Tree-oriented silviculture in an oak coppice

Estimation of financial profitability and possible public funding

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One of the actions planned by the Project Life + PProSpoT was dedicated to the evaluation of the financial feasibility of investments for the implementation of the silvicultural tree oriented in favour of the sporadic tree species. In this article we report the results of evaluations about a silvicultural model that provides for the implementation of a management system that combines the traditional silvicultural treatment and a tree-oriented sylvicolture in a coppice of oak in prevalence from 24 years of age.

Key words: LIFE+ PProSpoT Porject, protection of biodiversity sporadic species, tree oriented silvicolture, field data analysis, finacial analysis.

Tree-oriented sylvicolture allows the use of sporadic species within forest stands and may represent an actual improvement of forest production especially from the point of view of wood quality. Conceptually this forestry treatment is based on the selection and differentiation of target plants, or on the future value of logs without living branches on a portion of the stem that will represent about 25% of the final tree (Möller C.M. 1931, Bastien and Wilhelm 2003). After getting logs of future value, it aims to encourage the maximum diametric growth and finally we seek to encourage the maximum diametric growth.

The project aims to introduce the tree-oriented silviculture technique for the management and preservation, in a specific territory, of rare tree species, which are called sporadic species., and it provided for a specific action on the assessment of the financial feasibility of the investment necessary to change a coppice system to a mixed one that includes in some areas the three oriented silviculture. This action plan has been developed by the Department TESAF of the University of Padua and the Department GESAAF of the University of Florence with the task of analysing investments in high forests (TESAF) and coppice (GESAAF). In this paper it is reported an application case of tree oriented silviculture in an oak coppice in Tuscany, in the territory of the Colline Metallifere (GR) .

Application in a coppice

The adopted model (Mori *et al.*, 2007) takes into account a prevalence of oak coppice of 10 hectares, with a rotation of 24 years in which they identified 198 species of plants sporadic that will be utilized from the age of 72 years and treated with specific interventions every 8 years (payback time). The sporadic species considered are: cherry, pear, wild service tree, ash, maple, linden and elm. Forest tree oriented provides a transition period of settlement of 72 years (at which point we

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begin to cut the first species, with repetition every 8 years).

The variables that were taken into account to calculate the costs and revenues of the transition and final period in relation to the new management model are:

- identification and marking of sporadic species;
- assortment allocation of sporadic species;
- sales prices of the assortments of the sporadic species;
- average volume of the sporadic plants after n years;
- yield decrease of the standard treatment forest in relation to the selected sporadic species;
- costs of thinning in favour of the target plants (cutting and possible logging depending on compulsoriness and convenience);
- utilization costs of the forest without the project;
- prices of wood assortments obtainable from the forest without the project.

Before analysing the results of simulations that are related to the described model, we highlight the ways in which they were made and organized the technical surveys in forest with the aim to determining the timing and costs of forest operations.

Observation on the measured parameters

Data on the use of techniques to be adopted for the economic evaluation of tree-oriented sylvicolture, and the related costs, derive from both direct surveys in the demonstration areas of the Project PProSpoT and from the existing data in the literature. The data detected in the demonstration areas, in particular the capacity utilization, turned out to be particularly useful as the teams that operated the thinning on approximately 200 target plants in non-homogeneous areas, allowed to detect the utilization costs in very different silvicultural situations, as it actually happens frequently.

The non-homogeneity of the areas concerned the amount of wood used, the time of utilization and the cost per cubic meter.

Two groups of technical operators (of three people for each) have operated in demonstration areas, and the technical reliefs have concerned respectively 15 and 13 areas where were performed localized thinning in favour of a number of plants target between 3 and 9. In a subsequent step of the work it was possible to organize a database that contains, for each thinning carried around a single plant selected, the working time and the amount of timber used. These data made it possible to calculate the costs of utilization[1] for each area and for the amount of timber utilized (Table 1).

The two factors that mainly influence the cost of the intervention are related to downtime and travel time, while the utilization times are more comparable. These differences in the downtime and travel time are related to the localization of the identified plants and to the environmental factors that characterize the forest parcel on which to operate. The costs of utilization intervention for thinned area are divided into: travel cost, downtime cost, cutting cost. The average overall cost for thinning resulted to be equal to € 44,12. This datum has been used to express the economic convenience in relation to different models of tree-oriented sylvicolture.

