

Potential impacts of climate change on wildfire dynamics in the midlands of KwaZulu-Natal, South Africa

S. Strydom¹ · M. J. Savage¹

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Abstract The influence of climate change on wildfires has been studied at a global scale, but uncertainties on the influence at regional and hyper-regional level still exist. As the KwaZulu-Natal (KZN) midlands rely heavily on agro-forestry and tourism to support the local economy, changes in fire dynamics need to be taken into consideration. This study aims to investigate fire dynamics under different climatic scenarios for the KZN midlands, South Africa. Using 25 years of meteorological data allows for the stochastic generation of long-term meteorological data. Six climatic scenarios, describing a warmer and wetter climate and a warmer and drier climate, are used to adjust the generated data. The Lowveld fire danger index is applied to the adjusted data and analysed. Results indicate that annual average fire danger in the KZN midlands is likely to increase significantly under all climate scenarios. Annual average fire danger under baseline conditions (no climate adjustment) averages at roughly 25. When adjusted for the worst case scenario, the annual average fire danger increases to an average of roughly 28—a statistically significant difference. Increased air temperatures are shown to influence fire danger significantly. The KZN midlands are likely to experience an increased frequency of high fire danger days. Changes in daily rainfall are shown to significantly influence the onset and length of the KZN midlands' fire season. Overall, the study indicates that the KZN midlands are likely to experience different fire dynamics under a changed climate, with significant implications for local landowners and local governments.

Keywords Climate change · Fire danger · Stochastic modelling · Wildfires

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✉ M. J. Savage
savage@ukzn.ac.za

¹ Agrometeorology Discipline, Soil-Plant-Atmosphere Continuum Research Unit, School of Agricultural, Earth and Environmental Sciences, University of KwaZulu-Natal, Pietermaritzburg, South Africa

1 Introduction

1.1 Climate change

Fire frequency, intensity and seasonality are all dependant on weather and climate while fire ignition and behaviour are dependent on precipitation and ignition mechanisms such as lightning (Dale et al. 2001; Pitman et al. 2007). Any changes in climate (which may be due to increased biomass burning) may lead to changes in the frequency and seasonality of fires (McKenzie et al. 2004; Pitman et al. 2007; Archibald et al. 2010). Keywood et al. (2013) discuss weather modification processes associated with fires. It is believed that, with a change in global climate, regional vegetation zones may transition or change. Research by Masubelele et al. (2014) indicates that grass cover has actually increased in semi-arid shrub lands over the last 50 years. While fire affects both shrub lands and grasslands, the increase in grasslands may lead to more intense and fast moving wildfires.

1.2 Fire as a management tool

Agriculture is a large sector of the economy in the KZN midlands, and as the area is also largely rural, fires, either in the form of prescribed burning or from accidental ignition, are expected. Bowman et al. (2011) describes humans as being unique for our fire making abilities. Prescribed burning, defined by Fernandes et al. (2013) as the planned use of fire to achieve precise and clearly defined objectives, plays a crucial role in agricultural management. Styger et al. (2007) noted that fire is often used as an agricultural tool for the removal of primary forest or secondary vegetation. According to Fynn et al. (2004), prescribed burning promotes the dispersal of seeds from certain fruit species as well as the germination of hard seeds. Removal of ground litter can also increase the amount of solar radiation available to plants and may result in increased soil temperatures. Southern Africa has a varied climate in terms of rainfall and air temperature (Anyamba et al. 2003). However, the sub-Saharan region of Africa also has distinct wet and dry seasons which have a notable influence on fire activity (Mbanze et al. 2013). Alternatively, due to seasonal variations in climate, Africa can be prone to recurring droughts which can reduce available fuel loads and as a result reduce fire activity (Pricope and Binford, 2012; Mbanze et al. 2013). The use of fire as a management tool in South Africa has been widely researched (van Wilgen et al. 1990; Tainton 1999; Teie 2009; Archibald et al., 2010).

