FOREST FIRES IN THE AMAZON

A STUDY OF "LUNGS OF THE EARTH"

SUMMARY

This project is an analysis of forest fire in the Amazon rainforest,extent and effect on the world.

First there is a brief introduction about the Amazon rainforest.It also deals with the issue of deforestation in the Amazon.

The second part consists of the core of the project.It is regarding the forestfires in the Amazon.Here,we divide the selected states having Amazon rainforests cover into three groups.Then we go on to perform three case studies on the representatives of each groups.

The third part mentions some data regarding how these forest fires are destroying these forests and in turn,are affecting the world negatively.

The fourt part gives possible steps that can be taken by the world to protect the Amazon rainforests.

The last three parts respectively concludes the analysis,provides two appendixes and the references of the data that are used in making the project.

1.INTRODUCTION:

1.1.Amazon rainforest

THE AMAZON RAINFOREST or Amazonia, is a moist broadleaf tropical rainforest in the Amazon biome that covers most of the Amazon basin of South America. This basin encompasses 7,000,000 km2(2,700,000 sq mi), of which 5,500,000 km2(2,100,000 sq mi) are covered by the rainforest. This region includes territory belonging to nine nations. The majority of the forest is contained within Brazil, with 60% of the rainforest, followed by Peru with 13%, Colombia with 10%, and with minor amounts in Venezuela, Ecuador, Bolivia, Guyana, Suriname and French Guiana. The Amazon represents over half of the planet's remaining rainforests, and comprises the largest and most biodiverse tract of tropical rainforest in the world, with an estimated 390 billion individual trees divided into 16,000 species.

The rainforest likely formed during the Eoceneera (from 56 million years to 33.9 million years ago). It appeared following a global reduction of tropical temperatures when the Atlantic Ocean had widened sufficiently to provide a warm, moist climate to the Amazon basin. The rainforest has been in existence for at least 55 million years, and most of the region remained free of savanna-type biomesat least until the current ice age when the climate was drier and savanna more widespread.

Following the Cretaceous–Paleogene extinction event, the extinction of the dinosaurs and the wetter climate may have allowed the tropical rainforest to spread out across the continent. From 66–34 Mya, the rainforest extended as far south as 45°. Climate fluctuations during the last 34 million years have allowed savanna regions to expand into the tropics. During the Oligocene, for example, the rainforest spanned a relatively narrow band. It expanded again during the Middle Miocene, then retracted to a mostly inland formation at the last glacial maximum. However, the rainforest still managed to thrive during these glacial periods, allowing for the survival and evolution of a broad diversity of species.

Wet tropical forests are the most species-rich biome, and tropical forests in the Americas are consistently more species rich than the wet forests in Africa and Asia. As the largest tract of tropical rainforest in the Americas, the Amazonian rainforests have unparalleled biodiversity. One in ten known species in the world lives in the Amazon rainforest. This constitutes the largest collection of living plants and animal species in the world.

The region is home to about 2.5 million insect species, tens of thousands of plants, and some 2,000 birds and mammals. To date, at least 40,000 plant species, 2,200 fishes,1,294 birds, 427 mammals, 428 amphibians, and 378 reptiles have been scientifically classified in the region. One in five of all bird species are found in the Amazon rainforest, and one in five of the fish species live in Amazonian rivers and streams. Scientists have described between 96,660 and 128,843 invertebrate species in Brazil alone.

The biodiversity of plant species is the highest on Earth with one 2001 study finding a quarter square kilometer (62 acres) of Ecuadorian rainforest supports more than 1,100 tree species.[40] A study in 1999 found one square kilometer (247 acres) of Amazon rainforest can contain about 90,790 tonnes of living plants. The average plant biomass is estimated at 356 ± 47 tonnes per hectare.To date, an estimated 438,000 species of plants of economic and social interest have been registered in the region with many more remaining to be discovered or catalogued. The total number of tree species in the region is estimated at 16,000.

The green leaf area of plants and trees in the rainforest varies by about 25% as a result of seasonal changes. Leaves expand during the dry season when sunlight is at a maximum, then undergo abscission in the cloudy wet season. These changes provide a balance of carbon between photosynthesis and respiration.

The rainforest contains several species that can pose a hazard. Among the largest predatory creatures are the black caiman, jaguar, cougar, and anaconda. In the river, electric eels can produce an electric shock that can stun or kill, while piranha are known to bite and injure humans. Various species of poison dart frogs secrete lipophilic alkaloidtoxins through their flesh. There are also numerous parasites and disease vectors. Vampire bats dwell in the rainforest and can spread the rabies virus. Malaria, yellow fever and dengue fever can also be contracted in the Amazon region.

