior to it (DPLG, 2009), then the person will not be in a financial position to pay for the fire brigade call outs. In such a case, the cost recovery would be unethical on the part of municipality as the controlling authority (see Results and Discussion section for details below). Inequality of path will be a key consideration in the invoicing here. A means test must be in place to decide on whether to invoice or not to invoice for the fire brigade call outs to particular Makana residents. The use of residents' information, that is available to the local municipality, will likely play a critical role in that context…as quantitative and qualitative data perspective of fire vulnerability and resilience of the Makana population at risk and under disaster.

In relation to invoicing for firefighting, there is another consideration that must be addressed. This third consideration is the estimation about the charges that a Makana household can expect to incur for a likely fire brigade-call-out scenario. For the third cost consideration, the Makana fire tariffs were extracted from the available online and open sources. To the best of the authors' knowledge, only fire tariffs for following financial years are available in the public domain for Makana Local Municipality: 2015/2016 and 2016/2017 (Makana, 2015-2017) and 2019/2020 (Makana, 2019-2020). Given the findings of Madondo et al. (2022), majority of the fire brigade call outs are related in South Africa to fires dwellings, at household level. Therefore, a model fire case, and the related tariffs likely

to be charged for it to residence in Makana Local Municipality, was run as follows. A fire response would require the mobilisation of one major appliance, one medium appliance and one auxiliary appliance. The service vehicle would also have to be deployed to fight a fire in the high-income household in Makana. For the informal dwelling, a flat rate would be charged (see Results and Discussion for details). Regression analyses were done for each appliance and fire tariff, and the *r* values were compared with the inflation rate in South Africa at the time. The water volume and flows were estimated from the information by Fire Protection Association of Southern Africa (FPASA, 2021) and the pricing of water used was estimated from the monthly water statement at the last author's house. The total cost of the hypothetical model case was estimated for the 2019/2020 financial year and calculated as shown in Equation (3).

$$FTMC = \sum(FTMA + FTMEA + FTAA + FTST + WC) \quad (3)$$

In Equation (3), *FTMC* is the fire tariff charged for the use of major appliance. *FTMEA* stands for the fire tariff charged for the use of medium appliance and *FTAA* is the fire tariff charged for the use of auxiliary appliance. Finally, *FTST* is the fire tariff charged for the use of service truck and *WC* stands for the cost of the water used. The costs were also compared to the income of a Makana household, namely 2016.96 and 3653.76 ZAR per month (1 USD = 16-17.5 ZAR; Iheanetu and Tandlich, 2022).

2.4. Compounding factors of fire disaster management in Makana

Drought in SBDMuni will lead to a decrease in the volume of available water in the district and in Makana Local Municipality. There are infrastructure problems in Makana Local Municipality that are linked to provision of public goods and service delivery. One of these challenges is the process of loadshedding, when a controlled shut down of part of the electricity grid in a geographical area/South Africa is done (Western Cape Government, 2019, page 2). Loadshedding is necessary as the generation capacity of the electricity system is not able to meet the demand for electricity (Western Cape Government, 2019, page 2). Such infrastructure problems will increase the problem in water delivery to fire sites and the electricity to pump the water to the necessary parts of the reticulation system. In South Africa and in Makana, loadshedding has been in place since 2007-2008, but the extent has been deepening since 2015 (CSIR, 2022). Loadshedding is spread geographical across the territory of South Africa and the electricity supply is cut to a particular area in 2.5-hour increments at a time (Eskom, undated). At the time of writing of the current article, there were 8 possible stages of loadshedding that Eskom, the national electricity company and the almost-monopoly of power supply in the country, had in place to deal with shortage of generation and the high demand for electricity in South Africa (Eskom, undated). The breakdown in the electricity delivery will have several implications for the fire disaster management in South Africa. Firstly, the loss of electricity can lead to the use of alternative fuel, e.g. wood and charcoal or gas, to heat residences of the Makana households (similar to the findings of Francioli, 2020). In addition, the ability to contact the fire department could be compromised. Therefore, the daily probability of loadshedding for Makana (*PLDY*) was calculated as shown below.

The power cuts in Makana Local Municipality are done by splitting the area in two sections, namely Grahamstown 1 and Grahamstown 2 (Loadshedding Schedule, 2022). For both sections of the Makhanda area, the number of hours of loadshedding at stages 1-6, which had been observed in South Africa between 2015 and 2021, were averaged out over a three-week period (see Results and Discussion for details). Raw data from the CSIR (2022) was extracted and can be found in Appendix I. In addition, the total hours of loadshedding in a given year were extracted for the 2015-2021 period (*THL*) were as follows: 852 hours in 2015, 0 hours in 2016 and 2017, 127 hours in 2018, 530 hours in 2019, 859 hours in 2020 and 1136 hours in 2021. The *PLDY* value was calculated in Equation (4):

$$PLDY = 100 \times \frac{THL}{365.33 \times \sum_1^6 X \times MRSPC} \quad (4)$$

In Equation (4), *X* and *MRSPC* definitions are found in Appendix I. The number 365.33 is the average number of days in a year between 2015 and 2021.