1.3 Economic activities in the KZN midlands and the impacts of climate change

According to Hitayezu et al. (2014), almost 1.6 million people inhabit the KZN midlands of which 80% practice small-scale dryland farming. Roughly 86% of the inhabitants practicing small-scale farming utilize less than 2 ha of communal land each for crop production used in household consumption. The area also has an active commercial agriculture sector. Mkhabela (2011) states that roughly 21% of South Africa's dairy product was produced in the KZN midlands, amounting to roughly 500 million litres making the region an important part of the KZN dairy industry. Natural mist-belt forests are found in the KZN midlands, and the area also has a strong commercial forestry sector (Eeley et al. 1999). According to Eeley et al. (1999), the altitudinal range of these mist-belt forests is likely to shift significantly in response to changing air temperatures and rainfall patterns. Tourism also accounts for a large portion of the

local economy of the KZN midlands. According to Viljoen and Tlabela (2007), the region has become a popular location for so-called adventure tourism. All these sectors of the KZN midlands are vulnerable to climate change. The study aims to contribute to the understanding of the region's fire meteorology to allow for timely mitigation and adaptation plans to prevent any further death and destruction at the hand of wildfires.

2 Methodology

2.1 Study site

Historical daily meteorological data were collected at the Cedara Agricultural College located in the KZN midlands—an area known to experience severe wildfire events. The Cedara College can be found at a latitude of -29.5333° and a longitude of 30.2667° at an elevation of roughly 1130 m asl. The KZN midlands are described as an inland area adjacent to the Drakensberg mountain range on the western border of KZN (Hitayezu et al. 2014). The local climate of the KZN midlands is a subtropical oceanic climate zone due to cool, dry winters and warm, wet summers.

2.2 The ClimGen model

The ClimGen weather model is a stochastic weather generator which generates synthetic data that retains the climatological characteristics of the input data (Semenov 2008; Safeeq and Fares 2011). Utilizing a daily time step stochastic model, detailed literature on the parameterization techniques utilized by the ClimGen model are documented elsewhere (McKague et al. 2005; Semenov 2008; Safeeq and Fares 2011, and references therein). The ClimGen model is only one of many stochastic weather generators utilized in the agro-environmental sciences. However, a study by McKague et al. (2005) found the ClimGen model to be better suited for the generation of daily temperature and solar radiation data.

2.3 Generating long-term fire danger index data using the ClimGen model

The ClimGen model requires at least 10 years of daily T_x and T_n data, 730 days of RH_x and RH_n data as well as daily wind speed data, 25 years of daily rainfall data and 5 years or 730 days of solar radiation data to generate synthetic data. For this study, all variables were selected to be generated, for a period of 100 years. Generated and actual data spanning 1 year were compared for significant differences. All generated variables were found to not be significantly different ($P > 0.05$) suggesting a good representation of meteorological characteristics by the ClimGen model for the KZN midlands.

The Lowveld fire danger index (FDI), based on a nomogram, was utilized to convert daily air temperature and relative humidity to a burning index (BI). The BI adjusted for wind speeds using a lookup table (BIPWS). The BIPWS is always greater than the BI as it is applied only when speed is greater than 2.3 m s^{-1} . Fire danger is then calculated by multiplying the BIPWS with rainfall correction factor (RCF). The RCF takes into account the number of elapsed days since last rainfall and the daily total rainfall and ranges up to a unitless value of 1 (Laing 1978; Meikle and Heine 1987; Willis et al. 2001). Equations utilized to calculate the Lowveld fire

danger index (LFDI) can be found in the [Electronic Supplemental Material](#) and were based on a report by Willis et al. (2001).

The LFDI was applied to the generated data to assess the influence of climate change on fire danger in the KZN midlands. To assess the influence of climate change on fire season onset and length, the study utilized a methodology similar to that described by Jolly et al. (2015). The onset of a specific year's fire season was defined as the point at which two consecutive weeks both experienced at least three consecutive days of fire danger higher than the long-term average. The end of the fire season was defined as the point at which two consecutive weeks do not experience three consecutive days of fire danger higher than the long-term mean. Fire season length was calculated as the period between the onset and the end of the year's fire season. The study conducted by Jolly et al. (2015) utilized the US Burning Index, the Canadian Fire Weather Index, as well as the McArthur Forest Fire Danger Index. Operationally, the LFDI is most similar to the McArthur Fire Danger Meters, although the LFDI has been developed for southern African environments.

