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Occurrence and Management of Wildfires in Northern Hhohho, Swaziland

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Abstract: A study was conducted to determine the status of wildfire and fire management practices in Swaziland. The northern Hhohho region was used as a case study. Information for occurrence of fires was sourced from MODIS fire alert system over a period of 12 months (August 2011 to July 2012). A proforma was used to collect data on land tenure, land use and cover and fire management and suppression measures from land users adjacent to 130 fire sites that were randomly selected from the case study area. Climatic data (rainfall and wind) were obtained from local weather stations. A total of 1,779 fires were recorded over the 12 months period in the whole country and 50% of the fires occurred during the months of August and September. The majority of fire spots (58%) were found in private land as opposed to 42% found in communal land. A significant difference for fire intensities (confidence levels) was observed for forest plantations and cultivation as well as for forest plantations and grazing ($\rho < 0.05$). Honey hunters were the main causes of wildfire, with 29% of the fires attributed to them. This was more prevalent in the forest plantations though some forest plantations provided forest scouts to assist honey hunters to extract the honey, in an effort to reduce the incidents of wildfires. About 56% of wildfires were not suppressed and they caused the maximum possible destruction. The forest plantations had trained fire brigades and yet the rural communities did not have such and they laced incentives to manage fires, especial when the fires were in adjacent private farms.

Key words: Fire spots · Land tenure · Land use · Wildfires

INTRODUCTION

The Kingdom of Swaziland is a monarchy and land-locked country located in the south eastern part of Africa covering an area of 17,363 km^2. It is bounded by the Republic of South Africa on the north, west and south and by the Republic of Mozambique to the east. The population of Swaziland was estimated at 1,067, 773 in 2007, with one ethnic group called Swazi [1]. In Swaziland, uncontrolled wildfires start in many ways; accidentally (e.g. misuse of appliances, dropping a cigarette or match on a sofa or mattress, etc.), deliberate ignition or arson, equipment failure, including electrical malfunctions and overheating, honey collection as well as ritual performances, where candles are used and left burning. Some fires start from neighbouring countries (South Africa and Mozambique) and spread over the border into Swaziland. For example, in July 2007, fire that originated from South Africa and fanned by high winds destroyed 23,343 ha (76%) of Peak Timbers plantations and one timber mill was destroyed [2].

Fires are mainly used to prevent abandoned fields from growing over and clear areas for planting crops. They are also used in pest management to reduce insects and rodents and to kill invader weeds as well as in clearing vegetation to facilitate growth of grasses and tree sprouts to benefit animals. Most communities use fire as a management tool at the end of the dry season to promote new grass growth and for parasite control. Fires controlled or uncontrolled have profound impacts on the physical environment including; land cover, land use, biodiversity, forest ecosystem and climate change. The environmental impact of fires includes loss of vegetation and de-forestation and loss of biodiversity. Wildfires have an impact on hydrological cycle where trees which act as carbon sink are reduced and the smoke from these wildfires contaminates the air. The socio-economic impacts include reduction of grazing lands, disruption of critical infrastructure, destruction of power disruptions, deaths, homelessness and job losses in plantation industries.

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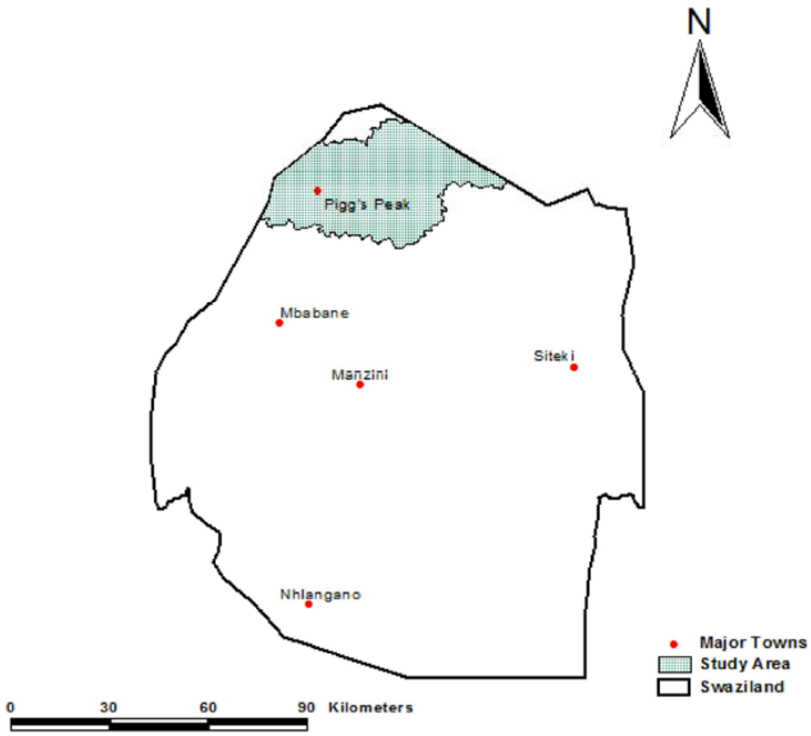