Municipal reticulation infrastructure will play a critical, namely conveyancing, role in delivering the drinking water to the consumer or residents Makana Local Municipality. It will also be used to deliver water to fire hydrants (Świętochowska and Bartkowska, 2022). That infrastructure in the Makhanda/Grahamstown area of Makana has long suffered from the pipe breaks and the results in the drinking water supply outages. This can be demonstrated by data which had been collected in the last author's house. There have been about 18 visible pipe breaks a year that have occurred over the pipe length of 1000 feet or 304.5 metres of road/pipe surface (designated as *N* in further text of the article) between 2015 and early 2022. The pipe break rate was accounted for until the time period of 2015-2022 and is based on visual observations by the authors in the area of the current study site. In early 2022, the asbestos/cement pipes were exchanged for the PVC pipes. The inner diameter of both types of pipes was equal to 148 mm and the outer diameter was equal to 200 mm. The pipe break rate can be used to estimate the age of the municipal pipes in the study area. Based on the data available to the author, the model of Shamir and Howard (Dehghan, 2009, page 37) is used and shown in Equation (5):

$$N(t) = N(t_0) \times e^{A \times (t-g)} \quad (5)$$

In Equation (5), $N(t)$ is the number of pipe breaks in the given year and $N(0)$ represents the same term in year 0 of pipe age. The number of pipe breaks is counted per 1000 feet or 304.5 metres. *A* is a constant and (t-g) represents the age of the pipe. It might also be an indication about the problems with water delivery during firefighting, as the age of the pipe might be indicated by the number of pipe breaks.

3. RESULTS AND DISCUSSION

3.1. Public interest as an open-system and quantitative data example

The monthly and yearly search volumes for fire in South Africa are shown in **figure 2**, as a function of the number of month in the search history (a) and the fire brigade callouts/fires reported in the country between 2004 and 2017 (b). The search history was counted as 1 in January 2004 and 222 in June 2022.

There was an increasing trend in number of searches for fire by the South African public in Google between January 2004 and June 2022, and that trend was statistically significant at 5 % of level of significance (Mann-Kendall test with p-value = 2.5×10^{-7}). The South African public's interest in fire was directly proportional to the number of fires in the country, as the Spearman correlation coefficient was equal to 0.6429. That correlation was statistically significant at 5 % level of significant p-value = 0.0178. At the same time, the Spearman correlation coefficient between the *TFSSA* and *TLFR* was equal to 0.4780, but the correlation was not statistically significant at 5 % level of significance (p-value = 0.0985). Madondo et al. (2022) derived Equation (3) to predict the total number of fires outside of the 2004-2017 time period for which the fire brigade calls out statistics were available from the Fire Protection association of Southern Africa. Some of the data from that study are reused here, namely the total number of the Google searches for fire in South Africa between 2004 and 2017. However, the data here are based on three data extraction occasions and reported as averages, which are slightly different than the previously reported data by Madondo et al. (2022). That difference is minimal but is the results of the time sliding scale of the reverse data production by Keywordseverywhere.com plugin (Kovalenko et al., 2021). The average percentage of variation of the monthly and yearly search volumes for fires on Google, by the South African population was equal to 6.6 ± 1.2 %.

To gain more understanding in the causality of the public interest in fires in South Africa, the *TFSSA* were correlated with the access to the internet by the population, i.e. the percentage of South African population to the internet between 2004 and 2017 (WB, 2022 and see also **Table 1** for details).

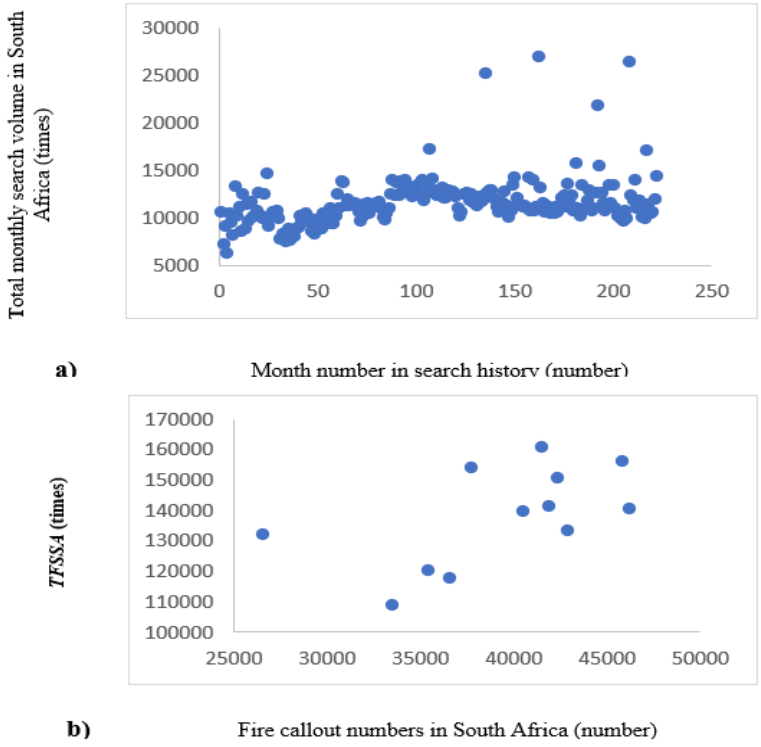

Fig. 2. The monthly search volumes for fire in South Africa from January 2004 until June 2022, as a function of the search history or month number (a), and the correlation between the total number of the fire brigade callout in South Africa from 2004 until 2017, as a function of the respective yearly search volumes on Google in the country (b). Terms are defined in the text of the article, e.g. Equation (1).

