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| Analyzing forest fires | Multivariate Analysis  Aqueel Jivan  Harsh Joshi  Anurag Sharma |
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1. **Introduction** (authored by Harsh Joshi, Aqueel Jivan and Anurag Sharma)

In today’s world among various environmental crises, we selected a problem that is very serious in today’s environmental crisis. Wildfires (also known as Forest Fires) for Multivariate analysis project. Wildfires can burn millions of acres of land at rapid speeds and can consume everything—trees, homes and even humans in their paths. The rolling flames travel up to 14 miles an hour, which converts to about a four-minute mile pace and can overtake the average human in minutes [1]. Wildfires have been a major environmental issue creating ecological and economic damage endangering natural wealth as well as human lives. In order to prevent these wildfires, Fast detection is a key parameter to controlling this phenomenon [2]. Wildfires occur all across the world but are most common in the western United States. Destruction caused by wildfires in the United States has significantly increased in the last two decades. In 2015, the largest wildfire season recorded in U.S. history, wildfires burned more than 10 million acres of land. Though they are classified by the Environmental Protection Agency as natural disasters, only 10 to 15 percent of wildfires occur on their own in nature. The other 85 to 90 percent result from human causes, including unattended camp and debris fires, discarded cigarettes, and arson. Naturally occurring wildfires can spark during dry weather and droughts. In these conditions, normally green vegetation can convert into bone-dry, flammable fuel; strong winds spread fire quickly; and warm temperatures encourage combustion. With these ingredients, the only thing missing is a spark in the form of lightning, arson, a downed power line, or a burning campfire to wreak havoc [1].

In order to analyze these factors influencing Wildfires, we chose a dataset with the data recorded about the forest fires at Montesano park in Portugal. This analysis would help us understand which factors have the most influence on these fires and which combination of factors pose the highest risk of a forest fire to occur. The dataset can also be used to potentially predict the area that is likely to be burned and the severity with which that could occur. The dataset includes metrics collected by the meteorological stations at the park such as wind, rain, temperature and relative humidity along with the month and day of the forest fires. This dataset was used by Paulo Cortez and Anibal Morais in their paper “A Data Mining Approach to Predict Forest Fires using Meteorological Data”. With the help of their paper we realized that in the past, meteorological data has been incorporated into numerical-indices, which are used for prevention (e.g. warning the public of a fire danger) and to support fire management decisions (e.g. level of readiness, prioritizing targets or evaluating guidelines for safe firefighting). In particular, the Canadian forest Fire Weather Index (FWI) [3] system was designed in the 1970s when computers were scarce, thus it required only simple calculations using look-up tables with readings from four meteorological observations (i.e. temperature, relative humidity, rain and wind) that could be manually collected in weather stations. The FWI includes the following components [3]: Fine Fuel Moisture Code (FFMC), Duff Moisture Code (DMC), Drought Code (DC) and Initial Spread Index (ISI). The first three are related to fuel codes: the FFMC denotes the moisture content surface litter and influences ignition and fire spread, while the DMC and DC represent the moisture content of shallow and deep organic layers, which affect fire intensity. The ISI is a score that correlates with fire velocity spread.

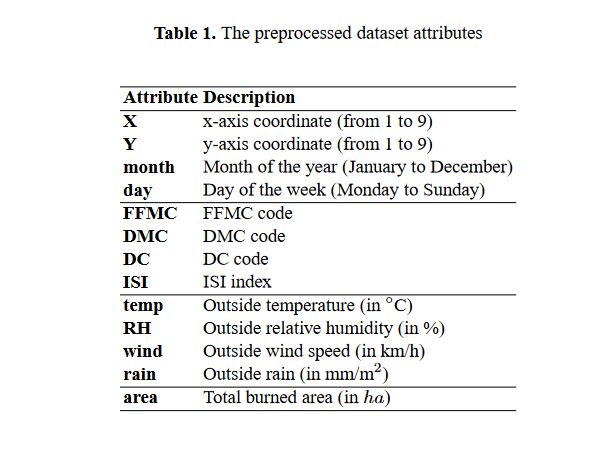


Figure1: Dataset Variables

The data used in the experiments was collected from January 2000 to December 2003 and it was built using two sources [2]. The first database was collected by the inspector that was responsible for recording the data about Montesinho fire occurrences. Every time a forest fire occurred, several features were registered daily, such as the time, date, spatial location within a 9×9 grid (x and y axis of Figure A), the type of vegetation involved, the six components of the FWI system and the total burned area. The second database was collected by the Braganca ̧ a Poly-technic Institute, containing several weather observations (e.g. wind speed) that were recorded with a 30-minute period by a meteorological station located in the center of the Montesinho park.