The estimation of the minimum and maximum costs, broken down into their three components (travel, downtime and net time costs) allowed us to link these values to the different characteristics of the areas, where the work will be performed, in relation to their main characteristics (topography, practicability, forest structure, accessibility, distribution of sporadic plants) and to climatic conditions (cold days, rain, etc.). The different characteristics of the forest have been parameterized and correlated to the relative costs in order to obtain the total cost of thinning in a quick way and by simply inserting a limited number of explanatory variables related to the characteristics of the forest (Table 2).

As for what concerns the logging too, the data used in the simulations are the result of both the information collected in the demonstration areas and the literature. In relation to the specific characteristics of the environments under analysis, the logging to be used inside the coppice area is mule hauling lumber.

In this case too, the average minimum and maximum values can be used in relation to different land orography and to the condition/viability of the forest roads. The average cost adopted for thinned area around a single target plant was about of 16 € (Table 3).

The areas on which it was possible to perform demonstration activity have a high fer-

Statistical test	Shift time per area	Downtimes per area	Net time per area	Total
Min	**0.01.33**	0.03.20	0.39.13	
Max	0.13.34	0.30.00	1.03.17	
Media	0.04.55	0.12.13	0.52.40	
Standard deviation	0.03.09	0.04.07	0.06.59	
Median	0.04.17	0.12.09	0.52.56	
Cv	64%	34%	13%	
Min	€ 0,91	€ 1,95	€ 22,93	**€ 25,78**
Max	€ 7,93	€ 17,54	€ 36,99	**€ 62,46**
Average cost. € 44.12				

Table 1 - The main statistics for the utilization phases in the thinned areas (1 mst=0,6 tons).

***(1)** For a better definition of utilization costs we have consulted some specialized publications (Hippoliti, Piegai, 2000).*

tility per unit area, and a wood production almost double that which we consider the average of the forest of Tuscany. Also thinning were carried out on stands older than 40 years, while in the silvicultural models proposed in the project LIFE + PProspot is assumed to work in stands that most young people, aged between 8 and 40 years.

Therefore, in the demonstration areas described above wood production was about 1,14 t in the models used for financial simulations production depends on the year in which make the thinning.

It's correct to suppose that the production varies from a minimum to a maximum of 0,3 to 0,57 t per area, in the model proposed below, we have adopted an average production per area of 0,26 t. We have recalculated the utilization costs on the basis of a cost per ton of product timber, taking into account that a part of the cost is fixed and another is proportional to the amount used (see Table 4).

Economic Model adopted

The aim of this study is to provide an economic and financial evaluation of tree-oriented sylvicolture and, at the same time, indications on the impact that different variables (such as timber prices or silvicultural operations costs) may have to the results that could be achieved. The evaluations and the related simulations will be carried out using the technique based on the convenience evaluation of forest investments at market prices, including support systems, taxes and other money transfers (in other words, a financial analysis will be done, that is the first phase of the standard procedures for a Cost-Benefit Analysis). Thus, an estimation of the cash flows for the investment period has been done, considering, market prices. This option has the advantage of simulating the behaviours of the entrepreneurs (as forest owners for example) towards an investment, but it does not take into account all the positive externalities (such as improving biodiversity, etc.) and reducing the negative ones (such as decreasing the coppice area) that can be linked with tree-oriented sylvicolture in terms of the Cost-Benefit Analysis). For encouraging the development of sporadic species has been hypothesized to carry out localized thinning every 8 years and also at the final cut of the remaining plants (every 24 years). Furthermore, to facilitate the growth of sporadic species is necessary to release a sleeve of plants to protect the individual plants objective, at least until the growth of the plant is able to not be damaged due to sudden isolation coppicing.

The dimensions of this protective sleeve in terms of the surface must be equal to the projection of the crown at the end of the production cycle. From the 72th year onwards we will start to utilize also sporadic species of plants, with an interval of 24 years between utilization and the other, while up to this year will be carried out only interventions of marking and thinning aimed at increasing the sporadic species.

The use of coppice will continue both in the transitional period (from year 0-72 year) and in unlimited period of time (from 72th year onwards).