2.4 Climate scenarios

The following climate scenarios were selected based on previous research and theoretical models (Abraha and Savage 2006; Hewitson and Craig 2006; Walker and Schulze 2008). As the aim of the study was to investigate the influence of climate change on fire danger, adjustments were made to daily average air temperature and daily rainfall only. The relationship between increased greenhouse gases and global air temperature is well known. Between the early 1950s and 1990s, a decreasing trend in the daily temperature range (DTR) has been observed. The decrease of the DTR is likely due to increased daily minimum air temperatures (Karl et al. 1993). Abraha and Savage (2006) state that climate change studies for the KZN midlands should adjust the daily average air temperature between 2 and 4 °C to account for the decreased DTR. The exact effect of climate change on rainfall is not as certain as that of air temperature. Some models suggest an increase in atmospheric water vapour pressure due to the warmer temperatures (Trenberth, 1998) while other models suggest a decrease in actual precipitation despite increased atmospheric water vapour pressure (Held and Soden, 2006). Due to the uncertainty of the effects of climate change on rainfall, climate scenarios often include both increased and decreased rainfall adjustments (Walker and Schulze, 2008).

The following scenarios do not include any [CO₂] component as it is assumed that the climates represented by the scenarios will be a result of increased [CO₂]. Also, input data as well as the LFDI do not include any data of vegetation growth or curing—which is likely to significantly influence future fire activity. The aim of utilizing these scenarios is to investigate future fire danger and associated characteristics under different climates. The scenarios can effectively be characterised into 'wet' and 'dry' scenarios as they all include a component of increased air temperature but do differ in terms of increased or decreased daily rainfall. The presented scenarios are based on studies by Abraha and Savage (2006); Hewitson and Craig (2006); Walker and Schulze (2008). According to Walker and Schulze (2008), the scenarios (derived from General Circulation Model simulations) are not representative of combinations of future climates but are useful in determining the influence of climate change on an 'exposure unit' (i.e. fire danger and season characteristics). The climate scenarios are as follows:

1. Scenario A: no climatic adjustments. 100 years of synthetic data representative of current or baseline conditions (TOP0);

2. Scenario B: an increment of 2 °C to the daily average air temperature and an increase of 10% to daily rainfall (T2P10+);
3. Scenario C: an increment of 2 °C to the daily average air temperature and a decrease of 10% to daily rainfall (T2P10–);
4. Scenario D: an increment of 4 °C to the daily average air temperature and an increase of 10% to daily rainfall (T4P10+);
5. Scenario E: an increment of 4 °C to the daily average air temperature and a decrease of 10% to daily rainfall (T4P10–);
6. Scenario F: an increment of 4 °C to the daily average air temperature and a decrease of 20% to daily rainfall (T4P20–).

It is important to note that these climatic scenarios (as well as this study), applied to a certain location, do not represent a changing climate. By applying these scenarios to generated data, one assumes that the climate has already changed and that conditions experienced are a result of climate change.

3 Results

3.1 Annual average fire danger

Cedara's annual average fire danger baseline (Scenario A) indicated that the area is prone to low to moderate fire danger, with an annual average of roughly 25, with a maximum of 26 and a minimum of 22.67. Scenarios B to F were all compared to Scenario A and tested for significant differences. A *t* test conducted at 5% confidence level indicated that the annual average fire danger for Scenario B to F were all significantly different to Scenario A ($P < 0.05$). Scenario B resulted in an annual average fire danger of 25.77, with a maximum of 27 and a minimum of 23.85. Scenario C resulted in an average of 26.23, with a maximum and minimum of 27.84 and 24.45, respectively. An additional *t* test indicated significant differences between Scenarios B and C. Scenario D resulted in an annual average fire danger of 27.34, with a maximum of 29.09 and a minimum of 25.31. Scenario E (one of the more severe climate scenarios) resulted in an annual average fire danger of 27.83, with a maximum and minimum of 29.52 and 25.95, respectively. Scenario F, by far the worst case scenario, resulted in an annual average fire danger of 28.16, with a maximum of 29.71 and a minimum of 26.23. An additional *t* test indicated that the annual average fire danger results of Scenarios E and F are significantly different ($P = 0.001$) despite small differences. Figure 1 illustrates the above results.

