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Cost Analysis of Wildfire Suppression Activities in the Black Hills of South Dakota

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CERTIFICATION STATEMENT

I hereby certify that this paper constitutes my own product, that where the language of others is set forth, quotation marks so indicate, and that appropriate credit is given where I have used the language, ideas, expressions, or writings of another.

Signed:____

Abstract

The research purpose of this correlational study was to identify and analyze the cost drivers of wildfire suppression activity in the Black Hills of South Dakota. Both correlational analysis and regression modeling were used as procedures to answer the research questions of the identification of the cost factors and their interrelationships to total wildfire suppression costs. Results showed that the factors of size and the cost of aviation resources were the only significant variables showing any correlation or predictive power for the total cost of a wildfire, ($r^2 > .8$, $p < .0001$). Recommendations are to increase oversight for aviation operations and to maintain aggressive initial attack to keep wildfires starts small in size in the fire department's service area.

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Introduction

The Black Hills of South Dakota are located in the southwestern part of the state. The landscape features of this area contain an uplift of a small mountain range that is isolated from other mountain ranges that are located farther west on the North American continent. A dense forest cover type of ponderosa pine covers most of the Black Hills. This ponderosa pine forest coupled with mountainous terrain features provides for a complex wildfire suppression situation at any given time when the weather conditions are in place for large scale fire growth. Further complexity is added into incident management by the patchwork ownership of land of federal, state, and private landholdings which can create jurisdictional issues as the incident grows in both size and scope. Given the values at risk of private residences and community infrastructure that are present in the Black Hills, swift action coordinated on an interagency basis is needed to support the primary objective of firefighter and civilian life safety on the incident scene. However, the interagency coordination and swift response to emerging wildland fire incidents in the Black Hills does come with a financial cost that seems to increase every fire season, and this cost increase does not go unnoticed by elected officials, government administrators and the general public.

However, before a strategy can be created to contain or mitigate any costs associated with wildfire suppression activities, the South Dakota Division of Wildland Fire Suppression needs to undertake the problem of cost analysis of wildfire suppression activities in the Black Hills. The purpose of the research is to identify and analyze the causal factors that determine the cost drivers of wildfire suppression activities and to recommend a possible strategy that will seek to reduce any future increases in the cost of wildfire suppression activities in the Black Hills.

A descriptive research method utilizing a correlational analysis of data was used for this research project. The research questions deal with the cost analysis of fire suppression activities and are summarized in the following two points: (a) the identification of the causal factors that determine the cost drivers of wildfire suppression activities; and (b) the analysis of any relationship of those identified factors that drive the costs of wildfire suppression activities.

Background and Significance

The problem of cost analysis of wildfire suppression activities in the Black Hills is a critical area of study for the South Dakota Division of Wildland Fire Suppression (SDWFS). South Dakota state law is similar to most states in that during times of forest fire emergencies, SDWFS is preauthorized to deficit spend from an emergency fire suppression account to pay for fire suppression activities in the Black Hills, pending reimbursement through special appropriation from the South Dakota Legislature at a later date. (SDCL § 41-20-5). The ability for SDWFS to be able to defict spend during the fiscal year allows the prompt reimbursement of equipment and personnel costs to local fire departments and contractors for suppression services rendered to SDWFS on wildfires.

Given the fact that the State of South Dakota authorizes SDWFS to carry out its jurisdictional responsibility to suppress wildfire on state and privately owned forested lands in the Black Hills, the potential for the South Dakota Legislature to appropriate ever increasing amounts of budget monies for emergency fire suppression activities in the Black Hills remains a certainty. Therefore it is a significant expectation for the fire department that SDWFS officials will have to be prepared to explain to executive management from the Governor's office and legislators the need to make these increased appropriations at the end of every fire season. Additionally, another concern of significance for SDWFS is the ability to be able to analyze wildfire suppression costs in such manner as to find support for increased up-front investment in SDWFS suppression capability that may offset the need to ask for increased emergency fire fund reimbursements at the end of the fire season. It would also be expected of the fire department that before any explanations are offered in support of increased expenditures for fire suppression capacity, that a completed cost analysis would be in hand for reference at that time of presentation. Therefore this research project would provide linkage to the daily field operations of SDWFS if it can be used to justify increased investment into capacity or show continued support for increased emergency fire fund reimbursements.

