Methodology Used in Cuba for Estimating Economic Losses Caused by Forest Fires[1]

Marcos Pedro Ramos Rodríguez[2] and Raúl González Rodríguez[3]

Abstract

Assessment of economic losses caused by forest fires is a highly complex but important activity. It is complicated first by the large number of effects, in different periods, brought about in the social, economic and environmental fields. Secondly, the difficulty of assigning a market value to resources such as biodiversity or endangered species should be mentioned. It is important because it allows showing, with numbers, how much is lost each time one of these phenomena occurs, which can help in the decision-making process for resource allocation. This paper presents the methodology used in Cuba for estimating economic losses caused by forest fires. It is the result of the practical experience gained with similar methodologies and research work carried out. It bases its estimates of direct losses on indicators such as: reforestation losses, harvested timber losses, standing timber losses, non-timber forest product losses, suppression losses, and protection work losses. In this methodology, indirect losses may be many times higher than the possible results obtained from factors such as fire size, the slope of the land, vegetation structure, the recovery time of vegetation cover and the percentage damage to vegetation cover. The application of the methodology in a 6 ha-area covered by a plantation of *Pinuscaribae* Morelet, var. *caribaea* allowed estimating losses totaling 508,121.04 Cuban pesos (240,331.47 USD).

Keywords: Direct losses, indirect losses, indicators, Market value

Introduction

Assessing economic losses caused by forest fires is an activity of great complexity and importance. It is complex due to the large number of effects, in different periods, which they cause in the social, economic and environmental areas. Secondly, the difficulty of assigning a market value to resources such as biodiversity or endangered species must be mentioned. It is important because it

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[2] Professor, Forestry Department, School of Agronomy and Forestry, Pinar del Río University, Cuba; Email: cmramos@af.upr.edu.cu

[3] Forest Management Department, Forest Rangers National Directorate, Cuba

can show, with numbers, how much is lost each time one of these events occurs, which can help in the decision-making process for the optimal allocation of resources for fire management activities.

Today, despite the progress made, the methodologies for assessing the economic effects caused by forest fires are not as accurate as one would like; nonetheless, they allow showing impressive values. According to González-Cabán (2000), from 1980 to 1994 the U.S. Forest Service participated in controlling 164,000 wildfires that affected approximately 3 million hectares of forests. The U.S. Forest Service spent more than $5.5 billion US on fire suppression activities to protect national forests and other adjacent lands, both private and public. This amount represents only a fraction of the total loss caused by forest fires in the U.S.

In 1998 in the area of Yellowstone National Forest (Palzin and others, cited by González-Cabán 2000), direct losses of $21 million in tourism revenue due to wildfires were estimated. Between 1988 and 1990, the estimated loss was $60 million, and fires also caused a decrease in the rate of visits almost equal to a year's growth. The long-term impacts on tourism in the area were difficult to assess because the surrounding communities had different levels of dependence on the tourism industry. Other losses such as damage to wildlife habitat, threatened and endangered species, and soils or other resources or noncommercial services were not included in this estimate. The 1998 fire in Yellowstone National Park is an example of the hundreds of situations where fire damage and total losses have only been partially estimated.

In Cuba, according to Croton (2006), from 1961 to 2005 forest fires caused an economic loss of 545,115,000.00 pesos. The largest percentage of these have been estimated in the five-year period from 2001-2005, with losses of 103,069,000.00 pesos.

The objective of this paper is to present the methodology used in Cuba to estimate the economic losses caused by forest fires. It is the result of experience gained using similar methodologies and through research work.

Methods

Methodological elements considered in designing the methodology

According to Batista (2004) and Rodríguez (2010), the important elements found by them in different methodologies are:

- Some authors (Oharriz, 1991 and González-Cabán 2000) take into account the growth stages of a tree. It has been shown that fire affects a sapling more than a juvenile or adult tree. They also consider for estimates that a sapling does not yet have any usable timber volume.

