VALUE FOR MONEY, ECONOMIC VIEW ON EMERGENCY SERVICES, HOW PROTECTION PRODUCES VALUE

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Abstract

Progressively, and after years, the new public management increased its influence in French public bodies, to better respond to citizen wishes, governance and state incentives as well. This lead to build a continuum of processes and methods, to monitor quality of provided services and global performance of public institutions.

Fire and emergency services didn't escape to. In the same time, the difficulty to witness of the "value for money" emerged: how to describe on an economic point of view, a non-monetisable service?

In the last five years, some studies focused on value of saved lives, and on the transfer some already existing statistics to evaluate the value of residential surfaces saved by the fire department. Last year, studies gave evaluation to the spared losses during wildfires fighting. Ongoing works are, currently, aimed on industrial and collective public access buildings to complete the scope.

With some study cases, authors will highlight:

- How is it possible to give a value to each ambulance operation?
- How to evaluate added value for structure firefighting?
- How is it possible to approach value of the preserved losses during forest fires?

If this kind of evaluation is typically uncertain and not easy, authors demonstrate, though, the real added value to do on large scale with –at least provincial or state level- common ratios. The idea is to provide to each emergency service, very simple calculation models, based on usual service statistics, to give an approach to this economic value.

This virtuous practice could give some curbing ideas to policy makers having intended purpose to cut resources to emergency services. It could also demonstrate the "value for taxes" to citizens.

Keywords: economic value, losses, quality, performance, value, wildfire, housing fire, lives.

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Introduction

Progressively, and after years, the new public management increased its influence by French public bodies. Citizens' exigency, but also governance and state incentives, let eventually build a continuum of processes and methods to monitor the quality of provided services and the global performance of public institutions.

Fire and emergency services didn't escape to. In the same time, the difficulty to witness of the "value for money" emerged: how to describe on an economic point of view, a non-monetisable service?

The following paper is built on the cumulated knowledge of three main publications (Canouet, 2016) (Goninet, 2018) (Amir, 2019), and, the studies of Bouches-du-Rhône fire department (BDRFD). BDRFD is a French fire department located in Marseille, defending the county surrounding the city, on a vast industrial and populated area (1.2 million of inhabitants) submitted to a harsh and permanent wildfire risk.

Of course, in this context, whereas important patrimonial values are endangered each day, by structures or natural fires, lives are also daily saved by the fire service. For these reasons, the issue of the saved value is posed more acutely.

The organisation of the publication is the following:

1- At first we will describe the problematic identified and the hypothesis of the work in answer
2- Then, a heading will focus on the value of saved lives
3- A following one will aims on housing structures preservation
4- The last heading is tackling to wildfires reality and natural areas + structures value

Problematic and main hypothesis of the work

The idea is to provide a simple calculation model, to estimate the economic value of French fire departments.

While French ministry of interior manages a very robust data base on Fire department activities, no real economic value is evoked, other than budgets of the Fire departments.

At first, we want to manage a systemic study. The work is based on a holistic approach of all values potentially saved during Fire department interventions

- Lives
- Structures (housing, industrial, public reception facilities)
- Forests (CO_2, biodiversity, wood…)
- Crops

We consolidated the values in accessing the several national data of national statistics institute (INSEE), national forest service (INRAE + ONF), national order of solicitors and national insurance federation (FFA).

Main hypothesis of the work is a counter factual approach: « what if… the fire service would have not existed? »

For lives, we achieved to estimate a ratio, giving a number of saved lives by territory (cities, county, fire department, country…), and to model the calculation by introducing « life value » (OECD, 2012) (Quinet, 2013)

For all fire structures we based our model on full patrimonial values (insurance) or housing market values and we assumed that the spared value was simply deduction of losses (insurance reparation indemnities) from values of affected structures.