The Spearman correlation coefficient was equal to 0.7565 and correlation was statistically significant at 5 % level of significance as the *p*-value was equal to 0.0028. Therefore, the South African public's interest in fires will be driven by the number of fires in the country and the access to the internet. The Google searches are the result of the South Africans accessing the information in the open system of the internet. Setting the searches geographical scope to South Africa, the qualitative drivers of the interest in fires can be established by examining the related keywords, the keywords people also searched for, the long-tail keywords and additional information from the plugin of Keywordseverywhere.com. Out of the 431 words extracted, the top qualitative drivers of public interest were 'fire extinguisher, fire fighter learnership, fire fighter course, fire brigade and fire hydrant'. The number of monthly searches ranged from 2400 to 9900. However, large portion were terms related to entertain 'chicago fire' which might refer to the respective television series, with 18100.

The relative importance of the searches for fire in South Africa and in the Eastern Cape was compared and the data had following characteristics. For South Africa as a whole, the average *g* score was equal to 47 ± 10, the median for *g* was equal to 46 and the mode *g* score was equal to 47. On the other hand, the Eastern Cape average *g* score was equal to 6 ± 10 and the median and mode value for *g* were both determined to stand at 5. The values of the relative interest in fire were higher for the whole of South Africa compared to the Eastern Cape. That conclusion was based on the results of the Mann-Whitney test at 5 % level of significance (*p*-value = 0.0001). Based on the additional information, South African with access to Google search for fire in terms of interest in disasters and their impacts, but also based on the popular culture links of the term 'fire'.

Table 1.

The total number of fire brigade call outs and estimation of the total public interest in fires in South Africa.

Calendar year	*TFBC*[a] (times)	*TFBCM*[b] (times)	*TFSSA*[c] (number of searches)	*TLFR*[d] (ZAR)	*PSPAI*[e] (%)
2004	36591	159	118082	492120909	8.43
2005	42863	194	133400	350056296	7.49
2006	33499	135	109224	2023916105	7.61
2008	35434	218	120413	504966938	8.43
2009	40481	144	139960	667102742	10.00
2010	26574	145	132134	613802753	24.00
2011	37721	172	154112	728144691	33.97
2012	41481	152	161039	744278394	41.00
2013	42343	146	150982	1008867283	46.50
2014	46187	144	140693	680486831	49.00
2015	45784	99	156477	1186434833	51.92
2016	41873	280	141392	1843930163	54.00
2017	49567	136	156377	2773495906	56.17

[a] *Fire brigade callout in a given calendar year in South Africa as summarised for the 2004-2017 by Madondo et al. (2022) and as extracted from the fpasa.co.za database.*
[a] *Fire brigade callout in a given calendar year in Makana Local Municipality as summarised for the 2004-2017 by Madondo et al. (2022) and as extracted from the fpasa.co.za database.*
[c] *The total searches for fires in South Africa between 2004 and 2017, as extracted from Google by using the Keywordseverywher.com plugin*
[d] *Financial losses from fires in a given calendar year in South Africa as summarised for the 2004-2017 by Madondo et al. (2022) and as extracted from the fpasa.co.za database.*
[e] *Population percentage with access to the internet in South Africa as extracted from the World Bank database (WB, 2022).*

The assessment of accuracy of the Keywordseverywhere.com plugin in extracting correct Google search volumes, the veld fire and veldfire monthly searches from South Africa vs. global landscape were assessed. The average percentage of the searches from South Africa as a portion of the global searches was equal to 50 ± 39 %. This is very different from 90-100 % as was expected and not achieved. Between February 2004 and July 2007, the search volumes from South Africa were higher than the total search volumes for the global landscape (see **Fig. 3** below).

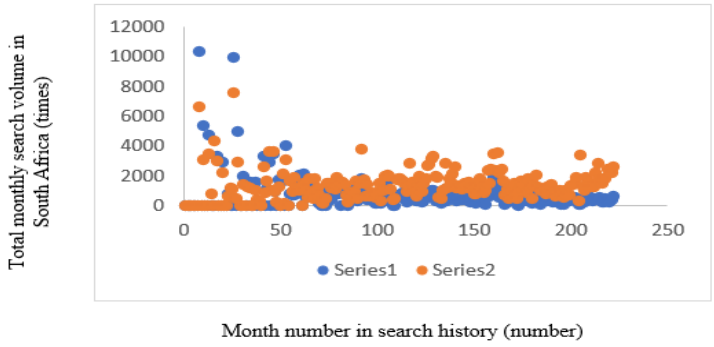

Fig. 3. The monthly search volumes for veld fire and veldfire in South Africa (series 1) and globally (series 2). Data was extracted from |the Keywordseverywhere.com plugin.

The data from the test indicate that some issues, with extracting accurate search volumes from Google by Keywordseverywhere.com, do exist. There was large number of the months in which the search volumes for veld fire/veldfire in South Africa, and globally, were equal to 0. The statistical characteristics of central tendency and variability were equal to the following number for South Africa: 741 ± 1221 for the average and standard deviation, 448 for median and 0 for mode. For the global landscape 1355 ± 1039 for the average and standard deviation, 1200 for the median and 0 for mode.

