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Forests and commons-based resources

From resources to landscape: institutions, forest products and the case of Tuber magnatum in Piedmont

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1. Executive Summary

The core idea of this thesis was born from the author's *personal experience* during the design of a *metropolitan-scale network* linking *rural* areas nearby *forests* to the main city of *Rio de Janeiro*, Brazil. One of the project's key issues was the *management* of *water resources*, originating from the *forests*, that stretched across a big portion of the metropolitan area. These resources were substantially *open-access* for all users, but their *management* was not shared by all and often generated *conflicts* and misuses, resulting in severe *damages* to the *resource* themselves. It was, in fact, a *common resource* granted by tropical forests whose *externalities* were not equally translated into *shared benefits* for all users. The question that this experience gave rise to was: how should *planners* deal with *natural resources* that are *open-access* and *profitable* for all users, but whose bad *management* and *over-exploitation* would exhaust irreversibly? To answer this question was the crux of that project, but it's also one of the main questions that planners (be them architect, politician, economists and so on) face when dealing with *territorial planning*.

This work wants to tackle such a question starting from an *architectural background*, and it tries to reach a general idea of what working in these complex settings would imply, and what solutions could be proposed. Dealing with similar situations require a *multidisciplinary approach* that is beyond the scope of architectural practice, calling for *contribution* from *economics*, *sociology*, *biology*, and many other specific *disciplines*. To comply with such an extensive need for *knowledge*, this thesis is based on an extensive *documentation* and *critical reading* of various disciplines and sources, producing an eclectic and extensive reference bibliography.

The starting points of the analysis are two major entities: *Forests* and *Commons*. Forests ought to be universally known to the public, since they are the most diffused *terrestrial ecosystems* on Earth, covering 30,6% of global land area in 2015. And yet, having an idea of forest and understanding all their facets are two completely different stories. Humans have always relied on forests and their *resources* to develop societies, with different *attitudes* depending on *historical periods*. But forests have not only provided humans with resources to be used. They also represented a *leisure* to enjoy, a way to *clean* our pollution, and, most importantly, they are Earth's main *life-supporting systems*. The values that forests have for human societies are then not only from their *direct use*, given by the *exploitation* of products they supply. They also come from their *indirect use*, intended as the *services* they grant; from the possibility to *enjoy* them, or even just from their *existence*. Even if these values are *many* and various, most of them are *not easily assessable* in monetary terms, the only quantification understood by all users. In fact, what usually represent the *dominant factor* considered in forest management strategies is just the *economic value* of forests products. Unfortunately, these products do not always have a high or *stable* economic *evaluation*, especially in *developing countries*. This directly translates into general *disinterest* towards *sustainable forests management*, leading to many cases of *land-use conversion* and consequent forest destruction. However, forests *preservation* and services do not only concern local realities but affect the whole world. Therefore, many efforts have been made to ensure *international cooperation* on forest governance. The most recent and notable action in this sense has been FAO's effort of framing forests' role contributions to 2030 UN Agenda Sustainable Development Goals (*SDGs*), an international *framework* of action aimed to achieve a better future for all human society. Their work shows why forests represent a fundamental reality for all humankind since they hold resources that are *accessible* to all, *free* to use and their management could offer many potential shared *benefits*. However, FAO also highlights how these global resources are greatly *threatened* by human activities across the

globe, and in many cases face *deterioration* and *exhaustion*. Forests could thus be seen like *common resources*, which are useful for human societies but that are also facing threats to their survival.