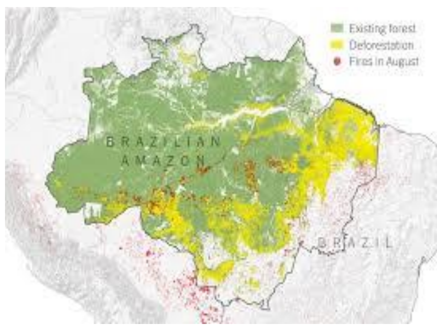


Figure showing Amazon Rainforest

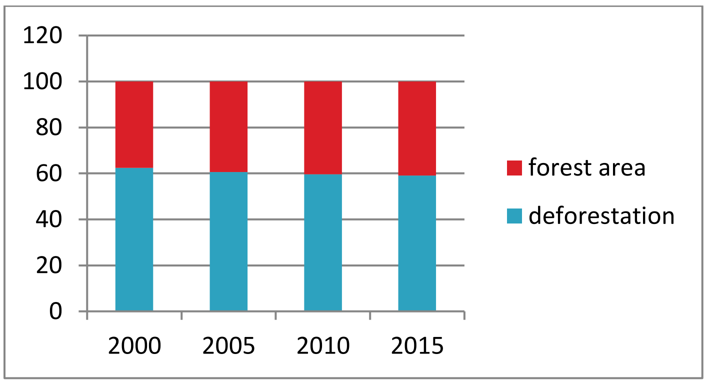
1.2.DEFORESTATION IN THE AMAZON

Deforestation is the conversion of forested areas to non-forested areas. The main sources of deforestation in the Amazon are human settlement and development of the land. In 2018, about 17% of the Amazon rainforest was already destroyed. Research suggests that upon reaching about 20–25% (hence 3–8% more), the tipping point to flip it into a non-forest ecosystems – degraded savannah – (in eastern, southern and central Amazonia) will be reached.

Prior to the early 1960s, access to the forest's interior was highly restricted, and the forest remained basically intact. Farms established during the 1960s were based on crop cultivation and the slash and burn method. However, the colonists were unable to manage their fields and the crops because of the loss of soil fertility and weed invasion. The soils in the Amazon are productive for just a short period of time, so farmers are constantly moving to new areas and clearing more land. These farming practices led to deforestation and caused extensive environmental damage.Deforestation is considerable, and areas cleared of forest are visible to the naked eye from outer space.

In the 1970s, construction began on the Trans-Amazonian highway. This highway represented a major threat to the Amazon rainforest. The highway still has not been completed, limiting the environmental damage.

Between 1991 and 2000, the total area of forest lost in the Amazon rose from 415,000 to 587,000 km2 (160,000 to 227,000 sq mi), with most of the lost forest becoming pasture for *cattle.Seventy percent of formerly forested land in the Amazon, and 91% of land deforested since 1970, have been used for livestock pasture. Currently, Brazil is the second-largest global producer of soybeans after the United States. New research however, conducted by Leydimere Oliveira et al., has shown that the more rainforest is logged in the Amazon, the less precipitation reaches the area and so the lower the yield per hectare becomes. So despite the popular perception, there has been no economical advantage for Brazil from logging rainforest zones and converting these to pastoral fields. The needs of soy farmers have been used to justify many of the controversial transportation projects that are currently developing in the Amazon. The first two highways successfully opened up the rainforest and led to increased settlement and deforestation. The mean annual deforestation rate from 2000 to 2005 (22,392 km2 or 8,646 sq mi per year) was 18% higher than in the previous five years (19,018 km2 or 7,343 sq mi per year).Although deforestation declined significantly in the Brazilian Amazon between 2004 and 2014, there has been an increase to the present day. Since the discovery of fossil fuel reservoirs in the Amazon rainforest, oil drilling activity has steadily increased, peaking in the Western Amazon in the 1970s and ushering another drilling boom in the 2000s.As oil companies have to set up their operations by opening roads through forests, which often contributes to deforestation in the region.*



Graph showing deforestation in Amazon over the year.

2.FOREST FIRES IN THE AMAZON

There have been 72,843 fires in Brazil in 2019, with more than half within the Amazon region. In August 2019 there were a record number of fires. Deforestation in the Brazilian Amazon rose more than 88% in June 2019 compared with the same month in 2018.

Thousands of fires were burning across a southern swath of the Amazon. They belched smoke and soot, blanketing those who live downwind with thick, dirty air, hurting wildlife in their path and destroying part of one the most important carbon storehouses left on the planet. About 76,000 fires were burning across the Brazilian Amazon at last official count, an increase of over 80 percent over the same time period last year, according to data from Brazil's National Institute for Space Research (INPE). Since then, even more fires have appeared in the satellite imagery that scientists use to assess the extent and intensity of burning, and they expect the number to increase over coming months as the dry season intensifies.

So far in 2019, the number of fires burning across the Amazon is higher than at any point since 2010, which was a particularly bad year of drought, says Ruth DeFries, an expert on sustainable development at Columbia University. By last week, about 7,000 square miles of the forest were in flames, an area just smaller than the size of New Jersey.