The research purpose of identifying and analyzing the cost factors of wildland fire suppression activities in the Black Hills is congruent with the third year Executive Analysis of Fire Service Operations in Emergency Management course objectives of incident management and documentation. The identification of the factors that are the cost drivers of wildfire suppression activities in the Black Hills will be guided by the documentation of such efforts on the ground by incident commanders and any future effort to contain costs will be implemented operationally through the Incident Command System (ICS).

This applied research project attempts to meet the United States Fire Administration Operational Objective "*To respond appropriately in a timely manner to emerging issues.*" This objective will be met by a cost comparison analysis of data from agency records and by using the products of that research to formulate a strategy for more effective incident management of wildfire suppression expenditures.

Literature Review

The literature review of wildfire suppression cost analysis has mostly focused on the federal level in the United States and is mostly specific to the land management mission of the United States Forest Service (USFS). Other research activities have worked with the aggregate picture of the cost analysis of all federal and state fire expenditures across the United States. The main body of the research is drawn primarily from the field of applied economics with contributions from the behavioral sciences of psychology and sociology.

Identification of Causal Factors: The Cost Drivers of Wildfire Suppression Activities

USFS research on wildfire suppression cost analysis is primarily focused on large fires (> 121 ha) given that small fires (< 121 ha) represent only 6.2% of the total fire suppression expenditures from 1980-2002 (Wildland Fire Leadership Council, 2004). This report pointed out that between 1980 to 2002, large fires only represented only 1.4 percent of the total fire occurrence on USFS lands, but accounted for 93.8% of the suppression cost (Wildland Fire Leadership Council, 2004). This finding correlates with a long held assumption in wildland fire management that the spatial factor of fire size is the most significant determinant of forest fire suppression cost (Calkin, Gebert, Jones, & Neilson, 2005; Donovan, Noordijk, & Radeloff, 2004; Abt, Prestemon, & Gebert, 2008). Other research identifies the spatial factor of the presence of residential housing near the vicinity of the wildfire to be another fundamental factor in the increase of wildland fire suppression expenditures at the national level (Gebert, Calkin, & Yoder, 2007; Wildland Fire Leadership Council, 2004). However, a study of 58 large wildfires tested the relationship between wildfire suppression costs and the amount and density of residential housing in close proximity to the wildfire. This study of the 2002 fire season in Oregon and Washington yielded no explanation in the variance of suppression costs when associated with the proximity of housing near the incident, but did identify extreme terrain as a significant spatial factor in determining wildfire costs (Donovan et al., 2004).

Recognition that forest fuel loadings are increasing in size and quantity on both a national level and in the study area of the Black Hills of South Dakota is well documented. On a national level, the issue of increasing wildland fuel loading due to the exclusion of fire from the landscape resulted in the creation of the 1995 Federal Wildland Fire Management Policy which calls for the use of fire to restore forest health and reduce fuel loadings in the wildland fire environment, in addition to mechanical fuel treatments (Stephens & Ruth, 2005). This policy was enacted to direct efforts on national level to decrease the threat to human life, community infrastructure, and to reduce costs to the federal government from the suppression of large wildfires. Busenberg (2004), points out that implementing the goals of the 1995 Federal Wildland Fire Management Policy in response to ever increasing fuel loadings requires an adaptive policy that will take a commitment of many years over a large landscape scale to reduce fuel loadings and the concurrent risk of large fire suppression expenditures.

Throughout the western United States, ponderosa pine forests exist in an overstocked condition with above normal fuel accumulations and abundant tree regeneration primarily due to fire exclusion (Fitzgerald, 2005). Brown and Sieg (1996) studied fire return intervals in the Black Hills of South Dakota prior to settlement and concluded that the disruption of the normal cycle of fire in the Black Hills landscape leads to overstocked conditions, insect and disease outbreaks in the forested stands of ponderosa pine, and higher fuel loadings throughout the forest.

Drought conditions are a climatic variable that has been identified as a factor that leads to increased wildfire suppression expenditures. A drought index that was created to predict large and expensive forest fires in the southeastern and northeastern parts of the United States was formulated in late 1960’s by Keetch and Bryam (1968). By late 1990’s and into the first decade of the 21st century, climate research had shown a strong correlation of summer drought periods and increased fire activity in ponderosa pine dominant forests (Westerling, Hidalgo, Cayan, & Swetnam, 2006). Research into suppression expenditure trends on large U. S. Forest Service wildfires from 1970 to 2002 by Calkin et al. (2005) show a positive association between prolonged dry periods and larger and complex (i. e. more expensive) wildfires.