Fig. 1: Map of Swaziland showing location of study area and ecological zones

The factors that have influence on occurrence and behaviour of wildfires are fuel, weather and topography [3]. Usually, the greatest volume of fuel readily available for burning the more intense the fire will be [4]. When the moisture content is high, fires are difficult to ignite and burn poorly if at all [5]. With little moisture in the fuel, fires start easily and wind and other driving forces may cause rapid and intense fire spread [6]. Size and shape affects the surface area to volume ratio of fuels [7] hence small fuels and flat fuels have a greater surface area to volume ratio than larger fuels [8]. Wind makes fire burn faster by increasing the supply of oxygen and by driving radiant heat into adjacent fuel [9].

Predicting the potential behaviour and effects of wildfire is an essential task in fire management. Mathematical surface fire behaviour and fire effects models and prediction systems are driven in part by fuel bed inputs such as load, bulk density, fuel particle size, heat content and moisture of extinction [10]. The MODIS fire products build and improve on the experience of fire assessment primarily using NOAA-AVHRR and GEOS satellite system [11]. The fire products include an identification of the occurrence of thermal anomalies and estimate the total emitted power from the fire or burned area [12]. To mitigate these fire-related problems, forest and land management agencies, as well as property owners and communities require an early warning system to identify critical time periods of extreme fire danger periods in advance [13]. The Swaziland Meteorological Services, through e-mail, provides fire danger ratings as a tool for early warning of possible fire outbreaks in the country. The system gives a four day warning based on prevailing weather conditions [14]. The effective involvement of the local people has been recognised as a prerequisite for the successful implementation of fire management programmes, especially at the interfaces between wild lands, managed systems and residential areas [15].

The objective of the study was to determine the status of wildfires and fire management systems in the northern Hhohho region of Swaziland.

Methodology

Description of Case Study Area: The study area is bordered by Lomati River in the north and the Komati River in the south in the northern part of Swaziland (Fig. 1). It covers an area of 3,888 km^2. The study area consists of communal land and private land covering an area of 1,998 km^2 and 1,883 km^2, respectively. The dominant land uses are communal grazing, ranching and subsistence cropping and forest plantations. A small portion (17 km^2) is under wildlife conservation.

Data for Fires: The author s subscribed to the NASA FIRMS (Fire for Resources Management System) e-mail alert system that gives global location of fires on daily basis. FIRMS is based on MODIS (Moderate Resolution Imaging Spectroradiometer) system on board Terra and Aqua satellite systems [16]. Data showing the location of fires within the country for 12 months period, from 1st August 2011 to 31st July 2012 was used for the research. A total of 1,779 fires were recorded in the country during this period. Information that was sourced from the e-mail alert included latitude and longitude of fire points, date and time of fire, satellite from which observations were made and confidence level of fire detection.

Selection of Sampling Sites: A total of 198 fires were found to have occurred within the case study area over a period of 12 months. A sample calculator [17] was used to determine the ideal sample size at 95% confidence level and 5% confidence interval. The fires within the case study area were allocated identification numbers and 130 fire sites were randomly selected for field verification and collection of additional information from land users.