1. **Data Cleaning and Visualization** (authored by Harsh Joshi)

Data cleaning is a process that is required to be done in order to ensure that the data used is correct and is in a usable format to perform analysis and obtain better visualization results. The data set used for the Analysis of Forest fires is almost already available in a clean format with 517 observations and 13 variables with no missing values.



Figure2: Sample of the Data.

As we can see in Figure2, the first 4 variables in the dataset describe locations, month and date of occurrence of forest fires. Hence, more focus was put into the variables with numerical values which are FFMC, DMC, DC, ISI, temp, RH, wind, rain and area. First, we generated a correlation matrix(figure3) between the 9 variables and found out that variables such as temp, RH, wind, rain and area does have a good correlation between each other and also with most of the remaining variables. Variables FFMC, DMC, DC and ISI (FWI components) have almost good correlation with each other.

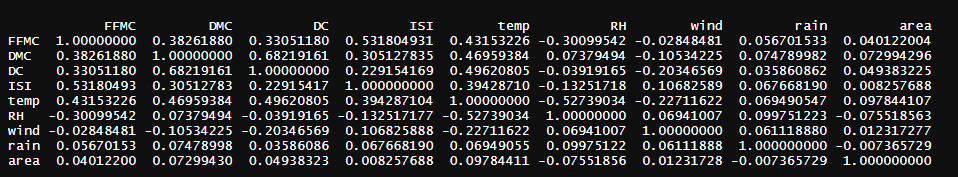


Figure3: Correlation matrix without removing outliers.

While, performing further analysis on the data we only considered the variables FFMC, DMC, DC and ISI (FWI components) as these variables are derived from the remaining 5 variables and using all the variables into consideration will lead to collinearity problem. Also, there is no correlation between those variables.

Then, we thought of performing some analysis to check for outliers in the data if any to obtain accurate results in the data if possible. We created some bivariate boxplots in order to identify outliers.

![A screenshot of a cell phone

Description automatically generated](data:image/jpeg;base64,/9j/4AAQSkZJRgABAQEAYABgAAD/4RDuRXhpZgAATU0AKgAAAAgABAE7AAIAAAAMAAAISodpAAQAAAABAAAIVpydAAEAAAAYAAAQzuocAAcAAAgMAAAAPgAAAAAc6gAAAAgAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAGhhcnNoIGpvc2hpAAAFkAMAAgAAABQAABCkkAQAAgAAABQAABC4kpEAAgAAAAMyNwAAkpIAAgAAAAMyNwAA6hwABwAACAwAAAiYAAAAABzqAAAACAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA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Figure4: Bivariate Boxplot between variables FFMC and DC.

![A picture containing map

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ABWXZeH7Ww8SaprcMkzXOqJCkyMw2KIgQu0YyPvHOSfwrUooAy9R8P2up67pGrTyTLPpLyvAqMArGRNh3AjJ4PGCOaPEnh+18U+H7nR9Qkmjt7jZvaBgHG1wwwSCOqjtWpRQBzU/gTSbjxJquuO9yLvVLA2EwEg2IhABZARwxCqCefuLxSy+B9PbSNItLa6vbO50aFIbHUbeRRcRqAFIJKlGDBRuVlKnrjIBHSUUbf16/5sP6/r7jB0XwnbaTq1xq1zfXurarcRiFr2/ZC6RDkRosaoiLnk7VBJ5JPFb1FFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAf/Z)

Figure5: Bivariate Boxplot between variables FFMC and DMC.

![A screenshot of a social media post

Description automatically 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UUUAcf8TLK6v8AwvaRWNtNcyLq1jIyQxlyFW4Qs2B2ABJPYCsbVf7MvdU1CD4g+ELie9t5t2n6ppekTztLbhi0WyeAM8UikcgsnPI4Nek0Ulov68v8h/1+f+Z5b4U0nxFb+MfDE+vQXshh0vUEaa4/eNCjXEZhjlkGVMnlgZ5JJB5OCa9SooquiX9bt/qT1b/rawUUUUhhRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFAH/9k=)

Figure6: Bivariate Boxplot between variables ISI and FFMC.

