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Chapter

Operative Machinery Costs Analysis within Forest Management Implementation Frame

Francesco Carbone and Rodolfo Picchio

Abstract

Forest management affecting most of the world's forests is based on the implementation of forestry interventions. Their execution requires preliminary preparation based on technical documents, submission of the administrative procedures, and the execution of the forest harvesting. Market value of wood is achieved by determining the most probable transformation value. It is obtained as the difference of the revenues derived from the sale of marketable timber net of all the costs involved in transforming the tree into salable products. The chapter provides a theoretical framework of the evaluation approaches and the calculation methods of the timber value, considering the different forms of assignment of the forestry intervention to the logging company, as well as the types of ground and the types of product achievable based on the level of mechanization.

Keywords: legal aspects, transformation process steps, types of costs, stumpage value, entrusting approach

1. Introduction

Forests cover about 4.0 billion hectares in the world. All decisions and/or actions adopted in order to preserve, to conserve, and to harvest forests and trees within them Bettinger et al. [1] Grebner et al. [2] are expression of the forest management. It is also defined as a tool that forest-owners use to achieve social, economic, and environmental targets or also to implement sustainable forest management. Two of the following approaches characterize forest management:

- Monitoring approach, through observation, monitoring, elaboration data, and e-reporting of forest ecosystem state

- Technologic approach, through machines, tools, materials, and forest workers

The first approach concerns primary forest area, while the second is adopted in modified forests, planted forests, and other areas with trees that consist of 2.7 billion hectares (**Figure 1**) of the global forest area. For the modified forests, one of the most relevant actions is stand management. This management is
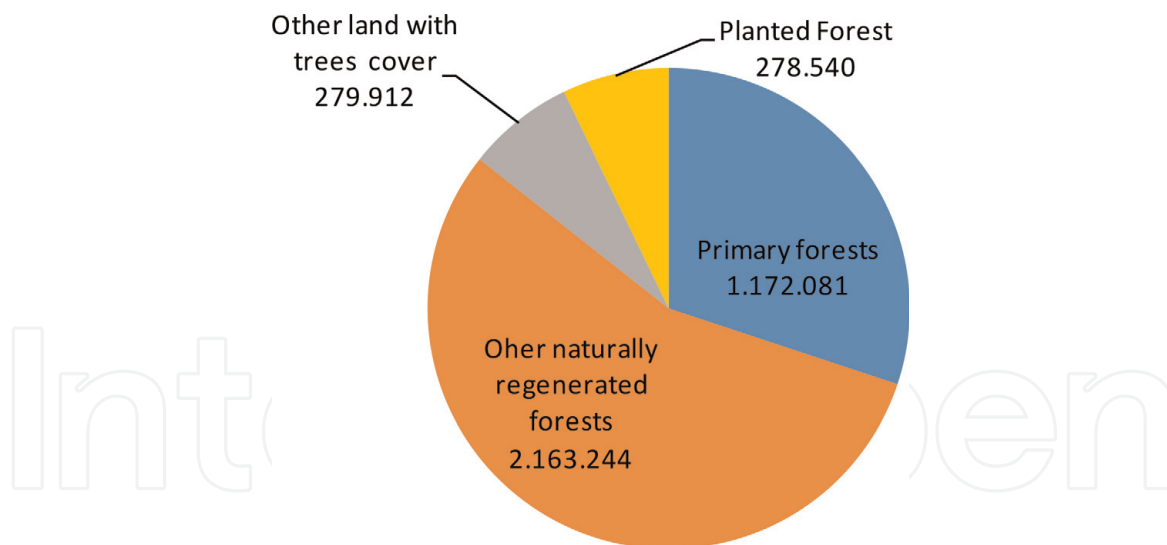
Figure 1.
The 4.0 billion hectares of forest area in the world articulated for anthropization categories (data × 1000 hectares). Source: FAO (2015).

- necessary, given the alteration (structural and compositional) these ecosystems have recorded over the centuries due to human activities;

- functional, to ensure the ecosystem perpetuity and guarantee overtime forest ecosystem services that influence the well-being of the humankind; and

- appropriate, in order to increase the resilient capacity of ecosystems currently under strong pressure due to socio-economic activities, climate change, and other global and local disturbance processes.

This action satisfies the aims of both forest landowners (FLOs) and logging companies (LCs). Using silvicultural criteria and proper manners, FLOs quantify the intervention in order to ensure the perpetuity of ecosystem (long-term vision) given by the forest's natural renovation capacity. LCs' point of view concerns the wood fraction exploitable (stand removal), which is the main output in timber transformation chains (short-term view). In the sustainable economic development policy, forests assume relevant roles [3]. That can be shortly explained as follows:

- Wood is a renewable natural resource.

- Timber is the main tangible output compared to other nontimber products.

- Timber in itself is an ecosystem service provider that provides bio-based resources and also biomass for clean energy production.

- Forest ecosystems guarantee regulative ecosystem services related to climate change contrast strategies and other global degradation processes.

- Forest ecosystems are areas where individuals or groups can live important social and sensorial experiences and increase their knowledge on natural life processes.
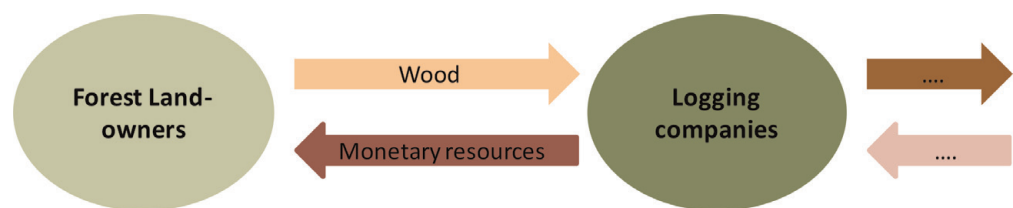
Figure 2.
Relationship between forest land owners and logging companies. Source: Our elaboration.

Using the Italian forest system as background, this topic has been developed in order to provide an international dimension.