3.2 Fire danger frequency distribution

While annual average fire danger under different climate scenarios provides some insight into the potential effects of climate change, understanding the frequency distribution and incidence of fire danger is also important. For this analysis, scenarios have been categorized as either wet—indicating an increase of 10% in daily rainfall or no change in daily rainfall (Scenarios A, B and D) or dry—indicating a decrease of either 10% or 20% in daily rainfall (Scenarios C, E and F). Both the wet and dry categories have scenarios reflecting increases in daily average air temperature.

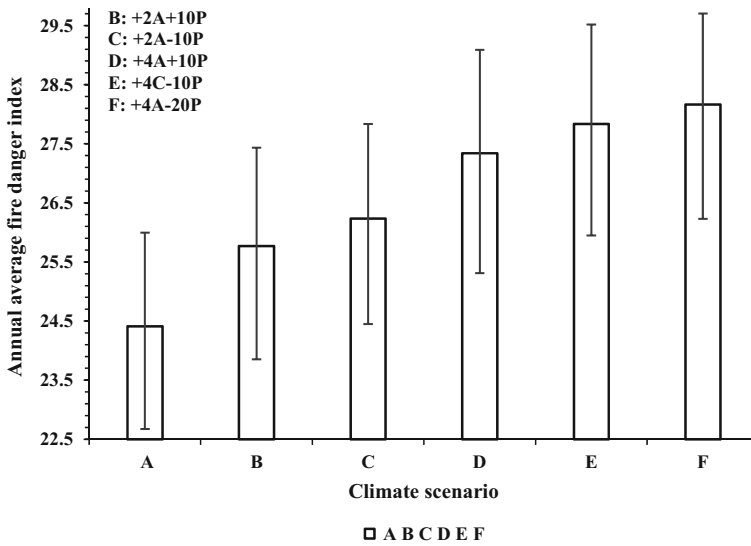


Fig. 1 Annual average fire danger experienced under each climate scenario. Whisker bars represent maxima and minima values

Scenario A (TOP0), for which no climate adjustment was performed, indicated that fire danger frequency would be centred on the mean, with a maximum frequency of 24.06% for an FDI of 30, a low FDI (Fig. 2a). As expected, higher fire danger days (FDI ≥ 36), under Scenario A would be unlikely accounting for only roughly 13% of the duration of the dataset