Research into various managerial actions or inactions as factors that can influence wildfire suppression costs has been studied with regards to the type and quantity of suppression resources used and what type of strategic and tactical limitations were involved during the suppression of the wildfire. In a study of USFS wildfire suppression expenditures from 1970-1995, it was determined that approximately 55.6% of all expenditures were for supplies and services, such as contract aviation resources and food catering/restaurant contracts. Salaries, benefits, and travel payments to personnel working in suppression duties amounted to approximately 33.3% of the suppression bill. Other miscellaneous payments such as claims and administrative expenses rounded out the remaining 10% (Cleaves, Schuster, & Bell, 1997). Another managerial action that has been found to lower costs on a large fire is the selection of type of overhead team used to manage the incident. A study comparing large fire costs between 2006 and 2007 showed that using more Type II IMT’s in the 2007 fire season resulted in lower costs per fire when the Type II teams were used as part of a strategy to lower costs for staffing on longer term fire situations (USDA Independent Large Wildfire Cost Panel, 2008). Mangan

(1999) noted that from his experience as a Fire and Aviation Management Program Leader for the USFS in the Northern Rockies, that some large wildfires will incur aircraft expenses in excess of one-third of the total suppression costs. This contrasted with the Independent Large Wildfire Cost Panel Study of the 2007 fire season where use of aviation resources on both long term and short term large fires averaged about 18% of total suppression costs (USDA Independent Large Wildfire Cost Panel, 2008). Mangan (1999) also noted that further cost savings in fire suppression expenditures could result with increased efficiency in the operations section of the Incident Command System, but most importantly, the incident commander and the agency administrator or elected officials must make the clear the objective of cost reduction as an incident objective and strongly support any strategy towards that end.

In 2006, the results of research conducted through an in-depth survey of 48 members of the command and general staff of national Incident Management Teams (IMT's) identified many cost drivers as factors for increased fire expenditures such as: (a) increased use of higher priced service contractors; (b) more use of heavy lift helicopters; (c) outside costs such as Burned Area Rehab teams not controlled by the IMT and chargeable against the suppression bill; (d) implementation of computer and software technology with the concurrent need for dust free environments in camp for use; and (e) external decisions made by political entities with no input from the IMT (Canton-Thompson, Thompson, Gebert, Calkin, Donovan, & Jones, 2006).

The Relationship of the Causal Factors: Interrelationships between Cost Drivers

The Wildland Fire Leadership Council (2004) observed in its study of large fire suppression costs that "climate, fuels, demographic and social considerations – serve as a 'suite of indicators' about wildland fire costs" (p. 13). Within this grouping of indicators, several interrelationships between cost drivers have been studied at the national level. A national study of USFS wildfires from federal fiscal year 1995-2004 looked at 1,550 incidents that totaled $2.07 billion in expenditures. The study revealed an average fire cost as adjusted to 2004 dollars of approximately $1.3 million with an average cost per acre of $979 (Gebert et al., 2007). The regression equation used in this study showed that the drought indicator of an Energy Release Component (ERC), combined with higher flame lengths at the head of the fire as reported by initial attack forces, and the increasing valuation of housing stock within a 20 mile perimeter of the fire, were the most important variables in the predictive model designed by the authors; with other variables such as topography, fuel, or managerial decisions playing a subordinate role. Calkin et al. (2005) in their study of suppression expenditure trends from 1970 to 2002 modeled acres burned as a function of the Palmer Drought Severity Index (PDSI), and concluded that weather is the best predictor of acres burned, and in turn, suppression expenditures. This was based on the fact that increasing fuel loads and WUI development could not alone or together explain certain structural shifts in actual acres burned, especially after 1987, whereas the regional PDSI variables provided a better explanatory value in the model.

The National Academy of Public Administration (2002), reported that drought, combined with the accumulation of hazardous wildland fuels and the increasing settlement of the WUI are factors that will lead to trending higher costs for all wildfire suppression activities in the future. The report also showed that in the 2002 wildfire season, 95 percent wildfires burned on lands that were cover-typed under hazardous fuels conditions. In addition, the Academy researched six case studies of large wildland fires that were managed by Type I and II IMT's in the 2001 season and found that per acre fire costs ranged from $26/acre to a high of $2975/ac. A national interagency large fire cost reduction plan (USDA, USDI, & NASF, 2003) indentified several relationships between cost drivers that could be modified by managerial action that could lead to cost reductions in wildfire suppression. This cost reduction plan called for: (a) increased oversight on aviation operations, (b) more aggressive initial attack to prevent small fires from becoming large fires, (c) building up local Type III IMT capability so that national Type I and II IMT's do not have to be ordered; and (d) serious consideration to night shift operations when safety concerns are properly mitigated.