A complementary relation exists between FLOs and LCs (**Figure 2**). FLOs are responsible overtime for the stand management. Silvicultural managements implemented during forest lifetime have influence on timber and nontimber products. However, FLOs normally do not have resources and knowledge to implement silvicultural management by themselves and sell timber products. The high investments needed for achieving an efficient and technological mechanization level, from an economic and financial point of view, would not be justified if the FLOs manage periodically small forest area, as the majority of FLOs in Europe. According to these evidences, FLOs entrust this job to specialized units, such as LCs, which have machines, technologies, materials, and workers with the knowledge of timber transformation process. Finally, LCs have proper knowledge to achieve the highest market price, given the market situation and the current economic trends.

Wood	It is the hard, fibrous, and structural tissues, composed of chains of cellulose, which forms the main substance of the trunk, branches, and roots of trees or shrubs.
Timber	It is the term to identify products obtained from the trunk, branches, and roofs of trees, at any stage after the tree has been felled. It includes the raw material, also known as rough timber or the processed material, used for construction, as firewood, and as other bio-based products.
Price	It is the amount of money that a buyer and a seller agree at the end of a negotiation to exchange between goods for money. In particular, there are a buyer willingness to pay and a seller willingness to accept in order to exchange the property right of goods and services. That information is collected specifically from the market.
Value	It is an amount (or datum) expressed in monetary metric, produced by experts or single individuals, using simple or complex elaborations, with the support of higher or lower technologies. Given a market price if it was subjected to any elaboration, example timber market price (€) multiply by quality (ton), the result is a value [€ × ton].
Forest management	It is all decisions and/or actions adopted in order to preserve, conserve, and use forests and trees within them.
Stand management	It is all decisions and/or actions related to the stand.
Silviculture management	It is the mode by which forest management is implemented.
Forest utilization	It is the action usually developed from the LC. Selected trees are felled and processed to obtain marketable timber.

Table 1.
Glossary of the terms used in the chapter.

Regardless of how stand management is entrusted to LCs, one of the mandatory steps is to determine the related costs. In dedicated literature [4–6], this topic is solved considering the operative cost only. However, differences exist between the type of costs and the calculation method, while transaction and overhead costs and revenues are not considered at all.

In the 1990s, the reducing impact logging (RIL) technique [7, 8] was introduced in the tropical region. It was defined as an "Intensively planned and carefully controlled implementation of harvesting operations to minimise the impact on forest stands and soils, usually in individual tree selection cutting" [9, 10]. The main idea was to adopt a more rational and structured method for forest exploitation. So far, new transaction and overhead cost were introduced in the forest management. More recently, according to the social and environmental relevance of forests, in many countries, forest management is strongly influenced by decisions of forest institution. The main institutions concern the: (a) introduction of forestry and environmental laws and rules; (b) introduction of administrative procedures for safeguarding forest public interest; (c) definition of roles and responsibilities for the economic subjects involved in the transformation process; and (d) redaction of the accidental risks and promotion of high health standards to forest workers.

The main assumptions adopted in the contribution concern economic subjects, operators, and capitals (workers, machines, material, etc.) involved in the transformation processes. Each of them must be paid for the performances provided. Technical and legal aspects are presented as background, while the core is based on the introduction of transformation steps, from being trees of the forest ecosystem to becoming market products. Timber production is one of the ecosystem services of forest ecosystems. Using the analytical approach, costs and revenue have been identified for each technical centrum of expenditure. Dedicated presentation and information have been provided on calculation method and data sources; however, in **Table 1**, a glossary of the main controversial terms has been developed.

2. Legal and technical aspects

2.1 Legal aspects

2.1.1 Public interest on forest ecosystems

Forests provide a large spectrum of ecosystem services that produce well-being to the humanity. Consequently, many institutions currently put silvicultural management under laws and regulations discipline. The target of institutions and administrative proceedings is to safeguard the public interest on forest ecosystems [11].

The following are the two main consequences:

- Introduction of administrative procedures, at the end of which the FLOs obtain the right to perform the silvicultural intervention

- Introduction of transaction costs to prepare the technical documentation necessary to satisfy the administrative process

2.1.2 Entrustment of the silvicultural intervention

Utilization intervention can take place under the regime of the following:

- Sale: with which the property transfers to the LCs the property rights of the forest stand destined to be felled

- Contract: with which the FLOs entrust through the acquisition of LC services, the forest harvesting operations, while they maintain the timber ownership

- Economy: where the FLOs, in particular the public ones, decide to carry out the work in-house, using the own property, in particular machinery, other tools, and forest workers enrolled

Regardless of the regime, the entrustment can be done in terms of the following:

- Purchase all timber at fixed price: LC undertakes to carry out the intervention at the agreed and invariable price respecting the identified unit and following technical indications from the project and the subsequent notes of the competent institutions.

- Based on a fixed price for unit: regime that requires the commitment by the property to pay the intervention at the fixed price per unit (usually volume or area), as well as the commitment by the company to quantify ex-post the volume or the area.

- Mixed, partly defined at fixed price, and partly on the fixed price for unit.

- These aspects are usually clearly stated in the contract. Further mutual fundamental obligations are:

- for the FLOs: to certify that they have fulfilled all procedures necessary to obtain the authorization to carry out the silvicultural intervention and all provisions have been transposed in area (boundaries of the forest area under management have been marked, trees that shall be fell are also marked, etc.). Documents produced and received must be available to the LCs, which will be used at the end for monitoring the correctness of developed activity; and

- for the LCs: to be aware of the territorial unit where they must operate, the characteristics of the stand and the area, as well as the nature of the silvicultural intervention to be implemented. The LCs certify to be fully aware of the technical and technological complexity level of the silvicultural intervention, to be aware of the appropriate methods to carry it out, as well as to have availability of equipment, workers, and materials necessary for its execution in due time.

2.2 Technical aspects

Evaluation processes require relevant technical information such as: (a) the forest areas in which the stand involved in the management activity is located; (b) the timber volume that should be felled; and (c) the type of marketable products that could be obtained.