For this cultivation, has been built a model, an Excel file called VESA (Economic Evaluation of Tree-Oriented Sylvicolture), has been set up. The economic indicators used are the Net Present Value (NPV)(2), which refers to the start of the investment, and the Net Benefit (Value of soil and topsoil), was also used, since it allows us to express an opinion on the asset value of the investment (Andrighetto, Pettenella, 2013).

Economic results

The assumption has been to work on a coppice with stumpage value equal to 0 in order to understand whether the introduction of the model of forestry tree allows obtaining a financial benefit (Table 5).

The realized model allows us to verify whether or not the introduction of tree-oriented sylvicolture represents an advantage or a disadvantage for that coppice, depending on the increase or decrease in the income with the new management. The observed time period is 120 years, even though the situation at standard use starts from the year 72nd: by doing so, however, it is possible to evaluate the contribution given by the sporadic plants, which from that year can be regularly used. The economic indicator adopted for evaluating the convenience is the Net Present Value (NPV). In the case study the stumpage value of the coppice turns to be equal to 0 with a price of firewood of 0,5 €/t. If tree-oriented

Distribution of sporadic sporadic species in the forest parcel (€)		Optimization of time working (€)		Factors related to cutting (€)	
€ 0,91	Very dense	€ 1,95	Excellent	€ 22,93	Extremely simple
€ 1,54	Dense	€ 6,32	Good	€ 27,58	Simple
€ 3,61	Scattered	€ 7,52	Indifferent	€ 34,53	Difficult
€ 7,93	Very scattered	€ 17,54	Scarce	€ 36,99	Extremely difficult

Table 2 - Costs per thinned area in relation to the characteristics of the forest parcel.

	mst	€/mst	Euro per thinning area
Min	1,21	4,29	5,19
Max	2,83	13,01	36,82
Average	1,9	8,31	15,79

Table 3 - Logging cost per thinned area in the demonstration areas.

Costs	Cutting (€)	Logging (€)
Min	8	5
Max	20	7
Average	14	6

Table 4 - Costs of forest utilization.

***(2)** Values of the discount rate recommended by HM Treasury, 2011, The Green Book: Appraisal and Evaluation in Central Government.*

silviculture is introduced in this wood, then the NPV of the wood (the observed period is 120 years) will be negative (€ -226 per hectare). This means that keeping all the variables described in the data model as they are, tree-oriented silviculture does not bring an improvement in the profitability of the forest. This happens because the usable surface of coppice decreases due to the thinning for leave sufficient space for the development of sporadic tree species. As the surface taken away from coppice depends on the number of selected sporadic species and because their selection is done gradually (in 48 years), this surface keeps decreasing until it stabilizes when the forest reaches a steady state. The thinning, scheduled every 8 years to eliminate direct competitors, represents a cost because the value of timber is lower than the utilization costs. The contribution of the higher value given by the cutting of sporadic species chosen takes place after many years: in the case of this model it occurs after 72 years, when the cut of the first sporadic takes place, but, even if it is positive (in this case it is equal to 1.008 € / ha), it does not cover the costs of the transition period, given the price of firewood equal to 0,5 € / t, imposed at the beginning.

The above analysis can be easily observed looking at Graph 1, in which the trend between revenues and costs, referred to the time period of 120 years, is showed.

In the graph it is clear that throughout the transitional phase (from 0 to 72 years) costs are significantly higher than revenues and only from the cutting of the sporadic (72°, 96° and 120° year) discounted revenues are greater than the costs.

To better understand the role that tree-oriented silviculture can have on a stand like the one suggested, the prices of the sporadic species, the amount of timber from thinning and the volume of sporadic species at maturity have been modified. The price of firewood is kept equal to 0,5 €/t to avoid any influence related to the income that the coppice may provide before the introduction of the tree-oriented silviculture practice. We therefore performed a series of simulations with the intent to find the point of break-even point compared to the NPV and NB.