For forests and crops fires, the model is based on implementation of free fire behaviour (without fight) to estimate the endangered area. Then deduction of the real burned surface gives the saved area. This calculation applied to a big data of fires give a « saved surface average » by fire. The approach of wood, CO_2, biodiversity, tourism values are bound to this surface, giving an average value saved by fires. We do also the same for accounting the structures in the endangered forest zone, which are protected and saved. Identically we calculate an average value of saved structures by fire.

Even if reasoning remains the same, we have to distinguish these « systemic studies » from « monographic » ones. Monographic are single study cases. More precise, and tackling to reality of one disaster, monographic studies are usually done for an inquiry or in a lessons learnt study context.

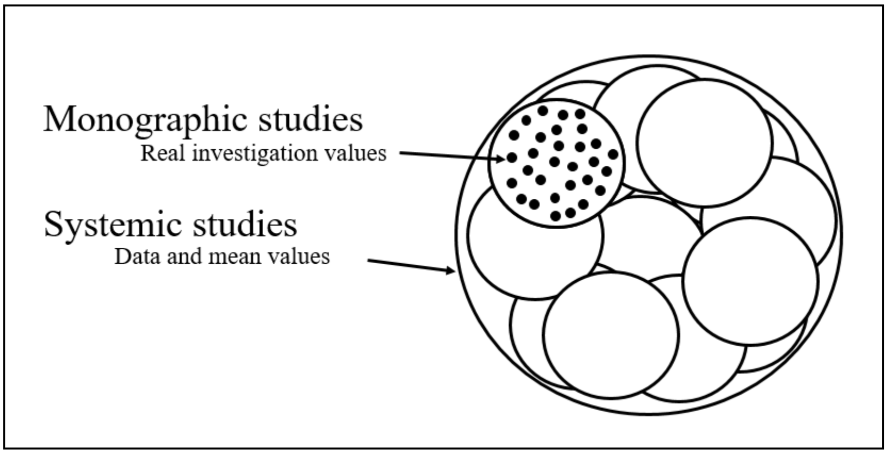

Figure 1: Monographic vs systemic studies

In such cases, fight costs are generally deduced to highlight a « net saved value » for the case. Ordinarily, as these study cases are uncommon operations, the saved value is very far from averages issued by our work.

On another hand, the model of systemic study proposed in this paper is relevant for all operations in the considered territory and the obtained outcomes are a « gross saved value », not integrating a deduction of fighting or supply costs of Fire departments. The fact is that this resulting amount is unavoidably compared to Fire departments (or agency in charge) budget. Deducing fighting costs would act in this case, as duplication.

These two levels of studying our problematic could be compared to microeconomic studies versus macroeconomic ones.

Saved lives case

Evaluating the value of a saved life or serious injuries avoided, allows, in comparison against Fire departments' annual budgets, to sketch a real benefits study of this emergency domain.

Working on this topic aims on answering to several questions:

a) How discriminate the saved lives, with adapted criteria?

b) How to provide a proper account of saved lives, for example in a city or a territory?

c) What is the common understanding in the given value to a (saved) live?

Criteria of evaluation

During our study we bore in mind the "counter factual hypothesis" supporting all our works: if Fire Department would have not existed, would the victims have died?

Furthermore we considered that, if first responders from fire departments mainly save from worsening of severe injuries, they sometimes clearly save lives. We identified a full range of cases where/when without responders actions, the situation would have end by fatality.

Mainly:

- When after CPR (cardiac pulmonary resuscitation) and/or electric choc, the victim is alive

- When, during a structure fire, trapped victims are rescued by fire departments ladders.
- When after car or transportation crashes, injured and trapped victims are extracted by fire fighters
- When in case of brain stroke, rapid intervention allows quick implementation of dedicated hospital treatment

Account of saved lives

Since neither fire department nor hospital is, in France, able to give an account of number of saved lives, we had to launch a very peculiar statistical methodology, using representative samples.

Each year, the studied fire department drives more than 120,000 emergency operations with its ambulances, representing 85% of the global number of missions.

To estimate the number of lives preserved, we have deeply analysed more than 4,000 interventions reports within two years (2019- 2020).