Data Collection: Information on climatic and weather conditions (rainfall, wind speed, wind direction) for the period when fires were reported was sourced from the Swaziland Meteorological Services, Mhlume Sugar Estate and Peak Timbers Plantation. The coordinates for the sampled fire points acquired from NASA FIRMS were loaded into a Global Positioning System (GPS) and the GPS was used to navigate to the locations for data collection.

Field Verification and Interviews: A proforma was designed to collect data from the field for the selected fires. The information collected from the field included land tenure, land use and land cover. Respondents from farms or homesteads within the vicinity of each fire site were asked to provide information on likely causes of the fire, effects of the fire, how fire was suppressed and constraints in management and suppression of wildfires.

Data Analysis and Presentation: The data obtained from the satellite e-mail alert was converted to spreadsheet format and imported to ArcView GIS [18] for plotting maps showing distribution of fire spots both at national level and at the level of the case study area. The same data was further exported to SPSS software [19], were information on weather conditions and that collected from field surveys were added. SPSS software was used for data analysis using descriptive analysis (frequencies) and comparison of means for the different parameters. The level of confidence of fire as reported on the satellite alert was taken as dependent variable and the factors which were considered to control the occurrence of fire were moisture content, wind direction, wind speed, land tenure, land use and type of vegetation. One way ANOVA was used to determine the significance in level of confidence on reporting fires for wind speed, land use and type of vegetation cover. The LSD was used to separate significant mean differences. The Independent Samples T-Test was used to determine if there was a significant difference in confidence level for different land tenure systems.

RESULTS AND DISCUSSIONS

Distribution of Fires at National Level: The 1,779 fires spots that were recorded over the one year study period are shown in Figure 2. They were denser on the western part of the country and sparse on the southern part. Since fires depend highly on climatic, topographic and fuel factors, [20] the study confirmed that most fires occurred in the Highveld because of higher altitude and steep areas. The forest plantations were found mostly in the eastern part of the country. The majority of the fires occurred during the months of August and September (dry season) and confirmed other findings that wild fires are the most widespread ecological disturbances in winter and before the onset of the first rains when the forests would be dry and highly inflammable in southern Africa [21]. During these months the vegetation would be dry due to frequent winds that were experienced during the winter season. Subsistence farmers also use fires to clear land in preparation for cultivation and in anticipation of the start of the rainy season.

Occurrence of fires in relationship to last rains and prevailing winds: The influence of rainfall on wildfire occurrence is due to its influence on fuel moisture and load [22]. About 43% of the fires occurred within a month after rainfall of less than 10 mm was received. As expected very few fires were recorded when heavy rains had fallen (wet periods). The study area recorded the highest number of fires between 0.0-9.9km/hr, having 99 (76%) of the fires. The 20.0-29.9 km/hr had the least number of fires recorded with 4 (3%) counts in the study area. There were 7 (5%) fire recorded when the wind speed was between 30.0 and 39.9 km/hr. Under atmospheric conditions suitable for controlled burning, wind plays a significant but non-prevalent role in affecting fire intensity as studies