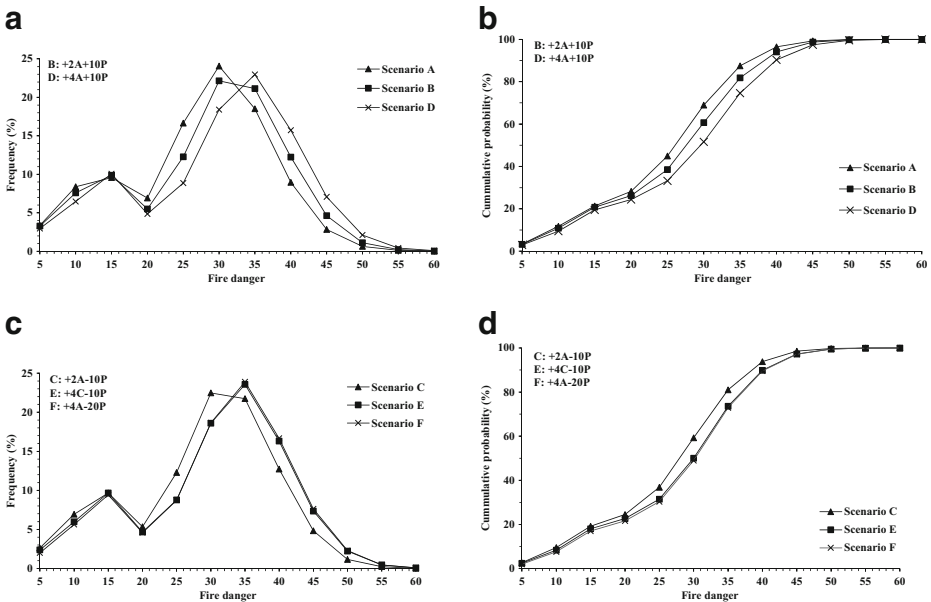


Fig. 2 Frequency distribution and cumulative probability plots for wet and dry scenarios, **a** frequency distribution for dry scenarios, **b** cumulative probability for dry scenarios, **c** frequency distribution for wet scenarios and **d** cumulative probability for wet scenarios

($n = 36,888$ days). Alternatively, the cumulative probability of a day experiencing a low fire danger ($FDI \leq 35$) is roughly 0.87 (87%). Scenario B (T2P10+), considered a wet scenario, also experienced a maximum frequency of 22.16% for an FDI of 30 too. However, unlike Scenario A, the incidence of fire danger lower than 35 was reduced. The cumulative probability of a day experiencing a low fire danger decreased to roughly 0.81 (81%) with fire danger larger than 35 accounting for 18% of the duration of the dataset. Scenario D (T4P10+), the final wet scenario, had a surprisingly different maximum frequency of 22.97% for an FDI of 35. While still falling in the ‘low’ fire danger category, the shift from a maximum incidence of 30 under Scenarios A and C (T2P10–) to 35 is quite noteworthy. Furthermore, under Scenario D (T4P10+), the cumulative probability of a day experiencing a fire danger lower than 35 has further been reduced to roughly 0.74 (74%). As the daily rainfall characteristics of Scenarios B (T2P10+) and D (T4P10+) are the same (an increase of 10%), it may indicate that fire danger in the KZN midlands may be more sensitive to increases in air temperature than to rainfall.

Scenario C (T2P10–), the first dry scenario, experienced a maximum frequency of 22.47% for an FDI of 30, again falling under the ‘low’ fire danger category. Similarly to Scenario B, the incidence of fire danger greater than 35 for Scenario C accounted for roughly 19%. The cumulative probability of a day experiencing a FDI less than 35 under Scenario C was roughly 0.81 (81%). The fire frequency distribution and cumulative probability results were found to be very similar to that of Scenario B (T2P10+). As Scenarios B and C only differ in their rainfall adjustments, it is again indicative that fire danger in the KZN midlands may be more severely affected by changes in air temperature and less so by daily rainfall. Both Scenarios E (T4P10–) and F (T4P20–) experienced a maximum fire danger frequency of 23.88% with an FDI of 35. The higher incidence of days with a fire danger of 35 can be attributed to the fact that both Scenarios E and F involve an air temperature adjustment of 4 °C to the daily mean air temperature. While both Scenarios E and F have the same maximum fire danger frequencies, they do differ slightly in terms of lower and higher fire danger distribution. Under Scenario E (T4P10–), high fire danger frequency ($FDI > 35$) is slightly lower accounting for roughly 26.40% of the data duration.

Alternatively, the cumulative probability of a day experiencing low fire danger ($FDI \leq 35$) is roughly 0.736 (73.6%). Under Scenario F (T4P20–), high fire danger frequency ($FDI > 35$) is both greater than Scenario E (only somewhat) and greater than all other scenarios, accounting for 27.11% of the dataset duration. The cumulative probability of a day experiencing a lower fire danger under Scenario F is still high, but lower than other scenarios at 0.728 (72.8%). Due to the similarity of both Scenarios E and F, a *t* test was performed. The *t* test (5% level of significance) indicated that the distribution frequency of fire danger under Scenarios E and F was not significantly different, despite the large difference in rainfall adjustments under both scenarios.