From the above plot’s values 23, 380, 200, 313, 300 were considered to be outliers and were removed from the dataset. The new correlation matrix generated better results between the FWI components.

![A screenshot of text

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Figure7: Correlation matrix after removing outliers.

We also created a Kdepairs plot for better visualization of the dataset. From the plot, we can observe that there are 2 clusters between variables DMC and DC, DC and ISI; and correlation between all 4 FWI components.

![A screenshot of a cell phone

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Figure8: Kdepairs plot for the dataset. (after removing outliers)

1. **Dimension Reduction** (authored byHarsh Joshi)

**Principal Component Analysis**

As explained earlier, we are considering only 4 variables which are FWI components. Dimension reduction analysis was performed to reduce the number of random variables under consideration by obtaining a set of principal variables. We chose the method of Principal Component analysis for dimension reduction analysis.

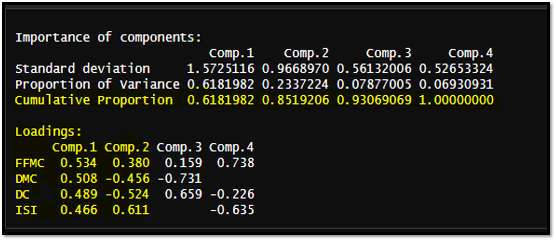


Figure9: Result of Principal Component Analysis.

From the result of principal component analysis (Figure9), it is observed that first 2 components represent approximately 85% of variance in the data. Also from the loading generated for the components, we can see that component 1 has similar values for all the observations; so one can conclude that all the FWI components are equally responsible for the forest fires and from the loadings of component 2, we can see that DMC and DC components have negative values and FFMC and ISI values have positive values, this is because DMC and DC components represent moisture content of the deep and shallow surface, and FFMC and ISI components represent the fire intensity and speed. Hence, the loading values between those FWI components in principal component2 are similar.

**Multidimensional Scaling:**

Multidimensional scaling is performed in order to visualize the similarities between the observations by finding out the distances between all the observations. From the plot in figure10, we can observe that most of the variables in the dataset are close to each other apart from certain observations which are far away from majority of variables which can be seen at bottom left of the plot.

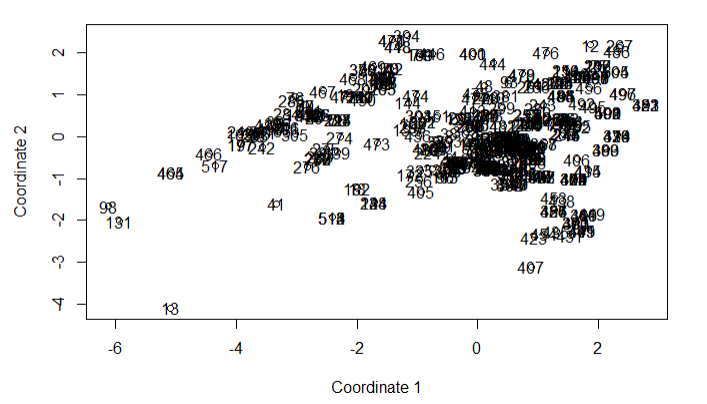


Figure10: Multidimensional Scaling.

1. **Cluster Analysis:** (authored by: Anurag Sharma)

Cluster Analysis is a numerical method for uncovering and discovering groups or clusters of the observations which are homogeneous and separated from other groups.

In Cluster Analysis we performed three types of analysis techniques.

1. Hierarchical Clustering
2. K- Means Clustering
3. Model Based Clustering.

The variable Area represents the total area burnt by forest fires in hectares. This variable can be used as a label for assessing the performance of cluster analysis and for creating predictive models. The Area variable is numeric, and the values of this variable have been converted to categories as follows:

* Area Burnt < 0.5 -> Low​
* 0.5 < Area Burnt < 6.5 -> Moderate​
* Area Burnt > 6.5 -> High

**Hierarchical Clustering**

In this type of clustering method hierarchical clustering of data is produced. Here data is not partitioned into a particular number of classes or groups at a single step instead the classification consists of a series of partitions.

For measuring the between group distances, we used 3 types of logic.

1. Single Linkage: smallest distance between two groups.
2. Complete Linkage: maximum distance between two groups.
3. Average Linkage: average distance between all possible pairs.