2.2.1 Entity of the volume removal

If the stand of volume, silvicultural intervention, and felled timber are expressed in cubic meter, among them, the following relation subsists:

$$\text{SoV} = \text{SI} + \text{TH}$$

And solved for SI, it becomes

$$\text{SI} = \text{SoV} - \text{TH}$$

where [*SoV*] is the volume of stand invested in the ground until cutting intervention starts; [*SI*] is the volume of trees left in the ground at the end of the harvesting process; and [*TH*] is the volume of the trees felled and transformed in market goods from the LCs. Silvicultural intervention is indirectly obtained by felling wood volume in excess, given the adopted forest management system. In other words, it is the result of the forest left in the ground after the trees cut by LCs are already in the market. The function is always verified at the time that felling activity starts.

Silviculture proposes different management methods, in relation to the auto-ecology of the species and forest community, as well as the land characteristics, forest state and type of the previous management, objectives pursued, and infrastructures. The characteristics of each intervention are defined in terms of the following:

- Volume of the stems that must be released

- Characteristics of the trees to be released with respect to the horizontal (territorial distribution) and vertical (stand stratigraphy) plane

- Characteristics of the trees to be released for environmental needs, biodiversity, and other nonproductive functions

Given the total volume that insists in the area just before felling activity starts, the magnitude of the intervention can be quantified in terms of volume to be withdrawn $\pi = \left[\frac{TH}{STM}\right]$ or to be released $\rho = \left[\frac{SI}{STM}\right]$.

Magnitude of treatment	Mechanization level	Workers' qualification	Productiveness	Monetary results		
				Costs	Revenue	Budget performance
Slight	Low	Low skill	Low	High	Low	Negative
	Intermediate	Medium skill	Moderate	Moderate—high	Low	Negative—variable
Moderate	Intermediate	Medium skill	Moderate—high	Moderate	Medium—good	Positive
	Advanced	Skill	High	Moderate—high	Variable results	Variable
Effective	Advanced	Skill	Very high	Moderate—low	Substantial	Positive
	Intense	High skill	High	Moderate	Medium—good	Variable
Intensive	Intense	High skill	Very high	Low	Substantial	Positive

Source: our elaboration [12, 15].

Table 2.
Orienting economic results for treatment magnitude types.

Intense	**High-tech advanced machines, developed for forest works, capable of performing combined operations (e g., felling-processing, or extraction-processing or bunching-extraction-transport) for the final assortment production.**	
Harvester + Forwarder		
Labor career	10 years	10 years
Productivity	25–80 m^3/h felling and processing	20–90 m^3/h extraction-transport
Market price (VAT excluding)	360,000–600,000 € per harvester	130,000–380,000 € per forwarder
Operative cost	Harvester 2.2–8.5 €/t	Forwarder 15.0–42.0 €/t
Sources	[13–15]	[13–16]
Cable yarder + processor + chipper on forwarder		
Labor career	10 years	10 years
Productivity	6.2–9.95 m^3/h bunching, extraction, and processing by cable yarding and processor	8.0–55.5 m^3/h bunching, extraction, and chipping by forwarder with chipper
Market price (VAT excluding)	150,000–295,000.00 € Cable yarder and processor	180,000–420,000 € per forwarder with chipper

Intense	**High-tech advanced machines, developed for forest works, capable of performing combined operations (e g., felling-processing, or extraction-processing or bunching-extraction-transport) for the final assortment production.**	
Operative cost	Cable yarder and processor 19.00–57.00 €/t	Forwarder with chipper 4.0–16.0 €/t
Sources	[13–16]	[13–17]
Chainsaw		
Labor career	2.5 years	
Productivity	0.5–4.0 m^3/h felling and processing	
Market price (VAT excluding)	750–2000 € per chainsaw	
Operative cost	Chainsaw 6.5–28.0 €/t	
Sources	[13–16, 18, 20]	

Table 3.
Level of mechanization applied in the forest yard: intense. Chainsaw is the machine common in all the levels, but reported only in this table, in order to limit the repetition.

Description	**Technologically advanced machines, developed for forest works, capable of performing single operations (e g., felling or extraction or processing)**	
Skidder + forest crane or winch		
Labor career	10 years	
Productivity	Skidder equipped with dual arch grapple or winch 3.5–8.5 t/h)	
Market price (VAT excluding)	150,000–330,000.00 € skidder with forestry equipment	
Operative cost	Skidder with forestry equipment 5.6–18.50 €/t	
Sources	[13–16]	
Cable yarder + chipper		
Labor career	10 years	10 years
Productivity	Cable yarder 0.8–5.5 t/h	15.0–65.5 m^3/h movement, load, and chipping
Market price (VAT excluding)	15,000–180,000 € cable yarder	80,000–260,000 € per chipper
Operative cost	Cable yarder 3.5–19.50 €/t	Chipper 3.0–15.5 €/t
Sources	[13–16]	[13–17]

Table 4.
Level of mechanization applied in the forest yard: advanced.

Basing on the size of the withdrawal, it is possible to have a qualitative indication of the intervention and consequently an estimation of expected revenue (**Table 2**). Minor interventions, refereed to particularly small volume withdrawals, don't need a high mechanization level, which determines the growing employment of workers and a modest productivity. The unit costs of the intervention are high, if compared to constant revenues, with a negative balance. Interventions with higher withdrawals allow the use of higher levels of mechanization, lower use of labor, and consequently greater productivity. These conditions lead to a growing budget balance.

2.2.2 Types of forestry yard

There are different types of forestry yard. The first classification is based on 4 mechanization levels (**Tables 3, 4, 5**, and **6**). The former is characterized by high

	Low-tech advanced machines, developed for rural works, with forestry equipment, capable of performing single operations (e g., felling or extraction or processing)	
Rural tractor with forest winch + forest trailer		
Labor career	12 years	12 years
Productivity	Rural tractor with forest winch 1.5–5.0 t/h	Rural tractor with forest trailer 2.2–7.0 t/h
Market price (VAT excluding)	40,000–100,000 € (rural tractor with forest winch)	50,000–120,000 € rural tractor with forest trailer
Operative cost	Rural tractor with forest winch 10.5–26.5 €/t	Rural tractor with forest trailer 9.5–25.0 €/t
Sources	[13–16, 18]	[13–17]
Rural tractor with bins + rural tractor with chipper		

	Low-tech advanced machines, developed for rural works, with forestry equipment, capable of performing single operations (e g., felling or extraction or processing)	
Labor career	12 years	10 years
Productivity	Rural tractor with bins 1.5–5.5 t/h	Rural tractor with chipper 1.0–15.0 t/h
Market price (VAT excluding)	35,000–75,000 € rural tractor with bins	55,000–145,000 € rural tractor with chipper
Operative cost	Rural tractor with bins 7.0–16.0 €/t	Rural tractor with chipper 12.0–36.0 €/t
Sources	[13–16, 18]	[13–15, 17, 19]

Table 5.
Level of mechanization applied in the forest yard: intermediate.