First, we asked to call center supervisors to fulfil a file estimating the daily toll of saved lives.

Then, each mission report has been individually and carefully reviewed (following previous cited criteria) to identify and count saved lives during the period, by some of the authors of the publication.

We also checked the representativeness of our samples, by using chi-square test (Chadli-Mauricio and Monet, 2020).

The outcome of this work : after finely studying two whole weeks of operations (one in 2019, one in 2020) we identified 51 saved lives during the periods, to be accounted for 4,521 health missions (ambulance interventions).

This gives a global ratio of 1.1% :
One week in 2019 with 2,369 health interventions: 28 lives saved → 1.18%
One week in 2020 with 2,152 health interventions: 23 lives saved → 1.07%
In two weeks, 51 lives saved represented 1.1% of health operations. In absence of a better approach we implement this result in all our simulations.

Value and outcomes

As we said previously, Bouches-du-Rhône fire department drives annually more than 120,000 health missions, 120,477 exactly in 2019, for a whole amount of 142,193 operations previous year (2019).

Considering:

n_v as number of saved lives yearly by the Fire department,

λ as experimentally estimated ratio,

U the annual number of health operations of Fire department,

in 2019 FD saves: (ratio) x (whole number of health missions):
$n_v = \lambda.U$
applied to BDRFD:
$n_v = 1.1\% \times 120{,}477$
$n_v = 1325$

But, what is the monetary value for each life saved? The organisation for economic co-operation and development (OECD) considers that the human life statistically represents 3 million euros, regardless age, gender and health following publications (OECD, 2012). So we directly calculate the whole saved value for lives (VS_l):

$VS_l = 3.10^6 \times n_v$
$VS_l = 3.10^6 \times 1{,}325$
$VS_l = 3{,}975.10^6$ €

Meaning that the saved lives in **2019 represent 3.9 billion euros**.

This very direct evaluation, allowed us to communicate and publish these values to our board of policy makers. This study shows the profitability of the service and traces pathway towards future mortality reduction.

Finally, we decided to study the costs benefit for the fire department missions. To refer previously cited values, we estimate that firefighters action have preserved 3.9 billion euros to the society in one year considering emergency intervention, in the Bouches-du-Rhône county, so each action value is evaluated at 32,993 euros. As the average cost of a health operation is about €1,000 in our department, we can say that any health operation would have a benefit of 32 times its cost.

Cost of health intervention ≈ € 1,000

"Benefits" of one health intervention = $3{,}975.10^{6}$ / 120,477 = € 32,993

To conclude, the main limitation to this type of study is the cultural reluctance to evoke monetization of life. Improvement could be a systematic accounting of saved lives in each operation report. Of course, we don't survey the victim's health status after arriving at the hospital, demonstrating that this study is to be consolidated, involving a multiagency model. Finally, this study is really important for our strategic and financial master plan.

Housing structure case

This chapter deals with housing value preserved due to the intervention of fire departments: How much do the FDs usually save during housing firefighting?

This analysis is less complex because prevention and firefighting are exclusive tasks of fire departments. On another point of view, fire missions represent 6% of operations. Additionally, unlike forest fires, structures fires only involve marketable values, which makes them easier to study. The data for housing is fully accessible in terms of losses (costs of furniture, paintings, decoration) and of course insurances play an important role, in founding robust data.

By avoiding total destruction of the building, fire departments interventions save some valuable parts of the structure, and we based our work on this very obvious equation:

Saved value = (initial structure value) – (losses value)

To solve it, we use national averages.

- Initial structure value: The structures value are given by housing market quotation (Compta et al., 2018). Of course we have strong variations across the French territory, but we choose to use national averages to be fully compliant to all fire departments requests. We will write vi_h, for this initial and total value of houses.
- Collective housing, as well, is documented by market and the National Statistics Office, based on the average number of apartments by building. We will write vi_a, for this initial and total value of apartments.
- To estimate damages, we use the French insurance federation data and we consider the average of compensation payments (i_h in the following) for houses and apartments fires as value of losses.