The Boksburg explosion was used to test whether the Keywordseverywhere.com plugin can provide search volumes on a short time scale, i.e. if there is a correct and sudden spike in interest of the South African public in particular disasters right after their onset. This would be especially true in terms of disaster which have local significance, e.g. to the territory of South Africa. The daily search volumes for the 'Boksburg explosion' are shown in **figure 4** below. The individual values ranged from 0 on all days from 26th October 2022 until 23rd December 2022, with one exception on 17th December 2022. On that day, the search volume was equal to 4600 and it could be considered at indexing issue, or the result of recalculation of the search volumes on a sliding scale by the plugin. However, the daily search volumes spiked to a maximum of 458300 searches on 24th December 2022 and then they declined steadily until 22nd January 2023.

The final search volumes on that day ranged from 600 to 1200 daily searches. Therefore, the temporal trend in Boksburg explosion has the shape expected by the authors, and it indicates that the Keywordseverywhere.com plugin provides reliable daily volumes on Google searches. Results of the study so far indicate that there has been a constant and increasing trend in the South African public's interest in fires. That trend is driven by interest in firefighting equipment and possible also by the interest of the South African population in firefighting as a career. On causality front, the interest in fires is quantitatively driven by the number of fires in South Africa between 2004 and 2017, as well as access to the internet by the South African population. The plugin used in this article provides data from Google which have various levels of accuracy and thus there must be some caution in the application of the plugin, i.e. results should be interpreted on a specific basis for each keyword studied or used.

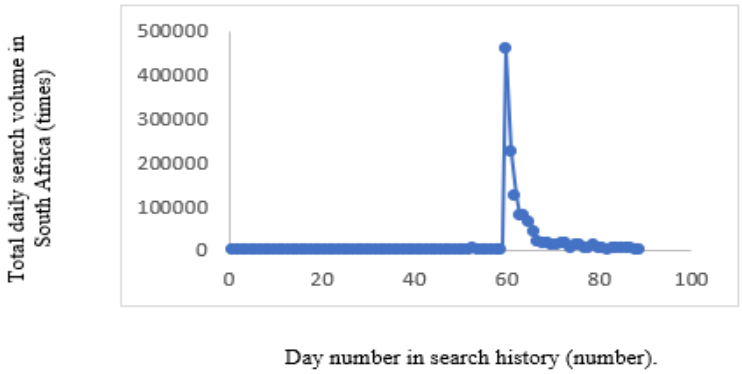

Fig. 4. The daily search volumes for Boksburg explosion from 26th October 2022 until 22nd January 2023, as extracted from Google using the Keywordseverywhere.com plugin. Day number in the search history is counted as follows: number 1 is 26th October 2022 and then the number increase by one per day until 89 on 22nd January 2023.

The plugin data is also an example of a low-cost and/or (near) real-time tool to evaluate the public interest in fires and related topics in South Africa. The plugin, along with Google trends, produces quantitative data which describe the space/place/time perspective of fires in South Africa. Extraction of this data provides for the DRM practitioner in South Africa with information and can be seen as an expression of the open geographical system and flow of information between the community of South Africa, a population at risk from fire, and the DRM practitioner to stop that.

3.2. Makana public interest and the DRM planning for fires at the local municipality level

Only single *g* scores could be extracted for the towns in the SBDMuni and those ranged from 41 to 54. For the Grahamstown/Makhanda area of Makana Local Municipality, the single *g* value was 41 or zero on two separate data-extraction occasions. Therefore, the relative interest in fires in South Africa was higher than in the Eastern Cape, but it was comparable to national values in urban centres of the SBDMuni. Based on this data, the interest in fires is high enough to ensure the penetration of awareness campaigns in towns and cities in SBDMuni. However, some door-to-door awareness campaigns might be needed in the rural parts of the district and Makana…places where internet access might be lower than provincial and national coverage. The yearly probability of fire in Makana Local Municipality ranged from 27.1 to 76.7 % between 2004 and 2017. From the data source by Madondo et al. (2022), it was not possible to estimate the number of false call outs for the fire brigade in Makana Local Municipality. However, as shown below, the Fire Department in the Makana often received all the complaints from the residents and so not all fires/emergencies were likely responded to. Tis uncertainty needs to be addressed in the future research. Therefore, it seems that the fire is always a possible hazard in the Makana territory and should thus be seen as a priority for planning at the local government level. The Integrated Development Plans (IDP) for Makana Local Municipality should take this into account. Only the annual IDP documents were analysed over time and evaluated for consistency. The word frequency and related analysis results are shown in **table 2** below. The word frequency ranged from 34 to 69 for disaster and from 29 to 61 for fire. The frequency was not dependent on financial year for disaster, but it seemed to increase for fire.

In the 2014-2015 financial year, firearms remained a concern and are mentioned extensively throughout the IDP, but no directly related to fires. Local government plans for the disasters and fires are in place in Makana Local Municipality. However, logistical and capacity challenges remain to be addressed. Compounding factors in firefighting include water provision. The 2015-2016 IDP document analysis indicated the following. Monitoring and evaluation of the influence of the geomorphological features of the Makana topography are still in focus. There was mentioning of the funding being sought to deal with damages from the 2008 disaster, i.e. a tornado which had hit Makana Local Municipality. Funding for fire services and the over-burdening of the fire services, as the designated complaints centre for Makana, were a challenge. SBDMuni and its DRM structures were asked for assistance. Topology and other geomorphological features of Makana geo-surface remain a target for DRM monitoring, as in the 2014-2015 financial year.

