Environment and Ecology Research 5(2): 93-99, 2017
DOI: 10.13189/eer.2017.050202 http://www.hrpub.org

Fire Statistics in Pinar del Río Province, Cuba (1994 – 2013)

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Abstract The database on fire statistics is useful tool for efficient planning of preventive suitable measures to each area. Base on that, it allows to establish the trend of occurrences of fires and their affectations, periods the day and year with increased risk for emergency and spreading; but also the causes of emergence, the forest and species to be damage. Likewise, it is possible to analyze the effectiveness of fire protection services. The present study aims to analyze through the database, the trend of forest fires dynamic in Pinar del Río using a series of 20 years since (1994-2013), to improve the prevention actions. The results have shown a total of 1,466 fires and 31,881.6 ha of burned areas during the last 20 years mainly at 14:00 to 17:00 hours of pine plantation.

Keywords Fire Statistics, Fire Management, Protection, Prevention

1. Introduction

Forests are integral elements of the life support systems on Earth and play an important role in the regulation of the atmosphere and climate. It is estimated that about 13 million hectares of forests were converted into land for other uses or lost through natural causes each year over the past decade.

Every year a large number of forest fires occur regularly around the planet with an increase in both the number of registered as fires burned areas and the consequences resulting therefrom. Although the technologies are available, the will of governments and international to confront this phenomenon worldwide organization for their overall trend is still rising. Increased forest fires, in turn, are influencing climate change and this is contributing to the growth of forest fires (FAO [1]).

According to NASA [2], climate change will increase the frequency of fires, droughts in some regions, as well as the duration and intensity of tropical storms. All these factors directly affect the combustible material and its availability to be affected by forest fires.

According to data provided by the National Bureau of Statistics and Information (ONEI [3]) in the year 2015, during the five years (2010-2015), it was determined to have occurred in Cuba 2,741 fires have affected 44,352.1 ha. In 2015, the figure for economic losses resulting from forest fires for the province of Pinar del Río of 541.32 thousand dollars was reached, which proved to be the one with the greatest loss at the national level. This behavior confirms that as historically one of the provinces most affected by forest fires.

These effects can be reduced if as a result of analysis of the fire statistics in the province, an appropriate plan to increase the effectiveness of prevention against these phenomena is implemented, then deriving the importance of defining in each territory the time of fire and studying their behavior is implemented.

In this sense it is important to take into account some of the elements forest fires statistics used by some authors in different regions of the world, some examples are: (Canakcioglu [4], in Turkey, Vélez [5], in Spain; Soares and Santos [6], in Brazil), as well as the experiences of the studies in Cuba for this purpose such as: (Oharriz [7]; Rodríguez [8] Ramos and Soares [9] Ramos [10]; Ramos *et al.*, [11]).

The elements to consider for a good evaluate of the fire statistics are: establish the trend of the number of fires and of the affected areas as this indicates the need to maintain or continue to improve the levels reached in the protection of forests. It is equally important to know its distribution throughout the year, the week and the day to determine the

periods in which the preventive measures must be extended. The analysis of the causes, on the other hand, allows improving the planning of the prevention, whereas to determine on which vegetation occurs the greater number of fires and the greater affectations it allows destining the available resources to the areas of more vulnerable vegetation.

2. Materials and Methods

The research was carried out in the province Pinar del Rio, located on the western of the island of Cuba (Figure 1). It has a total area of (888,374 ha) ranking as the fourth largest in Cuba and is located between 21°52' north latitude and 84°57' west longitude, according to the National Names Committee Geographic (2000), cited by (ONEI [3]).

Figure 1. Location of the province of Pinar del Río

According to the statement made by the State Forestry Service (SEF) at the end of 2015, the province had a land area without internal waters of 853,300 ha and of them 400,629.10 ha were forested which represents 47% of the area covered by forests, which classifies it as the province with the largest forest area.

Natural forests cover an area of 288,584.80 ha, established plantations of 112,044.30 ha, as well as young plantations of 11,016.60 ha. The forest area is distributed in the following categories of forest producers, protection and conservation; representing a percentage of 49%, 29% and 22%. Its composition is given in 46,796.50 ha of natural forests and 86,132.90 ha of plantations of *Pinus spp.* in addition to 20,393.30 ha and 676 ha of plantations of *Eucalyptus spp.* and *Casuarina spp.*, respectively. In these types of vegetation, it is where most fires occur.

According to Köppen (1936) cited by Wadsworth [12], the weather in Pinar del Rio is Aw (tropical climate, the coldest month, with the highest temperature of 18^{o}C and a dry season with at least one month with less than 600 mm). The annual rainfall is 1,589.64 mm, the average annual temperature of 25.10°C and the annual average relative humidity of 76.23%.