3.3 Fire season onset

The onset of the fire season significantly influences fire activity and the resultant destruction and devastation of wildfires. Under Scenario A, the average onset of the fire season occurred on DOY 93, with an earliest onset recorded on DOY 55 and a latest onset on DOY 147. Scenario B experienced an average onset day of 80, with an earliest start recorded on DOY 40 and a latest start on DOY 119. Scenario C experienced an average onset day of 70, with the earliest onset occurring on DOY 37 and the latest onset occurring on DOY 114. Scenario D experienced an average onset occurring on DOY 94, with the earliest onset occurring on DOY

56 and the latest onset occurring on DOY 135. Scenario E experienced an average onset of the fire season on DOY 60, with the earliest onset occurring on DOY 23 and the latest onset occurring on DOY 107. Scenario F experienced an average onset day of 47.14, an earliest onset on DOY 23 and the latest start on DOY 108. The onset of the fire season under each climate scenario was compared to Scenario A by means of a *t* test. The *t* test (5% level of significance) indicated that all other scenarios (B–F) were significantly different to that of Scenario A ($P < 0.05$) with the exception of Scenario D (T4P10+) ($P = 0.47$). It is evident that each scenario experienced an earlier onset of the fire season (with the exception of Scenario D). Figure 3a illustrates the above results.

In order to illustrate the influence of daily rainfall on the onset of fire season, two scenarios which only differ in terms of rainfall were compared. A *t* test indicated that Scenarios B (T2P10+) and C (T2P10–) are significantly different in terms of fire season onset. As both Scenarios B and C apply an air temperature adjustment of 2 °C, it is likely that the differences in fire season onset are due to different daily rainfall adjustments. An additional *t* test was performed using two dry scenarios with different daily rainfall adjustments. The *t* test indicated that Scenarios E (T4P10–) and F (T4P20–) were significantly different. The fact that both Scenarios E and F apply an air temperature adjustment of 4 °C further supports the statement that daily rainfall will influence the onset of the fire season.

3.4 Fire season length

The length of a fire season is dependent on a number of factors, including the microclimate. Investigating fire season length may provide some insight into the effects of climate change on fire weather. Under Scenario A (T0P0), Cedara experienced an average fire season length of 170 days, with a minimum fire season of 99 days and a maximum fire season length of 223 days. Scenario B (T2P10+) experienced an average fire season length of 190 days, with a shortest season of 147 days and a longest season of 259 days. Scenario C (T2P10–) experienced an average fire season of 200 days, with a short fire season of 137 days and a maximum of 252 days. Scenario D (T4P10+) experienced an average fire season length of 174 days, with a minimum length of 122 days and a maximum length of 230 days. Scenario E (T4P10–) experienced an average of 213 days during the fire season, with a minimum fire season length of 161 days and a maximum fire season length of 284 days. As with the onset of the fire season, the different fire season lengths of Scenarios B–F were compared to Scenario A. The *t* tests (5% level of significance) indicated that the fire season length of each scenario

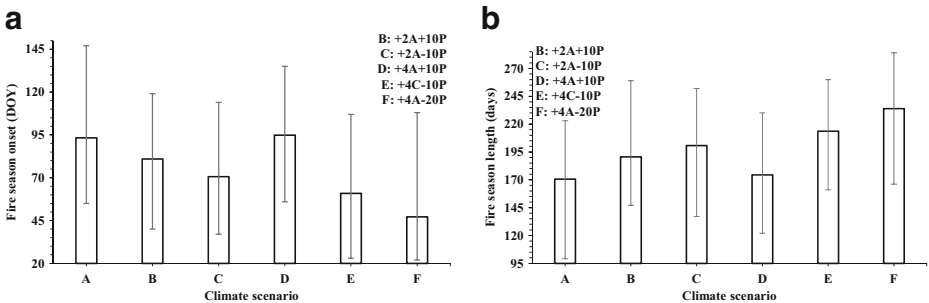


Fig. 3 a Onset and b length of the fire season at Cedara under different climate scenarios. Whisker bars represent maxima and minima values