- The principle of stand persistence is considered applicable. This means that after the fire the woodland is not transformed into urban or agricultural use (González-Cabán 2000).
- Considered in the calculations are losses relating to non-timber forest products such as firewood, cork, resins, fruits, seeds, grasses, hunting, fishing, and protection values and recreation (Vélez 2000, Haltenhoff 2001).
- The concepts of damage and lost future value are used. Damage relates to what has been lost and lost future value estimates the potential value of the stand lost by having had to log it before the end of the rotation because of the fire (Vélez 2000).
- To determine indirect losses, Haltenhoff, 2001 introduces the idea of not just considering them as 4 or 7 times (Oharriz 1991) or 10 times (Soares 1985) greater than direct losses, but taking into account the size of the fire, the slope of the land, vegetation structure, the recovery time and the percentage damage to the vegetation cover.
- All methodologies (Oharriz 1991, Rodríguez 1998, Vélez 2000, and Haltenhoff 2001) take into account the wood affected by fire and its depreciation should it still be possible to use it for other purposes.
- Some authors (Vélez 1982, and Haltenhoff 2001) when trying to quantify losses caused by damage to the wood consider only standing timber, while others (Oharriz 1991, Rodríguez 1998) also take into account harvested timber located in piling areas or within the forest.

Methodology used in Cuba to assess economic losses

From 1979 to 1998, a methodology that considered four elements was used in Cuba: reforestation costs, m^3 of timber lost, area clean-up costs and firefighting costs. In 1999 a new methodology resulting from a research project developed at the Universidad de Pinar del Río, entitled "Fire management in forest ecosystems," was introduced. In 2001, as a result of the FAO Project "Designing a strategy for controlling forest fires," which was developed in Cuba, the corresponding elements for assessing indirect losses was added to the 1999 methodology. This methodology, with some modifications resulting from work carried out by Batista (2004) and Rodriguez (2010), is presented below:

The methodology considers both direct and indirect losses. Data collection for the assessment can begin once the fire is extinguished. The amount of time required for this activity depends on the size of the area affected and its characteristics. The work is performed by a team made up of specialists from the company or entity concerned, the State Forest Service (SEF) of the municipality and the Ranger Corps (CGB); the SEF is responsible for approving the estimate.

Direct losses are estimated by the following equation:

$$P_d = \left(P_r + P_{mt} + P_{mp} + P_{ex} + P_{tp}\right) \quad (1)$$

where P_d is the direct losses, P_r is reforestation losses, P_{mt} is harvested timber losses, P_{mp} is standing timber losses, P_{pnm} is non-timber forest product losses, P_{ex} is Suppression losses, and P_{tp} is protection work losses.

Reforestation losses (P_r) include the costs of all operations performed in the affected forest until the time of the fire, as expressed by the following equation:

$$P_r = \left(S_t * K\right)\left(C_{pt} + C_{pp} + C_{pl} + C_{ac} + C_{ts}\right) \quad (2)$$

where S_t is the total area affected, K is the coefficient of damage (per-unit basis of the affected area), C_{pt} is cost of land preparation, C_{pp} is Cost of seedling production, C_{pl} is cost of planting, C_{ac} is cost of stand improvement, and C_{ts} is cost of silvicultural treatments.

The factors that determine fire behavior during the development of a forest fire (topography, combustible material and weather conditions) are always different. As a result, fire behavior parameters (linear intensity, crown scorch, residence time, heat released per unit area, flame length, rate of spread) usually do not show uniform values for an entire burned area. Except when extreme fire behavior occurs, fire causes varying degrees of damage to the stand throughout the entire area. In order not to overestimate the losses caused by fire, it is desirable to determine the actual area affected. To determine both the total and actual area affected, the following points should be observed:

a). To determine the total area affected by the fire, first a sketch of the area must be made using any of the known methods such as using a compass and a tape measure, GPS or delineation on aerial photos. Then the calculation is done using a dot stencil, a polar planimeter, the grid method or by triangulation. Today this area can also be obtained through satellite imagery.