Most fires observed in the region are caused by humans. Many are set in previously cleared lands in *order to quickly remove any excess vegetation that has popped up. Others are set in land that is still in the process of being cleared, in order to make more open land for crops or cattle. Farmers and ranchers down forest earlier in the year and leave the felled trees to dry out. Once the fallen trees have desiccated, they set them on fire, leaving behind an open swath of land ready for agricultural activity.*

But fires have been worse in the past—because deforestation was more acute. Amazon deforestation peaked in late 1990s and early 2000s. In the worst phases of those peak deforestation periods, over 10,000 square miles of forest could be cut down in a year, much of that cleared area converted directly to cropland for soy or grazing for cattle. In some years, like in 1998 and 2005, that deforestation activity coincided with major El Niño droughts, and fires were abundant and widespread

DATA TABLE

	1998												1999						
	Jan	February	March	April	May	June	July	August	Septembe	October	Novembe	Decembe	January	February	March	April	May	June	July
AMAZONA	0	0	0	0	0	2	71	321	267	83	6	196	3	43	7	2	0	7	
MARNHA(	0	0	0	0	0	78	274	1.176	3.935	5.137	2.237	1.399	54	6	17	4	3	32	
MATOGRC	0	0	0	0	0	2.201	3.712	15.406	10.363	2.707	182	76	39	28	18	76	731	2.201	
MINAS GE	0	0	0	0	0	70	232	875	1.981	1.093	32	21	36	112	13	27	51	132	
PERNAMB	0	0	0	0	0	1	5	12	177	372	141	59	102	13	27	2	6	7	
RIO	0	0	0	0	0	1	5	4	51	55	41	19	32	11	9	21	1	4	
RONDONI	0	0	0	0	0	26	365	2.254	3.753	483	3	33	1	1	8	3	3	10	
RORAIMA	0	0	0	0	0	0	1	0	2	1	1	16	15	20	98	16	0	3	
TOCANTII	0	0	0	0	0	252	640	3.747	5.149	1.738	1	9	36	1	1	9	24	113	

Table whose 221 columns have been omitted.

Analysis

In this project,an attempt has been made to represent the seasonal characteristics of the forest fires by analyzing monthly forest fires data of the Amazon rainforest from 1998 to 2017 and to forecast the no. of forest fires in the subsequent three years.

Objectives

The study and analysis has been conducted with a view to fulfill the following objectives:

- *To represent the seasonal component of the forest fires by analyzing monthly forest fire data of the Amazon rainforest from 1998 to 2017.*
- *To fit the best possible model to the no of forest fire over the years.*
- *To forecast the number of forest fires for the subsequent years of 2018,2019,2020.*

Methodology

For analysing the forest fires in the Amazon rainforest we collected the required dataset for no.of forests fires in all the states containing a part of the rainforests from the year 1998 to2017. From within all these states,we select 9 states of geographical importance i.e containing a large area of the forest.

On plotting the time series plot of the 9 states we come to the conclusion that they can be broadly classified into catagories based on similarities:

- *GroupA: Randonio,Matogrosso,Amazona,Tocantius*

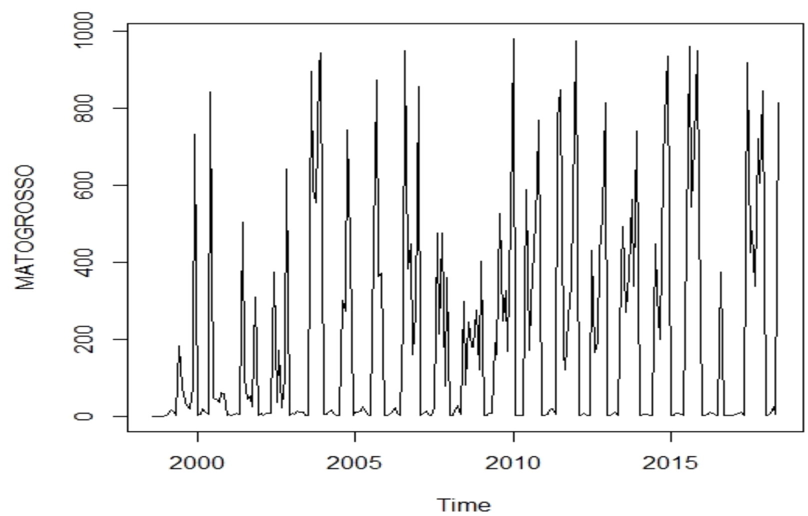
- *GroupB:Pernambuco,Rio,Roraima*
- *GroupC: Marnhao,Minas Gerais*

For analysis,we select Matogrosso,Pernambuco,Marnhao as the representatives of GroupI ,Group II and GroupIII respectively.

CASE STUDY I:MATOGROSSO

First we provide a visual representation of the data obtained from MATOGROSSO in a time series plot with R.

```
>matogrosso <-read.table("d:/matogrosso.csv",header=TRUE)
>library("ggplot2")
>matogrosso1<-ts(matogrosso,frequency=12,start=c(1998,1))
>matogrosso1
>plot.ts(matogrosso1)
```



From the plot we can see that the data might have seasonality with it.So we assume the additive model of the time series i.e.

