Journal of Agricultural Science and Technology A 14 (2024) 124-135
doi: 10.17265/2161-6256/2024.03.002

The Implementation of Fire Control Measures in Resettlement Farming Areas of Hwedza, Zimbabwe

Bowora Edmore[1] and Maponga Robert[2]

1. Environmental Management Agency, 1 Aster Close, Winston Park, Marondera 0021, Zimbabwe

2. Bindura University of Science Education, 741 Chimurenga Road, Bindura 0240, Zimbabwe

Abstract: Despite fire control in Zimbabwe's resettlement farming areas, fire continues to damage the environment, property, crops and causes loss of lives. The goal of this paper was to investigate fire control measures implemented by resettled farmers in Hwedza, Zimbabwe. The data used in the study were derived from both primary and secondary sources. Primary research data were obtained through questionnaires and interviews targeting households and key informants. Secondary data were collected from reports and records from relevant government institutions. Chi-square tests were conducted to establish the relationship between fire control measures and fire trends. The research findings show evidence of fire control in the study area with farmers implementing a combination of pre-suppression and suppression fire control measures. The use of fire breaks and fire brigades were the more prevalent pre-suppression measures implemented by 86% and 78% of the farmers respectively. The main fire suppression measures implemented were the use of fire beaters (92%) and dowsing with water (85%). Fire occurrence responded to control measures when burnt area declined by 24.1% for the period 2011-2014 when the number of farmers implementing control measures increased from 131 to 701. A negative association between the number of fires and fire pre-suppression measures; and burnt area and fire suppression measures was found. The study recommends early detection, education and awareness as the primary steps in ensuring effective fire control. Active participation of all responsible stakeholders and the affected farmers is also of importance to effectively manage fire.

Key words: Fire, implementation, resettlement, pre-suppression, suppression, fire control measures, fire break, fire beater.

1. Introduction

Globally, fire has been used for millennia as a land management tool. Today fire is still essential, especially in developing countries where resource constraints limit alternatives for example in land clearing. The use of fire among farming communities in Africa is very pronounced primarily because vast landscapes of tropical and subtropical savannahs are fire-prone [1]. In agriculture fire is used for clearing land; control of weeds, pests and disease; and management of pasture and/or rangelands. Although the use of fire for land management practices is important in many societies, fire often gets out of hand resulting in damage to the environment, property, crops, and loss of lives [2].

Large fires, "mega-fires" or widespread veld fires, sometimes develop due to failure to control small fires. For example, in 2008, a "mega-fire" developed from a runaway fire event in the neighbouring communities of Central Kalahari Game Park Botswana causing damage to 3.6 million hectares of land, estimated at a value of US$239,000.00 [3]. Notably, in Zimbabwe, between 2009 and 2012, approximately a million hectares of grazing land were lost annually to veld fires [1]. In Manicaland, approximately 190 km^2 of pine plantations were gutted by veld fires in 2008 [4] and earlier in 2005, a veld fire burnt seven school children to death in Matabeleland [5]. Thus, implementation of fire control measures is critical so as to ensure that damage to property and life is contained or controlled.

The runaway veld fires are mainly due to anthropogenic causes, which can be divided into two categories—deliberate and accidental fire events. In

Corresponding author: Bowora Edmore, M.Sc., research fellow, research field: sustainable utilization and management of natural resources.

both cases, fire spread is due to lack of proper fire management practices. Fires stem from land clearing, hunting, improving pasture, arson and smoking out bees during harvesting of wild honey. Accidental fires include throwing away smouldering cigarette butts and ash as well as the use of fire to burn rubbish in homes [6]. An assessment of the implementation of control measures among communities in fire prone regions becomes critical for fire management planning.

There are many causal factors for the outbreak of runaway fires. Phiri et al. [4] attribute the upsurge in frequency of veld fires in Zimbabwe largely to the land resettlement programme. About 80% of veld fires in the country are recorded in resettlement farming areas despite the farmers reportedly persuaded to employ fire control measures [7]. Thus, the fire control measures implemented in these farming areas need to be investigated. In addition, there is need for updated information on implementation of fire control measures in resettlement farming areas that have become frequent fire zones.

The control of fire in the country has loopholes hence the proliferation of runaway fires in resettlement farming areas. Farmers are blamed for the outbreak and failure to contain the runaway fires. However, there are reports of resettled farmers taking up fire control as an important component of addressing the fire problem. This is seen by an increase in fireguard construction in some areas [8]. These fire control measures, however, need to be assessed to appreciate their impact on fire control.

Fire control is an important component of environmental management. It reduces the loss of biodiversity, lives, and property. Fire control should be centred on early detection, quick reaction, and suppression [2]. Unless fire is properly managed it will continue causing land degradation in the country. Thus, investigating the implementation of fire control measures in land resettlement farming areas helps decision makers appreciate what is required to deal with the fire problem in fire prone zones. In this paper, multiple sources of information including review of published literature; reports and records from government institutions; and questionnaires targeting households and key informants were used to address four specific objectives: (1) to identify fire control measures implemented by resettled farmers, (2) to evaluate the performance of fire control measures implemented by resettled farmers, (3) to determine the relationship between fire control measures and fire trends and, (4) to determine what is required to contend with the runaway fire problem in fire prone zones.

2. Materials and Methods

The study was carried out in Hwedza which is approximately 136.6 km south of the capital, Harare. The location map of the study area is shown in Fig. 1.