However, interviews of national IMT members shows that these team members do not necessarily think that any more policies, directives or standard operating procedures will influence wildfire suppression expenditures until the interaction between IMT's and agency administrators, dispatch centers, and critical suppression resources such as Type I handcrews are better understood as factors influencing the cost drivers (Canton-Thompson et al., 2006). The U.S. Department of Agriculture, Office of the Inspector General audit report on large fire suppression costs recommended that interaction between incident commanders and agency administrators be evaluated with an assessment of the cost effectiveness of strategy and tactics at the close-out of an incident (USDA- Office of the Inspector General Western Region, 2006). This audit report also identified the cost of protecting structures in the WUI as the single largest cost driver in USFS suppression expenditures. This finding is also corroborated by the research of 16 non-managerial cost factors in which regression models showed that the size of the wildfire and the proximity of private land could explain 58% of the variation in large fire costs for the USFS in the Northern Rockies (Liang, Calkin, Gebert, Venn, & Silverstein, 2008).

A summary of the literature review shows that most of the research involving large fire expenditures in the United States is conducted at the federal level and is mostly specific to the USFS, given that on an annual basis, 71% of federal wildfire suppression expenditures are attributed to that agency (National Academy of Public Administration, 2002). Specifically to the Black Hills of South Dakota there are no published peer-reviewed studies on wildfire expenditures with regards to the two research questions of the identification of the factors and the relationship of those factors wildfire suppression expenditures. However, research findings at the national level with case studies of large fires and review of seasonal expenditures in coniferous forest fuel types such as the local fire department's area point to the possible identification of potentially important variables on local basis. The literature of the interrelationships of these possible identified variables has been studied specific to suppression expenditures in coniferous forest types were reviewed and the interrelationships of climate, hazardous fuels, managerial decisions, and the social factors of population movement into the WUI were observed to be important factors in other coniferous ecosystems that exhibit the same characteristics as the study area.

Procedures

Research procedures were as follows: (a) description of the study area; (b) setting the null (H_0) and alternative hypotheses (H_1) under which to identify the factors that drives costs on wildfires; (c) construction and validation of the database used for analysis; and (d) conducting the statistical analysis and for both research questions.

The general location of the study area is shown on page 31 (figure 1). The study area comprises all of the state and private land within the Black Hills Forest Fire Protection District (BHFFPD) which is the jurisdictional area for SDWFS fire management activities.

The null (H_0) and alternative hypotheses (H_1) for both of the research questions of the identification of the cost drivers and their relationships were tested by a correlational research design (Gay & Airasian, 2003). The H_0 for all testing was that there is no statistically significant correlation between any tested factor and the dependent or response variable labeled *FireCost* which is the total cost of the wildfire suppression expenditure effort on a per incident basis.

The H_1 was that there exists statistically significant relationship between the tested cost driver and the response variable, FireCost, and that relationship is of a linear type, in that if the quantity of x increases, so does the quantity of the response variable, FireCost. The H_0 was the expected outcome for the first research question in this correlational study and the H_0 was only to be rejected in favor of the H_1 in a one-tailed directional test when it can be statistically proven that the observed correlation coefficient was expected to be observed at least 95% of the time, or conversely, the H_1 was accepted when the probability level is less than 5 percent ($\alpha < 5\%$) that this observation would not be the case.

The second research question of the relationship of any identified factors to contributing to an increase in the response variable was tested by the use of multiple linear regression analysis to see if any of the quantitative cost drivers modeled could predict an increase in the response variable of FireCost.