An interesting and fitting concept to this condition is what economists define as a *common-pool resource*, or simply *commons*. Commons are a popular topic among scholars, as they can encompass a wide range of different entities sharing some similar *analytical* features, thus making possible to comparatively analyze them together. To be defined as commons, the essential requisites any resource must have is to be non-excludable to all appropriators (i.e. users exploiting the resource) and offer rivalrous benefits (the individual consumption/use of the resource deny the possibility to all other appropriators). They are often wrongly confused with *public goods*, which however are non-rivalrous, as the use of the resource does not affect other appropriators. Commons have been extensively studied because, more than any other type of resources, their fate is intrinsically related to the management strategy they are subjected to. Since these resources are open to all but limited in the benefits they can give, some appropriators might adopt egoistical behaviors to get more benefits, consuming more than their sustainable share of the resource. However, if these behaviors become the norm for all appropriators, as it has happened in many settings, the resource would inevitably deplete and disappear. This is the core of what Garrett Hardin defined as "*Tragedy of the Commons*", arguing that commons were destined to such ending if no intervention was carried out on them. The solutions devised by successive scholars can be summed up into three main theories: the state intervention, which Hardin supported, where management of local resources is delegated to central government; the privatization, with Harold Demsetz as main proposer, indicating private ownership as the best solution to ensure the resources' future; the community model, elaborated by Elinor Ostrom, which debated for the importance of existing local communities in the management of resources alongside the privates and the state. These theories suggest different views of what type of institutional arrangement should govern the commons to ensure their right management; they represent an everyday object of interest for all planners. Things as disparate as sidewalks, street trees, hospitals or even neighborhood community bonds are all commons. In fact, commons include intangible concepts such as pollution, reputation, and noise. All these different things are key components of human settlements, and especially of the metropolis, which can be defined as a "factory *for the production of commons*". But then again, as varied as these commons and the settings they exist into can be, a one-cure-all solution to the commons' dilemma doesn't exist.

Similar issues are faced with forests resource management. Because, though forests can be defined as commons, the variety of product and services they supply are greatly different from each other. Forests' own characteristics (climate, vegetation, history, …) vary too much to be classified as a unique, comprehensive common. Rather, forests can be said to be a *special* kind of commons, comprising of many different common-pool resources. Facing objects such as forest commons, the management of these resources become a complex matter. The first idea which might come to mind would be to define who holds the property over these resources and start from them. Property, however, is not a simple matter when talking about commons, and in general, there is no shared definition of what property imply. More than a single right, the property is generally interpreted as a "*bundle of rights*", which Schlager and Ostrom (1992) identified into five: *access*, *withdrawal*, *management*, *exclusion,* and *alienation*. One of the main functions of property rights, as expressed by Demsetz, is to "*internalize externalities*" granted by resources. Nonetheless, property rights are not intrinsic to the resources they apply to, instead, they are artificial constructs reflecting the social context they

are born from. Property rights are thus nothing more than "primary" institutions, applied to resources in order to govern them in an economically structured society, and they vary according to where, when and how resources are managed. In the last analysis, ensuring the sustainable management of forest common-pool resources cannot be obtained without two specific requirements: an in-depth knowledge of the *resources* and a correct design of the *institutions* governing them.

Discussing forest resources could be misleading for the purpose of the analysis, as many forest services still do not have clear value for appropriators. What is most valued about forests in many settings are the *products* they supply. Therefore, analyzing products rather than services can be more useful for operating in many contexts. The first thing to know is that forest products are many and quite different from each other, making a uniformly agreed definition hard to achieve among scholars and institutions alike. In general, forest products can be classified into two major categories: *timber*-based products and non-timber forest products (*NTFPs*). A first difference can be that timber extraction involves the *destruction* of the resource base, i.e. the trees, while most NTFPs can potentially be harvested without destroying the source of the products. This represents no fixed rule, as erroneous harvesting techniques or misjudged timing could damage the *resource regeneration capacity*, consequently leading to resource *depletion*. Most notably, many forest products, both timber-based and NTFPs, can be classified as *commons*, since appropriators cannot be easily excluded from them and they are rivalrous in their exploitation. It's the case of long-growing trees, mushrooms and medicinal herbs, which can be harvested almost freely but require adequate attention to be preserved. Analyzing forest products management is of great relevance, not only because they have clear market values, but because these values are quite relevant to the worldwide economy, especially in developing countries. The global market contribution of forestry and logging in 2011 have been estimated in USD117 billions, with such activities contributing to as much as 1,4% GDP of low-income countries. Aside from timber and roundwood, forests represent vital sources of woodfuel, providing basic energy services to 2.4 billion people worldwide in 2014. NTFPs are another important source of income and benefits for many societies, since they include, depending on the definition adopted, several resources, from plants to animals. NTFPs market contribution, however, is not easily quantifiable, as most of harvesting and selling activities are carried out in informal channels. A conservative, probably underestimated, evaluation done by FAO quantified their market in USD88 billion in 2014. A great portion of this income is generated in developing countries, where NTFPs constitute an essential source of profits and supplement resources for households. Even if NTFPs offers valuable opportunities of income for many, they represent a minority of total forest land use. Of the existing 4 billion ha of forests in 2015, only around 1 billion ha were destined to multiple-use, where NTFPs were harvested in combination with timber. Comparatively, timber-production forests amounted to 1.2 billion ha. This difference could most certainly be attributed to several factors: general *lack of information* on NTFPs characteristics and management, difficulty in establishing clear *property rights*, the *fragility* of the market, *fragmentation* of the communities and strength of the *institutions*. The institutions usually represent the favored target of action of planners, economists and many other experts. Analyzing institution can be challenging, as they not merely represent established physical entities like public governments, military forces or NGO.