Hwedza is one of the country's twenty districts with resettlement farming areas classified by the Environmental Management Agency (EMA) as veld fire "hotspots". The EMA is a government department which is responsible for monitoring the environment including veld fire. The study area was purposively selected based on its characteristics i.e. having a resettlement component and being veld fire prone thus representative of other districts faced by the fire problem. Ward 1 was randomly selected from the three wards that have resettlement areas in the district. The ward is approximately 60 km from Hwedza Business Centre along Fair Adventure road in the western direction. It is usually referred to as Watershed West. It is a former commercial farming area which is predominantly a semi-intensive farming area. Maize and tobacco are the major cash crops grown mainly under rain-fed agriculture. Livestock rearing is also practised in the area, cattle ranching being dominant. Annual rainfall amounts range from 650 mm to 800 mm [9]. The seasonal weather conditions promote the growth of a high fuel load in form of crop residue and grass. The high fuel load increases fire risk. Farmers prepare tobacco seedbeds using fire, which subsequently run away. Ward 1 has a total population of 4,813 people comprising 2,613 males

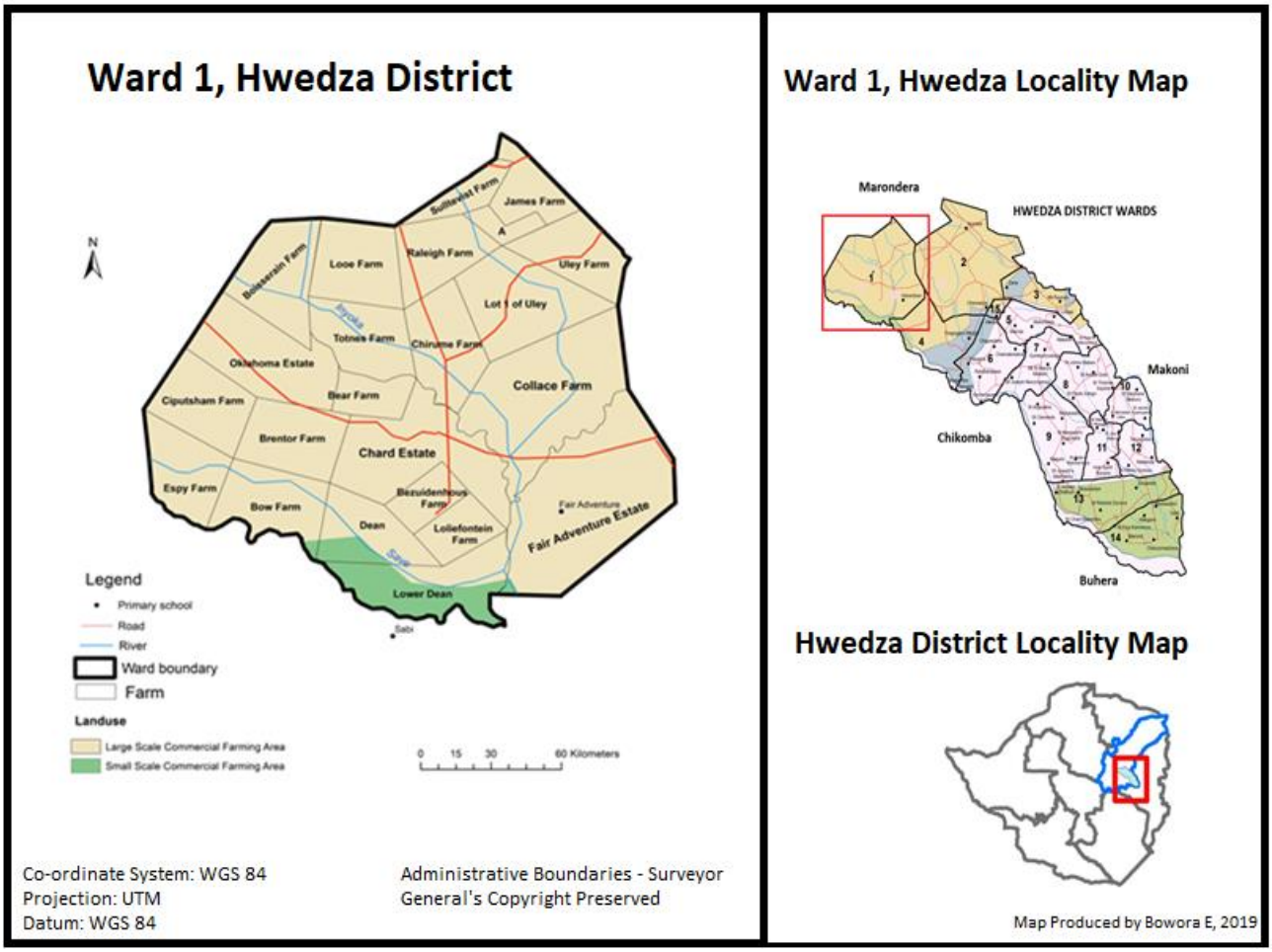

Fig. 1 Location of the study area.

and 2,200 females. It comprises 21 farms with 1,136 households each with an average size of 4.2 members [10].