Database

The database used for statistical analysis was gathered from the fire department's archival records maintained by the Fire Business Program Manager at the WFS State Office Headquarters in Rapid City, SD. The set contained fire occurrence and suppression expenditure cost data from January 1, 2005 to December 31, 2007, which was inclusive of three years of fire occurrence on fire department jurisdictional lands in the BHFFPD. The dataset contained 199 occurrences of wildfire suppression activity that was > $100 per occurrence. The truncated limit of $100 was selected to eliminate those fire occurrences which contained expenditure records only linked to dispatcher or investigator time, and where no direct suppression expenditure expenses were incurred. Several wildfire records showed total fire suppression expenditures > $2,000,000. In that dataset of 199 wildfire occurrences, the dependent or response variable of FireCost was quantified in USD ($) for each occurrence and was tested against five other independent variables in the database that were observed for each record of occurrence. These five independent or explanatory variables were: (1) *Size*, size of wildfire as measured in hectares, (ha); (2) *Slope*, the general slope of the area of the point of origin of the wildfire occurrence within a 35 meter radius and expressed in percent (Environmental Statistics Group, Montana State University, 2005); (3) *PDSI*, The Palmer Drought Severity Index rating for Black Hills area in that week of the wildfire occurrence (NOAA, National Weather Service, 2010); (4) *WPDSI*, which is a weighted PDSI index based on both the PDSI of the week of occurrence and the preceding week's PDSI index rating; and (5) *Road-Dist*, which is the distance in meters between the fire and the nearest road system as mapped by the terra-server at the Environmental Statistics Group, Montana State University (2005). The Road-Dist variable was used as a surrogote for residential housing density or the presence of man-made improvements in the WUI.

The dataset was further prepared for analysis by establishing a subset (n = 32) of occurrence data for the most expensive wildfires that accounted for 97% of the total expenditures for the three calendar year study period and extracting the total expenditure outlay for aviation costs per wildfire occurrence as another explanatory variable called *AvCost* for this subset of data.

Statistical Procedure

The first research question of identifying the individual cost drivers by correlating the quantitative measure of the explanatory variables against the response variable FireCost and testing for the significance of the coefficient of determination, r^2, in a one tailed directional test for positive correlation, in that if the quantity of the cost driver increases, so does the value of the variable FireCost. The explanatory variable of Road-Dist was tested in a one tailed directional test for negative correlation, in that as the distance between the wildfire and the road system decreases, an increase in FireCost will be observed.

The second research question of how the identified cost drivers and their relationships can explain the value of FireCost was tested by creating a multiple regression model. A major limitation of this statistical procedure as designed is that wildfire occurrence data is sometimes skewed away from a normal distribution due to the efficiency of fire suppression efforts in the field (Stephens, 2005), therefore a larger sample size was used to overcome this limitation.

The computational analysis for the statistical testing was performed by a free statistical calculator website provided by R. Lowry, Department of Psychology, Vassar College, NY (2010).

Results

The analysis of the first question of identification of the cost drivers identified a strong correlation across both datasets for the relationship between Size and FireCost. The other variables of Slope, Road-Dist, PDSI and WPDSI showed no correlation with FireCost.
Table 1 contains the results of basic linear correlation between the explanatory variables and the response variable of FireCost for all wildfires in the dataset (n = 199).

Table 1

Summary of Linear Correlation for Factors Influencing FireCost for All Wildfires

Factor	Pearson product moment correlation (*r*)	Coefficient of determination (r^2)	*p*
Size	.8948	.8007	<.0001
Slope	-.0484	.0023	.24
Road-Dist	-.0602	.0036	.19
PDSI	.0118	.0001	.43
WPDSI	.0103	.0001	.44

Note. * Significant at $p < .05$, where $p_{(1)}$ indicates the directional or one-tailed test.

Table 2 shows the results of the linear correlation analysis for the 32 most expensive wildfires in the dataset, which comprise 97% of all wildfire suppression cost expenditures for the fire department from 2005 to 2007 ($n = 32$).

Table 2

Summary of Linear Correlation for Factors Influencing FireCost for the Most Expensive Wildfires

Factor	Pearson product moment correlation (r)	Coefficient of determination (r^2)	p
Size	.8895	.7912	<.0001*
Slope	-.1757	.0309	.18
Road-Dist	-.2267	.0514	.11
PDSI	.0597	.0036	.37
WPDSI	-.0175	.0003	.46
AvCost	.9690	.9389	<.0001*

Note. * Significant at $p < .05$, where p indicates the directional or one-tailed test.

The results of the correlational study show strong positive correlation in linearity for the relationship between the explanatory variable of Size and the response variable FireCost for both datasets. The subset of data containing the most expensive wildfires, expenditures for the deployment and support of aviation resources showed the strongest positive correlation with FireCost. The other explanatory variables of PDSI, WPDSI, Slope, and Road-Dist showed no significant correlation with the response variable of FireCost, and no rejection of the H_0 concerning the causality of any of those relationships.

The results for the second research question of the relationships between the identified factors were derived from multiple regression analysis. The explanatory variables were regressed against the response variable FireCost to determine if any interrelationships between factors could produce a more robust model in predicting the variance in FireCost than just the single variables of Size or AvCost. The assumption of no multicollinearity between independent variables in the regression model was maintained by only using PDSI as the explanatory variable for drought severity instead of both PDSI and WPDSI. The results of the regression analysis are summarized in Table 3.