In the truest sense, according to Hodgson (1988), the term *institutions* should include all those systems based on *social rules* that govern *social interactions*. Such definition, which is an object of debate among scholars, gives a wider perspective on what should be considered the target

of intervention by planners. The efficacy of institutions is thus inevitably linked to human *behavior*, which they can both constrain and enable according to their action. The best way institutions can influence human behavior is through the successful establishment of so-called *social rules*. *Rules*, however, do not necessarily coincide with *laws*. Unlike laws, rules do not require strict enforcement to be accepted and observed, rather, they are born from their *social context* and followed without the need for formal formulations. The transition from formal laws to social rules – i.e. the successful establishment of *habits* – is a crucial role of institutions. Habits supporting laws compliance are what give institutions the *authority*, the *power*, and the *durability*. In this perspective, all the systems involving the definition of habits and rules, including *formal* and *informal* organizations, should be considered as *institutions*, and thus part of the scope of action of planners. If the institutions can be seen as the representations of the societies from which they come, they should inevitably share their fate. It's a fact that, along with human history, social *behavior*, *rules,* and *habits* have changed greatly in response to unpredictable and relevant events. Just as societies have changed, so (supposedly) did their institutions. *Institutional change* has always happened, sometimes with disruptive and *abrupt* changes, but more often with subtle and *gradual* modifications to existing institutions. Understanding how institutions are born and change is fundamental to analyze how they operate and the tools they have at disposal.

When discussing *institutional tools* applied to forest resources management, one of the most famous and somehow successful ones have been certifications programs. *Certifications* are a tool to overcome the existing *information asymmetry* among actors of a system. In time, many different programs have been developed (FSC, PEFC, CSA, …), assessing various parameters related to the preservation of forests resources, with special focus on *timber*. So far, there has been lacking attention for *NTFPs*, which face severe threats of *depletion* in many settings. Issues with forest certifications are significant: they are not equally adoptable in every setting, as they require the build-up of extensive users' knowledge of the system in its *social*, *economic*, *biologic* and *technical* aspects. This represents a major obstacle for many areas, especially when dealing with common-pool resources, generally characterized by high *informative gaps* among users. Certifications are just one possible institutional tool to manage commons that can offer some advantages but also have important setbacks, making them generally not the deciding factor for successful commons governance.

When looking for which characteristics any successful institution should have to manage common-pool resources, Ostrom's "*Governing the Commons*" (1990) is a fundamental work. She presents a comprehensive analysis of different commons, both successful and unsuccessful ones, from which she extrapolates some guiding principles for community-based management. The principles which observed successful commons governance were: *clearly defined boundaries*, *collective-choice arrangements*, *monitoring*, *graduated sanctions*, *conflict-resolution mechanisms*, *minimal recognition of rights to organize*, *nested enterprises for resources part of larger systems*. Even if contested by some scholars, they proved to be generally valid worldwide, thus setting a goal for institutional action. However, these principles are rather difficult to achieve given the complexity of commons settings. This is true especially with forests, that are generally large and intricated *natural networks* of interlinked resources and services. The best course of action is to *design institutions* which can gradually achieve these goals through their capacity to respond and *adapt* to system changes. Once again, Ostrom elaborated a list of general guidelines institutions should follow to achieve *adaptive governance* of common-pool resources. They are: *achieve accurate and relevant information*, *deal with conflicts*, *enhance rule compliance*, *provide infrastructure*, and, finally, *encourage adaptation and change*. These principles do not prescribe a

specific institutional arrangement, rather, they should be the backbone of every institution designed to successfully deals with commons.