The study adopted both quantitative and qualitative research approaches. Triangulation was done to overcome intrinsic bias. The quantitative data were used to describe and test relationships between variables such as the number of fires and burnt area from questionnaires and satellite data. The qualitative data catered for farmer perceptions on fire control measures. Qualitative data were derived from key informants and resettled farmers. A survey approach was used to gain insights into fire control measures in resettlement farming area. Results for the period before fire control measures were intensified, i.e. 2009-2010 were compared with results for the period 2011-2014, when fire control was improved.

A total of 143 questionnaires were administered to plot holders or their representatives to get information on the fire situation and management interventions in the study area. The questionnaires had both closed and open-ended questions. Targeted respondents were heads of households who could be males and/or females from 16 years of age and above, had resided in the area for at least five years and had witnessed the occurrence of the fire situation in the area. A multi-stage random sampling approach was employed in the selection of questionnaire respondents. One hundred and forty-three plots (27.2%) were randomly selected from 526 plots. The farmers were afforded an equal opportunity to participate in the study. Respondents for the study are shown in Table 1.

Table 1 Questionnaire survey respondents.

Farm	Plot holders	Respondents
Chard	251	63
Collace	201	50
Fair adventure	74	30
Total	526	143

The consent of respondents and permission from government departments, local authorities, and traditional leaders was sought for the research to proceed. Names of respondents and/or plot numbers were kept anonymous during the study—at data collection and eventual analysis to ensure confidentiality. The respondents were assured that the information they provided was for academic purposes only. Secondary data were collected from reports that could not leave off the respective offices.

A pilot study was undertaken to pre-test the instruments using ten randomly selected respondents from the study area. This was done to validate the research instruments. The pilot study checked how long it took the respondents to respond to questions, assessed the interpretation of questions and whether there was need to tune or rephrase some of the instrument items. Draft questionnaires were also assessed by two Environmental Management Agency (EMA) provincial officers for determining whether they were reliable tools for data collection in this study. The pre-test revealed that there was a need to separate fire control measures into pre-suppression and suppression to clarify the focus and to address the study issues. Ambiguous questions, for instance, one on the extent to which fire control measures were implemented needed a brief explanation to clarify the meaning of various extents. The open-ended questions were closed to allow the respondents to answer within a shorter period of time and made it possible to quantify the response options at analysis.

Face to face interviews were conducted with key informants to confirm responses from questionnaire respondents. They were conducted with five government departments responsible for fire management (monitoring and assisting communities) in the district—EMA, Forestry Commission (FC), Agriculture Extension (AGRITEX), Zimbabwe Republic Police (ZRP) and Hwedza Rural District Council.

Burnt area data were obtained from the United States (US) Geological Survey derived from Moderate Resolution Imaging Spectro-radiometer (MODIS) for free at a spatial resolution of 250 m × 250 m and processed using a computer-based Quantum Geographic Information System (QGIS) software. Burnt area scars data in the form of shape files for the whole country for the period 2009-2014 were downloaded then exported to QGIS. Hwedza district wards boundaries were over layered on the country data and then Ward 1 data were clipped. Burnt area (in hectares) was calculated for each year using a measuring tool. Qualitative data were first coded and classified to enhance data interpretation and highlight important findings. The findings were grouped into themes, presented as descriptive statements under relevant sections and in graphical form to help explain the results.

Chi-square tests were carried at a 95% significance level out to determine the relationships between fire control measures and fire trends. For the Chi-square test, the Null Hypothesis (H_0) and the Alternative Hypothesis (H_1) were first specified. Research data (observed values) were then tabulated and expected frequencies were calculated for each observed value. The test static was calculated and compared against the critical value and a decision was made whether to reject H_0 or not. Finally, a conclusion was made on the relationship between fire control measures and fire trends.

The research data (observed values) were then tabulated and expected frequencies were calculated for each observed value. The test static was calculated and compared against the critical value and a decision was made whether to reject H_0 or not. Finally, a conclusion was made on the relationship between fire control measures and fire trends.

The collected data are presented in tables, graphs, and maps. Tables and graphs were meant to show frequencies of fire control measures and compare fire trends. Fire maps were used to show the extent of area burnt by fire for each year.

3. Results and Discussion

Data on household respondents' characteristics, fire suppression measures, trends in the burnt area, fire frequency, losses to fire, implementation of control measures and the association between fire control and fire trends are presented and discussed in this section.

3.1 Household Respondents' Characteristics

A total of 143 farming households (114 males and 29 females) were sampled during the questionnaire survey. Respondents comprised 117 plot holders, 19 managers and 7 wives, children or relatives of plot holders. The characteristics of the respondents are shown in Table 2. The largest proportion of respondents (31%) was in the 35-44 age range whilst the least (7%) was more than 55 years old. The majority of the respondents (62%) resided in the study area for more than 10 years; none had been there for less than 5 years. The largest proportion of respondents (65%) had attained secondary education, whereas the smallest proportion (5%) had no formal education.

3.2 Fire Pre-suppression Measures

The results for fire suppression measures implemented in the study area are shown in Fig. 2.

Table 2 Respondents characteristics.

Gender		Age		Period of residence		Level of education	
Male	Female	Range	Number	Years	Number	Level	Number
114	29	16-24	20	< 1	0	Tertiary	15
		25-34	39	1-4	0	Secondary	93
		35-44	44	5-9	54	Primary	27
		45-54	30	10+	89	None	8
		55+	10				

Source: Research findings (2015).

