An investigation of possible effects of global warming on forest fires in Kentucky from 1945 to 2004

Samuel J. Ivy
Morehouse College
Samj_ivy@yahoo.com

Ashley J. Sullivan
Spelman College
ajsullivan88@aol.com

Kevin Wingfield
Morehouse College
kwingfie@students.morehouse.edu

Jamika Baltrop
Elizabeth City State University
jmbaltrop@yahoo.com

Amanda Eure
Winston-Salem Sate University
aeure106@wssu.edu

ABSTRACT

This investigation seeks to find a relation between the frequencies of forest fires with acreage burned in the state of Kentucky and the factors of global warming. Under global warming, we focus on the components climate change and precipitation rate in hopes of establishing this relationship. In delving deeper into the effects of forest fires, or wildfires, we explore a mathematical model offered as a solution to optimally contain these disasters while minimizing the costs of resources and eventually recovery.

NOMENCLATURE

Symbols

t,	time where $t > 0$
$R(t) \subset \nabla^2$,	burned or contaminated region
∇^2,	two-dimensional
$F: \nabla^2 T \nabla^2$,	the Lipschitz continuous function
$R_0 \subset \nabla^2$,	bounded set
$\dot{x}\ \varepsilon\ F(x)$,	reachable set for differential inclusion
$\dot{x}(0)\ \varepsilon\ R_0$,	initial position for differential inclusion
$\psi: \nabla^2 T R_+$,	continuous & strictly positive function used to construct a one-dimensional rectifiable curve
$\gamma(t)$,	the portion of the wall constructed within time $t \geq 0$
σ	constant
$R^\gamma(t)$	reachable set determined by the blocking strategy γ
B_r	fixed ball centered at the origin with radius r.
Γ	adjacent arcs
F	free arcs
B	boundary arc

PURPOSE

The intent of this project is to investigate the relationship between the factors of global warming and the number of square acres burned in forest fires from 1945-2004 in the state of Kentucky.

Keywords

Forest Fires, Global Warming, Wild fires, Differential Inclusions.

1. INTRODUCTION

Each year millions of hectares of wild land worldwide are consumed by forest fires. From this it may seem that all forest fires are bad and unwanted, but this is not so. Forest fires are a natural and vital part of some ecosystems. Forest fires become problematic when they burn in the wrong places such as forested areas used for harvesting lumber or residential areas. When forest fires burn in these unwanted places, they become huge financial burdens on the federal and state governments. Due to the huge financial burdens imposed on state governments, the factors that increase the likelihood of more intense wild fires have moved to the forefront of the concerns of these governments.

According to a research paper [7] published in July 2006 by the journal *Science*, global warming is thought to be creating conditions that increase the likelihood of more intense wild fires. Through regression analysis and analysis of variance, we investigate some of the potential factors that may be leading to more intense wild fires throughout the state of Kentucky. In the section that follows we also investigate containment strategies for containing the spread of wild fires once they have begun using a method based on differential inclusions.

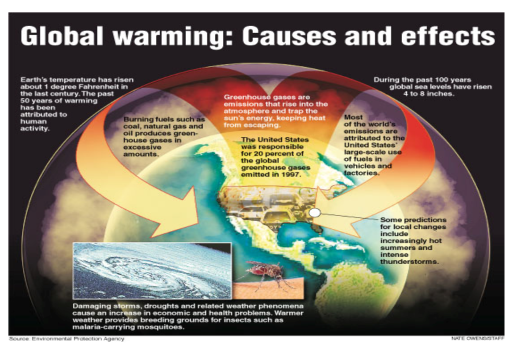

Figure 1: Global warming: causes and effects.

2. APPROACH TO SOLVING THE PROBLEM

In order to observe the relationship between global warming and forest fires several mathematical and statistical tools are used: regression analysis, ANOVA and differential inclusions. Regression analysis will yield a correlation between the particular factors of global warming and forest fires in the state of Kentucky. In addition, this analysis will lead to future predications of the dreaded potentiality of global warming on forest fires in the state of Kentucky if not remedied. A regression analysis of a mathematical equation for the number of acres burned will determine the impact of each global warming factor on the forest fires from 1945-2004. Under this investigation, we focus on the frequency of forest fires and acreage burned.

In the explanation of containing such wildfires, we use differential inclusions and optimization in calculating an optimal strategy of confining wild fires. A two dimensional differential inclusion is used to describe areas affected by fire and outside land used to seal the fires. In addition, an optimization problem is developed to eventually minimize resources, man power, and costs to prevent further forest fire expansion.