b). The actual area affected is determined by sampling 10% of the area; 100 m^2 systematically-distributed plots are used. Each plot is classified according to its degree of damage. For this, the degree of damage of the trees within them is taken into account, according to the following classification:

- Slight damage: Those trees that have only suffered slight damage to the bark and/or the first branches.
- Moderate damage: Those trees whose crowns have been affected by up to about 60 %.
- Total damage: Those trees whose crowns have been completely affected.

The plots are classified according to the degree of damage estimated for more than 70 % of the trees in them. Then the zoning is done by grouping together plots with the same degree of damage. The actual area affected corresponds to those classified as having total and moderate damage.

Knowing the total area and actual area affected, the coefficient of damage (K), which is no more than the per-unit basis of the area affected, is calculated.

The costs of site preparation, seedling production, planting and stand improvement are obtained from the accounting department of the different entities.

Harvested timber losses (*Pmt*) considers the volume of affected timber harvested that was in piling areas or in the forest. As this damage is sometimes not total, it is necessary to consider the wood that was not affected or despite being affected will be sold, which should be at a lower price than was planned before being affected by the fire. The following equation is used:

$$P_{mt} = \sum_{i=n}^{i=n+1} (V * P_v) - (V' * P'_v) \tag{3}$$

where n is the number of different types of timber, V is total volume of harvested timber affected by the fire (m^3), Pv is price of the timber prior to being affected by the fire (\$.m^{-3}), V' is volume of timber that despite its damage will be sold at another price (m^3), and Pv' is the new sale price (\$.m^{-3}).

Standing timber losses (P_{mp}) considers the volume of standing timber that is in an adult or juvenile state of development. An assessment must be performed to estimate the volume per type of timber. During the calculation, one must bear in mind if any amount of wood was sold, albeit at a price below that established for each type of timber before being affected by the fire. The following equation is used:

$$P_{mp} = \sum_{i=n}^{i=n+1} (S_t * K * V * P_v) - (S_t * K * V' * P'_v) \tag{4}$$

where P_{mp} is the standing timber losses, n is the number of different types of timber, S_t is total area affected, K is coefficient of damage (per-unit basis of the affected area), V is Total volume of standing timber that was affected by the fire (m^3.ha^{-1}), Pv is price of the timber prior to being affected by the fire (\$.m^{-3}), V' is volume of timber that despite being damaged will be sold at another price (m^3), and *Pv'* is new sale price ($\$.m^{-3}$).

Non-timber forest product losses (P_{pnm}) takes into account the different NTFPs in the affected area, both those already used and those intended to be used, including resin, seeds, foliage, flowers, fruits, mushrooms, medicinal plants, etc. In the case of resin, the volume already extracted and that which was lost or which would have been obtained if the affected forest is suitable for its extraction must be considered. Seed production is valued if it is a seed mass. In this case, the number of years expected for the new planting at the site to supply the same amount of seeds must be taken into account. The following equation is used:

$$P_{pnm} = \sum_{i=n}^{i=n+1} \left(S_t * K * V_n * P_v \right) \qquad (5)$$

where n is the number of non-timber forest products, S_t is total area affected, K is coefficient of damage (per-unit basis of the affected area), V_n is volume or weight of product n ($m^3.ha^{-1}$ or $kg.ha^{-1}$), and P_v is sale price of product n.