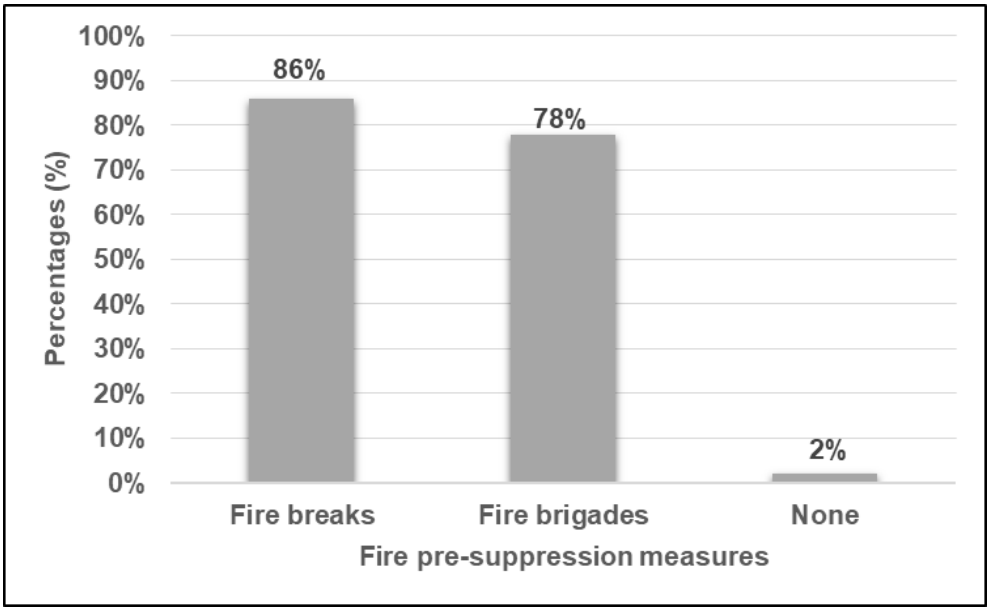

Fig. 2 Fire pre-suppression measures.
Source: Field survey (2015).

The results show that farmers implemented two fire pre-suppression measures to control runaway fires. These measures were fire breaks and fire brigades. The two were used by a large proportion of the respondents, over 75% indicating that the farming community intended to deal with the fire problem. An insignificant proportion (2%) of the farmers did not employ pre-suppression measures. Shaffer [11] revealed most communities using such methods as fire breaks as experienced in the Madjadjane and Gala areas of Mozambique. The high use of firebreaks and fire teams could be attributed to training by EMA [8] and suggests the probability of controlling fire outbreak was high. Nonetheless, an assessment of burnt area and the number of fires would be used to evaluate the performance of fire control measures in the study area.

3.3 Fire Suppression Measures

The study revealed that measures shown in Fig. 3 were implemented by farmers to suppress runaway fires.

The results show that farmers used fire beaters, counter fire and dowsed fire with water to suppress the spread of fires. Fire beaters and dowsing fire with water were the dominant measures confirmed by more than 80% of the farmers. Counter firing was not common among the farmers. Farmers augmented rubber beaters with brushwood beaters. The EMA pointed out that the use of rubber beaters became noticeable in the study area and other resettlement farming areas in the country at large because of awareness campaigns and fire awareness launches which were introduced in districts and wards [8, 12]. Farmers also pointed out that where water was available they used it to dowse fire. They had used knapsack sprayers, watering cans and any available water containers to fetch water from shallow wells in vegetable gardens, streams, and dams. Farmers who did not implement any fire control measures contributed to the spread of fires that could be spread as a result of lack of control. In some instances, these farmers were issued with tickets for failing to implement fire suppression measures but they remained passive.

3.4 Trends in the Burnt Area

Trends in burnt area are shown in Fig. 4.

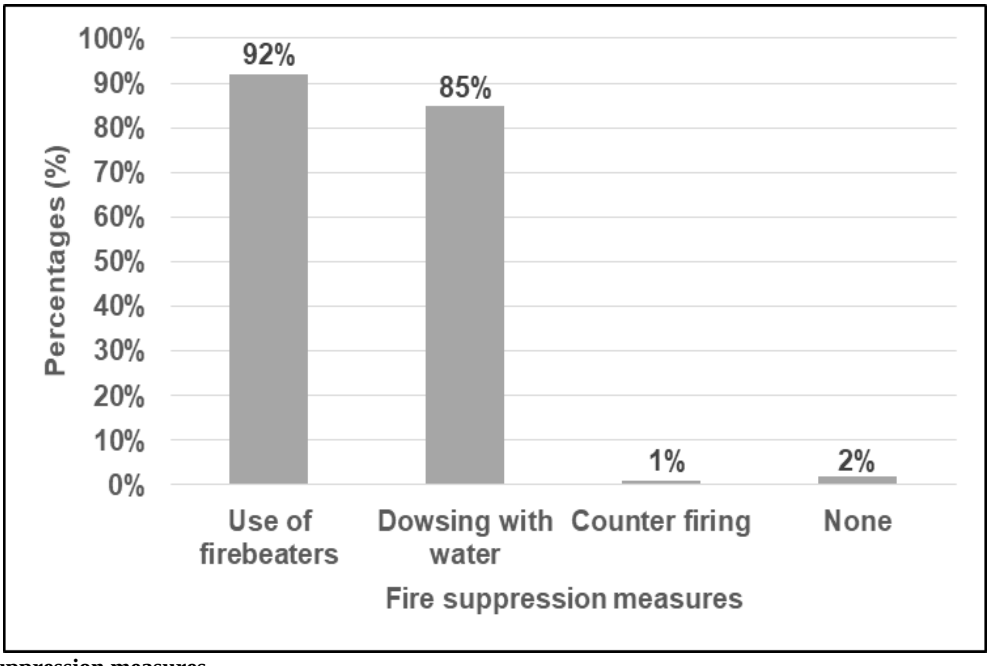

Fig. 3 Fire suppression measures.
Source: Field survey (2015).