Performing Hierarchical clustering using complete linkage gives the best results out of other H-clustering methods. The dendrogram of complete linkage clustering is as follows:

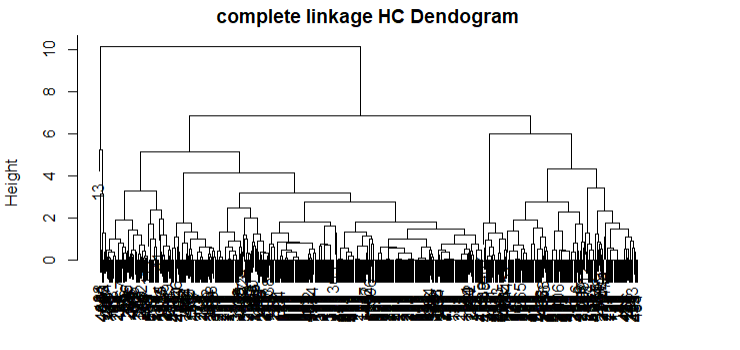


Figure11: Complete Linkage Dendogram.

A Scree plot helps us to determine the number of clusters in the dataset. However, since we are assuming 3 labels in data set, we will go with three clusters.

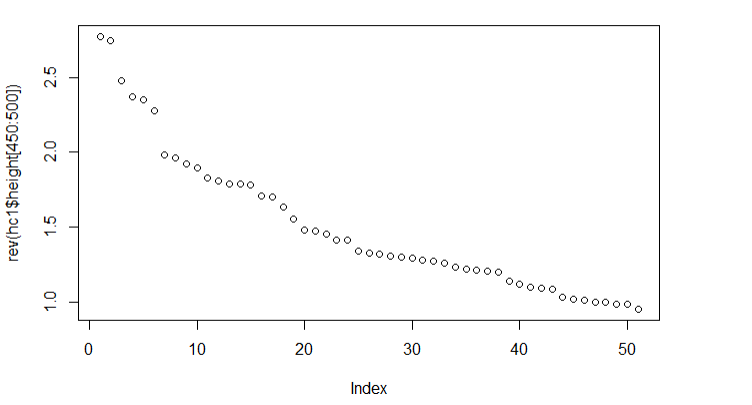


Figure12: Scree Plot

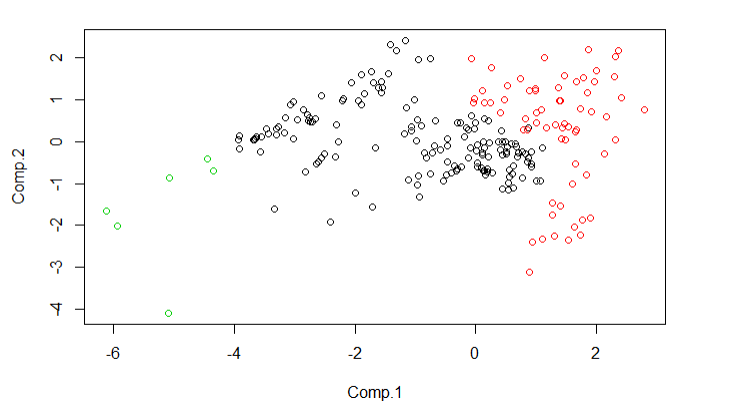


Figure13: H-Clustering on the First two principal components

The result of H clustering using complete linkage is as follows.



Figure14: Result of H clustering

The true clusters have been segregated as Low, Moderate and High as explained earlier.

However, classification of these clusters by H-clustering does not correspond to the true clusters.

**K-Means Clustering**

Here we find the partitions of n observations (rows of data) into k-groups that minimize **Within the Group Sum of Squares (WGSS)** over all variables.

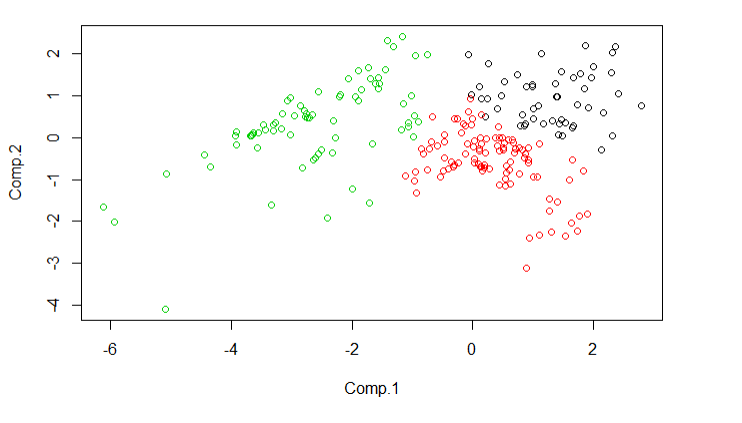


Figure15: K- means Clustering on the First two principal components



Figure16: Result of K-means clustering.