$Y_t=T_t+S_t+C_t+I_t$

Where

Y_t *= observations of the time series*

T_t*= the value attributable to secular trend*

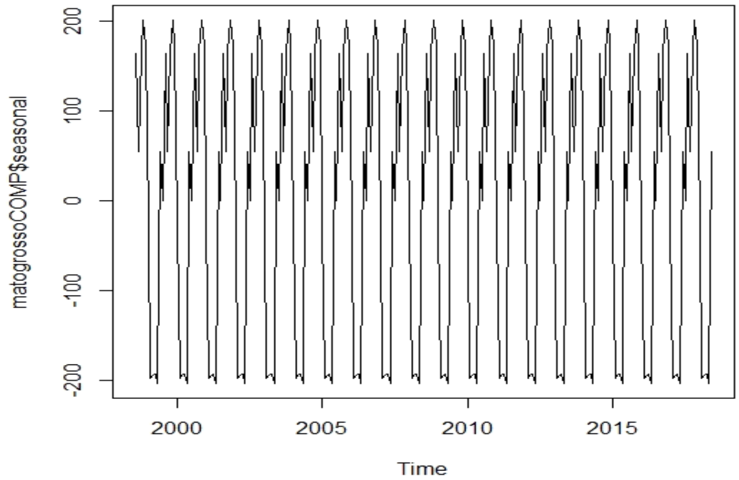
S_t*= the value attributable to seasonal component*

C_t*= the value attributable to cyclic component*

I_t*=the value attributable to variation component*

And decompose the time series into its seasonal component using R.

```
>matogrossocomp<-decompose(matogrosso1)
>matogrossocomp
>plot.ts(matogrossocomp$seasonal)
```



Here we can see the seasonal variation of the no. of forest fires in Matogrosso represented by the uniform crest and troughs over the years.

Fitting and Forecasting

Here,we fit the data on no. of forest fires in Matogrosso from 1998 to 2017 into a suitable model using auto.arima() function in R.
Here the SARIMA(seasonal ARIMA)model selected is (0,1,1),(0,0,1)
A SARIMA model is in the form of ARIMA(p,d,q)(P,D,Q)model,where,*
P=number of seasonal autoregressive(SAR)terms
D= numbers of seasonal differences
Q=number of seasonal moving averages(SMA)terms
p=number of nonseasonal autoregressive terms
q=number of non seasonal moving average terms
d=number of non seasonal differences

Coefficient:

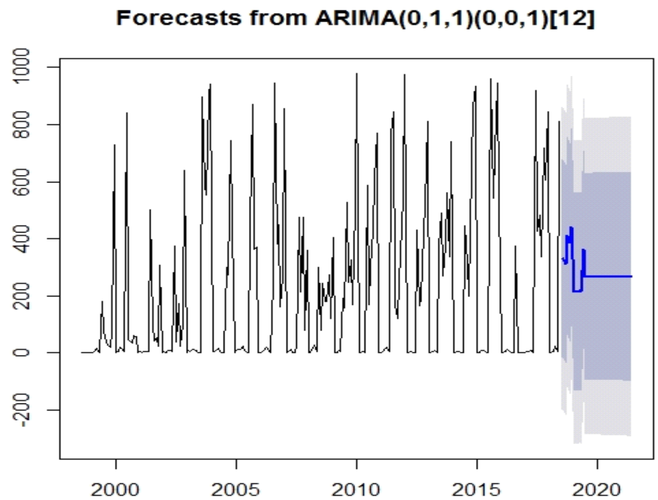
$MA_1(\boldsymbol{\theta_1})$	-0.9736
$SMA_1(\boldsymbol{\vartheta_1})$	0.2628

AIC=3348.39;AICc=3348.49;BIC=3358.81
*The model is so chosen by the auto.arima() function as it has the lowest AIC value.**[refer to appendix1]**.*
*The chosen model indicates that the data for Matogrosso is seasonal and non-stationary.[**refer to appendix2**]*
Now the forecasting model is given by

$$\boldsymbol{y_t = y_{t-1} + \varepsilon_t - \theta_1\varepsilon_{t-1} - \vartheta_1\varepsilon_{t-12} + \vartheta_1\theta_1\varepsilon_{t-13}}$$

Using which we forecast the no. of monthly forest fires for the years 2018,2019,2020 in R.

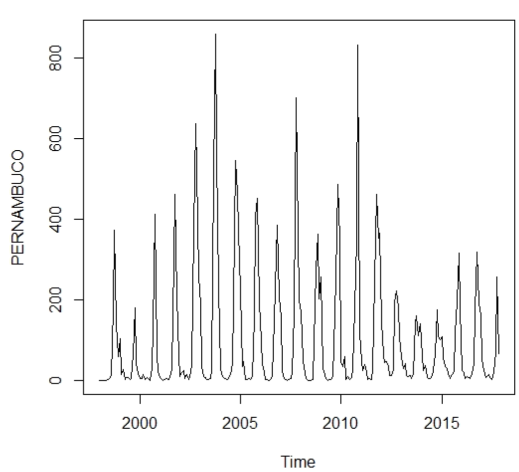
>library("forecast")
>matogrosso2<-auto.arima(matogrosso1)
>matogrosso3<-forecast(matogrosso2,h=36)
>plot(matogrosso3)