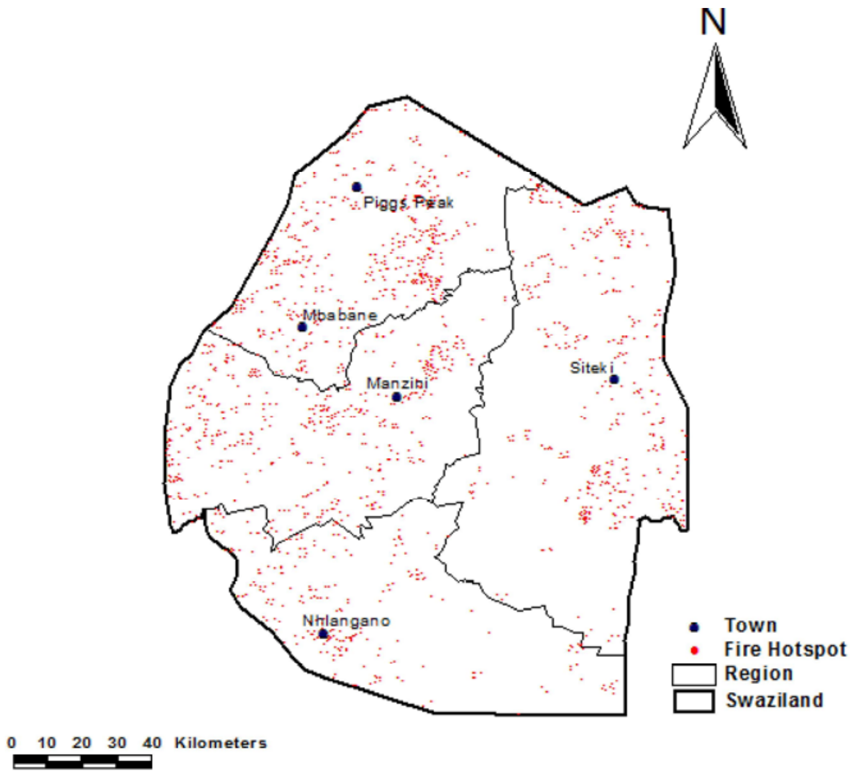

Fig. 2: MODIS fire hotspots observed over 12 months period

showed that wind was rapidly changing environmental factors affecting fire behavior on plain surface conditions [23]. The study area was dominated by forest plantations and shrubs which reduces the wind speed. The fact that there were few fires during periods of high wind speeds may also be attributed to the fact that the wind speed of between 0 and 9.9 km/hr occurs more often in the study area than high wind speeds. The fires were recorded on all wind directions during the study period. Since Swaziland has rugged topography, the results obtained are in agreement with earlier studies that wind flows along the direction of hills and mountains [24]. The dominant wind directions for occurrence of fire were the east, north-east and west. The least fires were reported when the wind direction was south-west and north-west.

Effect of Land Use and Land Tenure on Occurrence of Fire: The majority of fire spots (58%) were found in private land as opposed to 42% found in communal land confirming that the high influence of land cover to wildfire activity had a significant effect on and close association with land use [25]. About 46% of the fires occurred in grazing land (both communal grazing and private ranching). The study area recorded 28% of the fires in forest plantations (Table 1). Wildlife conservation covers about 0.5% of the total study area and yet about 4% of the reported fires were in wildlife conservation area.

Table 1: Occurrence of fire in relation to land use and land tenure (N=130)

	Land tenure		
Land use	Private	Communal	Total
Forest plantations	31	5	36
Settlement	2	9	11
Wildlife conservation	5	0	5
Cultivation	2	14	16
Grazing	33	27	60
Other	2	0	2
Total	75	55	130

There was no significant difference between fire intensity (confidence level) for private land and communal land ($\rho > 0.05$), even though the average for private land was higher at 69.88 (Table 2). The land tenure system in the study area had similar topography, climate and vegetation pattern.

There was a significant difference between fire intensities (confidence levels) for the different land uses ($\rho < 0.05$) (Table 3). The significance was observed between forest plantations and cultivation as well as between forest plantations and grazing (Table 4).

Table 2: T-Test results for land tenure and fire intensity (confidence level)

Tenure	N	Mean	Std. Error Mean	Sig
Private land	75	69.88	2.58	0.059
Communal land	55	67.44	2.24	

Table 3: ANOVA for different land uses

Interaction	Sum of Squares	d.f	Mean Square	Sig
Between Groups	4911.30	5	982.26	0.029
Within Groups	47135.6	124	380.13	
Total	52046.92	129		

Table 4: Multiple comparisons for means for different land uses

Land use	Mean fire intensity	Standard Deviation
Forest plantations	77.36*+	20.69
Settlements	67.55	15.73
Wildlife conservation	65.20	25.27
Cultivation	59.06*	13.03
Grazing	67.45+	20.33
Others	52.00	14.14

*+ Mean difference is significant at the 0.05 level for respective land uses

Table 5: Reported causes of fire (N=130)

	Land tenure		
Causes	Private	Communal	Total
Non (Controlled Fire)	22	9	31
Abandoned campfire	3	7	10
Honey hunters	23	15	38
Poachers	8	0	8
Children at play	0	2	2
Cigarette smokers	6	4	10
Warming fire	0	1	1
Escaped fire	3	8	11
Arson	8	3	11
Others	2	6	8
Total	75	55	130

The fire intensity was higher for forest plantations compared to cultivated land and grazing land. The cultivated land and grazing land had very little biomass during the period when wildfires were dominant (August to September). The overall effect of fire intensity was that grasses are generally not sensitive to increasing fire intensities than forests and bushes [26].