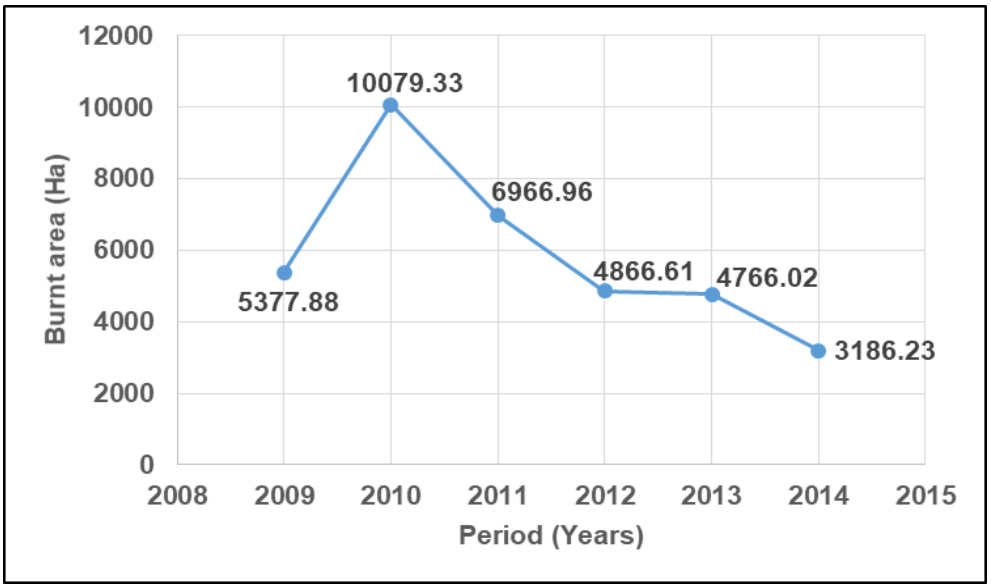

Fig. 4 Area burnt by veld fire for the period 2009-2014.
Source: EMA [13].

Results show that land burnt in 2009, rose by 88.8% between 2009 and 2010 but declined by an average of 24.1% thereafter until 2014. During this period, approximately 85% of the farmers either did not have fire control measures or did not employ them. The result shows lack of fire control despite the presence of traditional and government institutions mandated to manage natural resources [14].

Fire trends started to decline as from 2010 mainly due to fire awareness and capacity building programmes that were introduced by EMA—more farmers began to appreciate fire control [8]. The continued rise in fire incidences and fire losses also motivated farmers to implement fire control measures to safeguard their livelihoods—the use of fire breaks became widespread in the study area afterward [14].

The spike in fire events, from 2009 to 2010, can be attributed to lack of enforcement of penalties to offenders or non-engagement of farmers in the control of fire [14]. It could also be attributed to a break up of strict fire control by former commercial farmers, who had the equipment to make fire breaks and could control the fires [14, 15]. The steady decline (24.1%) in the annual burnt area recorded between 2011 and 2014, could be attributed to cooperation, enforcement and appreciation of employing fire control measures among the varied stakeholders in the study area.

3.5 Trends in Fire Frequency

Data on fire frequency were collected to explain the prevalence of veld fires in the study area. The results are shown in Fig. 5.

The results show an upward trend (42.9%) in outbreak of fire between 2009 and 2010, thereafter a decline of 88% from 50 to 6 fires occurred. The highest number of fires was in 2010 (50 fires) and the steepest decline of 60% was between 2010 and 2011.

The decline in the number of fires after 2010 may be attributed to the implementation of fire control measures in the study area. As more and more farmers became aware of the dangers of runaway fires, a reduction in the number of fires was achieved. Goldammer et al. [16] also observe that in the East Caprivi, the frequency of unwanted fire events decreased by 70% due to fire awareness and public education campaigns, which was commensurate with a 54% annual reduction in burnt area. The study area, however continued to experience fires despite the fire measures that were implemented. This may be attributed to accidental fires during land clearing or to arson. Nyamadzawo et al. [1] stress