According to some methodological elements developed by Ramos [10] was considered the distribution of the variables occurrence of fires and burned area during the years of the period, the months, days and hours of the week, in the case of temporal context.

To verify the existence or not of significant difference between the mean values of the different variables, the nonparametric Kruskal-Wallis Test was used, and the Mann-Whitney to analyze the significance between natural forests and plantations the data processing was performed using the Integrated System for the Management of Wildland Fire Databases. (SIMBDIF) 1.2 (Ramos [13]), statistical software IBM SPSS for Windows, version 22.0, and the processor computing system for Windows Microsoft Excel 2016 version 16.0.7167.2060.

3. Results and Discussion

The meteorological variables affect the fire behavior, influencing the occurrence and propagation of the same. According to the annual average rainfall measured at 13:00 h ranged from 1,202.97 and 2,279.70 mm is observed in the period under review, observed during a rainy period (May to October) in an increase in electrical activity and a bit rainy (November to April) is presented, while the average wind speed ranged from 3 m/s in September and 6.66 m/s in March. The temperature fluctuated throughout the year between 21.93ºC in January and 27.34ºC in August, the temperature of the dew point oscillated between 16.99ºC in January and 23.46ºC in September and the relative humidity had 68% in April and 85% in September (Table 1).

Table 1. Meteorological data from the Pinar del Río province (monthly mean on period 1994 - 2013

Month	Ws	T	Hr	Dp	P
	(m/s)	(ºC)	(%)	(ºC)	(mm)
January	4,78	21,93	74,18	16,99	53,42
February	5,44	23,06	72,06	17,59	53,70
March	6,66	24,07	68,48	17,71	52,03
April	6,34	25,69	67,78	19,03	62,59
May	5,25	26,81	72,20	21,13	139,12
June	4,21	27,25	77,80	22,88	247,16
July	3,40	27,34	77,86	23,01	159,70
August	3,05	27,04	80,89	23,36	159,70
September	3,00	26,33	84,60	23,46	279,59
October	3,86	25,49	82,48	22,20	155,07
November	4,17	23,65	78,53	19,61	63,98
December	3,90	22,53	77,95	18,41	51,03
Media/Total	**4,51**	**25,10**	**76,23**	**20,45**	**1477,09**

V: Wind speed; T: Air temperature; Hr: Relative humidity; Dp: Dew point temperature; P: Precipitation

Table 2. Forest fires occurrence and burned area distribution by year in Pinar del Río province (1994-2013)

Years	Fires		Burned areas		Aba
	(No.)	(%)	(ha)	(%)	(ha/fire)
1994	67	4.57	661.15	2.07	9.87
1995	51	3.48	533,69	1.67	10.46
1996	57	3.89	331.42	1.04	5.81
1997	70	4.77	595.11	1.87	8.50
1998	85	5.80	1,395.89	4.38	16.42
1999	106	7.23	10,975.80	34.43	103.55
2000	79	5.39	936.99	2.94	11.86
2001	94	6.41	1,060.76	3.33	11,28
2002	39	2.66	505.95	1.59	12.97
2003	33	2.25	76.67	0.24	2,32
2004	71	4.84	705.47	2.21	9,94
2005	52	3.55	1,108.32	3.48	21,31
2006	101	6.89	3,828.35	12.01	37,90
2007	64	4.37	353.85	1.11	5,53
2008	71	4.84	432.83	1.36	6,10
2009	117	7.98	1,013.34	3.18	8,66
2010	57	3.89	148.10	0.46	2,60
2011	152	10.37	6,131.26	19.23	40,34
2012	36	2.46	343.68	1.08	9,55
2013	64	4.37	742.97	2.33	11,61
Total	**1,466**	**100**	**31,881.6**	**100**	**21,75**

Table 3. Forest fires occurrence and burned area distribution by month in Pinar del Río province (1994-2013)

Month	Fires		Burned areas		Abaf
	(No.)	(%)	(ha)	(%)	(ha/fire)
January	73	5	487.55	1.53	6.68
February	115	8	1,139.24	3.57	9.91
March	222	15	2,857.66	8.96	12.87
April	264	18	1,2370.29	38.80	46.86
May	297	20	1,2335.81	38.69	41.53
June	157	11	798.5	2.50	5.09
July	143	10	819.96	2.57	5.73
August	100	7	314.31	0.99	3.14
September	33	2	171.8	0.54	5.21
October	19	1	476.08	1.49	25.06
November	18	1	58.35	0.18	3.24
December	25	2	52.05	0.16	2.08
Total	**1,466**	**100**	**31,881.6**	**100**	**167.40**

In the period under study (1994 - 2013), a total of 1,466 fires and 31,881.60 ha of burned areas were reported, with a tendency to increase in recent years. Table 2 shows the distribution of fires, burned areas and average burned areas by fire (Abaf) over the period of years under study.