Description	Low technologies and trained animals	
Chainsaw + mules		
Labor career	2.5 years	18 years
Productivity	0.5–4.0 m^3/h felling and processing	Team of 5–7 mules 1.0–5.5 t/h
Market price (VAT excluding)	750–2000 € per chainsaw	8000–16,000 € team of 5–7 mules
Operative cost	Chainsaw 6.5–28.0 €/t	Team of 5–7 mules 15.0–35.0 €/t
Sources	[13–16, 18, 20]	[13–15, 18, 19]
Horses (TPRs)		
Labor career		
Productivity	Skidding extraction with TPR horse 0.7–3.5 t/h	
Market price (VAT excluding)	1500–6000 € per TPR horse	
Operative cost	Skidding extraction with TPR horse 16.5–22.5 €/t	
Sources	[14, 20]	

Table 6.
Level of mechanization applied in the forest yard: low.

investments and high productivity, with decreasing average costs by increasing processed volumes (intense – **Table 3**); the lower mechanization level is characterized by increasing operating costs by decreasing productivity of processes and work (low or based on animal power—**Table 6**). Other mechanization levels are advanced (**Table 4**) and intense (**Table 5**).

The second classification can be based on the type of productions in the forest (or productions at the felling site). There are four logging system classes (**Tables 7, 8, 9**, and **10**), such as the following:

- Full tree logging system (Whole tree harvesting system) (**Table 7**)

- Tree length logging system (**Table 8**)

First timber products	**Final timber production**
Images	Timber
	Chips
	Firewood

Table 7.
Logging systems: Extraction of full trees (TLS) (branch and top).

- Intermediate (mix) logging system (**Table 9**)

- Short wood logging system (**Table 10**)

Each type of forestry yard is characterized by different cost dynamics:

- Cost for activity in forest: decreasing costs by reducing the work for each tree

- Cost for bunching-extraction: increasing costs by increasing number of logs to be bunched to achieve that volume to make extraction efficient and economically convenient

First timber products	Final assortment
Images	Timber for construction use

Logs at landing site	Timber for minor use

Table 8.
Logging system: Tree length (TLS). Extraction of full stem.

Image	Final timber products
Full stand cross cutting to multiple market assortments	Timber

Table 9.
Logging system: Intermediate system: Tree length/short wood (cut to length CTL). Extraction full stand cross cutting to multiple market assortments.

Image	
	Fuelwood
	Chips

Table 10.
Short wood system (SWS): Wood processed in final assortment in forest.

3. Costs and revenue in the transformation process

3.1 Transformation process

The term "transformation process" refers to the whole process to get stand transformed in row timber material and allocated in the landing, in order to be sold. This process includes all actions that should be done by

- the forest owner, directly by it or indirectly through performance of forest consultant, as in majority of cases and

- the logging company, who develops the technological cycle.

The starting point is the decision assumed by the forest owner to perform silvicultural intervention, while the end is when final monitoring of LCs' activity is done and certification of the results is presented. This process is articulated in four steps, which are as follows:

- Preliminary: aimed to acquire the permit for the silvicultural intervention to be executed.

- Preparatory: which includes (a) the operations to transpose in the forest, the planning, and the administrative provisions; (b) the assignment of the work to an LC; and (c) the signing of the contract between FLO and LC.

Type of costs			Description		Calculation	Details
Land	Structure	Fixed costs	Fee for recovery and storage of machines	QRR	$= [CC * cc_\% * A]$	CC = building costs; cc% = recovery and storage coefficient; A = area
Working capital	Machines		Amortization rate	AR	$= \left[\frac{(MP-RV)}{n} \right]$	MP = market price; RV = residual value; n = life time in years
			Interest	Int	$= [QA * r]$	QA = amortization rate
			Maintenance fee	MF	$= [QA * mc_\%]$	QA = amortization rate; mc% = maintenance cost in percent
			Insurance and tax	I&T	$= [\sum (Ins.ce + Tax)]$	Ins.ce = insurance; tax
			Costs of rapid consumption parts	CRCP	$= \left[\frac{K}{n} * MP \right]$	K = cost of part; n = life time; MP = market price
	Other tools	Fixed cost	Fee for recovery and storage of machines	QRR	$= [CC * cc_\% * Sup]$	CC = building costs; cc% = recovery and storage coefficient; A = area
			Amortization rate	AR	$= \left[\frac{(MP-RV)}{n} \right]$	MP = market price; RV = residual value; n = life time in years
			Interest	Int	$= [QA * r]$	QA = amortization rate
			Maintenance fee	QM	$= [QA * cm_\%]$	QA = amortization rate; mc% = maintenance cost in percent
			Rapid consumption parts costs	CPRC	$= \left[\frac{K}{n} * MP \right]$	K = cost of part; n = life time; MP = market price

Type of costs			Description		Calculation	Details
Material and energy	Fuel and oil	Variable costs	Fuel costs	FK_{Carb}	$= [Kwh * \mu_{um} * C_{sc} * FK\_MP * h]$ or $= [C_{gl} * \mu_{um} * FK\_MP]$	Kwh = power; μ_{um} = technical coefficient; c_{sc} = specific consumption; FK_MP = market price fuel costs; h = hours of use
			Oil costs	OK_{Lub}	$= [Kwh * \mu_{um} * O_{sc} * OK\_MP * h]$ or $= [L_{gl} * \mu_{um} * OK\_MP * h]$	Kwh = power; μ_{um} = technical coefficient; O_{sc} = specific consumption oil; OK_MP = market price fuel costs; h = hours of use
	Consumables		Other material costs	OMC	$= [Q_i * MP_i]$	Q = quantity; MP = market price
Labor	Workers		Salary	S	$= \left[\sum\limits_{i \to 1}^{n} S_i * h_i \right]$	S = salary for hour; h = hours; i = qualification
Financial capital	Financial		Interest on capital advanced	ICA	$= \left[FC_i * r * \frac{t_{(j-s)}}{365} \right]$	FC = financial capital; r = discount rate; t = time in days
Business organization			Entrepreneur remuneration	ER	$= \left[\sum\limits_{i \to 1}^{n} (KT_j) * 10\% \right]$	KT = total costs; j = different cost types

The footnote symbol "" means multiplication.*

Table 11.
Transformation cost types and calculation procedures.