2.1 Graphical Representation

The data used is depicted as follows:

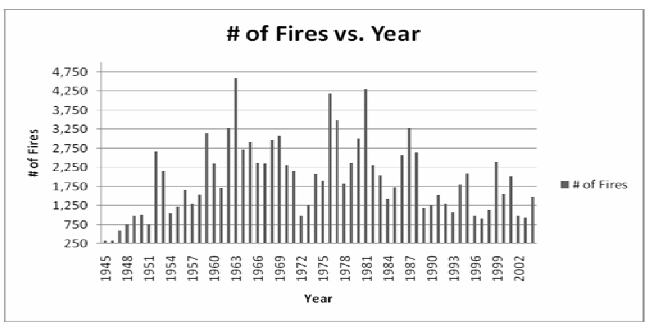

Figure 2: The visualization shows a change of the number of fires in Kentucky, ranging from 330 to 4,600 over the years of 1945 – 2004. The peak over this 60 year period was in 1963 with 4,579 fires. However, the smallest number of fires occurred in 1946 with 331 fires.

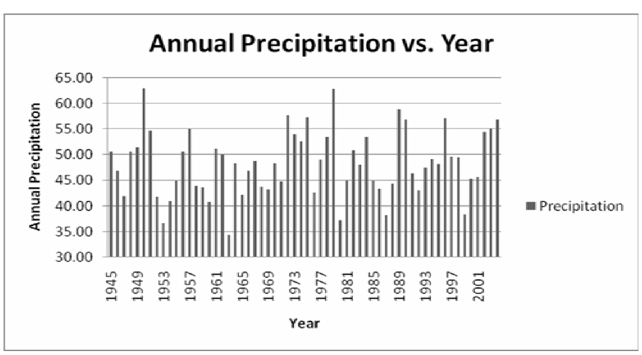

Figure 3: The visualization shows changes of annual precipitation in Kentucky, ranging from 34 to 63 over the years 1945 – 2004. The peak over this 60 year period was in 1950 with a precipitation of 62.93. However, the smallest amount of precipitation occurred in 1963 at 34.45.

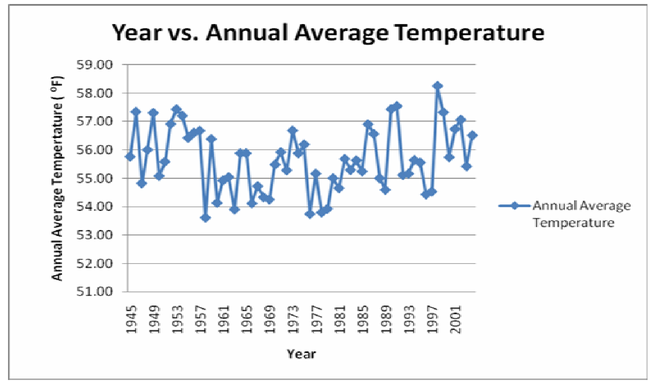

Figure 4: The visualization shows change of the annual average temperature, ranging from approximately 54 F- 58 F over the years of 1945-2004. The peak over this 60 year period was in 1998 where the annual average temperature was 58.25 F and the lowest is 53.61 F in 1958.

3. COMPUTATIONAL MODELING

3.1 Regression Analysis

3.1.1 Linear Regression Analysis: Sq. Acres Burned vs. Year

The regression equation is

Sq Acres Burned = 983113 - 458 Year

Predictor	Coef	StDev	T	P
Constant	983113	1695289	0.58	0.564
Year	-457.6	858.6	-0.53	0.596

S = 115172 R-Sq = 0.5% R-Sq(adj) = 0.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	3768322733	3768322733	0.28	0.596
Residual Error	58	7.69343E+11	13264529808		
Total	59	7.73111E+11			

Regression Analysis: Sq Acres Burned vs. Temperature

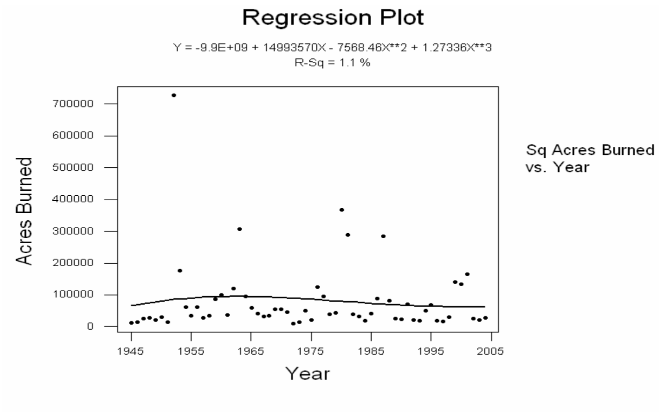

Figure 5: A cubic function of sq. acres burned over the years 1945-2005.