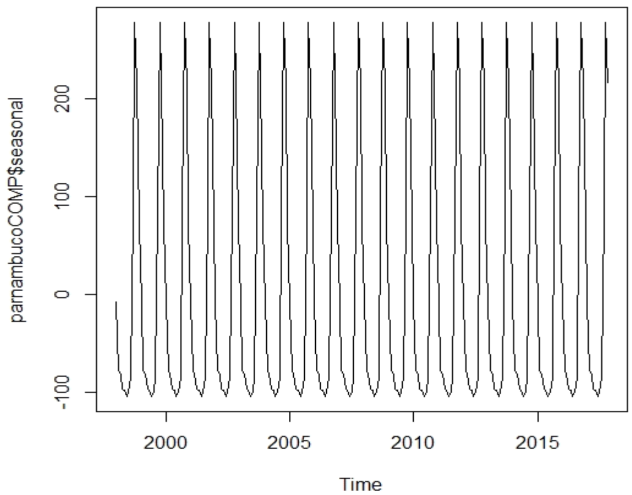
Here the forecast and 95% limits are given from for years of 2018 ,2019, 2020.Hence we conclude the analysis of Matogrosso and generalize their conclusion for group A as a whole.
In a similar way we can analyse the case of Pernambuco and Marnhao

CASE STUDY II:PERNAMBUCO
>pernambuco <-read.table("d:/pernambuco.csv",header=TRUE)
>library("ggplot2")
>pernambuco1<-ts(pernambuco,frequency=12,start=c(1998,1))
>pernambuco1
>plot.ts(pernambuco)

TIME SERIES PLOT:



Here also we can consider the additive model and decompose the time series into its seasonal component using R.
>pernambucocomp<-decompose(pernambuco1)
>pernambucocomp
>plot.ts(pernambucocomp$seasonal)



Fitting and Forecasting:

Here the SARIMA(seasonal ARIMA)model selected is (1,0,0),(0,1,2)

Coefficient:

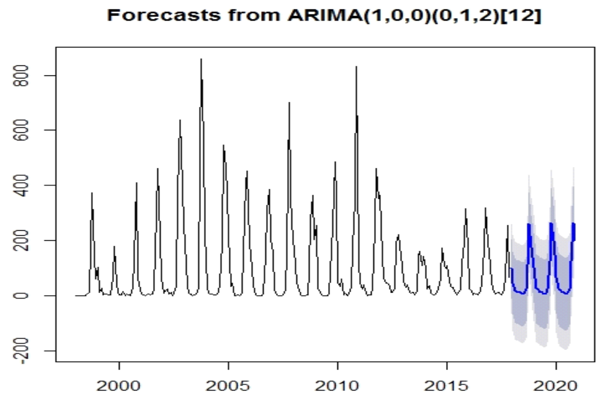
$AR_1(\varphi_1)$	0.3909
$SMA_1(\vartheta_1)$	-0.5581
$SMA_2(\vartheta_2)$	-0.1365

AIC=2664.31;AICc=2664.49;BIC=2678.01
*the model is so chosen by the auto.arima() function and it has the lowest aic value. [**refer to appendix1**]*
*The chosen model indicates that the data for Pernambuco is seasonal and non-stationary.[**refer to appendix2**]*

$$y_t = \varphi_1 y_{t-1} + y_{t-12} - \varphi_1 y_{t-13} + \varepsilon_t + \vartheta_1 \varepsilon_{t-12} + \vartheta_2 \varepsilon_{t-13}$$

Using which we forecast the no of monthly forest fires for the years 2018,2019,2020 in R.

>library("forecast")
>pernambuco2<-auto.arima(pernambuco1)
>pernambuco3<-forecast(pernambuco2,h=36)
>plot(pernambuco3)

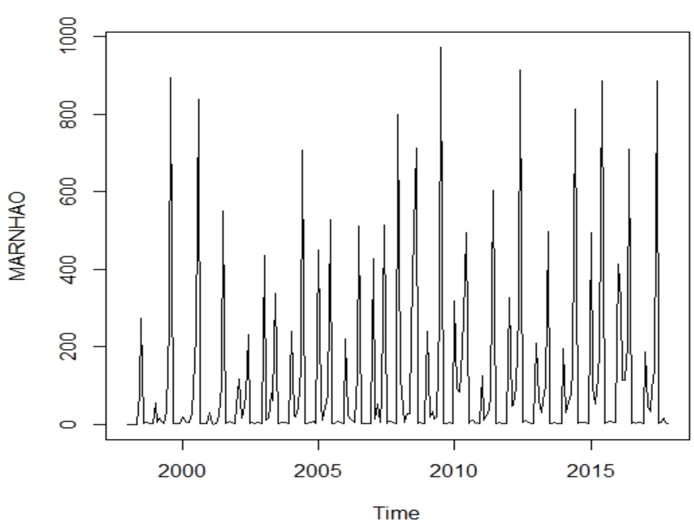


Hence we conclude the analysis of Pernambuco and generalize the conclusion for groupB as a whole.