Table 3

Summary Regression Statistics for the Interrelationships between Cost Drivers

Model	Multiple R^2	Adjusted Multiple R^2	Explanatory Variables
All fires	.8033	.7992	Size, Slope, Road-Dist, PDSI
All Fires	.7912	.7843	Size
Most expensive fires	.9592	.9514	Size, Sl*, RD*, PD*, AvCost
Most expensive fires	.9560	.9530	Size, AvCost

Note. * Indicates abbreviations for variables: Sl = Slope, RD = Road-Dist, and PD = PDSI.

The results show that explanatory variable of Size is an important contributor to the explanation of the variance of the response variable FireCost for both datasets. The addition of aviation costs as explanatory variable for the most expensive fires increases the predicative capability of the regression model. In addition, removing the variables of PDSI, Slope, and Road-Dist from analysis from both datasets does not weaken the model.

Discussion

The results for both research questions showed a strong correlation between the amounts of hectares burned (Size) as an explanatory variable for the amount of variance in the quantity of dollars spent in suppression activities per wildfire occurrence. This relationship is strongly positive for both the large dataset of all wildfires (n = 199) and the subset of data records (n = 32) derived from the wildfires that accounted for 97% of the suppression expenditures. This compares well with research conducted by Calkin et al. (2005) which showed a 0.76 Pearson's correlation coefficient between the explanatory variable of size and the response variable of fire suppression expenditures for large USFS wildfires from 1970-2002. This is compared to results from the applied research project showing a Pearson's correlation coefficient 0.88 to 0.89 for the same relationship of size to expenditure.

Another factor indentified as a potential cost driver for increasing fire costs is the proximity of single family residential structures in the area of the wildfire (Gebert et al., 2007), (Wildland Fire Leadership Council, 2004). The results of this study showed the that the surrogate variable created for housing density, Road-Dist, was not significantly correlated to FireCost, although Road-Dist showed a negative correlation as postulated in the H_1 in that as distance between the fire and road decreased, the fire cost would increase in the amount of expenditure. However, this negative relationship was not significant at the 5% level as required for the one-tailed test of the H_0. The results showing no significance for Road-Dist as an explanatory variable may suggest that a better indicator of housing density should be used for this type of study, or that the relationship of road density, residential development and fire suppression expenditures needs more study as pointed in a study of WUI wildfires in Oregon and Washington (Donovan et al., 2004). That study found no correlation between housing density and fire costs, but observed that the effects of road systems need to be better understood in the analysis of wildfire suppression costs.

The study of Oregon and Washington of 58 large WUI wildfires in the 2002 fire season did show that the difficulty of the terrain was a significant factor in determining total wildfire suppression costs (Donovan et al.). However, the results from this applied research project did not find the explanatory variable of Slope correlated with FireCost at any level of significance and the H_0 was not rejected. This may be due to the fact that variable Slope as derived from a GIS database in the applied research project differed from binominal variable of "difficult terrain" as derived from the surveyed opinion of the incident commanders (Donovan et al., pg. 3).

The question of linear correlation between drought conditions and increasing fire costs showed no correleation at any level in both datasets. This is in contrast to research reported by Calkins et al. (2005) on expenditure trends of large USFS wildfires from 1970 to 2002, and the findings of Westerling et al. (2006) that there is a significant correlation between wildfire activity in western ponderosa pine forests and summer drought periods. A possible explaination for this contrast is that variable of drought as used in the applied research project was not controlled by comparing fire costs between periods of drought and non-drought periods. That is because during the study years of 2005-2007, the study area in western South Dakota experienced 36 months of some degree or level of drought severity as reported by the Palmer Drought Severity Index. It may be more useful to report that this applied research project did not find any correlation between the different levels or severity of the drought periods as indicated by PDSI or WPDSI and the response variable of FireCost.