  So we state that:

  Saved value ≈ (initial house value) - (compensation indemnities)

  Let's call:

  vs_h the average of saved value for one house and

  vs_a the average of saved value for a single collective buiding.

  n the national average number of apartments in a collective housing

$vs_h = vi_h - i_h$

Introducingthe national value for these items:

$vs_h = 216.9 - 7.5 = 209.8$ k€

The first outcome of our methodology is: the **average saved value for individual housing is €209,000**.

Same calculation is done for collective housing

$vs_a = n \times vi_a - i_h$

$vs_a = 10.121.7 - 7.5$

$vs_a = 1210.3$ k€

The second outcome of our methodology is: the **average saved value for one collective building is € 1.2 million.**

Implementation into BDRFD study case

- 336 interventions on individual housing fire in 2019

  336 x €209,310 = **€ 70,328,160**
- 178 interventions on collective housing fire in 2019

  178 x €1,210,321 = **€ 215,437,138**

Ultimately, we demonstrate that this small fire department saves more than 280 million euros simply by tackling housing fire, more than the Bouches-du-Rhône Fire department annual budget (180 millions).

Some limitations of our model have to be enhanced. Some overestimation is possible because insurance compensations often don't totally cover the losses. On the other hand, we don't take into account indirect costs and values (like social cost, economic impact etc.). Of course, further studies are welcome to consolidate these findings. Eventually, these high amounts of money show the real reliability and profitability of Fire departments all over the world.

Forest fire case

The calculation of the value of spared losses in the case of forest fires is characterized by greater difficulty, because the forest represents mainly a non-market good, and this is one of the main problems studied in the following. In addition, the different values of use and non-use of non-market goods and their evaluation methods are explained in order to identify all the elements saved during interventions and which are to be valued. The objective is to explain an economic model for calculating the value of the saved in case of forest fires that can be applied to any other Fire Departments.

Talking about forests fires, implies having a wide command on fire behaviour, or at least expertise on it. Indeed, the development of a fire depends on many factors, peculiarly the properties of the fuel, the quantity of fuel, the ventilation, and also the location of the fire and the ambient conditions (temperature, wind, etc.)

In the absence of firefighters' intervention while the event of a forest fire, we would think that the damage curve continues to grow exponentially, and the fire could continue to increase ad infinitum. In the present study, we limited fire spread model to four hours, which is clearly some underestimation factor. But, for different reasons, we assumed that this hypothesis was more close to our (local) status.

In this aim, we use a model, based on national wild fire school courses, giving rapidly a potential endangered surface (Pastor et al, 2020)

For the construction of our model, in alignment of FAO forest definition (https://www.greenfacts.org/fr/glossaire/def/foret.htm), the studied perimeter encompasses only the forest massifs (as well as the 200m strip around them), which means that the fires of crops and natural spaces in the broad sense will not be taken into account. The study also incompasses the value saved at the interfaces of urban or industrial areas.

To value a non-market good like the forest, it is necessary to establish its values in advance. In this regard, a distinction is made between use value and non-use value.

Use value arises from the economic use of the asset. Moreover, the non-use value refers to non-instrumental values, not associated with a use on which we can directly give a price. In other words, they refer to social utility, that is, to the set of streams of benefits that individuals can derive from it.

In this regard, economists use the definition of Total Economic Value (TEV): theoretical concept aimed at providing an overall utilitarian measure of the economic value of a natural asset, supporting a plurality of interests.