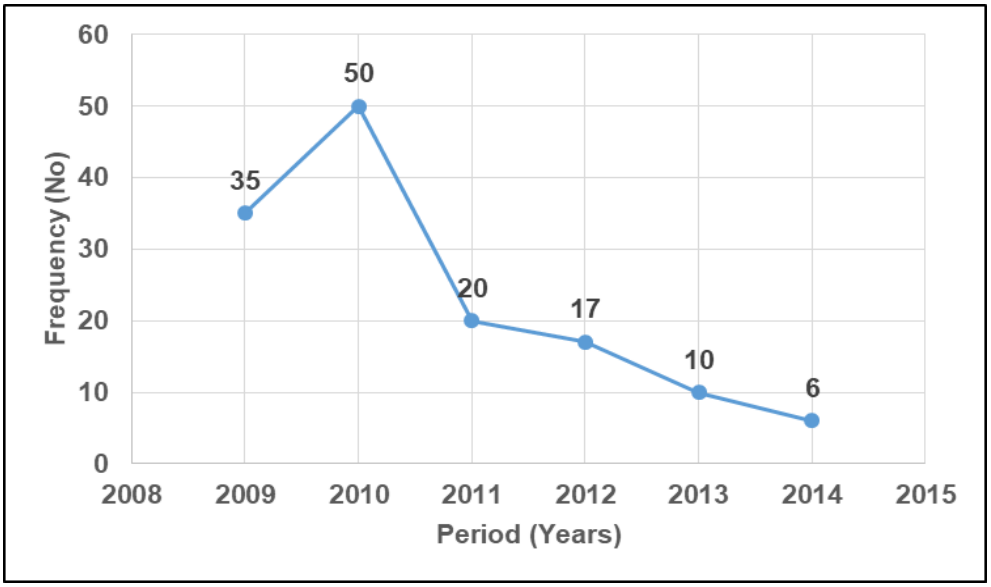

Fig. 5 Frequency of fire events.
Source: EMA [13].

Table 3 Area burnt and loss to veld fire.

Variables	2009	2010	2011	2012	2013	2014
Burnt area (ha)	5,377.88	10,009.3	6,966.96	4,866.81	47,66.02	3,186.2
Humans deaths	0	0	0	0	1	0
Livestock loss	0	7	0	0	0	0
Houses	4	2	1	0	0	0
Gardens	3	5	7	8	9	11
Plantations (ha)	0.5	0.5	0.25	0.5	1	0.5

Source: EMA [13].

that smallholder scale farmers in Zimbabwe use fire to clear land for cultivation and in some instances, fires get out of control and degenerate into runaway fires. It is also inevitable that runaway fire occurs as long as the use of fire remains part of the farming system. The implementation of control measures, early warning and monitoring of possible occurrence of runaway fires need to be in place to ensure that unwanted fire events are contained.

3.6 Trends in Fire Losses

The research sought to establish loss from fire in the study area, the results are shown in Table 3.

The results show that other than one fire-related death, there were losses in livestock (cattle), housing structures, gardens and tree plantations. One fire related to loss of human life was experienced in the study area after 2010. The death was unfortunate since it occurred when there was an improvement in fire control as an increasing number of farmers implemented fire control measures. It must, however, be noted that following a further decline in the number of fires and burnt area no deaths were experienced in 2014. The trends show that there was a decline in losses due to runaway fires in response to measures that were implemented.

The results show that in 2010, the period when there was the largest bunt area, even goats were lost to veld fire, none occurred thereafter. This suggests that an increase in fire provided more chances for loss of livestock. Brooks and Matchett [17] point out that high fuel load in form of dominant dry and dense thatch grass in the former commercial farming areas threatens

the security of livestock not only due to fire threat but also loss of pastures—the main livestock feed. A reduction in fire related livestock loss may be due to increasing adoption and implementation of fire control measures or that the farmers had become wiser and now safeguarded their livestock from veld fire.

Loss of housing structures to veld fire declined over the six-year period from 4 in 2009 to 1 in 2011 and none thereafter. The research results suggest that an improvement in fire control between 2011 and 2014 resulted in a decline in the number of housing structures lost to fire. Trends in loss of housing structures generally suggest a strong link between fire control measures and loss of housing structures to fire. Thus, adoption and implementation of fire control measures reduces the risk of losing houses to runaway fires.

There was a steady increase in the number of gardens lost to fire throughout the period 2009-2014. This was despite an improvement in fire control after 2010. Farmers normally use fire when preparing gardens, but sometimes fail to effectively manage it resulting in the proliferation of runaway fires. This is also supported by Ref. [2] who point out that in the agricultural system in developing countries such as Zimbabwe, fire is used for land clearing due to resource constraints which limit use of alternatives in clearing land.

The area of plantation affected by fire was variable throughout the period. It declined or rose by 0.5 ha throughout the period. The marginal variations on plantations persisted during the study period. When burnt area increased in 2010, plantation area burnt remained constant. This is in contrast to the case of Manicaland Province in Zimbabwe where the plantation area lost to fire increased from 2,908 ha to 9,586 ha in 2010 and 2011 respectively when fires increased [1]. The plantation area burnt did not follow the area burnt nor the implementation of control measures, rather plantations were lost as long as fire events occurred.

3.7 Performance of Fire Control Measures

The study assessed the performance of the main fire control measures that were implemented in the study area. Five fire control measures and burnt area are followed during the study in order to discern the changes that took place (Table 4).

The results show that trend in burnt area and uptake of the various control measures among farmers was variable—uptake of fire breaks, fire teams and fire beaters show a discernable pattern, while counter-fire and water dowsing were inconsistent. Except for fire teams, fire control measures were in force from the onset of the study and less than 5,400 ha of land was burnt. The trends in area burnt and uptake of control measures are depicted in two forms—upward (2009-2010) and declining (post 2010).

There was a spike in area burnt just as the uptake of fire control increased across the measures; burnt area rose by 86% from 5,378 ha for the period 2009-2010. The trend shows that burnt area had not responded to implementation of control mechanisms rather, the impact of fire control was not instant.

Table 4 Trends in the area burnt and adoption of fire control measures.