Here High, Low, Moderate are the true clusters. 1,2,3 represents the clusters and the number of values given by each cluster by K-means. Thus, K-Means gives us better results based on the true clusters.

**Model Based Clustering**

In Model Based Clustering it is assumed that the data is generated by mixture of probability distributions. Also, assumes that the data is generated by models and the model we recover from the data defines clusters.

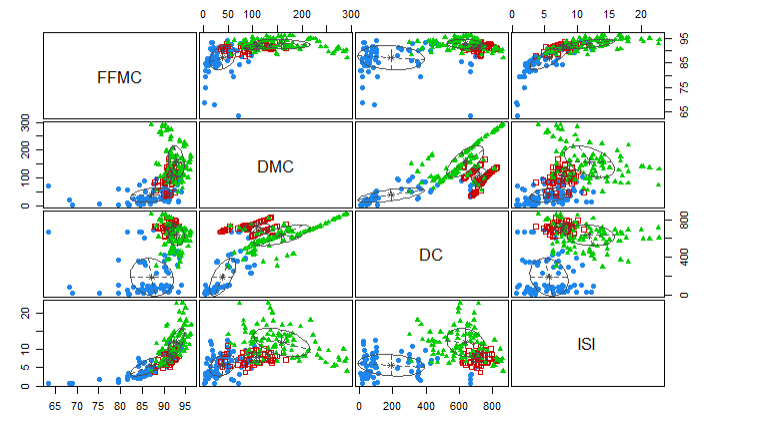
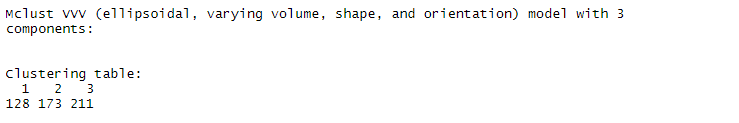


Figure17: Classification Plot of Model Based Clustering.

Following are the results of Model Based Clustering, it seems to work better than Hierarchical Clustering, but K-Means results are better than Model Based Clustering.



1. **Confirmatory Factor Analysis** (authored by Aqueel Jivan)

In this module the concept of Confirmatory Factor Analysis (CFA) will be covered. Before talking about CFA, the concept of Exploratory Factor Analysis (EFA) needs to be understood first. EFA is used to explore latent variables in the data. Latent variables are variables that cannot be observed in the data. Examples of latent variables include intelligence or motivation. On the other hand, the variables that are observable in the dataset are known as manifest variables. Examples of Manifest variables can include test scores. For the purpose of this study, the Exploratory Factor Analysis has been conducted first to explore the latent variables in the dataset. The results of EFA are then used to perform CFA. In CFA, certain manifest variables can relate to certain factors whilst other manifest variables are constrained to have zero loadings on some of the factors. A confirmatory factor analysis model may arise from theoretical considerations or be based on the results of an exploratory factor analysis where the investigator might wish to postulate a specific model for a new set of similar data. CFA is primarily used to confirm this proposed model of latent variables.

In the forest fires dataset, the exploratory analysis has been performed on the four FWI components of FFMC, DMC, DC and ISI along with temperature because the R function for EFA needs at least 5 variables to perform the analysis. The result of the analysis was as follows:

Call:

factanal(x = mydata.fa, factors = 2)

Uniquenesses:

FFMC DMC DC ISI temp

0.205 0.400 0.197 0.365 0.578

Loadings:

Factor1 Factor2

FFMC 0.339 0.824

DMC 0.721 0.281

DC 0.878 0.182

ISI 0.167 0.779

temp 0.471 0.447

Factor1 Factor2

SS loadings 1.656 1.599

Proportion Var 0.331 0.320

Cumulative Var 0.331 0.651

Test of the hypothesis that 2 factors are sufficient.

The chi square statistic is 0.01 on 1 degree of freedom.