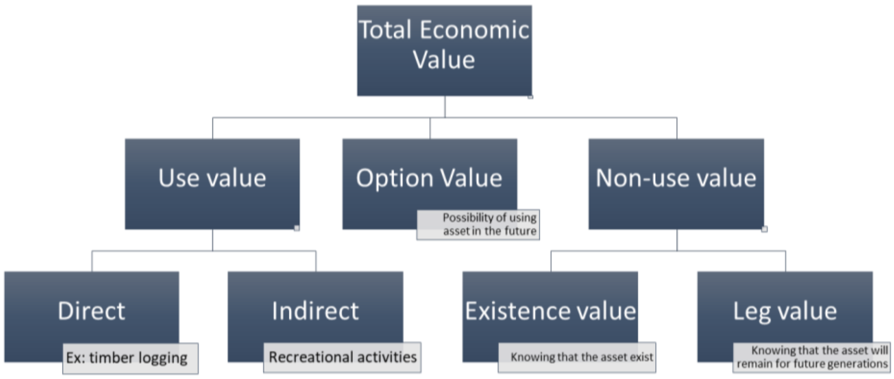

Figure 2: Total economic value

In other words, TEV is simply the sum of the use value and the non-use value.

Among the different valuation methods for non-market goods, there are two main ways:

- The revealed preference methods on the basis of which we deduce the value that individuals place on an asset which can be estimated from the observation of their behavior
- Stated preference methods by which individuals are directly asked about their preferences through questionnaires.

In our study, we used the revealed preference method, more precisely:

- The avoided costs method which consists in evaluating the costs that would have occurred in the absence of the existence of the environmental asset studied (in our case, among other things, for example the degradation of the air)
- The method of calculating travel costs making it possible to assess the environmental asset by calculating the amount that individuals are forced to pay in order to be able to use this asset.

However, we will also use the declared preference method using studies that have conducted real surveys to value certain goods and services (e.g. tourism).

Surface and wood

Among the first elements to be valued in forests, we spontaneously think of having a value per hectare. The latter varies depending on location, age, forest maturity, size, fire risk, potential or topography.

Regarding the number of hectares saved, they are represented by the difference between the part of the forest that could have burned (without the intervention of the firefighters) and the part actually burned.

The counterfactual hypothesis implies to evaluate clearly the saved from destruction surface. This has been done by deduction of real burned area from potential destructed surface (cf. figure 3 below), estimated through a model (Pastor et al, 2020).

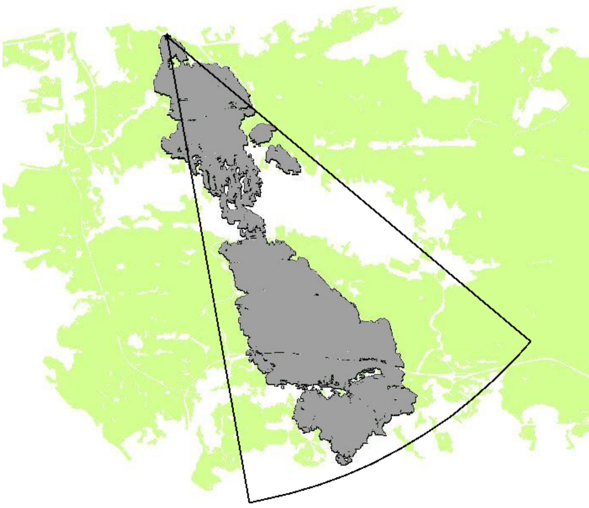

Figure 3: Estimation of spared surface

For the calculation of the value of the wood, we found more consistent to consider the density in cubic meters per hectare. Our research allowed to find this by the national forest service data, split state by state (in France, regions). So, we obtained the "average density" of wood in m^3 per hectare. This value will be multiplied by the number of hectares saved during forest fires as well as by the price of raw wood (μ), in order to determine the value of the wood saved thanks to the intervention of firefighters. According to the wood price indicator in 2017, the average price reached, μ, € 61 / m^3.

Tourism value

We assume that the tourism value of a natural space such as a forest exists if and only if the property is preserved. To quantify the tourist value, we refer to several studies which have carried out real surveys (data transfer method). Regarding the tourist value or the recreational value of the forest, a study carried out by AgroParisTech, INRA and BETA (Garcia and Jacob, 2009) shows the willingness to pay in the different French regions.