The high percentage of burned areas that the years 1999 and 2011 show are due to the occurrence of more than one fire of great proportions in those years, which influenced in the increase of the average of hectares burned by them during the same ones. However, it can be observed that in the exception of 1999 and 2011, the others have good results in this efficiency indicator, which are lower than those reported by Soares [14] for Greece from 1978 to 1982, Spain from 1977 to 1982, and Brazil from 1983 to 1987 and those reported by Madoui [15] for Algeria from 1979 to 1987, are similar to those obtained by Ramos *et al.*, [16] in the Pinar del Río province from 1997 to 2006, by Castro [17] for Integral Forest Enterprise (IFE) Macurije from 1999 to 2005 and Ramos *et al.*, [12] at Macurije IFE from 2006 to 2011.

Table 3 shows that, during the study period through the month, the highest values of occurrence of fires occurred during the end of the dry season (November-April) and the beginning of the rainy season (May to October), where the combustible material tends to increase its flammability and availability because of the low water content of the fibers. This result coincides with those obtained by Carrasco *et al.*, [18], related to the study of the flammability of plant species associated with the pine tree ecosystem.

In the case of burned areas, the highest values are concentrated between April and May. Similar results were obtained by Ramos and Soares [9] in the province of Pinar del Río from 1975 to 1996, Ramos and Soares [19] in the province of Pinar de Río from 1998 to 2001, Ramos and Cabrera [20] in the period from 1996 to 2005 and Ramos and Cabrera [21], who studied from 1997 to 2007. In addition to April as the month of greatest value for the areas burned by fire, which does not coincide with that obtained by Ramos *et al.*, [16] who analyzed the period from 1997 to 2006 for the Pinar del Río province, which turned out to be the month of greatest value for the middle burned areas. This result may be a function of climatic variability, which is influenced by the effects of climate change.

The distribution of the normality of the variables of occurrence of fires, burned areas and average burned areas by fire during the months was obtained as a result that did not follow the normal distribution. In consequence, nonparametric statistical test of Kruskall-Wallis was used, which showed the existence of a significant difference for each of the months with values of (p=0.000) for the occurrence of fires, areas burned and areas burned by fire.

The Figure 2 shows the percentages of the occurrence of fires during the days of the week on the period under analysis. These values did not follow a normal distribution, so the Kruskall-Wallis nonparametric statistical test was carried out, proving that there is no significant difference between the fires occurring on each day of the week (p=0.457). This coincides with results obtained for the province of Pinar del Río, in periods of different years, by Ramos and Soares [9], Ramos [10], Ramos and Soares [19] and García [23].

Figure 3 shows the distribution of the occurrence of fires during the hours of the day in which fires occurred. It is observed that between 14:00 and 17:00 hours occur 62.57% of them, while in the rest of the hours this occurrence decreases, this behavior that is influenced by the daily variation of temperature values of the air and relative humidity, which modify the state of saturation of the combustible materials. The results are similar to those obtained for the province of Pinar del Río by Ramos and Soares [9], Ramos [10], Ramos and Soares [19], Ramos and Cabrera [21] and García [22] during different periods of years. The existence of a significant difference between the means of the fires occurred at different hours was

demonstrated with Kruskall-Wallis non-parametric statistical test (p=0.023)

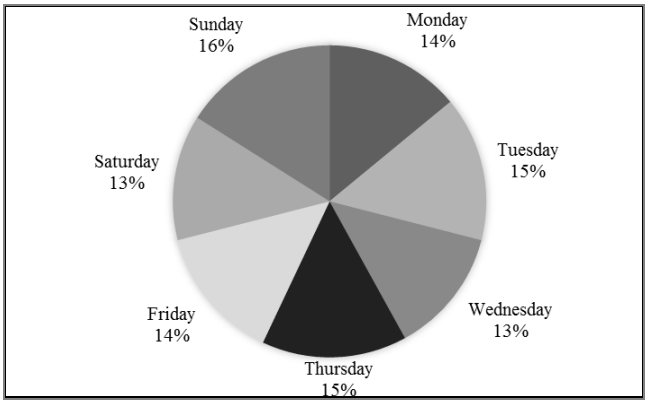

Figure 2. Distribution of the percentage of occurrence of fires throughout the week in the Pinar del Río province (1994-2013)