The last variable studied for correlation with FireCost was that of aviation expenditures as observed within the subset of the most expensive fires. The very strong positive correlation as indicated by the r^2 value of .94 shows that the use of aviation resources on a wildfire incident is a very significant cost driver of suppression expenditures within the BHFFPD. Comparing these findings with the research in the field supports the results of applied research project. Mangan (1999) noted that some large wildfires will see expenditures for aviation operations in excess of one-third of the total cost of the wildfire. The USDA's Independent Large Wildfire Cost Panel Study (2008) reported in its study of the 2007 wildfire season that aviation expenditures averaged 18% of total suppression costs. Increased aviation costs as related to heavy lift helicopters was a cost driver indentified by Canton-Thompson et al. (2006). Many of the most expensive wildfires in the subset of data studied incurred sizable expenses from the South Dakota National Guard's (SDNG) UH-60 heavy lift helicopter program. Therefore, it is not unexpected that as a fire grew in size and complexity, more heavy lift helicopters were used to haul water into wildfires to contain the forward spread of the fire's perimeter.

The results of the applied research project as to the second research question of the interrelationships of the cost drivers showed that explanatory variables of size and aviation cost provided the best fit regression model for determining the final cost of the wildfire. This interrelationship of size and aviation costs was also observed in the 2003 Interagency Large Fire Cost Reduction Plan by the USDA, USDI, and the National Association of State Foresters. This cost reduction plan called for the improved management of aircraft operations and increased initial attack capability to prevent small fires from getting larger. The two variable regression model of AvCost and Size support the findings of the 2003 Interagency Large Fire Cost Reduction Plan. However the regression analysis dropped drought indicators, topography features and WUI development as predictor or explanatory variables from the model. These findings are in contrast to the research by Gebert et al. (2007) which found that drought indicators and WUI development were significant contributors to the predictability of their regression model used on a dataset of 1550 large USFS wildfires from 1995-2004. And the study of suppression expenditure trends of USFS wildfires by Calkins et al. (2005) from 1970 to 2002 showed that drought indicators based on the PDSI were the best predictors of acres burned and suppression expenditures. Research by Liang et al. (2008) also pointed towards the relationship of fire size and the proximity of private land as two important variables in their regression models. In addition, the National Academy of Public Administration (2002) reported that the interrelationships of fuels, drought and WUI will lead to increased expenditures in the future for wildfires. Given that this applied research project did not find drought severity, WUI development, or topography to be significant cost drivers in the final analysis should be understood within the context of the following limitations. The first limitation is that of size of database under study. The research conducted on the USFS wildfires worked with more robust and larger datasets, sometimes in excess of 1000 wildfire occurrences as compared to the smaller datasets used in this applied research project. Other limitations were less than robust surrogate variables used for WUI development and no control for drought occurrence, as the regression models used in the applied research project tested only for distance from roads and drought severity, respectively.

In summary of the discussion, it appears that within the study period of 2005-2007, the best predictor or explanatory variables for determining the final cost of a wildfire in the BHFFPD are size and aviation costs. However understanding that that time period of the study was inclusive of a severe drought period in the history of the Black Hills and the small dataset involved for the wildfires that made up the 97% threshold of all expenditures at that time, caution should be used for using this regression model and the findings of the linear correlations outside of the fire department’s jurisdictional area.

Organizational Impact

The results of this applied research project will guide fire suppression strategy and tactics based on the predictions of long-term drought occurrence and the availability of aviation and non-aviation resources within the BHFFPD. And the fire department will be able to use the results of this applied research project to study the type and cost of certain aviation resources and to advocate the need to maintain an aggressive initial attack posture during times of drought, regardless of the severity of the drought.

Recommendations

This study identified the cost drivers and their interrelationships that influenced suppression costs in the BHFFPD and to better understand how to reduce those expenditures by the use of cost analysis. Based on this applied research project, it needs to be understood that during times of drought periods, the level of the severity of the drought should not determine preparedness levels of suppression resources, but rather, just the occurrence of drought should suffice to trigger orders for additional severity resources. The justification for a request of prepositioned resources will be to keep new wildfire starts small, as the size of the fire is a significant determinant of the total expenditure. In addition, the time-honored wildfire management strategy of reassigning resources from an on-going large wildfire to a new start is reinforced in the same manner by this study, in that by keeping any newly started wildfires small, overall cost reductions are realized.

Another recommendation for the department is increase oversight on fire department aviation operations as recommended in the 2003 USDA, USDI and National Association of State Forester's Large Fire Cost Reduction Plan. A cost analysis should be conducted within the fire department to receive best value from the department's aviation contractors. Special concern should be given to how heavy lift helicopters are ordered and used by the fire department. Given that SDNG UH-60's are on a Call-When-Needed hourly rate to the fire department of more than $7000 per hour when ordered under a Governor's State Disaster Declaration, further work needs to be done to secure contracts with private vendors that can provide heavy lift rotor services at a lesser rate.