Rehabilitation cost

After a fire, the soil is weakened. In fact, to compensate for the damage, it is necessary to carry out rehabilitation work, to protect the soil from erosion, including the planting of trees. Here we are trying to quantify the value of saved by the fire services, so we are talking about the areas not damaged after the forest fires, that is, the areas which were threatened and which were protected by the firefighters and save the cost of rehabilitating this soils.

This cost must be included in the case of monographic studies, because it is to be accounted as an expenditure bound to destructed surface.

Existence, option, legacy value

Among the non-use values are the existence value, the leg value, and the option value.

The existence value represents the willingness to pay for the preservation (therefore the existence) of a good or a resource even without ever using it.

Option value refers to the use value given to the conservation of an asset for future use, direct or indirect.

The value of leg constitutes, unlike the value of existence, the willingness to pay of an individual for the preservation of a good or a resource with a view to its use by future generations. This is due to various factors such as the morality or altruism of the individuals to protect and keep a good to the following populations.

For their valuation in monetary terms, it is necessary to conduct surveys to question the populations on their preferences. Given the time constraints, we were not able to set up this type of investigation. For this reason, in our model there will be no representative figures for these values. This obviously underestimates the value of the saved.

The buildings

Once the number of houses n_h and apartments saved is known, we apply the results provided by Sdis 13 housing case study, in order to value them economically (cf. above, **Housing structure case**):

- The used national average saved value for a house will be € 216,905 (vi_h)
- The used national average value of an apartment will be € 121,791 (vi_a)

CO_2 and CO_2 sequestration

In our study, it is necessary to obtain equivalent tons of CO_2 from the volume of wood and from the soil.
CO_2 sequestration is of course a dynamic process interrelated to photosynthesis. In our study, we have to take in account the stationary storage of the involved forest.
And of course, it is linked with wood density. If for wood market evaluation we took in account living wood, in this case, death wood, humus and roots have to be added. Relevant data was found.
To calculate tons of carbon equivalents, we have to follow the process:

Figure 4: calculation of CO_2 equivalent

Bio volume is the wood quantity estimation by hectare in m^3. It refers to living wood, death wood, roots and humus. It's possible to convert it into biomass through density (also called infradensity) which varies with wood species, living or not living wood, and soil bio volume.
The calculation is obvious, even if each compartment has to be accounted separately. Considering
B: Biomass
V: Bio volume
d: density

$$B = Vxd$$

We found the data of aerial bio volume, death wood bio volume and some Biomass expansion factor to estimate the addition of soil biomass.
After having total Biomass it's possible to convert it in ton s of carbon that can be evaluated by carbonisation to dry matter. Some reports give a ratio of 0,475 to obtain the weight of carbon, and then it can be converted it into tons of equivalent carbon by using the ratio of C / CO_2 molar masses.
However, if this method is the more robust, we also have direct ratio given by national data (ADEME Agency), linking bio volume directly to tons of equivalent carbon.

As a full range of ratios is given, we have to account separately living wood (differentiated in hard and soft wood) and death wood (differentiated in soil deadwood and timber deadwood). All this wood is converted in tons of CO_2 (M_{CO2} in the following)
The used equation is, considering:
d_r (m^3/ha) is living softwood bio volume and 1.19 its related coefficient,
d_f (m^3/ha) is living hardwood bio volume and 1.90 its related coefficient,
d_{mp} (m^3/ha) is timber deadwood bio volume,
d_{ms} (m^3/ha) is ground deadwood bio volume and 1.54 the common applied coefficient for both,
H (ha) is the preserved surface.

$$M_{CO2} = H.[d_r.1{,}18 + d_f.1{,}90 + (d_{mp} + d_{ms}).1{,}54]$$

The following tab gathers the collected values in the pre-cited publications. It allow a regional (provincial) adaptation for each territory where, of course forest fuels density and values vary.