Variables	2009	2010	2011	2012	2013	2014
Burnt area (ha)	5,377.88	10,009.3	6,966.96	4,866.81	4,766.02	3,186.2
Firebreaks	16	21	40	53	57	78
Fire teams	0	0	9	12	15	24
Beaters	20	31	54	68	70	88
Counter firing	15	18	31	13	21	3
Water dowsing	3	7	10	20	14	21

Source: EMA [13] and Field Survey (2015).

Burnt area began to respond to fire control in the post 2010 era when a steady increase in uptake of measures was commensurate with a decrease in burnt area by 30%. Thereafter, the number of farmers who adopted firebreaks, fire teams and beaters continued to rise as burnt area declined. The adoption of counter firing and water dowsing was variable—it therefore shows that the earlier three measures had a bearing on runaway fire control and that several measures complimented each other in tackling the fire challenge. The positive response to fire control could also be attributed to awareness and education campaigns by EMA and other government departments [12].

It is important to note that the uptake of measures was gradual. Farmers were reluctant at first, possibly because they did not understand the importance of embracing the measures in their farming practices or lacked knowledge on how to employ them. Further, the fire breaks constructed were less than the stipulated width of 9 m and were possibly breached by fire.

The results reveal that implementation of control measures played an important role in fire control. For instance, when the number of farmers who participated in fire break construction among other measures increased in Namibia's Eastern Caprivi Region in 1996, there was a 54% reduction in burnt area [16]. It must, however, be realized that veld fires continued to affect the area despite the increase in use of control measures which therefore calls for monitoring and continued exploration on what suits the affected areas in order to tackle the problem.

Overall, the results show a response to a package of measures that were used as complimentary. The standard firebreak was recommended at 9 m wide, fire teams were introduced by EMA in 2011; counter firing was gradually adopted however when it could not be contained, it increased area burnt; rubber beaters were introduced to compliment the brushwood type and the use of water cans or knapsacks were introduced to dowse the fires.

3.8 Relationship between Fire Control Measures and Fire Trends

The study sought to determine the association between fire control measures and fire trends. Chi-square test at 95% level of significance was done on the research data. The hypotheses for the number of fires and fire pre-suppression measures, and burnt area and fire suppression measures were specified as follows:

(1) The number of fires and fire pre-suppression measures:

H_0: There is no relationship between the number of fires and fire pre-suppression measures.

H_1: There is a relationship between the number of fires and fire pre-suppression measures.

(2) Burnt area and fire suppression measures:

H_0: There is no relationship between the burnt area and fire suppression measures.

H_1: There is a relationship between the burnt area and fire suppression measures.

3.8.1 Relationship between the Number of Fires and Fire Pre-suppression Measures

The data on fire pre-suppression measures used in conducting the Chi-square test are tabulated in Table 5. The number of fires experienced is shown against the number of farmers who implemented each fire pre-suppression measure.

Table 5 Number of fires and fire pre-suppression measures.

	Number of fires						Total
	None	1-5	6-10	11-15	16-20	20+	
Fire breaks	49	83	82	79	59	44	396
Fire teams	22	41	40	36	39	32	210
None	9	1	1	1	1	0	13
Total	80	125	123	116	99	76	619

Source: Research findings (2015).

Table 6 Burnt area and fire suppression measures.

	Burnt area (ha)						Total
	5,377.88	10,009.3	6,966.96	4,866.81	4,766.02	3,186.2	
Counter firing	15	18	31	13	21	3	101
Beaters	37	43	56	78	82	112	408
Water dowsing	3	7	10	20	14	21	75
None	71	62	55	51	14	3	256
Total	126	130	152	162	131	139	840

Source: Research findings (2015).

The test statistic ($\chi^2 = 34.9$) was compared to the tabulated value (10.85). Since the test statistic was greater than the tabulated value ($\chi^2 > 10.85$) a decision was made to reject H_0. It was therefore concluded that there was sufficient evidence that there was a negative association between the number of fires and fire pre-suppression measures for the period 2009-2014. As more farmers implemented fire pre-suppression measures, the number of fires observed was generally reduced to between 0 and 5. However, the implementation of more fire pre-suppression measures did not completely eliminate fire.

3.8.2 Relationship between Burnt Area and Fire Suppression Measures

The data used in conducting the Chi-square test are shown in Table 6. It shows area burnt and the number of farmers implementing each fire suppression measure.

The test statistic ($\chi^2 = 192.06$) was compared to the tabulated value (7.26). Since the test statistic was greater than the tabulated value ($\chi^2 > 7.26$) a decision was made to reject H_0. It was therefore concluded that there was sufficient evidence that there was a negative association between burnt area fire and fire suppression measures. When the number of farmers implementing fire suppression measures increased, burnt area declined in the area. This suggests that fire control measures played a role in reducing burnt area as more farmers implemented them.

4. Conclusions

The findings presented and discussed in this paper show evidence of fire control by resettlement farmers from Hwedza for the period 2009-2014. The measures were implemented before pre-suppression and during suppression of fire occurrence. The main fire pre-suppression measures were the use of fire breaks and fire teams. The use of fire beaters, use of water, counter firing and early warning were the fire pre-suppression measures implemented. The use of fire beaters was the most prevalent fire suppression measure. Fire control measures implemented in Hwedza brought about a reduction of fire frequency and burnt area when the number of fire control measures and farmers implementing the measures increased.