But ultimately, why should planners, architects, focus on analyzing and designing institutions governing common-pool resources, and especially forest? It has already been said that *commons*, as disparate as they can be, *are everywhere*. They constitute an essential reality in everyday architectural and metropolitan practice, therefore, architects and planners should be conscious of how they work and of their features. When speaking about forests and their resources, the perspective of planners and architects should immediately lead to the concept of landscape. It has been explained that forests can be considered *commons*, and they most certainly are essential components of the *landscape*. Then, can the *landscape* be considered a *common* too? The answers proposed by this work is that landscape can be considered a *common*. In particular, the landscape normally includes *common-pool resources* which are linked one another, where every alteration produces some effects on the entire system, then the *design/management of landscape* should follow the principles of *commons*. This further connotation does not necessarily exclude the essence of landscape as a public good, as many of its functions and values (as an *amenity*, its view, its *existence*) are not negated. Rather, landscape planning should follow *commons'* perspective when inside the landscape system some components respond to *commons*' criteria. In these cases, landscape planning should be more attentive towards *institutional design* and resource management models. This inevitably requires an in-depth understanding of system's components, i.e. the *resources*, as well as their management strategies, deeply related to the governing *institutions*. Adopting this attitude towards planning would improve design efficacy at every scale, as well as avoid the emergence of a "*tragedy of the commons*" for local resources. This way, the design of *institution* governing forest commons becomes an essential step when approaching *landscape* and territorial planning.

The last step of this thesis is to present an example of the effects that institutions and forest common-pool resources have on the landscape and society. The object of study is a highly-valued product, deeply connected with *local identities* and *traditions*, which grows into a specific and limited area: The Alba's white truffle, or *Tuber magnatum Pico*. There are several reasons why *truffles* are objects of great interest for our analysis. First, the genus *Tuber* represents a family of products which are quite different from each other, be it for their *diffusion*, *growth rate*, *climate* adaptability, and even *market value*. They all, however, share a common trait. The presence of truffles in any ecosystem constitute a *biological indicator* of the wellbeing of that *ecosystem*. Truffles, in fact, establish a complex and extensive *symbiotic relationship* with the entire *environment* they grow into, be it trees (with whom they exchange nutrients) or animals (which they mostly require for dispersing spores to reproduce). The presence of truffles is thus a good sign for the environment, but also for other aspects. Like many other NTFPs, truffles are mostly *spontaneous* and generally require few interventions to grow, simply having to dig to harvest them. They are also *accessible* to virtually everyone, as they grow underground in areas with similar geomorphological characteristics. They thus constitute an important source of *food* and *income* for several settings. However, truffles have important weak points to their own. First, many species are highly *vulnerable* to environmental changes, such as drought and floods, making their *production* rate *unstable* and subject to important variations. Secondly, most of them are threatened by *erroneous harvesting techniques*, which damage their reproduction cycle and significantly lower the regeneration rate of the resource. Thirdly, sustainable truffle harvesting and (if possible) cultivation require extensive botanic and geological competences from their producers, as well as established norms of harvest for appropriators. Finally, since

many species have clear (and usually high) *market value*, the *exploitation* of these products is uniformly *rising*, while, on the contrary, their *availability*, due to wrong management practices and exogenous phenomena like global warming, *is steadily decreasing*. All these characteristics clearly show how truffles can be considered *common-pool resources* based on forest systems.

Among all the truffles species which have been discovered, one of the most interesting species to analyze is the *Tuber magnatum*, commonly called *white truffle*. The white truffle is special compared to other species for several reasons. With an average market value oscillating between 1000 and 1500 €/Kg according to Riccioni et al (2016), it holds the primate as the *highest valued harvested fungi species* and among the top of NTFPs. Aside from economic interest, white truffles are the only studied species of truffles which have *yet to be successfully cultivated*. This means that are *based* solely *on natural production*, making management strategies of pivotal importance for the resources. *Tuber magnatum* is also the truffle species with *narrower diffusion* and *stricter requirements* for their growth, making production quite more variable than other fungi. All in all, white truffles represent a most-fitting example of common-pool resources with a high level of intrinsic *complexity*, thus making them the perfect object of study for this thesis. Aside from their economic and physical characteristics, white truffles are full of strong *social* and *historical* connotations, especially in *Piedmont*. They are considered among the most important gastronomic delicacies and have close ties with the Savoy nobility and history since the 18th century. Initially used as diplomatic gifts, nowadays white truffles possess a far-reaching tradition and culture, with *Alba* and neighboring areas as the spiritual, social and economic core. Although *white truffles* have a long-established relationship with *Piedmont*, in truth they have long since become *marginal* forest resources for the region. It has been estimated that of the entire production of *Tuber magnatum* in Italy, only 3% could be attributed to Piedmont. While estimation on *production* and *prices* have always been rather *aleatory* due to diffused market *informality*, such estimates cannot be too far-fetched from the truth.