Régions	**d_f (m^3/ha)**	**d_r (m^3/ha)**	**Forest surface (km^2)**	**$d_f + d_r$ (m^3/ha)**	**d_{mp} (m^3/ha)**	**d_{ms} (m^3/ha)**	**Tourim value by visit (€)**	**Hunting and other products (€/ha)**
Ile de France	158	17,5	2744	175	5,35	12,5	10,78	13,89
Centre Val de Loire	147,5	41,5	8887	189	4,25	11,45	10,78	13,89
Bourgogne Franche Comté	155	63,5	16351	219	5,25	17,15	55,3	13,89
Normandie	160	41,5	3922	200	2,35	5,6	24,04	13,89
Hauts de France	167	18	3899	185	3,4	7,6	24,04	13,89
Grand Est	149	66	18113	215	5,95	24,5	55,3	13,89
Pays de la Loire	113,5	61	3137	174	5,2	8,5	24,04	13,89
Bretagne	126	78,5	3234	205	8,7	14,35	24,04	13,89
Nouvelle Aquitaine	83,5	64	27343	147	5,5	17,25	10,78	13,89
Occitaine	84	64	21911	148	8,25	11,9	33,55	13,89
Auvergne-Rhône-Alpes	88	136,5	22189	225	10,45	22,8	17,65	13,89
Provence-Alpes-Côte d'Azur	29	62,5	13417	91	5,55	9,6	20,37	13,89
Corse	66	162	4003	151	3,5	17,5	20,37	13,89

Figure 5: summary of used data

It's easy to find CO_2 emission market price[2], called p in the following equations. It allows us to give a value to the CO_2 which has not been emitted, by preservation,
That could be written $p. M_{CO2}$

In our model, an approximation was made to represent the remaining carbon after fire : we estimate that the carbon in the soil (humus + roots) is not released during forest fires.

Forest Products

With regard to the estimation of this type of product / service, the economic report published each year by the ONF provides us with key figures.

Eventually, the value equation is the following, considering:

[2] On the day of publication of the study, a share of the CO_2 emission was worth around € 26/t.

vs_f is the saved calculated value for a single forest fire,

vs_f = [(Value of wood) + (Value of sequestered CO_2) + (Value of buildings) + (Use value) + (Non-use value)]

$vs_f = [H.\mu.(d_r. + d_f)] + [p. M_{CO2}] + [n_h.vi_h] + [H.\text{hunting value}] + [\text{tourism value}]$

By applying its fire behaviour "model" method, Sdis 13 estimates for each fire the average surface area saved at 243 ha in 2017. Likewise, the buildings saved by disaster are evaluated at 23 individual houses by fire. Thus, by applying the regional parameters and the departmental averages to our formula and neglecting the existence value, leg value, option value), we obtain:

vs_f = [243.91.61] + [26.(62.1,18 + 29.1,90 + (5,5 + 9,6).1,54)] + [23.216 905] + [243.13,89] + 20.37

We therefore obtain:

vs_f = 7 298 343,82

We can therefore estimate that Sdis 13 in 2017 with its actions on 202 forest fires (ff) saved a value of:

VS = ff. vs_f

VS = 202.7,298,343

Or € 1,474,265,451.64

Forests performs important ecosystem services that meet, directly or indirectly, the need of human species and guarantee the life of other species.

Nevertheless, if this kind of evaluation is typically uncertain and not easy, authors demonstrated the real added value to do on large scale – at least provincial – with common ratios. And even if further studies are fully necessary, it constitutes a first step toward economy and ecology connection.

It's interesting to notice, that our methodology is fully convergent with the "socio economic damages of forest fire" published by the Join research center of EU commission, (Pettenella et al., 2010).

Conclusion

In evidence, this model is only the first move, into a series of studies, which could be managed in the future. It provides some elements to be discussed or simply locally adapted by data triage. It's only an approach of some key-values that has to be consolidated through different and further studies allowing use of the model, in different contexts and countries.

This evaluation practice has some virtues, especially targeting policy and decision makers who might have intentions to cut resources to emergency services. It also has an educational role for citizens, highlighting a given « value for taxes », and the profitability of public services.

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