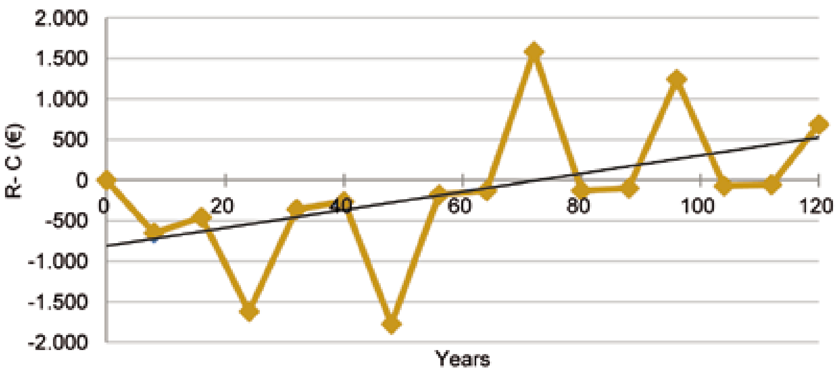
Thanks to this simulation (Table 6) it is possible to highlight that, despite tree-oriented silviculture once established provides a positive contribution to the income of the forest, it requires a long transformation period of the forest itself. The costs of this transformation, as noted above, result in a negative NPV. In order to reach a positive NPV it is necessary, as is clearly shown by the simulation (Table 6), a very high increase of the observed variables. For instance, the price of lumber of sporadic species should increase from 11% to 36%. The difference in the increase in value of the variable in relation to the chosen economic indicator is due to the fact that in the case of NPV the time considered period is 120 years, while in the case of Net Benefit it refers to a forest with unlimited duration. Obviously, from the point of view of the private entrepreneur, it is preferable to use a shorter time period, but the consequence of it is the convenience of the investment can be reached only relying on very high prices which, in the case of the model showed here, are at the time out of the market. This study used values of variables resulting from the surveys made

%	Species	€/m³	n/ha
34%	Cherry	340	6,6
18%	Pear, wild service tree	665	3,6
12%	Ash	340	2,4
12%	Maple	300	2,4
12%	Linden	225	2,4
12%	Elm	340	2,4
		Total	**19,8**

Silvicultural exploitation costs (€)	
Detection, sporadic marking (1 plant)	1
Stroke to the main competitors (1 plant)	5
Localized thinning per sporadic plant (1 plant)	14
Delimitation protection area per sporadic plant (1 plant)	5
Logging, thinning /plant	6
Exploitation of coppice (ha)	5.000
Mandatory logging Yes/No	no

Silvicultural data	Measures	
Percentage of sporadic plants usable for the production of timber	90	%
Percentage of sporadic plants NOT usable for the production of timber	10	%
Firewood from the exploitation of coppice (ha)	1.000	t
Firewood obtainable from coppice with tree-oriented silviculture in respect to the hypothesis without the project	da 78 a 93	%
Tons of firewood from the thinning of sporadic plants	2,6	t
Average usable volume from cherry	1,2	m³
Average usable volume from pear, wild service tree	1,1	m³
Average usable volume from other sporadic plants	0,9	m³

Table 5 - Technical parameters considered in the simulations.



Graph 1 - Trend between discounted revenues and costs (euro).

Ipotesi	Tree-oriented silviculture on coppice	
	NPV (€)	NB (€)
a) Increase in the price of sporadic species 36%	0	223
b) Increase in the price of sporadic species 11%	-156	0
c) Increase in the wood from thinning 51%	0	156
d) Increase in the wood from thinning 20%	-138	0
e) Increase in the volume of sporadic species 35%	0	223
f) Increase in the volume of sporadic species 11%	-156	0

Table 6 - Break-even point as a function of the parameters of the study.

(3) The rate of interest used in the simulations is decreasing over time and varies between 3.5% and 2.5% (HM Treasury.
(4) For the transitional period (transitory stands) is considered the time necessary to have sporadic species mature.

BOX 1 - SOME CONSIDERATIONS ABOUT PUBLIC INCENTIVES FOR THE TREE ORIENTED SILVICOLTURE

(Davide Pettenella e Nicola Andrighetto - Dipartimento TESAF dell'Università degli Studi di Padova)

The instruments of public incentives that can be adopted, such as the forestry measures of the rural development programme, must necessarily take into account some factors that characterize the tree oriented silvicolture.
The first element to consider is that this technique can provide, at economic and ecological level, satisfactory results only in the case of vigorous plants.
For this reason, any public incentives should be linked with the assurance that the operations financed involving only plants in area where the sporadic species are able to achieve a significant size.
The second element to consider is that the tree oriented silvicolture requires the activity of a technician forest for the initial target plants recognition (species, minimum distances and potential development) and for the identification of following operations.