Extinction losses (P_{ex}) can have great weight in the assessment of total losses. It includes losses incurred while suppressing the fire, and it takes into account the resources and crews involved. In the first case, the cost of a day's work (8 hours) of a resource is already established based on equipment wear and the operator's salary. In the second case, the average salary paid to a forestry worker for a day's work is used. In the case of Ranger Corps (CGB) resources and crews, equipment rental and workers' wages are not taken into account if the work is carried out during normal working hours. For the rest of the resources and crews, the time they are involved in firefighting operations during their normal working hours should be monitored. Outside of this time valuations are not made because participation is voluntary. All this can be recorded if the extinction crew boss tasks someone with this responsibility. The following equation is used:

$$P_{ex} = C_c + C_{al} + \sum_{i=n}^{i=n+1} \left(J_t * C_n \right) \qquad (6)$$

where P_{ex} is the extension losses, n is the number of resources, C_c is total cost of fuel consumed, C_{al} is total food cost, J_t is working days, and C_n is equipment or salary costs.

Protection work losses (P_{tp}) consider both the average cost of the various protection activities and the age of the trees. The calculation is done according to the following equation**:**

$$P_{tp} = \left(S_t * K * C_p\right) \qquad (7)$$

where P_{tp} is the protection work losses, S_t is total area affected, K = Coefficient of damage (per-unit basis of the affected area), and C_p = total protection cost.

Indirect losses: the following equation is used:

$$P_i = P_d\left(\frac{t + p + e + r + d}{5}\right) \qquad (8)$$

Where P_i is the indirect losses, P_d is direct losses, t = fire size factor, p is slope of the land factor, e is vegetation structure factor, r is Vegetation cover recovery time factor, and d is percentage damage to vegetation cover factor.

Table 1 shows the factors to be used in each case (Herbert y otros 2001).

Table 1—*Factors (F) per variable in each element.*

Fire size (t) (ha)		**Slope of the land (p) (%)**		**Vegetation structure (e)**		**Recovery (r) Time (years)**		**% damage to the cover (d)**	
Variables	**F**	**Variables**	**F**	**Variables**	**F**	**Variables**	**F**	**Variables**	**F**
< 10	1	< 15	1	Meadows	1	Annual	1	< 25	1
10 - 50	2	15 a 25	2	Scrub	2	< 5	2	25 - 50	2
50 - 500	5	25 a 35	5	Plantation	5	5 - 10	5	50 - 75	5
> 500	10	> 35	10	Natural F	10	> 10	10	75 - 100	10

Results

In order to demonstrate the feasibility of using the methodology presented in previous sections, a practical example of its use is given below.

The methodology has been applied to an area affected by fire in the Pinar del Rio Forest Enterprise. The fire was caused by lightning and affected 6 ha of a 25-year-old plantation of *Pinus caribaea* Morelet var. *caribaea*. The quality II site consists of undulating terrain with slopes between 15 and 20 %. The plant spacing used was 2 x 2 m. Machinery was used to prepared the land and soil. Before the fire, the plantation had been weeded, screefed twice, fertilized and thinned in working conditions classified as regular. Resin was soon going to be collected from this plantation; additionally, in two hectares every year an average of 50 kg of seeds were collected per hectare. The fire also totally burnt 10 m^3 of *P. caribaea* timber located in a piling area. During the firefighting operation, a bulldozer was used for five hours and two trucks for a total of 18 hours. In addition, 35 men from outside the Ranger Corps worked an average of 4 hours each. The commission tasked with recommending how to rehabilitate the area concluded that it was not going to recover, so it had to be logged and the timber harvested and sold at a price 10% below its current price. Tables 2 and 3 show the data required for the calculation.

Table 2—*Cost of forestry activities and mechanized equipment*

Forestry activities & use of crews and mechanized equipment	Costs (Pesos)
Clearing 1 ha for mechanized planting in undulating soil	11,000.00
Producing 1,000 nursery seedlings	58.11
Planting 1 ha with *P. caribaea* in a 2 X 2 m spacing arrangement in undulating terrain	88.36
Weeding 1 ha de plantation in regular working conditions	356.67
Screefing 1 ha planted at 2 X 2 m in regular working conditions	170.34
Fertilizing 1 ha of plantation in regular working conditions	151.34
Thinning 1 ha of *P. caribaea* in regular working conditions	786.94
Protection work in 1 ha of conifer each year	3,060.00
A working day (8 hours) for a bulldozer	12.46
A working day (8 hours) for a truck	13.40
A working day (8 hours) for a man	12.92