The p-value is 0.915

EFA analysis shows that DMC and DC are highly loaded on the first factor. FFMC and ISI are highly loaded on the second factor. Temperature is not highly loaded on any of the factors. Thus, the first factor represents the Moisture content of organic layers and the second factor represents Fire Spread as both variables influence the rate of spread of forest fires. Now moving on to the Confirmatory factor analysis, the following model is developed and is the input to the “sem()” function for structural equation modelling.

Moisture->DMC,lambda1,NA

Moisture->DC,lambda2,NA

Spread->FFMC,lambda3,NA

Spread->ISI,lambda4,NA

Moisture<->Spread,rho,NA

DMC<->DMC,theta1,NA

DC<->DC,theta2,NA

FFMC<->FFMC,theta3,NA

ISI<->ISI,theta4,NA

Moisture<->Moisture,NA,1

Spread<->Spread,NA,1

The output of sem() is as follows:

|  |
| --- |
|  |
| **Estimate**  <dbl> | **Std Error**  <dbl> | **z value**  <dbl> | **Pr(>|z|)**  <dbl> |  |
| lambda1 | 54.6996976 | 2.898978e+00 | 18.8686117 | 2.066566e-79 |  |
| lambda2 | 198.4970118 | 1.117987e+01 | 17.7548611 | 1.580612e-70 |  |
| lambda3 | 3.6692666 | 1.834215e-01 | 20.0045628 | 5.025739e-89 |  |
| lambda4 | 2.7725148 | 1.895805e-01 | 14.6244725 | 1.960848e-48 |  |
| rho | 0.5523217 | 4.204672e-02 | 13.1359039 | 2.050285e-39 |  |
| theta1 | 1111.3198704 | 2.105908e+02 | 5.2771534 | 1.312060e-07 |  |
| theta2 | 21951.9614042 | 2.956068e+03 | 7.4260685 | 1.118731e-13 |  |
| theta3 | -0.2895071 | 1.064527e+00 | -0.2719584 | 7.856540e-01 |  |
| theta4 | 8.3849836 | 8.027869e-01 | 10.4448442 | 1.547092e-25 |  |

A close up of a map

Description automatically generated

Figure18: The graphical representation of the model using a path diagram.

Now in order to check the accuracy of the CFA model there are certain parameters that can be checked. The root mean square error between the restricted and non-restricted Correlation matrix can give a measure of the accuracy of the model. The goodness of fit of the model depends on the discrepancy between these two-covariance matrices. The more similar the covariance matrices the better model. If those matrices are drastically different, it says the model is not right.

Goodness-of-fit index = 0.9986377

Adjusted goodness-of-fit index = 0.986377

SRMR = 0.006851266

The following results are obtained:

* SRMR is 0.007 which is good because it is less than 0.05
* GFI is 0.999 which is greater than 0.95
* AGFI is 0.986 which is greater than 0.95

Thus, the data supports the CFA model.

By Confirmatory factor analysis, it can be concluded that there are two latent variables in the dataset: Moisture and Fire Spread Intensity.

1. **Conclusion** (authored by Aqueel Jivan)

Using multivariate analysis, the forest fires dataset from Montesinho park was analyzed. To summarize:

* The outliers were removed to obtain a much better correlation between the variables
* Principal component analysis was performed for dimensionality reduction and the first two principal components explained 85% of the variance.
* Cluster analysis was performed using Hierarchical clustering, K-means clustering and model-based techniques and the K-means method gave the best result based on the assumed labels.
* Confirmatory Factor Analysis confirmed two latent variables in the dataset which were moisture and Fire spread.

Now after understanding the nature of the multivariate data using various analysis, a predictive model to determine the likelihood of there being a fire can be developed. This can be done using Model based Discriminant Analysis technique which is a classification method. The Area burned variable was categorized into two categorical variables for “Fire” and “No Fire”. The “No Fire” variable corresponded to those observations where the area burnt by the fire was 0. After using the even observations for training the dataset and the even observations for test, the following result was obtained.

Class Fire: fitting ...

|================================================================| 100%

Class No Fire: fitting ...

|================================================================| 100%

------------------------------------------------

Gaussian finite mixture model for classification

------------------------------------------------

MclustDA model summary:

Classes n % Model G

Fire 136 53.12 VVV 5

No Fire 120 46.88 VEV 5

Training confusion matrix:

Predicted

Class Fire No Fire

Fire 95 41

No Fire 52 68

Classification error = 0.3633

Brier score = 0.2998

Test confusion matrix:

Predicted

Class Fire No Fire

Fire 90 43

No Fire 66 57

Classification error = 0.4258

Brier score = 0.3408

* A classification error of 40% was obtained.
* The Brier score was 0.34 which is decent.