The most important recommendation for the fire department will be to use the results of this study to prevent any budget cut-backs to the current staffing levels of the department and to reinforce any fire prevention activities of the department. Only by preventing wildfires before they start, and by keeping size of the fire small, will total suppression costs be reduced. And it needs to be understood, that given the buildup of hazardous fuels and the increasing development of the WUI, that concomitant investments of staffing and budget will need to be used for fuel reduction activities during times of low fire danger and non-drought periods in the form of tree thinning and prescribed burning.   This adaptive strategy as recommended by Busenberg (2004) to counter ever increasing fuel loadings will be key to reducing wildland fire suppression expenditures in the future in the Black Hills of South Dakota.

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Figure Caption

Figure 1. Outlined border of the State of South Dakota, with the general location of the study area displayed in the left-hand side of the figure. The shaded area is the Black Hills National Forest (BHNF) that is located in both SD and WY. The study area comprises those private and state-owned lands adjacent to and within the BHNF in SD (Marchand, 2008).

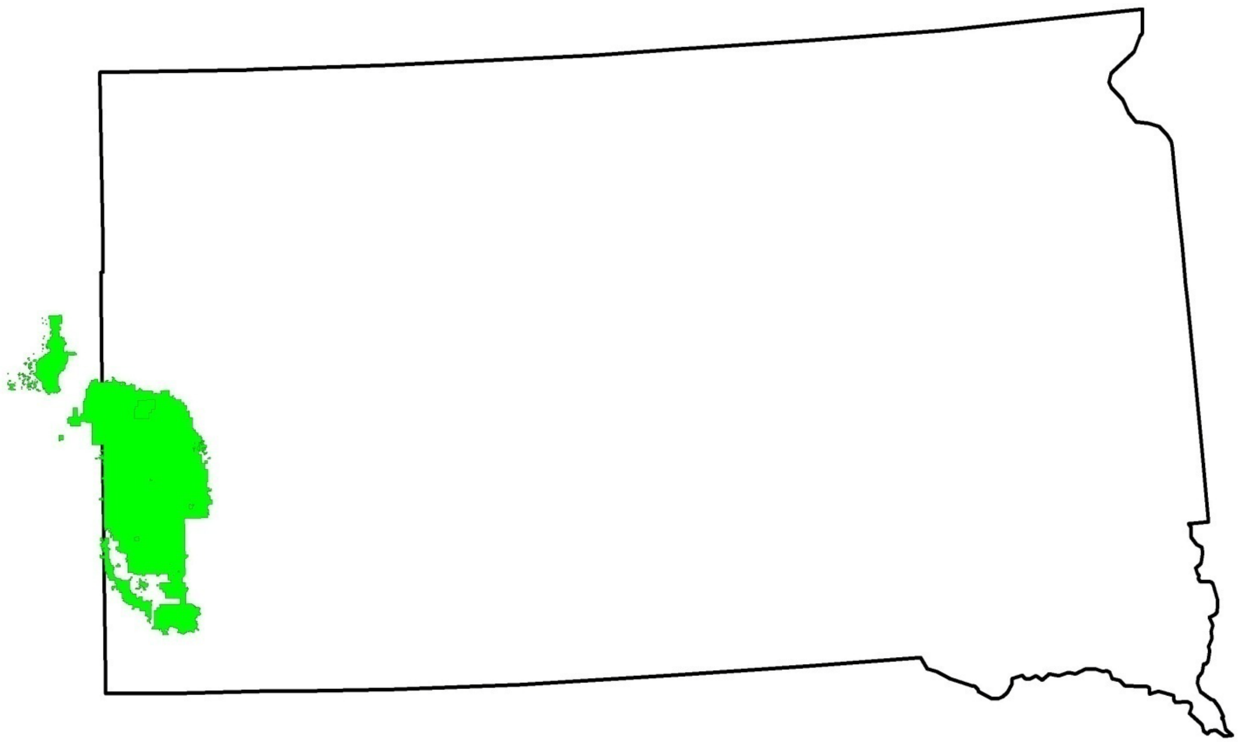

Figure Captions

Figure 1. Outlined border of the State of South Dakota, with the general location of the study area displayed in the left-hand side of the figure. The shaded area is the Black Hills National Forest (BHNF) that is located in both SD and WY. The study area comprises those private and state-owned lands adjacent to and within the BHNF in SD (Marchand, 2008)

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Any errors or omissions in this article are mine alone.

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