3.1.2 Linear Regression Analysis: Sq. Acres Burned vs. Temperature

The regression equation is
Number of Acres Burned = - 270077 + 6282 Annual Average Temperature

Predictor	Coef	StDev	T	P
Constant	-270077	737654	-0.37	0.716
Annual A	6282	13252	0.47	0.637

S = 115230   R-Sq = 0.4%   R-Sq(adj) = 0.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	2984226033	2984226033	0.22	0.637
Residual Error	58	7.70127E+11	13278048717		
Total	59	7.73111E+11			

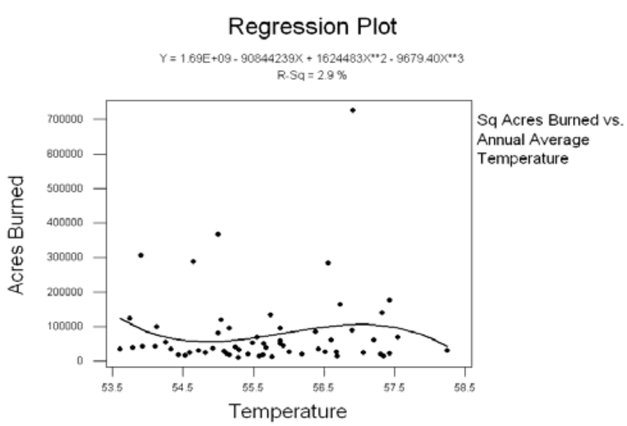

Figure 6: A cubic function of sq. acres burned as a function of temperature.

3.1.3 Linear Regression Analysis: Sq. Acres Burned vs. Precipitation

The regression equation is
Number of Acres Burned = 517465 - 9073 Annual Precipitation

Predictor	Coef	StDev	T	P
Constant	517465	98998	5.23	0.000
Annual P	-9073	2034	-4.46	0.000

S = 99620   R-Sq = 25.5%   R-Sq(adj) = 24.3%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	1.97514E+11	1.97514E+11	19.90	0.000
Residual Error	58	5.75597E+11	9924093455		
Total	59	7.73111E+11			

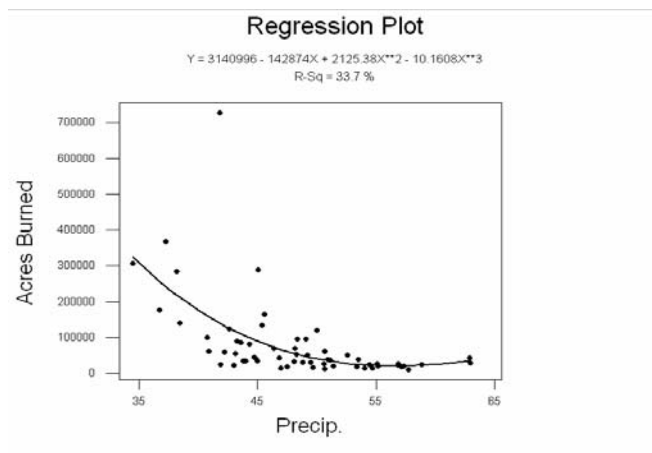

Figure 7: A cubic function of the number of sq. acres burned as a function of the annual precipitation.

3.1.4 Linear Regression Analysis: Sq. Acres Burned vs. Precipitation and Temperature

The regression equation is
Number of Acres Burned = 238416 - 9051 Annual Precipitation
+ 4995 Annual Average Temperature

Predictor	Coef	StDev	T	P
Constant	238416	652471	0.37	0.716

Annual P	-9051	2049	-4.42	0.000
Annual A	4995	11541	0.43	0.667

S = 100325 R-Sq = 25.8% R-Sq(adj) = 23.2%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	2	1.99399E+11	99699331625	9.91	0.000
Residual Error	57	5.73712E+11	10065129620		
Total	59	7.73111E+11			

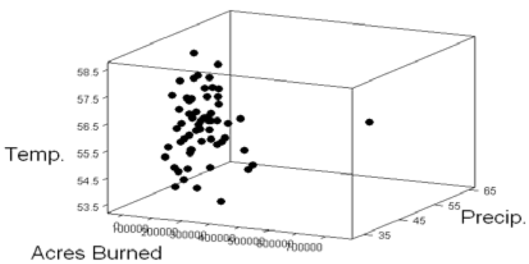

Figure 8: A 3-D scatter plot with the number of sq. acres burned along the y-axis, annual precipitation on x-axis and annual average temperature on the z-axis. The number of acres burned seam not to be affected with the temperature change.