Table 3— *Prices for the different products*

Products	Prices (Pesos)
1 m^3 of saw timber of *P. caribaea*	73.30
1 m^3 of round timber of *P. caribaea*	40.60
1 ton of resin de *P. caribaea*	784.05
1 kg of seed of *P. caribaea*	85.50

Other data:

- The *P. caribaea* in the quality II site at age 25 has a volume of 334.16 m^3ha^{-1}, of which 98 % is saw timber and 2 % round timber.
- A resin collection should produce a yield of 320 $kg.ha^{-1}$. This species at age 25 should have a diameter of 40.65 cm, so resin can be collected from it twice.

To apply the methodology described in this work, the following facts were taken into account:

- To plant 1 ha at 2 x 2 m spacing, 2,500 seedlings are needed
- The average seed yield per hectare is 50 kg per year and a plantation of *P. caribaea* to achieve the production that was obtained at the time of the fire must be at least 15 years old, so 1,500 kg of seeds were left to be harvested
- The estimated standing timber affected was 1,376.86 m^3 of saw timber and 28.1 m^3 of round timber.

Table 4 shows the results for each one of the indicators of direct losses.

Table 4—*Estimated losses for each indicator*

Indicators	Losses (Pesos)	%
Reforestation losses	77,215.56	10.16
Harvested timber losses	733.00	0.10
Standing timber losses	91,858.22	12.08
Non-timber forest product losses	131,250.56	17.26
Extinction losses	264.03	0.03
Protection work losses	459,000,00	60.37
Total	760,321,37	100.00

Indirect losses were estimated by allocating the factors in Table 1. Accordingly, the factors used were:

- Fire size: 1
- Slope of the land: 2
- Vegetation structure: 5
- Recovery time (years): 10
- Percentage damage to the cover: 10

Based on the above, indirect losses amounted to 4,257,799.67 pesos. These losses are 5.59 times higher than direct losses. According to this methodology, in each case this value will change, that is, these losses are not 5, 7 or l0 times higher than direct losses.

Total losses caused by this fire totaled 5,018,121.04 pesos, approximately 240, 331.47 USD.

Discussion

Table 4 shows that the highest value for direct losses corresponds to the money spent each year on protection work. However, it may be remarked that if in practice all that funding were used rationally and objectively on protection activities, the number of forest hectares affected by fire would be lower. Currently there are access roads in poor condition, hindering the arrival of firefighting crews and resources to remote locations. Nor are preventive forestry measures, such as reduction of combustible material or construction and maintenance of fuelbreaks, including hedgerows or greenbelts and artificial pruning, carried out.

The second largest direct losses value is for non-timber forest products. This shows once again that the most important thing in the forest is not necessarily wood. In addition to non-timber forest products, the forest provides other important services such as soil and water protection, biodiversity conservation and carbon sinks, all of which are elements that this methodology does not consider.

It is worth mentioning that indirect losses are generally undervalued and that in this methodology they are estimated in a very unique way.

Summary

This paper presents the methodology used in Cuba to estimate the economic losses caused by forest fires. It is the result of experience gained in practice with similar methodologies and through research. To estimate direct losses, the following indicators are used: reforestation losses, harvested timber losses, standing timber losses, non-timber forest product losses, extinction losses and protection work losses. Indirect losses are estimated from the allocation of factors to the variables fire size, slope, vegetation structure, recovery time of vegetation cover, and percentage damage to vegetation cover. The application of the methodology in a 6-ha area covered by a plantation of *Pinus caribaea* Morelet var. *caribaea* enabled estimating total losses of 5,018,121.04 pesos (240,331.47 USD).

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