In the following financial year of 2016-2017, the drought is showing as having an impact on the firefighting capabilities in Makana Local Municipality, reconstructions from 2008 tornado and 2013 floods still not completed. Fire services are available 24 hours a day but remain underfunded and working with the district municipality is again seen as a way to mitigate the impact on fire DRM in Makana. First time a figure of financial resources available for firefighting is available. Establishment of fire outposts in outlying areas of Makana remains a major hazard in fire DRM.

That trend and focus on awareness campaigns remain constant and appeared again the 2018-2019 IDP document. There was an account given of the reconstruction efforts, and financial expenditure related to that, given and the hiring of new fire-fighter seemed to be a new challenge identified in the IDP. In the 2019-2020 financial year protection of Makana municipal records from fire and motivating for filling firefighting and DRM vacancies was made a priority, along with drought impacts in the municipality. More financial information than ever provided in the 2021-2022 IDP document. Analysis of the IDP documents indicates that drought does have some impacts on the firefighting in Makana Local Municipality, but the extent is not well documented. The personnel situation and requiring the fire-fighters to undertake other work outside of their mandate, e.g. the receipt of Makana complaints about municipal services, poses a problem. Settlements which are geographically isolated, such as Riebeeck East and Alicedale, are in trouble during a fire, as fire stations are not available there. Makana places a strong focus on awareness campaigns as a mitigation measure, and this is to be commended due to financial constraints and the need for ongoing DRM assistance from the SBDMuni authorities. Therefore, challenges do exist in firefighting and fire DRM in Makana Local Municipality, but mitigation measures are in place…at least on paper.

Table 2.

Coverage of fire disaster management in the IDP documents for Makana Local Municipality.

Financial year	*WFD*[a] (times)	*WFF*[b] (times)	*Keywords associated with disaster*	*Keywords associated with fire*
2014-2015	34	29	Management, topography, soil, slope, hydrology, act framework, plan, emergency response, incident centre, IT recovery planning, housing, manpower challenges, review, conducting risk assessment	Increased risk, firearms, firefighting, fire prevention, Chief Fire Officer, fire office Grahamstown, fire brigade services by-law, fire and rescue services, water delivery and logistical challenges, satellite fire stations to be built, fire proof storage a challenge, fire station upgrades are needed
2015-2016	61	37	Management, topography, soil, slope, hydrology, act framework, plan, emergency response, incident centre, Makana 2008 – 20 million ZAR investments in assisting 161 housing claimants (problems with contractors), planning for reconstruction of housing in Wards 9, 10, 14, Road reconstruction from 2013 disaster, Fire awareness programmes, inspections, update disaster management disaster management plan is in place and contingency for fires exists	Increased risk, firearms, firefighting, fire belongs under public safety and community services, 24 hour fire service in place, Chief Fire Officer appointed, veld and forest fires identified as a risk, underfunding of the firefighting at local level and SBDMuni contacted to resolve, complaints at the municipal level not handled properly, contingency plan for fires exists.
2016-2017	55	33	Water shortages necessitate updates to the DRM plan, disaster management falls under public safety, risk assessments for fires and other disasters, 2008 tornado still being dealt with, 2013 floods recovery steering committee in place in cooperation with the province, target for housing reconstruction the same as previous year, review of the disaster management plan seemed to be underway and comprehensive risk management to be adopted, new DRM plan passed onto the SBDMuni structures, contingency plans in place	Topology and related topics to be mapped remains as a task to complete, water shortage and increased fire risk remain, firefighting is related to air pollution, some fire fighter positions were allocated funding but not filled, fire and rescue services had a manager in place, 24 hour firefighting service and a Chief Fire officer in place, the DRM plan accounts for veld and forest fire risk, funding of some firefighting needs the support from SBDMuni (funding allocated at 233010 ZAR, Alicedale and Riebeeck East do not have fire stations, DRM and Fire/Rescue plan to be reviewed, fire contingency plans in place
2018-2019	64	43	Topology and related topics as before, moratorium placed on hiring a disaster officer, disaster impacts in ward 1 require fixing of 20 housing units, ward 7 to have some disaster-stricken houses demolished and wards 9/14 reconstruction to be done or underway, ward 10 completed reconstruction, Vukani house reconstruction continues, 2008 disaster funds not possible to give percentage spent, the 2012 floods damage to electricity and pumps repaired partially by national government funds from 0.3 to 2.4 million ZAR, changes to the steering committee targets necessary, review of fire and DRM plans, awareness campaigns to be run, contingency plan and interactions with district remain unchanged	Fire DRM remains largely the same as in prior years, 1 fire-fighter interviewed for 3 positions, but hiring not happened due to moratorium, building of outlying satellite fire stations to be made a priority, fire manager in place and it is the same person as before, access control and fire suppression system installed in Makana buildings, access to firefighting services and types of fires unchanged from previous year, awareness campaigns to be run on fire disaster management and DRM in general
2019-2020	58	38	Makana was declared a local disaster area due to poor service delivery, which was approved by SBDMuni, disaster officer motivated to be hired, lack of business continuity for Makana records identified, housing reconstruction from previous disaster still not completed, SBDMuni infrastructure and economic development planning to assist Makana in mitigating drought, recovery plans to be strengthened.	Senior fire-fighter and three rank-and-file fire-fighters motivated to be hired, some fire plans claimed to be in place not in all parts of Makana is this the case, the fire-proof storage of records to be made a priority with fire sensor and suppression systems were installed in ICT, plan review and awareness campaigns to be run
2021-2022	69	61	Up to 3.184 billion ZAR in COVID19 relief assistance was provided, Makana allocated 14.96 million from disaster management reports done but not implemented into the IDP, disaster officer post still vacant, outstanding RDP house construction in wards 10 and 13, 18.85 million ZAR for disaster management in coastal areas and in cleaning them up	DRM plans for all local municipalities in SBDMuni underway to deal more effectively with fires, fire DRM plans still inadequately done, fire department functions impaired by not hired staff, but focus on developing new fire-fighters

[a] Word frequency for disaster in the given IDP document. [b] Word frequency for fire in the given IDP document.