3.2 ANOVA

3.2.1 ANOVA (5-yr. periods)

In order to determine if the means of the acreage burned in Kentucky over five-year periods are the same, we use a one-way analysis of variance (ANOVA). The average acreage burned during 1946-1950, 1951-1955…, 2001-2005 are tested using the hypotheses

$$H_0 : \mu_1 = \mu_2 = \ldots = \mu_{12}$$

$$H_a : \text{At least one } \mu_i \neq \mu_j .$$

Table 1: The output from the Data Analysis tool in Excel with five year period as a factor.

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.49E+11	11	1.36E+10	1.050807755	0.419289	1.99458
Within Groups	6.2E+11	48	1.29E+10			
Total	7.69E+11	59				

The P-value of the F-test is 0.419 and is more than 0.05 (for a 5% significance level). Therefore there is no significant difference between the average acreage burned across the twelve 5-yr periods.

3.2.2 ANOVA (Precip. Levels)

In order to determine if the means of the acreage burned in Kentucky over three precipitation levels are the same, we use a one-way analysis of variance (ANOVA). The average acreage burned for low (35-44 in), medium (45-54 in), and high (55-64) are tested using the hypotheses

$$H_0 : \mu_1 = \mu_2 = \mu_3$$

$$H_a : \text{At least one } \mu_i \neq \mu_j .$$

Table 2: The output from the Data Analysis tool in Excel with the precipitation levels.

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.58E+11	2	7.92E+10	7.339229	0.001458	3.158843
Within Groups	6.15E+11	57	1.08E+10			
Total	7.73E+11	59				

The P-value of the F-test is 0.001458 and is less than 0.05 (for a 5% significance level). Therefore there exists a significant difference between the average acreage burned across the three precipitation levels. Since there exists a significant difference between the average acreage burned across the three precipitation levels, then a pair-wise T-test can be used to determine if μ_1 is significantly larger than μ_2 and μ_2 is significantly larger than μ_3.

3.3 T-test

3.3.1 T-test (Comparing Low Precipitation with Medium Precipitation)

In order to determine if μ_1 is significantly larger than μ_2, we use the T-test. The average acreage burned for low precipitation (35-44 in) and medium precipitation (45-54 in) are tested using the hypotheses

$$H_0 : \mu_1 = \mu_2$$

$$H_a : \mu_1 \neq \mu_2 .$$

Table 3: The output from the Data Analysis tool in Excel.

t-Test: Two-Sample Assuming Unequal Variances

	Low Precipitation	*Medium Precipitation*
Mean	157732.4706	59550.62
Variance	3253804648 1	3.32E+09
Observations	17	29
Hypothesized Mean Difference	0	
df	18	
t Stat	2.179936306	
P(T<=t) one-tail	0.021391344	
t Critical one-tail	1.734063592	

The P-value of the T-test is 0.02139 and is less than 0.05 (for a 5% significance level). Therefore μ_1 is significantly larger than μ_2. Thus the average acreage burned for the low precipitation level is significantly larger than that of the medium precipitation level.

3.3.2 T-test (Comparing Medium Precipitation with High Precipitation)

In order to determine if μ_2 is significantly larger than μ_3, we use the T-test. The average acreage burned for medium precipitation (45-54 in) and high precipitation (55-64 in) are tested using the hypotheses

$$H_0 : \mu_2 = \mu_3$$

$$H_a : \mu_2 \neq \mu_3 .$$

Table 4: The output from the Data Analysis tool in Excel.

t-Test: Two-Sample Assuming Unequal Variances

	Medium Precipitation	*High Precipitation*
Mean	60247.33	21884.54
Variance	3.22E+09	65812096
Observations	30	13
Hypothesized Mean Difference	0	
df	32	
t Stat	3.618309	
P(T<=t) one-tail	0.000505	
t Critical one-tail	1.693889	

The P-value of the T-test is 0.000505 and is less than 0.05 (for a 5% significance level). Therefore μ_2 is significantly larger than μ_3. Thus the average acreage burned for the medium precipitation level is significantly larger than that of the high precipitation level.