were significantly different to that of Scenario A with the exception of Scenario D ($P = 0.19$). It is quite clear that under all scenarios (with the exception of Scenario D), a lengthening of the fire season can be expected. Results presented previously have supported the statement that daily rainfall has an important influence on the onset of the fire season. It would appear that the same is evident for fire season lengths. A t test indicated that the fire season lengths of Scenarios B (T2P10+) and C (T2P10–) were significantly different despite both having the same air temperature adjustment (increase of 2 °C). Figure 3b illustrates these results.

Scenarios E (T4P10–) and F (T4P20–) also resulted in significantly different fire season lengths, despite having the same air temperature adjustments (increase of 4 °C). While this may lead one to assume that daily rainfall has more of an influence on fire season length, an additional t test indicated that the fire season lengths of Scenarios C and E were also significantly different despite having the same daily rainfall adjustments (decrease of 10%).

4 Discussion

4.1 Annual average fire danger and fire danger frequency

The results presented in this study indicate that the annual average fire danger of the KZN midlands, under a number of different climate scenarios, will be significantly different to what the region is currently experiencing. The global and local increases in average air temperature, as well as other related microclimatic changes, are expected to result in more frequent and severe fire activity (Flannigan et al. 2013). While the Lowveld FDI is not a proxy of fire activity, it does indicate the potential for uncontrollable fires should ignition occur and thus may provide insight into how changes in the microclimate may influence fire activity. While the annual average fire danger for Cedara is considered low (FDI < 36), the clear rise in this figure with each climate scenario is concerning. Even scenarios where daily average air temperature was increased by only 2 °C yielded increased average fire danger. Increases in annual average fire danger experienced globally has been attributed to increased average air temperature (Hulme et al. 2001; Flannigan et al. 2013).

The annual average fire danger under Scenarios E and F were found to be significantly different despite having the same air temperature adjustments. A significant difference was also found between Scenarios B and C. Scenarios B and C, as well as Scenarios E and F, have equal air temperature adjustments (an increase of 2 °C for B and C and an increase of 4 °C for E and F), but different daily rainfall adjustments suggesting that the increase in annual average fire danger may be a result of changes in daily rainfall and not increased air temperature alone. The results presented here are supportive of and supported by a study by Chen et al. (2011), in which seasonal rainfall was found to influence fire intensity in southern America. The notion that rainfall can have a significant influence on fire danger in a changing climate may need to be emphasised in further research—particularly at a local and regional level and can build upon the research already done by Archibald et al. (2010).

While rainfall may have a significant influence on the annual average fire danger, based on the results presented, it does not appear to have a significant influence on the frequency of fire danger. Under low rainfall conditions, one would expect elevated fire danger, all things being equal. However, a comparison of Scenarios B and C indicated that their respective fire danger frequencies were not significantly different suggesting that changes to daily rainfall due to climate change may not always significantly influence the frequency of certain fire danger

levels. Reduced rainfall may be compensated by increased air temperatures, resulting in a generally normal distribution of fire danger values. It is important to consider this with regard to the increases in annual average fire danger presented in this study.

4.2 Fire season onset and length

The onset of a fire season and its subsequent length are important factors to consider when investigating climate–fire dynamics. Early onsets and longer seasons can severely reduce the ability of landowners and fire managers' ability to mitigate fire disasters and fight wildfires. Results presented in this study indicate that the onset of the fire season and fire season length in the KZN midlands may be significantly altered in a changing and changed climate. Studies conducted at a global and continental scale have provided some insight into how climate change may influence the onset time and length of fire seasons. In a study investigating fire seasons around the globe, Jolly et al. (2015) found that all regions experienced increases in fire season length and attributed this change to increases in global average air temperature. As all scenarios (with the exception of baseline Scenario A) included an increase of between 2 and 4 °C to the daily air temperature, the results may be supportive of the study by Jolly et al. (2015). Despite different air temperature adjustments, all scenarios indicated an earlier onset of the fire season (except Scenario D, which was not found to be significantly different from Scenario A). It is clear that increasing air temperatures may result in early onset of the fire season. A difference of only 2 °C was shown to be enough to result in a significantly earlier fire season (Scenarios C and E). With the same rainfall adjustments, an increase of 4 °C to daily air temperature (Scenario E) was shown to result in the onset of the fire season occurring 10 days earlier compared to the onset under an increase of 2 °C (Scenario C) and an astounding 30 days earlier than under the baseline scenario (Scenario A).