The qualitative data from the IDP documents seems to indicate that awareness campaigns about fires are a priority and this seems to match the medium level of interest in fires in the Makana Local Municipality, as indicated by the Google trends data. The qualitative data seems to indicate that the local government in Makana requires outside assistance to deal with budgetary consideration in DRM. Capabilities in outlying areas of Makana are limited and places the populations there at heightened level of risk. Financial resources required by Makana government to hire fire-fighters and to make further arrangements in fire DRM are quantitative data. They point to the need for Makana to function as an open system in term of geography of fire DRM. This is especially the case for people in the space and place of residence in the outlying settlements of Alicedale and Riebeeck East since the 2016-2017 financial year. Interpretation of the qualitative data from the Makana IDP in this paper, in combination with the other data from this article, makes then creata by the authors who reside in the Eastern Cape and Makana Local Municipality. The financial implications of fire DRM in Makana are critical to the delivery of effective unit operations throughout the entire disaster management cycle. The financial implications are further examined in the next section of this article.

3.3. Financial estimates of the fire DRM burden on Makana population and system

In South Africa, parts of the fire DRM are governed in part by the Fire Brigade Services Act no. 99 of 1987 as amended (designated as Act in further text of the article; SAG, 1987-2000). Section 1 of the Act contains the definition of the controlling authority, namely

""controlling authority" means a local authority in control of a service or the person in control of a designated service; [Definition of "controlling authority" substituted by s. 18 (a) of Act No. 134 of 1992.]".

Local government, i.e. the Makana Local Municipality here, is generally in charge of operating a fire brigade/firefighting service in South Africa (as proven above for Makana). In the same section of the Act, the definition of the Administrator is listed, as

""Administrator", means the competent authority within the government of a province to whom the administration in that province of this Act was assigned under section 235 (8) of the Constitution of the Republic of South Africa, 1993 (Act No. 200 of 1993);".

Therefore, there is a government official in each province, who is responsible for the administration of the Act in that province and who is de facto in charge of the fire DRM in it. Section 11(2) of the Act includes the provision that the Administrator may provide a so-called "grant-in-aid' to the controlling authority. In addition, SBDMuni will be involved based on the disaster management mandate of it as a district municipality and the Disaster Management Act no. 57 of 2002. In other words, the local municipality which operates a fire service can be awarded state funds to support running such a service. However, the controlling authority can also charge the residents of the local municipality fees for the firefighting call outs, as stipulated in section 10(1) of the Act. More specifically, the following text is written there

"Fees. - (1) A controlling authority may, subject to any condition contemplated in section 11 (2) (a), determine the fees payable by a person on whose behalf the service of the controlling authority is applied— (a) for the attendance of the service; (b) for the use of the service and equipment; (c)or for any material consumed."

Section 10(2) further states that conditions under which the chief fire officer issues a payment notice, namely

"A person on whose behalf, in the opinion of the chief fire officer concerned, a service of a controlling authority has been employed, may in writing be assessed by that chief fire officer for the payment of the fees referred to in subsection (1) or any portion thereof."

Based on the text in sections 10(1) and 10(2), it is possible for the residents of a municipality to might have to pay for fire brigade call outs if they require assistance with a fire in a residential or other setting. Such charges can pose financial burden on the residents, and it is necessary estimate the

burden such residents might be exposed to. The standard way of stipulating these charges is for the local municipality to issue a by-law and a yearly announcement of the fire brigade tariffs, as part of the annual budget. According to the Makana Tariff Policy, firefighting is considered a subsidised service provided by the municipality (Makana, 2014-present, section 9.3 on page 19). At the same time, the abstraction of water drawn at the fire station is to be charged a fixed water rate (Makana, 2014-present, section 15.4 n) on page 37). Subsidised services are defined in section 2.3 of the South Africa National Framework for municipal indigent policies (DPLG, 2009):

"Local government plays a role as part of the whole system of three spheres of government in addressing poverty through directly providing free or subsidised services to poor households."

As a result of the above definition, firefighting or fire brigade call outs will not be paid for if a person is deemed indigent, i.e. the person is deemed not to be financially able to pay for municipal services and other public goods. A guideline for the definition of an indigent resident of South Africa is provided in section 3 on page 13 of the

"The term 'indigent' means 'lacking the necessities of life4'. In interpreting this for the purpose of this policy a position has to be taken on the 'necessities of life' in a South African context".

In more detail, the term indigent would include the social/essential household service package, namely the provision of water, sanitation, refuse removal and assistance with housing (see section 3.1 on page 15 in DPLG, 2009). The subsidised service should be provided to those who cannot afford to pay (see section 5.1 on page 19 in DPLG, 2009). At the same time, the three pillars of an indigent local municipality policy should be "targeting the poor, gaining and maintain access" to services. This implies services should be provided to indigent residents in local municipalities such as Makana. By extension, firefighting should be part of the expanded social/essential services package provided to indigent residents in Makana Local Municipality (based on the authors' interpretation of section 3.1 on page 15 in DPLG, 2009).