3.4 Differential Inclusions [1, 6]

In relation to the frequency of forest fires, we change the focus slightly in an investigation on how to decrease the amount of acreage effect. We now seek a way to not only contain these natural disasters but contain them optimally. Thus, this presents the question on whether their actually exists a method to determine an optimal solution of fire containment via wall construction (or other methods if chosen). In order to continue this study, introduce the concept of differential inclusion to measure disturbances and uncertainties within the study. A differential inclusion takes on the form $\dot{x} \in F(x)$ where F: ∇^2T ∇^2 is a set valued function $(Note : \dot{x} = \frac{dx}{dt})$. Moreover, $\dot{x} \in F(x)$: where F is Lipschitz with Lipschitz constant *k:* That is $dist(F(x_1), F(x_2)) \leq k|x_2 - x_1|$.

Definition: Let X_0 be the initial set of the inclusion. Define reachable sets, Reach as follows:

$$\mathrm{Re}ach_F(X_0, t) = \{\varphi(t) | \varphi(0) \in X_0 \text{ and } \varphi \text{ is a solution of } \dot{x} \in F(x)\}$$

$$\mathrm{Re}ach_F(X_0, [0,t]) = \bigcup_{\tau \in [0,t]} \mathrm{Re}ach_F(X, t)$$

$$\mathrm{Re}ach_F(X_0, [0,\infty)) = \bigcup_t \mathrm{Re}ach_F(X, t)$$

Example: Consider the differential equation $\dot{x}$ = F(x) = x, X_0 = [0,4]:

$\frac{dx}{dt} = x$	$0 = ke^0 \Rightarrow k = 0$
$\frac{dx}{x} = dt$	$4 = ke^0 \Rightarrow k = 4$
$\ln(x) = t + C$	$\mathrm{Re}ach_F(X_0, t) = [0, 4e^t]$
$x = e^{t+C}$	$\mathrm{Re}ach_F(X_0, [0,t]) = [0, e^t]$

$$x = ke^{t} \qquad \mathrm{Reach}_F\left(X_0, [0,\infty)\right) = [0,\infty)$$

The reachable set describes the area of the inclusion with time.

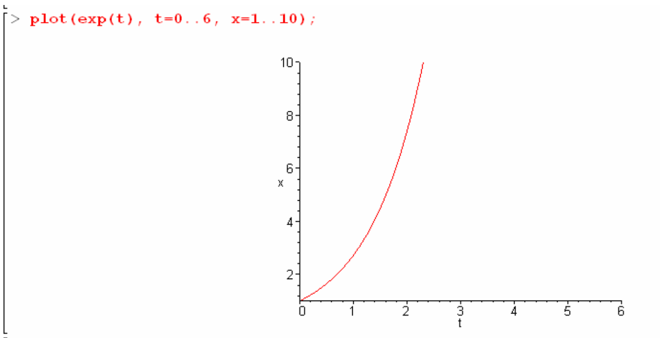

Figure 9: The solution to the example.

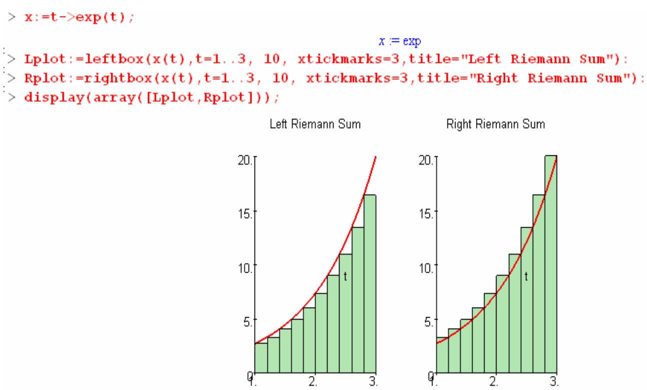

Figure 10: The graph of the reachable set using Riemann Sum.