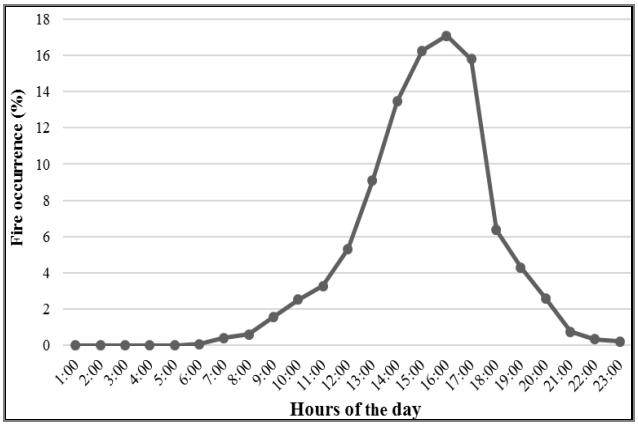

Figure 3. Forest fire occurrence distribution through the daylight hours in the Pinar del Río province (1994 - 2013)

The values corresponding to the percentages of the number of fires occurring according to each cause and the hectares of areas burned by them are presented in Figure 4. It is observed that negligence is the main cause of emergence, corresponding to 47.48% (696 fires) of the total, followed by lightning, unknown and intentional. Likewise, the cause of the greatest number of areas has been negligence, accounting for 59.85% of the total (19,080.77 ha), followed by rays, unknown and intentional. These results do not coincide in the cause of fire occurrence, but in the affected areas according to their cause, with those obtained by Ramos and Soares [9] for the Pinar del Río province, Castro [17] for Integral Forest Enterprise Macurije and Ramos *et al.*, [13] in the Minas de Matahambre Integral Forest Enterprise. This behavior reveals the growing participation of society in the problem of forest fires due to the population growth and the increase of productive activities in the sector.

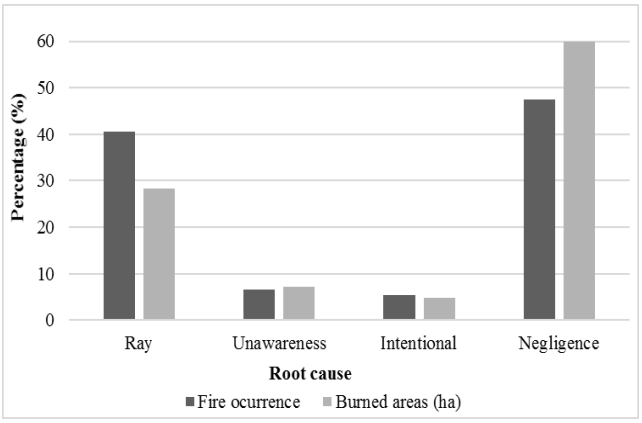

Figure 4. Forest fires occurrence and burned areas distribution by causes in Pinar del Río province (1994-2013)

Figures 5 and 6 show the values of the fires that occurred and the hectares affected during the 20 years of the study in natural forests and plantations. When applying the Mann-Whitney U-mean comparison test using a significance level of 0.05, a significant difference was detected between natural forest fires and plantations with (p=0.000), similarly for the case of the hectares affected in each type of forest (p=0.104). Increases in mean values are observed for the number of fires and hectares affected in planted forests, which coincides with the criterion of different authors who propose that the natural forest, mixed and distemper as it approaches its state climax, has less possibilities for the emergence and propagation of fires, so special attention should be paid to the protection against fires in the plantations adding also that the plantations increase each year and mainly with the most dangerous species. These results do not agree with those obtained by García [22] for the Pinar del Río province from 1997 to 2006, by Castro [17] for IFE Macurije during the period 1999 2008 and with Ramos *et al.*, [23], coinciding only by those exposed by Ramos and Soares [9] for the province of Pinar del Río.