Then at the operational level, it's possible assume **two types of public incentives:**

- **initial for the operations necessary to tree oriented silvicolture introduction, as the forest technician cost** for the target plants identification (numbering and georeferencing) and for making the scientific report to motivate the choice and indicate the environmental targets that it's possible achieve in the area due to the tree oriented silvicolture;
- **at management level for the single localized thinning**. This operation has to consider:
  - the cost to mark the competitors and to fulfill the documentary procedure to obtain the funds (technical forestry);
  - the cost for felling of competitors (**forest company**);
  - the economic incentives for owner to start this innovative selvicoltural technique

Translating in numbers these figures is not certainly easy, since the different factors that can affect the costs of localized thinning, as the physical **characteristics of the area** (slope or ease of access), the **age** of the target plants and the type of direct competitors that has to be eliminated.
So one of the first steps to do for making effective and credible the incentive system is the estimate of individual thinning cost in different situation developing a specific price list available for operators.
The funding body has to consider also the system to monitor the results, given the timing concerning the tree oriented silvicolture.
As noted in some of the documents produced in action 7 of PProSpoT project, the economic incentives should occur during the **transitional period**, which is the phase necessary to ensure that tree oriented silvicolture becomes operative and it is the period when, for the owners, the costs exceed the revenues.
Since, however, that such period may be significantly longer (up to 120 years) than the duration of financial instruments, it's necessary to adopt a public incentives based to a specific silvicoltural plan.
It should however be taken into account that if on one hand the funding body would be ensured by duty of user to comply with this detailed plan of management for a period which consider a number significant of years (eg 48, 72 or more), the other it is realistic to think that any entrepreneur would interested in funding plan that constraints him, and even his heirs, for such a long time.
So long selvicoltural plan would risk to make vain the hypothetical measure to finance these projects. However it's possible to require compliance with **certain conditions in the period between the year of the first operation financed and the following one** (average 6-8 years).
In addition, for the private owners, it can be assumed that the main input to start the tree oriented silvicolture is the perspective to obtain a significant profit through the sale of timber from target plants.

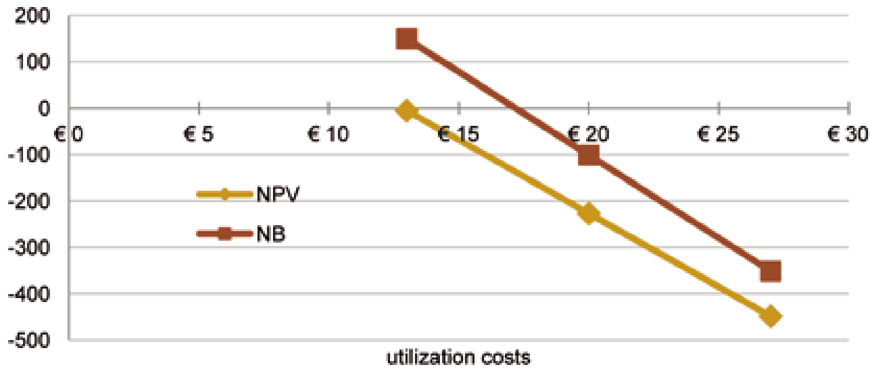
For this reason it is necessary to ensure that when the diameter exceed a certain diameter, it is possible to proceed to the cutting of target trees with no other constraints.

The tools of public funding for their implementation require standardized procedures. This standardization is not easy to link with tree oriented silvicolture that is based on the characteristics of specific plants, where specific ecological and environmental factors play an important role and requires very long period for an economic return.
In the context of LIFE + Project PProSpoT we have tried to provide some element to support the preparation of financing measures. The limited number of experiences and especially the variety of cases it is certainly not easy to find the correct system for a possible funding, although it could be very important to activate this system in the occasion the next rural development program 2014-2020.