- Executive: in which LC performs silvicultural intervention. It includes selected trees felling, extraction, transportation, and stacking of the timber in the landing.

- Conclusive: in which the goodness of the silvicultural intervention is verified.

3.2 Costs

In order to implement the four steps of the transformation process, many services and inputs must be purchased on the market. Total costs are the sum of three cost types (**Table 10**):

- Transaction costs

- Operative costs

- Overhead costs

3.2.1 Transaction costs

This type of cost includes all expenditures that have to be incurred in the process to fulfill the administrative procedures defined by rules, regulations, and laws, in order to manage the forest. Those expenditures are mainly necessary to acquire the permission to perform the silvicultural intervention, but they include the costs to prepare the forest area, to entrust LCs with the work, to ensure effectively results, and to monitor the results. The whole transaction costs are defined formally frame in which FCs and LCs must work in order to safeguard public interest as well as the forest and other social aspects (work safety aspect). Both FLOs and LCs sustain transaction costs.

FLOs' transaction costs include the following:

- Forest consultancy

- Technical documents and drafts

- Administrative fees

- Selecting and entrusting an LC with implementation of forest utilization

- Technical responsibility to safeguard the FLO's interest during the activity

- Verification of the forest utilization conformity to the standard defined by the permission and the forest rules, regulations, and laws

These costs per unit area usually decrease, but total cost increases according to the area interested in the process (proportional principle) (**Figure 3**). Expenditures for those performances are defined as bunched cost by

- dedicated market survey;

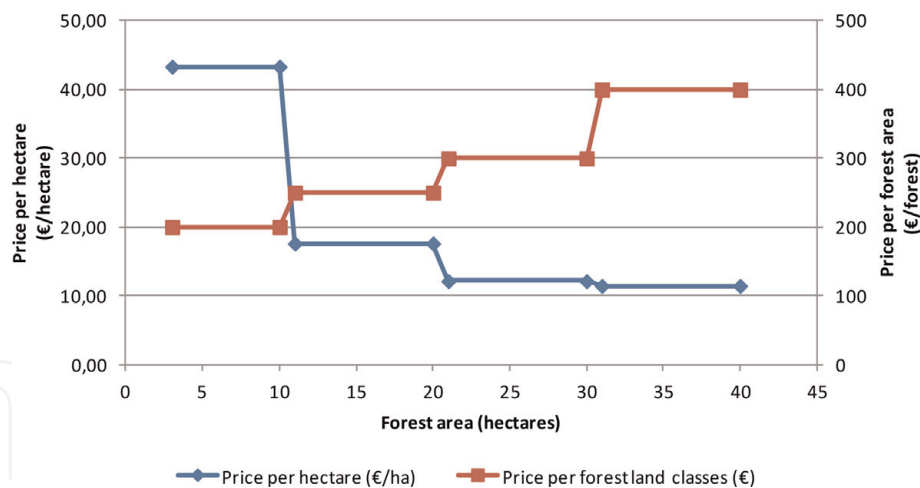- negotiation between the LC and forest consultant;

Figure 3.
Transaction costs. Source: Our elaboration.

- tables issued by competent institutions. The amounts are changed proportionally with the volume of timber felled or with the forest area under management;

- mixed approach, combining the two systems mentioned earlier; and

- surveys on the dedicated market.

The LCs' transaction costs are related to the obligations concerning the following:

- Healthy costs, capital investment to ensure high safety standard in the forestry yards and to the forest workers

- Cost of refund deposit, caution money that forest owners can operate when LCs don't pay the stumpage price and for penalty that LCs incurred during the activities

The LC costs are defined by market survey.

3.2.2 Operative costs

All expenditures to implement technological cycle are defined as operative cost (**Table 11**). These costs are sustained to transform trees into marketable timber products, mainly by the LC and only a few for FL. They include expenditure to buy primary and secondary productive factors.
Main primary factors are as follows:

- Land: capital permanently invested in the ground. While it is very relevant for FLOs, for LCs, it is limited to the structures for recovery and storage of working capital, as machineries, machines, and other tools.

- Capitals that include the following:

- Working capital such as machines (forwarder, harvester, chainsaw, etc.) and other tools (winch, etc.). Those have a multiple-year employment, so the use cost must be distributed through the years they will contribute to the activity (amortization costs and annual interest). These costs are added to the

maintenance costs, insurance and other contribution, cost of rapid consumption parts, etc. in order to define the cost machine.

- Financial capital necessary for the possession and use of working capital above described, to remunerate workers as well as to cover the interest of financial advances for the activity development.

- Labor, concerning employers involved in the transformation process, such as forest workers and other units that have administrative functions. In both cases, the remuneration changes according to the skill and qualifications. The fundamental information is not the payment for hour or day, but the costs sustained by the entrepreneur that include tax, insurance, and other costs paid as benefits or facilities for the future of workers.

- Entrepreneur organization, done by the person who assumes the forest activity risk. Currently, the payment is split between equity profit and extra profit. The first covers the responsibility assumed by the forest entrepreneur to manage the activity and it is estimated as about 10% of the total cost and named as equity net profit, while extra profit is obtained as differential between total costs (include equity profit) and total revenues. This amount covers the risk management activity.