CASE STUDY III:MARNHAO

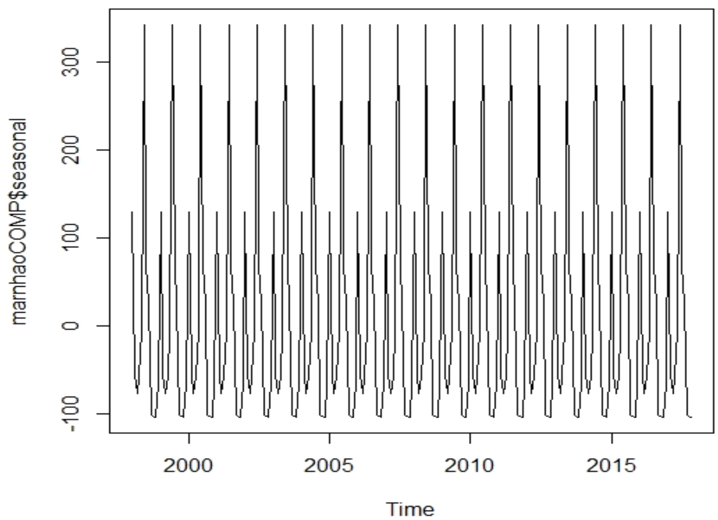
```
>marnhao <-read.table("d:/marnhao.csv",header=TRUE)
>library("ggplot2")
>marnhao1<-ts(marnhao,frequency=12,start=c(1998,1))
>marnhao1
>plot.ts(marnhao)
```

TIME SERIES PLOT



Here also we can consider the additive model and decompose the time series into its seasonal component using R.

```
>marnhaocomp<-decompose(marnhao1)
>marnhaocomp
>plot.ts(marnhaocomp$seasonal)
```



Fitting and forecasting

Here the SARIMA(seasonal ARIMA)model selected is (0,0,0),(2,0,0)

Coefficients:

SAR_1($\boldsymbol{\Phi_1}$)	*0.4331*
SAR_2($\boldsymbol{\Phi_2}$)	*0.2222*

AIC=3130.83;AICc=3131;BIC=3144.74

MEAN=101.8249

*the model is so chosen by the auto.arima() function and it has the lowest aic value. [**refer to appendix1**]*

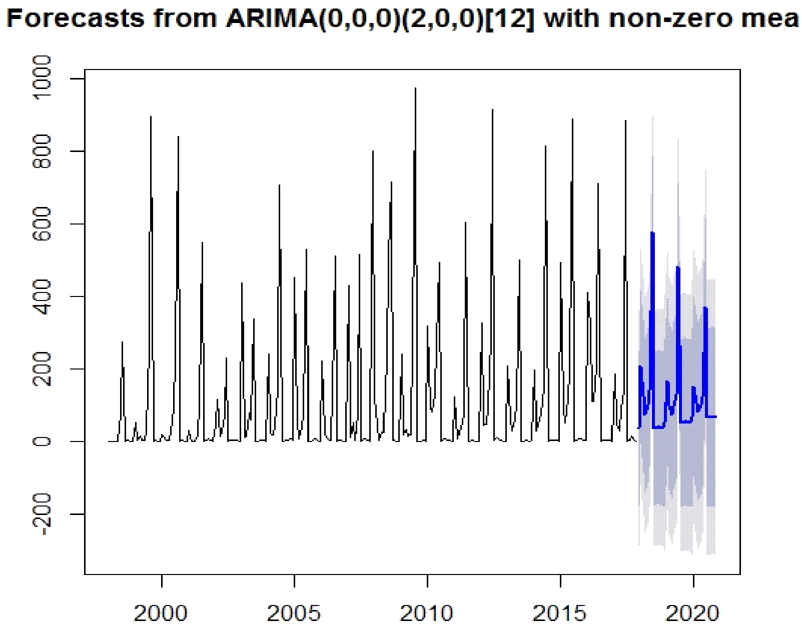
*The chosen model indicates that the data for Marnhao is seasonal and stationary.[**refer to appendix2]***

now the forecasting model is given by

$$\boldsymbol{y_t = \Phi_1 y_{t-12} + \Phi_2 y_{t-13} + \varepsilon_t}$$

Using which we forecast the no of monthly forest fires for the years 2018,2019,2020 in R.

```
>library("forecast")
>marnhao2<-auto.arima(marnhao1)
>marnhao3<-forecast(marnhao2,h=36)
>plot(marnhao3)
```



Hence we conclude the analysis of Marnhao and generalize the conclusion for groupC as a whole.
Thus,we conclude the analysis of the three groups

3. How these forest fires are affecting the world?

As forests burn and global warming worsens, the impact of Amazon deforestation continues to gradually undo the fragile ecological processes that have been refined over millions of years.

ironically, as rainforest continues to disappear, scientific work from the last two decades has shed light on the critical ties that link the health of rainforests to the rest of the world.

Environmentalists are concerned about loss of biodiversity that will result from destruction of the forest, and also about the release of the carbon contained within the vegetation, which could accelerate global warming. Amazonian evergreen forests account for about 10% of the world's terrestrial primary productivity and 10% of the carbon stores in ecosystems– of the order of 1.1 × 1011 metric tonnes of carbon. Amazonian forests are estimated to have accumulated 0.62 ± 0.37 tons of carbon per hectare per year between 1975 and 1996.