or from the analysis of existing literature. These values are however showing a wide variation, so it might be interesting to repeat the simulations considering different the values for timber from thinning, for the surface taken away from coppice due to the thinning and for the utilization costs. Starting from the first case (i.e. increase in the amount of wood obtainable from the thinning in favour of the target plants), if the value of production moves from 0,26 t per thinned area to 0,5 t, then the values of NPV or NB equal to zero are obtained with much more modest variations in both price of the sporadic plants and increase in their volume. This increase in production occurs using the information on standard deviation derived from the surveys carried out in the demonstration areas. In particular, it is possible to notice that to get a Net Benefit equal to 0 is enough an increase of sporadic species price of about 3% or an increase of their volume of the same extent (Table 7). If, instead, NPV is used as the economic indicator, the increase must be equal to 27% for both cases. In such a situation, i.e. with a higher production of timber from thinned areas, the cost of the transition phase is markedly reduced, since the utilization costs remain unchanged, while the revenues increase significantly.
In the latter case, the decrease in the costs of cutting and logging was considered. The wide variability in the values recorded during the experimentation in sample plots is linked to at least three factors: orography of the area, distribution of the identified sporadic plant species within the area selected for intervention, efficiency of the team assigned to the operations of utilization. Thus, the minimum and maximum values shown in Table 4 represent the extremes of the conditions in which we are going to operate; the minimum values represent the best conditions of the forest (good orographic conditions, excellent distribution of selected sporadic plants, team's efficiency), while, on the contrary, the maximum values are expressions of the most difficult conditions of this forest area.
Considering instead the cost of cutting and logging different from the average used in previous simulations, the results show an explicit variation (Graph 2). Were compared and the values of the NPV of the NB in relation to the minimum, average and maximum the cost of utilization as we can see in Table 4. If we take the lowest values of the cost of the logging we would have a NPV and NB value between - 5 € and 150 €/ha.
Under these conditions, and still keeping a price of firewood so as to obtain a stumpage value of the coppice equal to 0, the introduction of tree-oriented silviculture would play a positive role from the outset, being the values of Net Benefit no negative. In such a situation, tree-oriented silviculture could also improve the profitability of those forests currently characterized by a negative stumpage. Within this simulation, the decrease in the utilization costs would allow for the achievement of non-negative Net Benefit, even with a price of firewood lower than the originally set, being respectively equal to € 4,85.
The assumptions tested showed that the convenience to take a model of tree oriented sylvicolture in favour of sporadic tree species occur only in certain conditions, even in the case where the income in phase of maturity of a forest was positive.
Given that this forestry offers a real possibility in the preservation of sporadic species, impacting heavily on environmental biodiversity, it would be appropriate to pay charges designed to cover the costs of transition. Contributions should be bound to the presentation of a project in which it is shown that once the transitional phase has finished that management model can produce positive

Hypotheses	Tree-oriented silviculture on coppice	
	NPV (€)	NB (€)
a) Increase in the price of sporadic species 27 %	0	207
b) Increase in the price of sporadic species 3 %	-145	0
c) Increase in the volume of sporadic species 26 %	0	207
d)) Increase in the volume of sporadic species 3 %	-145	0

Table 7 - Break-even point as a function of the parameters of the study. Thinned amount of wood equal to 0,5 t.



Graph 2 - NPV and NB trend considering variations in the utilization costs.

income.

Furthermore, given the results of model, in which it is highlighted that the contribution of tree-oriented silviculture does not increase the profitability of the forest due to a transition period characterized by negative incomes, the role of Public Administration could be decisive since it could allow both the financing of the transition period and the increase in the value of the forest, which would remain such for an unlimited period of time. It could be thought of giving a support for each sporadic species kept in the stand during the transition period (Box 1). The level of the support could start from a minimum value which allows for reaching a positive NPV and Net Benefit.

In the case study, since the aim is to bring to maturity 20 trees per hectare, the contribution should be paid for plant. The value to be paid, given the variables used in the simulation, would amount to 4,22 € per tree. Assuming provide incentives only in the transitional period of the intervention (72 years), the funding should be granted every 8 years is 83,60 €/ha, with a total cost for the transitional period of 501,60 €/ha. It is important to highlight that this amount leads to a break-even point that is not certainly enough to encourage this type of sylvicolture. It is therefore necessary to encourage economic policy measures in favour of this type of forest management and to identify a level of contribution capable of encouraging the farmers to implement this different system.

As a final point, it is worth pointing out that the introduction of 198 plants in 10 hectare in this model is just a pure example. Since the model is perfectly linear (all the values identified are directly proportional to the number of sporadic species), the assumption of selecting a greater or lesser number of sporadic species would not result in any changes in the break-even point (i.e. the results for which our indicators are equal 0); the absolute values in relation to the number of sporadic species used do, instead, change proportionally, positively or negatively. This means that as soon as the sporadic species begin to give profitability, each additional plant will proportionally increase the economic convenience of the investment.

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