Now, we move to the actual mathematical modeling on the containment of forest fires.
Let: R(t) be the contaminated set, F(x) represents the dynamics of the flow of the fire. The inclusion is

$$\dot{x} \in F(x) \qquad x(0) \in R_0$$

$$R(t) = \left\{ x(t) \middle| \begin{array}{l} x(\cdot)\ \text{absolutely continuous}, \\ x(0) \in R_0,\ \dot{x}(\tau) \in F\left(x(\tau)\right) \forall\, \tau \in [0,t] \end{array} \right\}$$

$$0 \in F(x)\ \forall\, x \in \nabla^2$$

$$R(t_1) \subseteq R(t_2)\ \text{whenever}\ t_1 \leq t_2$$

First assume that the forest fire can be contained; then there exists some mechanism that could be implemented to halt further expansion of the fire. The controller can then construct a "wall", or one-dimensional rectifiable curve, that can reduce the size of the affected area. This blocking strategy γ can be defined as

$$R^{\gamma}(t) \doteq \{x(t) : x(\cdot)\ \text{absolutely continuous}, x(0) \in R_0, \dot{x}(\tau) \in F\left(x(\tau)\right) \forall\, \tau \in [0,t], x(\tau) \notin \gamma(\tau) \forall\, \tau \in [0,t]\},$$

where $R^{\gamma}(t)$ is the set reached by trajectories of differential inclusion at any given time τ

Definition: A set valued map $t \mapsto \gamma(t) \subseteq \mathbb{R}^2$ is an admissible strategy if certain conditions are held.

Consider the following two nonnegative functions $\alpha, \beta : \mathbb{R}^2 \to \mathbb{R}_+$ where $\alpha(x)$ is the value of a unit area and $\beta(x)$ is the cost of building a unit length of wall near the point x; $dm_i = \{i = 1,2 | i - \text{dimension}\}$

$$J(\gamma) = \lim_{t\to\infty} \left\{ \int_{R^{\gamma}(t)} \alpha\, dm_2 + \int_{\gamma(t)} \beta\, dm_1 \right\}$$

Taking the limit essentially gives an upper bound, or supremum. The following diagram gives an instance where at time T, the blocking strategy $\gamma(\tau) = \gamma(T)$ and $R^{\gamma}(\tau) = R^{\gamma}(T)$. If constructed too close, the wall proves to be useless and perilous.

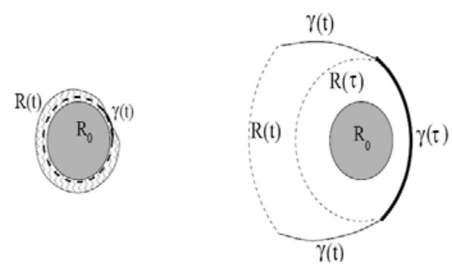

Figure 11: The left diagram shows the construction of the wall at the same time the contaminated set R_0 expands. The rright diagram takes into account additional area in time τ > 0 for wall construction.

In order to show that there exists an optimal solution γ^*, $J(\gamma^*)$ is minimized:

$$\min_{\gamma \in S} J(\gamma),$$
where S is the set of all admissable strategies.

During this investigation, the following observations were made:

Theorem 1. For the system described above, assume

$$F(x) \subseteq B_{\rho} \qquad \varphi(x) \leq \frac{1}{\rho'}$$

for some ρ'>2ρ and every $x \in \nabla^2$. Then, for every bounded initial set R_0, there exists r > 0 and an admissible strategy γ such that $R^{\gamma}(t) \subseteq B_{\rho}$, for all t ≥0.

If there exists an optimal strategy γ^*, then at every point of a free arc $\Gamma \in \mathcal{F}_1$ there exists a corresponding vector oriented in the direction of outer normal to the minimal time function, and the vector's curvature is proportional to cost. (Refer to Theorem 3, [1]).

Let there be an optimal strategy γ^*. By constructing two boundary arcs Γ_1, Γ_2 & $\bar{\Gamma}_1$ originating from the same point P in opposition directions with respect to the front of the fire and assuming that the contaminated region is encircled by walls, than this strategy is not optimal. (Refer to Theorem 5, [1]).

4. ANALYSIS/RESULTS

In the regression analysis a high P-value and a zero r-value in section 3.1.1 and 3.1.2 shows no correlation with the number of sq. acres burned. However, there is a negative correlation between the number of sq. acres burned and the annual precipitation based off the r-value, an increase in precipitation will result in a decrease in the number of sq. acres burned. All factors were combined in section 3.1.4 and still the analysis showed that a correlation exists but temperature plays no role in the number of sq. acres burned.

ANOVA was used to determine if the means of the acreage burned in Kentucky over twelve five-year periods were significantly different and if the means of the acreage burned in Kentucky over three precipitation levels are the same. It was found that there is no significant difference between the average acreage burned across the twelve 5-yr periods. From the analysis of variance, it was however found that there exists a significant difference between the average acreage burned across the three precipitation levels.