When the number of fire control measures and farmers implementing fire control measures increased after 2010, there was a general decline in the burnt area, number of fires and other losses. Therefore, a negative association existed between fire control measures and fire trends. The general decline in the number of fires, burnt area, and other losses after 2010 suggested that fire control measures implemented performed better when compared to the period 2009-2010 when increases were recorded. This suggests that it is possible to tackle the fire challenge in resettlement farming areas through improved fire control. Farmers in resettlement farming areas can effectively control fire if they diversify and increase the uptake of fire control measures.

Farmers ought to employ the range of measures available so that one method compliments the other in fire control. Law enforcement is needed to compel farmers to implement fire control measures to reduce veld fires. Government and farmer organizations

should support farmers with more firefighting equipment to augment fire beaters and knapsack sprayers which were the only equipment used by farmers to control fire in the study area. This firefighting equipment should include water bowsers, blowers, grass cutters, slashers, sickles, water hydrants, and water hoses. Fire control is improved when farmers have adequate firefighting equipment. Statutory institutions such as the Meteorological Office and the Environmental Management Agency ought to provide early warning mechanisms that could help farmers prepare for, and implement fire control measures. There is need to utilize earth observation systems and Geographical Information Systems to spatially investigate, understand, and map the fire occurrence and recurrence interval. Government and farmer organizations should capacitate farmers for adoption and implementation of measures to contain runaway fires. Cooperation and coordination among governments' agencies and farmers needs to be enhanced.

Acknowledgements

We are grateful for the assistance that was given by the Environmental Management Agency (EMA) of Zimbabwe. The EMA supported us with fire reports, records and maps.

References

[1] Nyamadzawo, G., Gwenzi, W., Kanda, A., Kundhlande, A., and Masona, C. 2013. "Understanding the Causes, Socioeconomic and Environmental Impacts, and Control of Veld Fires in Tropical Zimbabwe." *Fire Science Reviews* 2 (2): 3-10.

[2] Food and Agriculture Organization (FAO). 2011. *Community-Based Fire Control: A Review*. Rome: Food and Agriculture Organization of the United Nations Forestry, 9-13.

[3] Williams, J., Albright, D., Hoffmann, A. A., Eritsov, A., Moore, P. F., de Morais, J. C. M., Leonard, M., Miguel-Ayanz, J. S., Xanthopoulos, G., and van Lierop, Ir. P. 2011. "Findings and Implications from a Coarse-Scale Global Assessment of Recent Selected Mega-Fires." In *Proceedings of the 5th International Wildland Fire Conference, Suncity*, South Africa, p. 19.

[4] Phiri, M., Zingwena, S., and Mahamba, S. M. 2011. "Community-Based Fire Control; Experiences from the (2) Funded Project in the Provinces of Manicaland and Matabeleland North, Zimbabwe." In *Integrated Fire Approach: From Global Monitoring to Natural Fire Control, Fire Control Working Paper FM/27/E*. (2), Rome, pp. 51-60.

[5] Environmental Management Agency (EMA). 2009. *Fire Assessment Report*. Harare: WWF, p. 6.

[6] World Wide Fund for Nature (WWF). 2001. *Fire Management Manual: Wildlife Management Series*. Harare: WWF, pp. 6-8.

[7] Environmental Management Agency (EMA). 2011. *Fire Assessment Report*. Harare: EMA, p. 5.

[8] Environmental Management Agency (EMA). 2013. *Fire Assessment Report*. Harare: EMA, p. 23.

[9] Mugandani, R., Wuta, M., Makarau, A., and Chipindu, B. 2012. "Re-classification of Agro-Ecological Regions of Zimbabwe in Conformity with Climate Variability and Change." *African Crop Science Journal* 20 (Sup. 2): 361-9.

[10] Zimbabwe National Statistics Agency (ZimStat). 2012. *Census 2012: Mashonaland East*. Harare, p. 138.

[11] Shaffer, L. J. 2010. "Indigenous Fire Use to Manage Savanna Landscapes in Southern Mozambique." *Fire Ecology* 6 (2): 43-59.

[12] Environmental Management Agency (EMA). 2014. *Fire Assessment Report*. Harare: EMA, pp. 11-6.

[13] Environmental Management Agency (EMA). 2015. *Fires and Land Use Affected in Ward 1, Hwedza District.* Harare: EMA.

[14] Maponga, R., Ahmed, F., and Mushore, T. D. 2017. "Remote Sensing-Based Assessment of Veld Fire Trends in Multiple Interwoven Land Tenure Systems in Zimbabwe." *Geocarto International* 33 (6): 612-26.

[15] Le Maître, D. C., Kruger, F. J., and Forsyth, G. G. 2014. "Interfacing Ecology and Policy: Developing an Ecological Framework and Evidence Base to Support Wildfire Control in South Africa." *Austral Ecol.* 39: 424-36.

[16] Goldammer, J. G., Frost, P. G. H., Jurvélius, M., Kamminga, E. M., Kruger, T., Moody, S. I., and Pogeyed, M. 2005. *Community Participation in Integrated Forest Fire Control: Experiences from Africa, Asia, and Europe.* The Hague, the Netherlands: SPB Acad. Publ., pp. 33-51.

[17] Brooks, M. L., and Matchett, J. R. 2006. "Spatial and Temporal Patterns of Wildfires in the Mojave Desert, 1980-2004." *Arid Environ*. 67: 148-64.