Although the model doesn’t have the highest accuracy, it would be very useful in making the necessary provisions before time during fire season. Furthermore, the model accuracy can be improved by using different more potent classification techniques which is out of the scope of this study. Early detection of fires can help the relevant authorities take the necessary action to prevent the spread of these fires thereby preventing a lot of ecological and economic damage.

**Sources**

1. National Geographic on wildfires , <https://www.nationalgeographic.com/environment/natural-disasters/wildfires/>

2. P. Cortez and A. Morais. A Data Mining Approach to Predict Forest Fires using Meteorological Data. In J. Neves, M. F. Santos and J. Machado Eds., New Trends in Artificial Intelligence, Proceedings of the 13th EPIA 2007 - Portuguese Conference on Artificial Intelligence, December, Guimaraes, Portugal, pp. 512-523, 2007. APPIA, ISBN-13 978-989-95618-0-9.

3. S. Taylor and M. Alexander. Science, technology, and human factors in fire danger rating: the Canadian experience. International Journal of Wildland Fire, 15:121–135, 2006.

**Appendix**

R Code

Libraries:

library(ResourceSelection)

library(KernSmooth)

library(MVA)

library(sem)

library(semPlot)

library(mclust)

Reviewing DataSet:

data<-read.csv('forestfires.csv')

head(data)

Correlation of DataSet without removing outliers and excluding first 4 variables:

data.n<-data[,5:13]

cor(data.n)

Bivariate biplot:

1- ISI vs FFMC

set1<- mydata[,c("ISI","FFMC")]

bvbox(set1,xlab = "ISI",ylab = "FFMC")

text(mydata$ISI,mydata$FFMC)

2- FFMC vs DC

set2<- mydata[,c("FFMC","DC")]

bvbox(set2,xlab = "FFMC",ylab = "DC")

text(mydata$FFMC,mydata$DC)

3- ISI vs FFMC

set3<- mydata[,c("ISI","FFMC")]

bvbox(set3,xlab = "FFMC",ylab = "DC")

Removing Outliers:

outliers=c(23, 380 ,200, 313 , 300)

mydata.cln= mydata[-outliers,]

cor(mydata.cln)

Generating Kdepairs plot:

kdepairs(mydata.cln)

Performing Principal Component Analysis(PCA):

pc<-princomp(mydata.cln,cor = T)

summary(pc,loadings=T)

Multi Dimensional scaling(MDS):

cmd<-cmdscale(dist(scale(mydata.cln)),k=3)

plot(cmd,xlab = "Coordinate 1", ylab = "Coordinate 2")

text(cmd,labels = rownames(mydata.cln))

Code to categorize the data depending upon the area variable:

summary(data$area)

Area\_cat<-ifelse(data$area<0.5,"Low",ifelse(data$area<6.5,"Moderate","High"))

data\_new<-cbind(data,Area\_cat)

Area\_binary<-ifelse(data$area==0,"No Fire","Fire")

data\_new<-cbind(data\_new,Area\_binary)

data\_newc<-data\_new[-outliers,]

tail(data\_newc)

Heirarchical clustering using complete linkage

data.s<-scale(mydata.cln)

hc1 <- hclust(dist(scale(data.s)))

plot(rev(hc1$height[450:500]))

ct1<-cutree(hc1,3)

table(data\_newc$Area\_cat)

table(ct1)

plot (pc$scores[,1:2], col=ct1)

K-means clustering

km1<- kmeans(data.s,3,nstart = 50)

table(km1$cluster)

table(data\_newc$Area\_cat)

table(km1$cluster,data\_newc$Area\_cat)

plot (pc$scores[,1:2], col=km1$cluster)

Classification using Model Based Discriminant Analysis

odd<- seq(from=1, to=nrow(mydata.cln), by=2)

even<- seq(from=2, to=nrow(mydata.cln), by=2)

#ncol(data\_newc)

data.train=mydata.cln[even,]

label.train=data\_newc[even,15]

data.test=mydata.cln[odd,]

label.test=data\_newc[odd,15]

DA<- MclustDA(data.train,label.train)

summary(DA, newdata=data.test, newclass= label.test)