For the 2004-2017 study period, the 2008 Assistance to the Poor/Indigent by-law for Makana Local Municipality contained various sections that are applicable to the general process of registration and service delivery to indigent household. In Section 1 (i), the 2008 by-law contained a definition that indigent residents are entitled to (Makana, 2008-2013, page 4):

"An access to at least minimum level of basic municipal services, such as water/sanitation/electricity/security in a safe and healthy environment".

Firefighting services are not explicitly mentioned, but it can be argued that the provision of fire brigade call outs should be free of charge to residents of low-income parts of the Makana population…to ensure minimum basic level of security in a safe and healthy environment. Section 3 of the 2008 Makana by-law states provides more detail about the components of the social/essential services packages, e.g. solid waste removal (Makana, 2008-2013, page 4). Section 4 of the 2008 Makana by-law stated that the indigent status is awarded by the Chief Financial Officer of Makana Local Municipality to a household and must be renewed annually. At the same time, the principle is that the household should receive the service, i.e. the gaining and maintenance of the social/essential service package must be provided to all citizens/residents of the municipality (Makana, 2008-2013, pages 5-6). This is in line with the national framework for indigent policies (DPLG, 2009 and see above). Section 5 and 6 of the 2008 Makana by-law are aimed at stating that an account be issued to the resident, councilor (local elected representative in the Makana municipal council) and the municipal official work together to get the service provided indigent consumers. Practically, this is executed by subsidy being reflected monthly in the municipal account of the registered indigent household (Makana, 2008-2013, pages 6 and 7). The problem which would have arisen in part of the study period, is that many Makana residents inhabit informal settlements. That would have meant that their dwellings might have been tied to a title deed, might have been built on illegally-occupied land, or were built municipal land…they would not have a formal address to allocate a household to. As a result, those residents might have been ineligible for the indigent status and subsidised services, or any municipal services for that matter. Section 12 of the 2008 by-law states that the communication by all levels of political leadership of Makana Local Municipality, as well as the municipal staff and

the Makana community at large are key stakeholders in the communication and registration of the eligible citizens for indigent status (Makana, 2008-2013, page 8). Similar sentiment and strategy is outlined in the draft of the 2013. Assistance to the poor and indigent policy for Makana Local Municipality (Makana, 2013-present, b).

As a result, the indigent population of Makana must be provided with firefighting services free of charge. It would possible to classify this under the category of no charge for the rescue involving public safety of humanitarian nature. This would not apply to all fire DRM situations, but as fires can spread the definitions should be applied as broadly as possible. In the 2021-2022 financial year, there were 6083 indigent households in Makana Local Municipality and register of them was a priority. Therefore, assisting these indigent households will be in the public safety interest and so that financial charges for firefighting here should not apply. Indigent households generally receive basic services for free by a financial transfer from the National Government of South Africa to Makana Local Municipality, based on the verifiable details and register of indigent household. In case of firefighting services, the amount for callouts which are to be classified as emergencies of humanitarian origin, it would be possible and necessary to collect the information about the indigent Makana residents impacted by the fire. This information is routine from the perspective of post-disaster response and recovery assistance provision. However, the recovery of these costs would have to be covered from the budgets of Makana Local Municipality or the transfers from the National Government post-hoc. Depending on the amounts, such funds could pose a budgetary risk for the annual and overall Makana budget. Mitigating budgetary mechanisms must be put in place, e.g. based on the updated disaster risk management plan by the SBDMuni.

On the other hand, the IDP analysis from the previous section of the article indicates that Makana government is lacking financial and other resources to deal with fire DRM. The Provincial government of the Eastern Cape should therefore provide assistance to Makana, as per the Section 11(2) Fire Brigade Services Act no. 99 of 1987. Low-income households, or households who reside in traditional dwellings, would be charged a flat rate per fire and this ranged from 121.40 to 161.50 ZAR between 2015 and 2020 (Makana, 2015-2017; Makana, 2019-2020). Financial burden and its increases in Makana were assessed for the major appliance, the medium appliance, an auxiliary appliance, and service vehicle. The duration of the model fire was 1 hour and the average charges would be (in ZAR): 1061.86 for a major appliance, 744.90 for a medium appliance, 602.26 for an auxiliary appliance and 285.27 for a service vehicle.

The one-hour long fire is supposed to happen in the urban area of Makana and houses there are to be 10.1 to 30 metres apart, i.e. the fire will be doused with 1200 litres per minutes of water or 72000 litres per hour. Charge for this volume of water is 16 ZAR per 10000 litres. Therefore, this fire would allow the Makana fire brigade to charge the household owner, where the fire took place, 115.20 ZAR for water to fight the fire and the total charge would be 2809.49 ZAR. This accounts for 71.8-76.9 % of the average Makana household income of 2016.96 and 3653.76 ZAR (see Methodology section for details). If each fire in Makana was equal in duration and this duration is assumed to be 1 hour, then the 2017 fire number for Makana, i.e. 136, would allow the fire brigade to collect or charge 382090.64 ZAR. This amount should be sought from SBDMuni or the Eastern Cape Provincial government. It should be budgeted for by the district or the province, and it should be sought as a matter of urgency, as Makana Local Municipality has struggled to meet its fire DRM financial needs. This is in line with Section 11(2) of the Fire Brigade Services Act no. 99 of 1987. Ethically, the household impacted by fire becomes a closed system which needs to be opened up and the price that household pays is the loss of their objects of space/place/time perspective and it is opened up by fire brigade assistance. Fire fighters in Makana must in turn be reimbursed for the equipment use and for the consumables/wear-and-tear must be compensated for, so that the fire protection and DRM can be provided on a continuous basis. At the same time, Makana Local Municipality needs the SBDMuni and the province of the Eastern Cape to help keep the fire DRM open in the municipality. Awareness and mitigation measures for fire must be a top priority as the use of water during drought in firefighting is a challenge in Makana Local Municipality.