3.2.3 Overhead costs

Also named as indirect costs, these do not contribute directly to obtain the product but exist to ensure LC functioning. They are related to the LC unit as a whole, and they cannot be applied or traced to any specific unit of output. Overhead costs include the following:

- Costs for managing goods and material purchases involved in the forest utilization process; costs due to the activity of timber trade in the market

- Costs for managing of insurances, taxes, and other contributions due to the LC

- Costs for managing markets and operator networks

- Costs for the LC accounts

3.3 Revenues

The output of the silvicultural activity can be expressed in terms of volume or value. The first results by measurement operations of the standing, with special emphasis to the volume of row timber material removal from the ground [V] differentiated for market destination [i] and expected to be sold in the polder (first competitive timber market). The latter is the result of the volume of row timber material for the relative market price [MP]. Data can be collected by market survey, or dedicated statistical publication.

Formally,

$$VdM = \sum_{j \to 1}^{m} (V_i * MP_i)$$

4. Monetary evaluation of forest management

Main questions of forest management are:

• What is the standing forest market price?

• What is the timber forest products' market price?

• What is the forest management cost?

Literature offers three approaches to answer the questions above, which are as follows:

• Market price approach

• Cost approach

• Combination of the above-mentioned approaches

In all these approaches, results are based on common comparative method. This method ensures a strictly direct or indirect connection between market and the good under evaluation.

4.1 Appraisal theory

Theoretical background on evaluation method has been defined from International Valuation Standard Council [21]. In this contest, two main approaches are suitable: market comparison approach and cost approach. The first obtains the timber value by comparing the timber under evaluation with other similar timbers sold in the market; for which, price and at least one technical parameter are well known. The latter defines the value considering all expenditures that the enterprise have to sustain in order to obtain the product under evaluation.

Timber evaluation can have different assessments depending on whether one of the following two objectives is pursued:

a. Timber optimization uses: FLOs' target is to ensure the most appreciated market product.

b. Optimization of market functioning: FLOs target to create the most favorable conditions for large market participation by the LCs.

The first target tends to favor the major LCs, even if the LCs who would take part in the market are very few in number, at least only one. Those LCs are technologically advanced, have greater financial availability, and have wider timber markets, as they can be international timber markets. The hypothesis is that this setting should ensure an effective use of timber and that it can achieve the highest addend value. On the other hand, the second target tends to align itself with the most frequent conditions compared to the local area framework, so as to allow the greatest participation of the local LCs at the market. The hypothesis is that if a large number of LCs take part in the market, that should ensure highest LC competition and the highest stumpage price.

4.1.1 Market value

4.1.1.1 The stumpage value

    The first step is to acquire an adequate observation numbers, at least not less than 4 for each variable used in model, of

- market price (dependent variable);

- technical variables (independent variables),

the value of the stand can be determined through two procedures:
a) By direct comparison, using the fundamental proportion to evaluate a market good. Having market prices and at least one technical parameter value, the proportion adapted to evaluate forest stand marketable is

$$\sum_{i \to 1}^{n} SV_i : \sum_{i \to 1}^{n} Vol_i = SV_x : Vol_x$$

where $[SV]$ is the stumpage price, $[Vol]$ is the volume felled, $[i]$ is the number of market observations collected by a survey, and $[x]$ are the data related to the stand under evaluation. Developing the proportion above in favor of SV, it becomes

$$SV_x = \left[\frac{\sum_{i \to 1}^{n} SV_i}{\sum_{i \to 1}^{n} Vol_i} \right] * Vol_x$$

where the ratio in the square bracket is the stumpage value for cubic meter.
b) By indirect comparison, building an econometric model

$$Y = f(x_1, ..., x_i, ..., x_n, \varepsilon)$$

where $[Y]$ is the dependent variable vector of the stumpage price, $[x]$ are the generic technical variables, and $[i]$ is the type of variables such as forest area (hectares), timber volume (cubic meter), infrastructure index (qualitative data), and other parameters.
    The strong limits of both procedures are (a) the lower number of LCs that take the risk that low number of LCs have an informal agreement about the stumpage value, and the LC that acquire the stem it was decided before the timber market start officially; and (c) there isn't a well structured culture on how and what forest data, technical and market, should be collected. Each forest owner has its collection, and each forest owner itself selects the variables that should be registered.

4.1.1.2 Timber raw material market

    It is the market in which the trees, transformed in marketable products, are sold as timber raw material. That market has two relevant advantages for the evaluation proceeding: (a) even if the number of FLOs or LCs that support the supply is very low, the sawmills are much more so the market should have less distortion; and (b) it is the first market later to the stand felling.
    The market price of timber raw material is obtained by market survey. Database is built using the price registered in the market.

4.1.2 Forest management evaluation costs

The production cost approach concerns the technological cycle step and it includes only the expenses necessary to carry it out. This circumstance mainly happens when forest management has social objectives or the timber raw material has high market value and the FLOs prefer it to be sold directly in the timber raw material market because they expect strong completion among sawmills. The FLOs operate on service markets. They purchase the LC services for felling, processing and transportation of plant to an area which is easy to access (landing). Timber raw material can be

- evaluated to reduce forest management costs;

- made available to the local community to pursue their objectives;

- sold in the timber raw material, directly or through dedicated agencies.

FLOs have to pay the LCs in any case. Activity is developed within the regulation code of "tender" to fell stand. The characteristic of this entrust is that FLOs have to pay LCs for their performance. The main national law states that an enterprise, as LCs, "assumes, (...), the fulfilment of a work or a service towards a consideration in money"[1].

Production cost is formally obtained as

$$K_{Tot} = \left[\sum_{i \to 1}^{n} k_i\right] + \left(k_i * r * \frac{t_{(j-s)}}{365}\right)$$

where $[K]$ is the total costs, $[k]$ is the elementary costs, $[i]$ is the types of costs, $[r]$ is the discount rate, and $[t]$ time and $[j, s]$ are, respectively, the day when the work finished and the day when the expenditure has been done.

4.1.3 The transformation value

The last procedure provides the evaluation of the stand as a comparison between the value of the timber raw material market and all costs necessary to transform the stand into marketable products. The transformation process increases timber value step by step until it becomes timber raw material. The evaluation process, on the other hand, moves in the opposite direction: starting from the market products to achieve the stumpage value (**Figure 4**).