The mathematical model using differential inclusions yields necessary conditions for the existence of an optimal strategy of containing forest fires with the presence of an admissible strategy. The construction of the wall warrants the most advantageous placement of both boundary and free arcs. Although an exact solution has not yet been determined, there exist several conditions that would clarify a possible optimal strategy.

5. CONCLUSIONS

In conclusion we found that one of the factors of global warming, high temperatures in fact has no relationship with the frequency of forest fires and the amount of acreage burned in the state of Kentucky. On the other hand, there does exist a relationship between precipitation (i.e. levels of drought) and the number of sq. acreage burned. In addition, there exists a significant difference between the average acreage burned across three precipitation levels. Additional studies show that global warming affects precipitation, therefore there exists a relationship between global warming and forest fires.

6. FURTHUR INVESTIGATIONS

This research can be further investigated by comparing the forest fires of the coastal states to the non-costal states and observing the varying effects of global warming. The same methods that were used in this research can be used to obtain similar information. Moreover, further investigations include the development of more necessary optimal condition and eventually derive and optimal strategy for fire containment.

7. ACKNOWLEDGMENTS

This research was conducted at Elizabeth City State University's Computational Science-Scientific Visualization Center (CSSVC) and is supported by grants given by the Department of Energy and the National Association of Mathematicians. In addition, we would like to make the following acknowledgements:

Dr. Luttamaguzi, our faculty mentor
Dr. Johnny Houston, Institute Director
Dr. Farrah Chandler, Associate Director
Other faculty and peers

8. REFRERNECES

[1] Bressan, Alberto. Differential Inclusions and the Control of Forest Fires. Dept. of Mathematics, Penn State University. University Park, PA, 2006. 1-27.

[2] "Discover the Scientific Facts on Global Warming." GreenFacts.Org: Facts on Health and the Environment. 7 Apr. 2008. GreenFacts ASBL/VZW. 21 May 2008 <http://www.greenfacts.org/climate-change/global-warming/global-warming.htm>. ;

[3] "Forest Fire Statistics." Division of Forestry. 31 Jan. 2008. Kentucky Division of Forestry. 20 May 2008 <http://www.forestry.ky.gov/programs/firemanage/Fire%2BStatistics.htm>.

[4] "Kentucky Stats." Kentucky Virtual Library. Frankfort, KY: Kentucky Virtual Library, 2007. Kentucky Virtual Library.

[5] "Kentucky Wildland Fire Situation." Division of Forestry. 13 May 2008. Kentucky Division of Forestry. 15 May 2008 <http://www.forestry.ky.gov/situationreport/>.

[6] Puri, Anuj, Pravin Varaiya, and Vivek Borkar. Approximation of Differential Inclusions. Dept. of Electrical Engineering and Computer Sciences, University of California; Dept. of Electrical Engineering, Indian Institute of Science. National Science Foundation. 1-11.

[7] Running, Steven W. "Is Global Warming Causing More, Larger Wildfires." PERSPECTIVES 6 July 2006. 15 May 2008 <http://www.sciencemag.org/>.

[8] University of Wisconsin-Madison (2007, November 5). Wildfire Drives Carbon Levels In Northern Forests. *ScienceDaily*. Retrieved May 17, 2008, from http://www.sciencedaily.com/releases/2007/10/071031152918.htm

[9] West, Larry. "Global Warming Linked to Increase in U.S. Forest Fires." Larry West's Environmental Issues Blog. 25 May 2007. About.Com: Environmental Issues. 15 May2008<http://environment.about.com/b/2007/05/25/global-warming-linked-to-rising-number-of-us.htm>.