Carbondioxide in, oxygen out
Under natural conditions, plants remove CO2 from the atmosphere and absorb it for photosynthesis, an energy-creating process that yields:Oxygen, which is released back into the air,Carbon, which allows the plant to grow.
So, without tropical rainforests the greenhouse effect would likely be even more pronounced, and climate change may possibly get even worse in the future.
One computer model of future climate change caused by greenhouse gas emissions shows that the Amazon rainforest could become unsustainable under conditions of severely reduced rainfall and increased temperatures, leading to an almost complete loss of rainforest cover in the basin by 2100. However, simulations of Amazon basin climate change across many different models are not

consistent in their estimation of any rainfall response, ranging from weak increases to strong decreases.The result indicates that the rainforest could be threatened though the 21st century by climate change in addition to deforestation.

In 1989, environmentalist C.M. Peters and two colleagues stated there is economic as well as biological incentive to protecting the rainforest. One hectare in the Peruvian Amazon has been calculated to have a value of $6820 if intact forest is sustainably harvested for fruits, latex, and timber; $1000 if clear-cut for commercial timber (not sustainably harvested); or $148 if used as cattle pasture.

Effect of deforestation : Drought

In 2005, parts of the Amazon basin experienced the worst drought in one hundred years,and there were indications that 2006 may have been a second successive year of drought. A 23 July 2006 article in the UK newspaper The Independent reported the Woods Hole Research Center results, showing that the forest in its present form could survive only three years of drought. Scientists at the Brazilian National Institute of Amazonian Research argued in the article that this drought response, coupled with the effects of deforestation on regional climate, are pushing the rainforest towards a "tipping point" where it would irreversibly start to die. It concluded that the forest is on the brink of being turned into savanna or desert, with catastrophic consequences for the world's climate. According to the World Wide Fund for Nature, the combination of climate change and deforestation increases the drying effect of dead trees that fuels forest fires.

In 2010, the Amazon rainforest experienced another severe drought, in some ways more extreme than the 2005 drought. The affected region was approximately 3,000,000 km2(1,160,000 sq mi) of rainforest, compared with 1,900,000 km2 (734,000 sq mi) in 2005. The 2010 drought had three

epicenters where vegetation died off, whereas in 2005, the drought was focused on the southwestern part. The findings were published in the journal Science. In a typical year, the Amazon absorbs 1.5 gigatons of carbon dioxide; during 2005 instead 5 gigatons were released and in 2010 8 gigatons were released. Additional severe droughts occurred in 2010, 2015, and 2016.

Medical potential

Scientists believe that less than half of 1% of flowering plant species have been studied in detail for their medicinal potential. As the Amazon rainforest biome slowly shrinks in size, so does the richness of wildlife found in its forests, along with the potential use of plants and animals that remain undiscovered.

4.Possible steps that can be taken by the world

Ever since the Amazon forest fires in 2019 awareness has been spreading among masses very quickly. Many claiming that these fires are no accident.They are a result of the policies of Brazilian president Jair Bolsonars,who since coming to power in January has:

- *Weakened environmental protections in the region*
- *Slashed the budget of Brazil's environmental protection agency by 95%*
- *Encouraged the clearing of land for a business*
- *Failed to stem the illegal logging trade*

Even called for the eradication of the near 1million indigenous people living within the forests.

The fires in south America are not your fault,but it is now time for all of us to take steps to change the way are looked after our planet,and the future of objects on earth.

The steps are:

- *We should create awareness among masses about the importance of Amazon rsinforests and how it is being depleted.*
- *We need to evaluate ourselves on the situation.*

The fires are a direct result of soaring deforestation rates to illegally claim land and clear land for cattle ranching and agriculture.while fires are not unusual at the dry seasons,the sheer scale and intensity of these fires is exceptional and the direct result of increases in deforestation rates by farmers going largely unchecked by Brazilian government.

Conclusion

At the end of this project it can be concluded that:

- *In most cases,the seasonal peak in the number of forest fires corresponded with the dry seasons of the southern hemisphere where the amazon is located i.e. the months between May to September.*
- *However,in case of groupB represented by pernambuco,there is a surge in the numbers during the relatively wet seasons too.*
  On further research of cause we observe that coastal forests in pernambuco have a long history of deforestation for extraction of forest resources like Pau-brasil(a wood tree) and cultivation of sugarcane.
- *The forecasted plots exhibit that the forest fires in :*

a. Group A are projected to increase atleast as much as the previous peaks.on research of the 2019 amazonian forest fires it came out that matogrosso and rondonia (groupB) are in what is called the deforestation arc.

b. Group B are projected to decrease much more.as stated earlier pernambuco has been suffering fromn deforestation for decades and the forest cover has come down to 10 km reminant surrounded by sugarcane fields.hence, the forest fires, being agriculture cattle rearing and illegal logging.

c. Group C are projected to maintain their usual levels much below their all time high for 2008 2009.

APPENDIX 1

*The R package which enables the plot function is "**ggplot2**".The forecast is the another of the R packages which contains functions such as*

- *auto.arima()-----for fitting an arima model to the data.*
- *forecast()-------for forecasting a time series based on a model.*

Both the R packages can be downloaded from https:\\cran.rproject.org.

How does auto.arima() select a suitable model?