Daily rainfall has also been shown to significantly influence the onset and length of the fire season. Chen et al. (2011) found a strong correlation between rainfall and the fire season onset and length. All the climate scenarios investigated for this study included an adjustment to daily rainfall, both positive and negative changes. Comparing fire season onset under the wet scenarios provides for interesting results. Scenario B, which included an increase of 10% to daily rainfall as well as an increase of 2 °C, resulted in a significantly different fire season onset compared to the baseline (Scenario A). Even with increased rainfall, the onset of the fire season was on average 10 days earlier than that of the baseline. Scenario D was the only other scenario to include an increase in daily rainfall and was not found to be significantly different from Scenario A in terms of fire danger.

The lengthening of the fire season can then also be attributed to the climatic changes responsible for earlier fire season onsets. The average length of the fire season was significantly increased when air temperatures were increased and coupled with reduced daily rainfall. Results indicated that the average fire season length increased by roughly 20 days compared to the baseline. An increase of 4 °C in daily average air temperature was shown to increase the length of the fire by an average of roughly 35 days compared to the mean. Scenarios B and D also indicated an increased fire season length, despite increases in daily rainfall. While Scenario D did not result in significantly different fire season lengths compared to Scenario A, the results of Scenario B may indicate that an increase of 10% to daily rainfall may not be sufficient to compensate for increased air temperatures. However, all scenarios indicate some level of change. How rainfall may respond to climate change will influence fire danger and fire activity. This study investigated potential changes in daily accumulated rainfall on fire danger,

but further research on how changes in frequency and seasonality of rainfall may impact on fire danger and activity is needed. It is important to note that the results presented here do not include any investigations into the response of vegetation to a changing climate. The response of vegetation will significantly influence actual fire activity (Bowman et al. 2014). Results presented in this study are from a purely atmospheric dynamical perspective.

5 Conclusions and recommendations

This study aimed to investigate the influence of climate change on fire danger in the KZN midlands of South Africa. Long-term meteorological data were generated using the ClimGen stochastic model. Model evaluation indicated that the model reproduced micro-meteorological variables well, although caution is needed when analysing the generated data. Applying the Lowveld fire danger index to the generated data allowed for the investigation of different climate change scenarios on fire danger, fire frequency distribution and fire season onset and length. Results of the study indicated that microclimatic change is likely to negatively influence seasonal characteristics of fire danger in the KZN midlands. Projected changes of fire danger frequency and probability in the KZN midlands due to changes in air temperature and precipitation are in line with current climate theories. Changes in the seasonal characteristics of fire season onset and length are also in line with recent studies of global fire season onset and length. Changes in air temperature have been shown to significantly influence annual average fire danger and fire danger frequency in the KZN midlands. Changes in rainfall have been shown to more significantly influence fire season onset and duration. Overall, the study indicates that the KZN midlands are likely to experience different fire dynamics under a changed climate. As the KZN midlands relies heavily on agro-forestry and tourism to generate income and support the local economy, these changes in fire dynamics need to be taken into consideration. This study has provided insight into the future fire dynamics of the KZN midlands, but it must be emphasised that the study presented here does not, and cannot, provide any insight into actual fire activity of the future in the KZN midlands. The non-temporality of this study thus leaves room for further research using climate models which do include a time component. This study will serve as a foundation for future hyper-regional fire dynamics research.

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