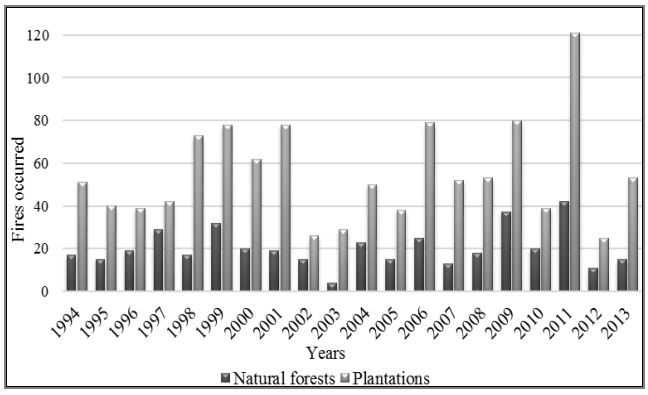

Figure 5. Fires distribution by forest classes

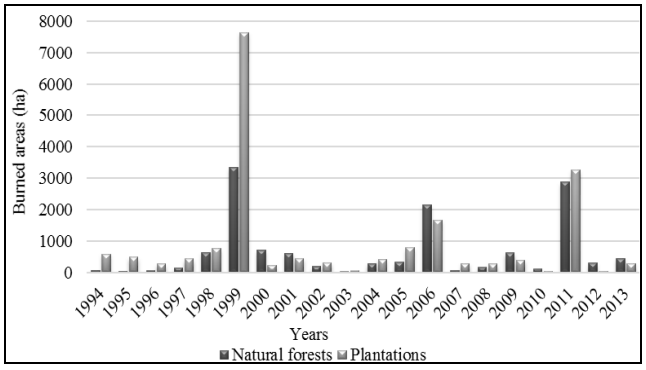

Figure 6. Areas burned distribution by forest classes

Figure 7 shows the percentage values of the fires started and the areas burned by them in the areas occupied by the different types of species. Reflecting the fact that during the study period, the highest number of fires (65. 69%) is present in the group of *Pinus sp.*, decreasing in order the degree of occurrence in the species of *Eucaliptus sp.* (23%), other broadleaf (11%) and *Casuarina sp.* (1%). The Kruskall-Wallis non-parametric statistical test (p=0.018) showed that there was no significant difference between the mean number of occurrences of fires among the types of species analyzed.

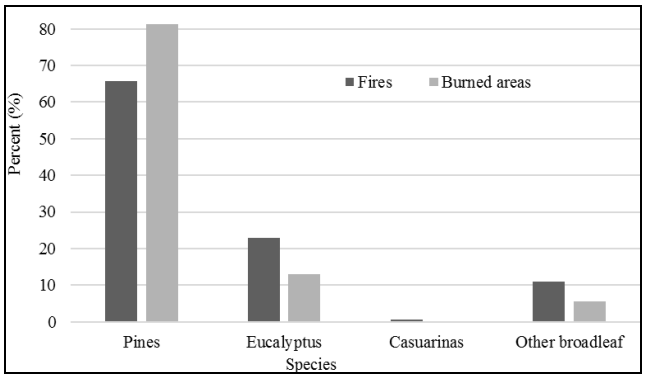

Figure 7. Forest fires and burned areas distribution by species in Pinar del Río province (1994-2013)

In the case of the burned areas according to the species types, they had the same behavior as in the fires occurring. Showing the greatest affectation in *Pinus sp.* (81.32%) following the *Eucalyptus sp.* (12.98%), other broadleaf (5.47%) and *Casuarina sp.* (0.23%), it was found that among the means of all types of species as the affected area there is significant difference with (p=0.098). These results are similar to those obtained in the province of Pinar del Río by Ramos and Soares [9], Ramos and Cabrera [21] and García [22].

The results obtained demonstrate the importance of giving a special interest to the areas occupied by the species of *Pinus sp.* which occupies the (32.29%) of the forest mass existing in the province.

In the case of burned areas depending on the types of species that had similar behavior in fires showing greater involvement in *Pinus sp.* (81,32%) following the *Eucaliptus sp.* (12,98%), other broadleaf (5,47%) and *Casuarina sp.* (0,23%), it was found that between the means of all types of species when the affected area exists significant difference (p= 0,098). These results similar to those obtained in the province Pinar del Río Ramos and Soares [9], Ramos and Cabrera [21] and García [22].

The results show the importance of paying particular interest to the areas occupied by the species of *Pinus sp.* which holds (32,29%) of the existing forest mass in the province.

3. Conclusions

The evaluation of the forest fires statistics in Pinar del Río, from 1994 to 2013, allows to specify very important elements on the spatial and temporal distribution of these, which is of great importance for the decision making both in prevention activities and of extinction, a total of 1,466 fires and 31,881.6 ha of burned areas were reported. A critical fire season was established that can be located between the months of March-May. There was no significant difference between the fires that occurred each day of the week, while the greatest number of fires occurred between 14:00 and 17:00 hours. The cause of the greatest number of fires and burned areas are neglect, and the same behavior occurs in the plantations, defining the group of *Pinus sp.* as the type of species where most of the fires and affected areas were recorded.

Acknowledgements

To thank the collaboration of the companions of the National and Provincial Forest Guard Corps, as well as the Provincial Meteorological Center for their help in the preparation of this work. Also thanks to the University of Pinar del Río for its support in the preparation and development of research.

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