***Forecast package** provides function auto.arima() for the automatic selection of arima model.the auto.arima in R uses a combination of unique root test,minimization of the AIC(akaike's information criterion) and MLE(maximum likelihood estimation) to obtain an arima model.*

A model is chosen and vaue of AIC is calculated.the best model is the one with the lowest AIC.the best model considered so far becomes the new current model.Now this process is repeated until no lower AIC can be found.

AIC,AICc and BIC:

AIC is an estimator of out of sample prediction error and thereby relative quality of statistical model for a given set of data.given a collection of models for the data,AIC estimates the quality of each model,relative to the each of the other model.Thus AIC provides a meanf for model selection.AIC is founded on information theory.when a statistical model is used to represent the process that generated the data,the representation will almost never be exact.So some information will always be lost by using the model to represent the process.AIC estimates the relative amount of information lost by a given model.The less information a model looses,the higher the quality of model.In estimating the amount of information lost by a model,AIC deals with the trade off between the goodness of fit of the model and the simplicity of the model.in other words,AIC deals with both the risk of overfitting and the risk of underfitting.

AIC =2k-2ln(L)

Let, k be the number of estimated parameter in the model.

L be the maximum value of the likelihood function for the model.

AICc is AIC with a correction for small sample sizes.the formula for AICc depends upon the statistical model.Assuming that the model is univariate,is linear in its parameters,and has normally distributed residuals then the formula for AICc is as follows:

$$AICc = AIC + (2k^2 + 2k) / (n-k-1)$$

Where n is sample size.

the formula for the BIC is similar to the formula for AIC but with a different penalty for the number of parameters.with AIC the penalty is 2k,whereas with BIC ,the penalty is ln(n)k.
AIC is asymptotically optimal for selecting the model with least mean squared error ,under the assumption that the "true model" is not in the candidate set.BIC is not asymptotically optimal under the assumption.

APPENDIX2

Different stochastic model:-

AR(autoregressive) and MA(moving average)

In an AR(p) model ,the future value of a variable is assumed to be a linear combination of p past observation and a random error together with a constant term.

AR(p) model :

$$y_t = c + \sum_{i=1}^{p} \varphi_i \, y_{t-i} + \varepsilon_t = c + \varphi_1 y_{t-1} + \varphi_2 y_{t-2} + \cdots + \varphi_p y_{t-p} + \varepsilon_t$$

i.e. $\varepsilon_t = \varphi(L) y_t$

where L is a lag operator such that $Ly_t = y_{t-1}$

On the other hand,MA(q) model,the future value of a variable is assumed to be a linear combination of q past error and the random error together with the mean of the series.

MA(q) model:

$$y_t = \mu + \sum_{j=1}^{q} \theta_j \, \varepsilon_{t-j} + \varepsilon_t = \mu + \theta_1 \varepsilon_{t-1} + \theta_2 \varepsilon_{t-2} + \cdots + \theta_q \varepsilon_{t-q} + \varepsilon_t$$

i.e. $y_t = \theta(L) \varepsilon_t$

ARMA model:

Auto regressive(AR) and moving average(MA) model can be effectively combine together to form a general and useful class of time series model,known as the ARMA model.

ARMA(p,q)model:

$$y_t = c + \varepsilon_t + \sum_{i=1}^{p} \varphi_i y_{t-i} + \sum_{j=1}^{q} \theta_j \varepsilon_{t-j}$$

i.e. $\varphi(L)y_t = \theta(L)\varepsilon_t$

Here, $\varphi(L) = 1 - \sum_{i=1}^{p} \varphi_i L^i$ *and* $\theta(L) = 1 + \sum_{j=1}^{Q} \theta_j L^j$

Now,ARMA model can only be used for stationary time series data.However in practice many time series show non stationary behavior.

<u>ARIMA MODEL :</u>

Time series which contain trend and seasonal pattern are also non stationary in nature.Thus from an application view point ARMA models are inadequate to properly describe non stationary time series,which are frequently encountered in practice.For this reason the ARIMA model is proposed which is a generalization of an ARMA model to include the case of non stationarity as well.

In ARIMA model nonstionary time series is made stationary by applying finite differencing of the data point.

ARIMA(p,d,q):

$$\varphi(L)(1-L)^d y_t = \theta(L)\varepsilon_t$$

i.e. $(1 - \sum_{i=1}^{p} \varphi_i L^i)\,(1-L)^d y_t = (1 + \sum_{j=1}^{q} \theta_j L^j)\varepsilon_t$

<u>SARIMA MODEL:</u>

The ARIMA model is for non seasonal,non stationary data.Box and Jenkins have generalized this model to deal with seasonality.their proposed model is known as the seasonal arima(SARIMA) model.in this model,seasonal differencing of appropriate order is used to remove nonstationarity from the series.

$$\Phi_P(L^s)\varphi_p(1-L)^d(1-L^s)^D y_t = \vartheta_Q(L^s)\theta_q(L)\varepsilon_t$$

REFERENCES

- *A.M.Gun,M.K.Gupta,B.Dasgupta,Fundamentals of Statistics Voulme 1*
- *A.M.Gun,M.K.Gupta,B.Dasgupta,Fundamentals of statistics Volume 2*
- *www.kaggle.com*
- *www.forestwatch.org*
- *www.wwf.org*
- *www.wikipedia.org*
- *www.reuters.com*