3.4. Compounding factors of fire disaster management in Makana

The loadshedding parameters are shown in **tables 3 and 4**.

Table 3.
Loadshedding parameters for Grahamstown 1 section of Makana Local Municipality for the time period from 2015 to 2021.

LS[a]	RSPC[b]	ARSPC[c]	MRSPC[d]	X(2015)[e]	X(2016)[f]	X(2017)[g]	X(2018)[h]	X(2019)[i]	X(2020)[j]	X(2021)[k]
1	10-15	13.2 ± 2.4	1.89	406/1325	0	0	62/192	43/1352	133/1798	79/2455
2	22.5-27.5	26.3 ± 2.5	3.76	874/1325	0	0	130/192	618/1352	1192/1798	1782/2455
3	37.5-40	39.4 ± 1.2	5.63	45/1325	0	0	0	93/1352	141/1798	210/2455
4	52.5	52.5	7.50	0	0	0	0	568/1352	332/1798	384/2455
5	52.5	52.5	7.50	0	0	0	0	0	0	0
6	52.5	52.5	7.50	0	0	0	0	30/1352	0	0

[a] Loadshedding stage.
[b] Range of duration of power outages in Grahamstown 1 per loadshedding stage per week (h).
[c] Average duration of power outages in Grahamstown 1 per loadshedding stage per week (h).
[d] Mean duration of a power outages in Grahamstown 1 per loadshedding stage per day (h).
[e] The average 2015 number of GWh loadshed per stage in a given year.
[f] The average 2016 number of GWh loadshed per stage in a given year.
[g] The average 2017 number of GWh loadshed per stage in a given year.
[h] The average 2018 number of GWh loadshed per stage in a given year.
[i] The average 2019 number of GWh loadshed per stage in a given year.
[j] The average 2020 number of GWh loadshed per stage in a given year.
[k] The average 2015 number of GWh loadshed per stage in a given year.

Table 4.
Loadshedding parameters for Grahamstown 2 section of Makana Local Municipality for the time period from 2015 to 2021.

LS[a]	RSPC[b]	ARSPC[c]	MRSPC[d]	X(2015)[e]	X(2016)[f]	X(2017)[g]	X(2018)[h]	X(2019)[i]	X(2020)[j]	X(2021)[k]
1	12.5-15	13.1 ± 1.2	1.87	406/1325	0	0	62/192	43/1352	133/1798	79/2455
2	25-30	26.3 ± 2.5	3.76	874/1325	0	0	130/192	618/1352	1192/1798	1782/2455
3	37.5-40	39.4 ± 1.2	5.63	45/1325	0	0	0	93/1352	141/1798	210/2455
4	52.5	52.5	7.50	0	0	0	0	568/1352	332/1798	384/2455
5	52.5	52.5	7.50	0	0	0	0	30/1352	0	0
6	52.5	52.5	7.50	0	0	0	0	0	0	0

[a] Loadshedding stage.
[b] Range of duration of power outages in Grahamstown 2 per loadshedding stage per week (h).
[c] Average duration of power outages in Grahamstown 2 per loadshedding stage per week (h).
[d] Mean duration of a power outages in Grahamstown 2 per loadshedding stage per day (h).
[e] The average 2015 number of GWh loadshed per stage in a given year.
[f] The average 2016 number of GWh loadshed per stage in a given year.
[g] The average 2017 number of GWh loadshed per stage in a given year.
[h] The average 2018 number of GWh loadshed per stage in a given year.
[i] The average 2019 number of GWh loadshed per stage in a given year.
[j] The average 2020 number of GWh loadshed per stage in a given year.
[k] The average 2015 number of GWh loadshed per stage in a given year.

The total duration of the of loadshedding in hours was equal to 121 in 2015, 127 in 2018, 530 in 2019, 859 and 1136 in 2021 (CSIR, 2022). In the Grahamstown 1 area and Grahamstown 2, the probability of loadshedding increased from 10 % in 2015, 12 % in 2018, 26 % in 2019, 52 % in 2020 and 70 % in 2021. Therefore, the population in both sides of Makana main urban area would be likely resorting to energy stacking, which could increase the possibility of the fire breaking out in that area. Finally, the age of the pipes was calculated to be equal to 60 years, i.e. the pipe breakages could pose problem in reticulation of water to the fire hydrants. Large part of this problem was addressed by sinking in PVC pipes into the ground in a large part of Makana. However, it remains uncertain whether the entire Makana reticulation has been upgraded.

4. CONCLUSIONS

The financial challenges and the personnel shortages, as well as compounded effect of drought and the loadshedding, can be seen as complicating the fire DRM in Makana Local Municipality. Open system between the local municipality and the outside stakeholders such as SBDMuni are needed to address the financial challenges and to maintain ethical delivery of the fire DRM to the Makana population.

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