Reported Causes of Fire: Out of the 130 fire spots in the study site, 31 of them (24%) were intentional fire that was under control and 76% of the fire could be classified as wildfire. The controlled fires were in sugarcane fields (burning sugarcane before harvesting), forest plantations (fire breaks) and also burning of fields after clearing bush (slash burn). Honey hunters were the main source of wildfire, with 29% of the fires attributed to them. The honey hunters started fire with the intention of smoking bees and the fire got out of control. This was more prevalent in the forest plantations and some forest plantations had come up with a strategy where they assisted honey hunters to extract the honey. The located bee hives in their plantations were harvested by trained forests scouts in an effort to reduce the incidents of wildfires. Cigarette smokers also contributed in causing wildfire, especially on forest plantations, as they threw away burning cigarettes along the roads or foot paths. To reduce the destruction caused by burning cigarettes, forest plantations often make buffer zones by clearing vegetation within about 50 metres along the road or busy footpaths. Arson was reported to have contributed about 8% of the fires (Table 5).

Fire Management and Suppression: Fifty one wildfires caused the maximum possible destruction because they were not suppressed. This was a clear sign of national problems in suppression and management of wildfires. The forest plantations had their own trained fire brigades that managed and suppressed fires. The brigades from forest plantations suppressed 23 wildfires. They were complemented by the Swaziland National Fire and Emergency in suppressing eight fires. The terrain in the study area, especially in areas used for forest plantations were very steep and in most cases not accessible by vehicles. Aircrafts and helicopters were sometimes used to suppress the fires. The aircrafts were hired from fires management companies in neighbouring South Africa and aircrafts from the air wing of the Swaziland Defence Force were sometimes involved in controlling the forest fires. In communal land, the communities were responsible for management and suppression of wildfires and they managed to suppress 22 out of the 99 wildfires in the study area.

Constrains in Fire Management and Suppression: The Rural communities did not have trained fire brigades, unlike in the forest plantations. They lacked training and knowhow in fire management and suppression. A lesson could be learned from the "community police" concept where each community in the country has a group of individuals who are trained on community policing and they assist in keeping law and order in the communities [27]. There were no early warning systems or alarms to inform rural communities about occurrence of fire. The communities lacked incentives to manage fires, especial when the wildfires were in adjacent private farms. They perceived the private land owners as competitors and constraining them on their desired harvesting of natural resources such as honey and wild fruits [28]. This often led to cases of arson, as there were 11 such reported cases in the study. The laws and legislation that intended to assist in management and control of wildfires were often not enforced because of lack of capacity to do so and also because of difficulties involved. Some of the laws were out-dated (such as the Forest Prevention Act of 1910 and Grass Fire Act of 1955) [29, 30] and they needed to be updated. The existing interventions lacked effective education to change public attitude, effective laws and enforcement, adequate technical strategies and appropriate community capacity to deal with fires.

CONCLUSION

The results indicated that the majority of the fires occurred during the months of August and September (dry period). Out of 130 fire spots that were used in the case study, 58% occurred in private land as opposed to 42% that occurred in communal land. The dominant wind directions for occurrence of fire were the east, north-east and west. There was a significant difference in fire intensities (confidence levels) between forest plantations and cultivation as well as between forest plantations and grazing. The fire intensity was higher for the forest plantations compared to the cultivated land and grazing land. About 29% of the fires were causes by honey hunters and this was prevalent in forest plantations. Out of the 99 wildfires, 51 were not suppressed and they caused the maximum possible destruction. The forest plantations had their own trained fire brigades yet communities lacked training in fire management and suppression. There were no early warning systems or alarms to inform rural communities about occurrence of fire. The communities lacked incentives to manage fires, especial when the fires were in adjacent private farms. There was evidence that some of the laws were out-dated (such as the Forest Prevention Act of 1910 and Grass Fire Act of 1955) and they needed to be reviewed.

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