The fundamental relationship at the base of the procedure is that timber raw material market price is equal to the sum of stumpage price with the costs of carrying out transforming process:

$$MP_{TRM} = SV + K_{Tot}$$

where $[MP_{RTM}]$ is timber raw material market price in the first market after the stand is felled; $[i]$ is the types of timber product obtained (timber construction, fuel wood, etc.); $[SV]$ is the stumpage price; $[K_{Tot}]$ is the total costs of transformation
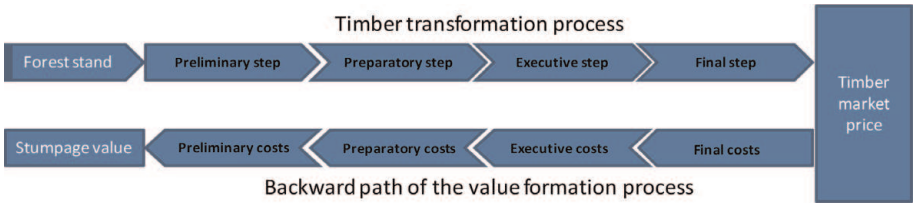
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[1] Civil Code, article 1655.

Figure 4.
Pathway of timber productions and value formation.

processes from stand to timber raw materials; and [*j*] is the types of costs. Resolving for the stumpage value, it becomes

$$SV = [MP_{TRM} - K_{Tot}] = \left[\left(\sum_{i \to 1}^{n} MP_{TRMi} \right) - \left(\sum_{j \to 1}^{m} K_{Totj} \right) \right]$$

The ex ante budget is the tool that foresters usually adopt, where in one site is reported the revenue and in the other site the expenditures. The balance between revenues and expenditures is the stumpage value that LCs take from the commitment to pay at the FLOs when agreement was signed.

4.2 Appraisal approach for entrusting types

4.2.1 Forest management in house

The common model of this forest management is based on the ability of forest property (public or private) to carry out the forestry intervention. The owner directly or through an agency of the same subsidiary carries out forest utilization using personnel, machines, and tools in its possession. The economic and financial questions that accompany this approach are as follows:

- What is the total cost of carrying out the intervention (K_{tot})?

- What is its operating cost (K_{Op})?

- What is the market value of the timber raw material (MV_{TRM})?
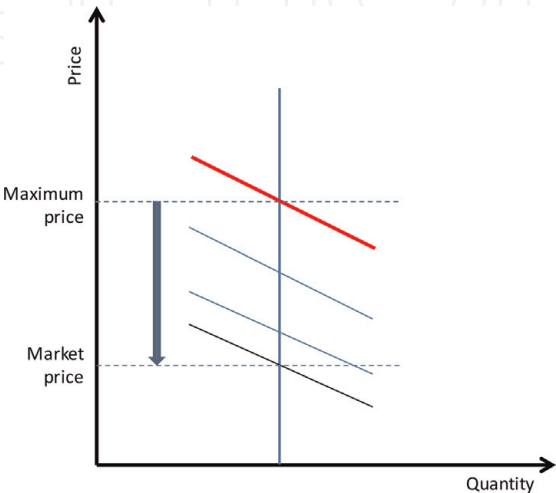

Figure 5.
Services market: forest land owner purchase logging company service for felling, extraction, and processing timber production at lowest price. Source: Our elaboration.

The total cost expresses the total amount of costs regardless of the evidence that the resources used are internal. The operating cost focuses only on the variable (additional) costs that are incurred only if the intervention is carried out, ignoring the costs related to the internal resources involved in the works and the costs that the property still support. The last question relates to the value of timber raw material, which is quantified through market surveys.

4.2.2 Forest management by tender

In this case, the silvicultural intervention is entrusted to an LC, which provides a service to the FLOs in exchange for payment of the service. The company that carries out the intervention is the one that, all other parameters being equal, ensures the service at the lowest price (**Figure 5**).

	A	B	C	D	E	E formula	G
1	Types of data	Description	Range	Units	Amounts		Sources
2	Economic data	Market price		€	45,000.00		Market survey
3		Percentuale di recupero		%	10.00%		Technical documents
4		Value at the end of the career		€	4500.00	=E2 × E3	Our elaboration
5		Annual amortization		€	4050.00	=(E2 − E4)/E10	Our elaboration
6		Market price tires		€	2000.00		Market survey
7		Gasoline price		€/l	1.12		Market survey
8		Discount rate		%	3.00%		Market survey
9		Average annual investment		€	27,000.00	=E2 × E18	
10	Technical data	Economic duration		year	10.00		Technical documents
11		Annual machine usage hours		hours	1000.00		Technical documents
12		Technical duration		hours	10,000.00		Technical documents
13		Work days in the year		days	240.00		Technical documents
14		Working days in hours		hours	4.20		Technical documents
15		Power		HP	80.00		Technical documents
16		Tires duration		hours	3000.00		Technical documents

	A	B	C	D	E	E formula	G
17		Gasoline consumption duration per hours		l/ hour	6.15	=(E20 × E15 × E22)/ E19	Our elaboration
18	Coefficients and parameters	Average annual investment coefficient		%	60.00%		Technical documents
19		Tires coefficient			1.20		Technical documents
20		Gasoline conversion coefficient (1 l = 0.84 kg)	0.70– 0.85		0.84		Technical documents
21		Gasoline consumption			0.17		Technical documents
22		Lubricants consumption		%	10.00%		Technical documents
23		Load factor	0.38– 0.70		0.38		Technical documents
24		Maintenance coefficient	100– 30%	%	100.00%		Technical documents
25		Variable expenditures coefficient	15– 5%	%	7.00%		Technical documents
26	Fixed costs	Annual amortization per hour		€/ hours	4.05	=E5/E11	Our elaboration
27		Interests per hours		€/ hours	0.81	=E9 × E8/E11	Our elaboration
28		Variable expenses		€/ hours	1.89	=E9 × E24/E11	Our elaboration
29		**Total fixed costs**		**€/ hours**	**6.75**	**=E25 + E26 + E27**	**Our elaboration**
30	Variable costs	Maintenance and repair costs per hour		€/ hours	4.05	=E5/E11 × E23	Our elaboration
31		Gasoline cost per hour		€/ hours	6.89	=E17 × E7	Our elaboration
32		Lubricant cost per hour		€/ hours	0.69	=E30 × E21	Our elaboration
33		Tires cost per hour		€/ hours	0.80	=E19 × E6/E16	Our elaboration
34		**Total variable costs**		**€/ hours**	**12.43**	**=E29 + E30 + E31 + E32**	**Our elaboration**
35	**Total costs**	**Total machine costs**		**€/ hours**	**19.18**	**=E28 + E33**	**Our elaboration**

Source: our elaboration on frame [4, 5].