9. APPENDIX [4, 5]

Kentucky

YEAR	Acres Protected	# of Acres Burned	Average Size	Percent Burned	Fire Occurrence Rate	# of Fires	Annual Percipitation	Annual Average Temp
1945	1,612,714	11,614	35	0.01	206	333	50.64	55.76
1946	1,667,193	12,690	38	0.76	199	331	46.93	57.34
1947	2,321,161	23,331	39	1.01	261	605	41.88	54.82
1948	3,280,414	25,603	34	0.78	229	751	50.57	56
1949	3,927,266	20,410	21	0.52	251	984	51.38	57.3
1950	4,090,927	27,936	27	0.68	249	1,019	62.93	55.08
1951	4,639,743	13,454	18	0.29	162	752	54.71	55.58
1952	5,694,118	728,087	274	12.79	466	2,654	41.79	56.91
1953	5,694,118	175,534	82	3.08	377	2,148	36.71	57.43
1954	6,096,217	60,088	58	0.99	171	1,045	40.86	57.2
1955	5,872,559	33,537	27	0.57	209	1,225	44.97	56.42
1956	6,521,093	60,494	37	0.93	254	1,657	50.65	56.6
1957	6,881,000	26,391	20	0.38	188	1,296	55.06	56.67
1958	7,140,000	33,119	22	0.46	215	1,533	43.96	53.61
1959	7,366,000	85,197	27	1.16	427	3,144	43.58	56.38
1960	6,982,000	99,823	43	1.43	335	2,339	40.78	54.13
1961	9,173,000	36,177	21	0.39	187	1,713	51.1	54.92
1962	9,854,000	119,566	36	1.21	333	3,277	49.97	55.04
1963	9,854,000	306,253	67	3.11	465	4,579	34.45	53.9
1964	9,854,000	95,198	35	0.97	275	2,710	48.35	55.88
1965	10,212,000	58,635	20	0.57	285	2,911	42.19	55.88
1966	10,774,000	41,039	17	0.38	219	2,358	46.86	54.11
1967	11,953,000	30,158	13	0.25	197	2,352	48.78	54.72
1968	11,953,000	33,122	11	0.28	248	2,965	43.77	54.33
1969	11,953,000	54,000	18	0.45	258	3,079	43.13	54.25
1970	11,953,000	53,008	23	0.44	192	2,298	48.27	55.48
1971	11,953,000	44,567	21	0.37	180	2,153	44.71	55.92
1972	16,886,000	9,424	10	0.06	58	977	57.73	55.28
1973	16,886,000	13,396	11	0.08	74	1,258	54.02	56.68
1974	16,886,000	49,775	24	0.29	123	2,073	52.6	55.88
1975	16,886,000	19,021	10	0.11	113	1,900	57.31	56.19
1976	16,886,000	123,789	30	0.73	248	4,185	42.62	53.74
1977	16,886,000	94,106	27	0.56	206	3,485	49.06	55.16
1978	17,025,098	38,440	21	0.23	107	1,816	53.48	53.79
1979	17,037,798	41,480	18	0.24	139	2,364	62.86	53.92
1980	17,037,798	367,019	122	2.15	177	3,011	37.22	55
1981	17,037,098	287,568	67	1.69	252	4,298	45.02	54.65
1982	17,037,098	37,561	16	0.22	135	2,302	50.9	55.68
1983	16,935,948	31,702	16	0.19	121	2,041	48.07	55.29
1984	16,935,948	17,728	12	0.1	84	1,422	53.39	55.63
1985	16,935,948	40,533	23	0.24	102	1,730	44.88	55.24
1986	16,935,948	88,735	35	0.52	151	2,565	43.29	56.9
1987	16,935,948	285,036	87	1.68	194	3,283	38.19	56.56
1988	16,935,948	80,452	30	0.48	156	2,643	44.34	55
1989	16,935,498	23,755	20	0.14	70	1,188	58.88	54.59
1990	16,935,948	22,437	18	0.13	75	1,266	56.9	57.43
1991	11,641,259	68,904	46	0.59	130	1,514	46.34	57.54
1992	11,641,259	20,574	16	0.18	111	1,297	42.99	55.11
1993	11,641,259	18,126	17	0.16	92	1,068	47.47	55.16
1994	11,641,259	50,263	28	0.43	155	1,802	49.2	55.64
1995	11,641,259	67,828	32	0.58	180	2,097	48.14	55.55
1996	11,641,259	18,066	19	0.16	84	973	57.12	54.43
1997	11,641,259	14,475	16	0.12	78	913	49.66	54.53
1998	11,641,259	29,224	26	0.25	98	1,140	49.45	58.25
1999	11,641,259	139,110	58	0.81	206	2,396	38.41	57.32
2000	11,641,259	133,347	86	1.15	138	1,545	45.35	55.74
2001	11,641,259	163,327	81	1.4	195	2,010	45.56	56.73
2002	11,641,259	23,542	24	0.21	86	976	54.41	57.06
2003	11,641,259	19,681	21	0.17	82	926	55.17	55.42
2004	11,641,259	25,916	18	0.24	129	1,470	56.9	56.51