Table 12.
Cost machines using the FAO frame.

	A	B	C	D	E	E explosed	G
1	Types of data	Description	Range	Units	Amounts	Formulas	Sources
2	Economic data	Market price		€	45,000.00		Market survey
3		Percentuale di recupero		%	10.00%		Technical documents
4		Value at the end of the career		€	4500.00	=E2 × E3	Our elaboration
5		Annual amortization		€	4050.00	=(E2 − E4)/E11	Our elaboration
6		Labor cost		€/hours	14.00		Market survey
7		Tire market price		€	2000.00		Market survey
8		Gasoline price		€/l	1.25		Market survey
9		Lubricant price		€/l	2.25		Market survey
10		Discount rate		%	3.00%		Market survey
11	Technical data	Economic duration		year	10.00		Technical documents
12		Annual machine usage hours		hours	1000.00		Technical documents
13		Technical duration		hours	10,000.00		Technical documents
14		Work days in the year		days	250.00		Technical documents
15		Working days		hours	8.00		Technical documents
16		Hours machine usage effectively		hours	4.20		Technical documents
17		Power		kW	60.00		Technical documents
18		Tire duration		hours	3000.00		Technical documents
19	Coefficients and parameters	Gasoline conversion coefficient (1 L = 0.84 Kg)	0.70–0.85		0.84		Technical documents
20		Oil conversion coefficient (1 L = 0.95 kg)	950–850		0.95		Technical documents
21		Gasoline specific consumption	280–300	g/kWh	300.00		Technical documents
22		Oil specific consumption	2–4	g/kWh	4.00		Technical documents

	A	B	C	D	E	E explosed	G
23		Use coefficient of available power	95–50%	%	66.67%		Technical documents
24		Maintenance and repair coefficient	0.10–0.13	%	0.13		Technical documents
25	Variable expenditures coefficient	2.5–0.5%	%	2.50%		Technical documents	
26	Fixed costs	Annual amortization per hour		€/ hours	4.05	=E5/E12	Our elaboration
27		Interests per hour		€/ hours	0.61	=(((E2 − E4)/ 2) × E10)/E12	Our elaboration
28		Variable expenses		€/ hours	1.13	=(E2 × E25)/E12	Our elaboration
29		**Total fixed costs**		**€/ hours**	**5.78**	**=E26 + E27 + E28**	**Our elaboration**
30	Variable costs	Maintenance and repair costs per hour		€/ hours	1.82	=E6 × E24	Our elaboration
31		Gasoline cost per hour		€/ hours	9.38	=1/E19 × (E21/ 1000) × E23 × (E16/ E15) × E17 × E8	Our elaboration
32		Oil cost per hour		€/ hours	0.30	=1/E20 × (E22/ 1000) × E17 × (E16/ E15)*E9	Our elaboration
33		Tires cost per hour		€/ hours	0.67	=E7/E18	Our elaboration
34		**Total variable costs per hours**		**€/ hours**	**12.16**	**=E30 + E31 + E32 + E33**	**Our elaboration**
35	**Total costs**	**Total cost machines per hours**		**€/ hours**	**17.94**	**=E29 + E34**	**Our elaboration**

Source: our elaboration on [6].

Table 13.
Cost machine per hour, using the USDA frame.

Different approaches to calculate operating costs are reported in the cost machine literature. The main frames are elaborated and reported in **Tables 12** and **13**, respectively, for FAO and USDA. The following are the common comments:

- Transaction and overhead costs are not included.

- Labor costs are not included.

- The frame proposed is developed for machine that works in huge areas or regions.

- Total costs have to be used as an approximation of the cost machines.

Figure 6.
Commodities market: forest land owner sells its stand to the logging company that makes the highest price.

- Some algorithms and parameters used for evaluating cost are not easy to understanding the economic ratio.

4.2.3 Forest management by sale of stand

In the forest appraisals, the approach is to elaborate an ex ante budget of the silvicultural intervention including the expected costs to transform trees in marketable products and the expected revenue that should be obtained from the products sold.

The differences between expected revenue and costs are the expected stumpage value of the trees that LCs should pay to the FLO to bay the stand, while only the amount of the expected costs is the price that FLO has to pay to the LC for the service of felling the stand. Stumpage price became the minimum price that FLO accepts to sell its stand. LCs that want to purchase it have to submit a proposal with a price higher than the minimum (**Figure 6**).

5. Conclusions

Growing awareness of the usefulness of forest ecosystems makes the operational cost significant as a component of the wider transformation cost. The latter includes both transaction costs in order to satisfy the provisions dictated by the legislative and regulatory forest and related forest disciplines, as well as the overhead costs that allow the correct functioning of the LCs.

Approaches introduced by international institutions lend themselves to an assessment, very approximate of the costs of managing uniform forests that cover large and flat areas. Their limits are given by concentrating on the component of operating costs, excluding overhead and transaction costs, as well as the introduction of simplifications in order to increase the territorial scale of application. They determine an underestimation of forest management costs [22].

A drawback instead overcomes the analytical approach, whose strong point is its adaptation to the context of intervention and to the specificities of the transformation cycle. This makes it possible to overcome the deformities that characterize forests, especially in the mountain areas, where it is possible to register a different stumpage value for two similar forests, close to each other and having the same

productions. This approach also ensures transparency and traceability of the assessment process, as well as flexibility being able to be adapted to the different process for entrusting the management of the stand.

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Author details

Francesco Carbone[1]* and Rodolfo Picchio[2]

1 Department for Innovation in Biological, Agro-Food and Forest systems (DIBAF), University of Tuscia, Italy

2 Department of Agricultural and Forestry Science (DAFNE), University of Tuscia, Italy

*Address all correspondence to: fcarbone@unitus.it

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