As a matter of fact, white truffles are gradually disappearing from Piedmont, thus making a real *tragedy of commons* a concrete possibility. To understand the causes of this situation, the planners' perspective must encompass all the various scales of institutional arrangements which have created such conditions. At the *international* level, institutions have quite limited impact on production, simply regulating *trade norms*. At the *national* level, truffles are regulated by the *framework law 752/1985*, which defines the norms of *harvesting*, *cultivation,* and *trade* of truffles in the national territory. The most relevant features of the law are: permit of *free truffles harvesting* in forests and uncultivated areas; *classification* of truffle grounds typologies (natural, controlled, cultivated); *delegation to Regions* of the assessment of harvesters' qualifications and of truffle harvesting management activities; general indications for *harvesting practices*; classification of truffle species for trade and their standards; assignment of *monitoring duties* to Corpo Forestale dello Stato and other local corps; establishment of *sanctioning principles* with delegation to Regions for their quantification. Overall, this plan has *delegated* several core functions to *Regions*, action which could make use of the consolidated *local knowledge* about truffles and their habitats, thus favoring their management in accordance to *traditions* and specific *social contexts*. However, this also favored legislative *fragmentation* across Regions, leading to a complex and sometimes *conflicting* legal setting. Many regional legislations were in fact in contrast with *higher level* institutional arrangements (Europe) and were unfavorable for the cooperation among Region themselves. To make things worse, the *framework law 752/85*, even if reviewed during the years, is greatly *outdated* and doesn't effectively respond to current conditions. That's why recently a collaboration among Regions, research institutes

and Mipaaf have produced the "*Piano nazionale della filiera del tartufo 2017-2020*". The goals of this *sectorial* plan are wide and bountiful, with the main concern over the establishment of an improved *harmonization* among all the actors of the truffle supply chain at the *national level*. The plan, besides giving a clear picture of truffle conditions in Italy thanks to the large *participation* achieved, proposes a list of *goals* and *actions*, both general and targeted, to improve the national truffle industry. The expectation of this plans is to form the backbone for a future *revision* of the framework law. While works for this legislative reform are ongoing, the *Regional legislations* are still the *key* focus of analysis. Since the white truffle have always linked to Piedmont, even if regional production is currently lacking, the focus of this thesis has been this Region.

For *Piedmont*, the framework law is *Regional law 16/2008*, later revised in 2011 and 2012. This law is quite interesting since it has a declared focus on *preservation* of *truffles ground* and the *indigenous species*. *Tuber magnatum*, in particular, is stated as a *priority* target of preservation efforts, showing the general concern over this product. The law also contains an extensive definition of *quantities*, *modalities*, and *sanctions* for truffle harvesting. These strict conditions, coupled with truffle harvesting diffused *informality*, place a relevant *burden* on *monitoring* bodies, thus affecting the entire system *efficacy*. Of notable interest is also the *qualification exam* procedures for harvesters, carried out by both Region and provinces, which require the *participation* of an expert belonging to local truffle hunters' *associations*. This is a sign of institutional effort for the *involvement* of local *realities* to the market regulation and resources management. Aside from the Region, several local institutions work in the truffle sector at different scales, thus composing a wide *network* of relationship which however often lack effective *coordination*. Following the guidelines of *Piano nazionale 2017-2020*, the Region elaborated a *research plan* for 2018-2020 which focus on the development of initiative towards truffle management. The main focuses are on *environmental protection*, *conservation of biodiversity*, improvement of *cultivation models* and the development of *certification protocols* for truffle products. The final goal is to *integrate* the regional research with *European regulations* and have a more in-depth *knowledge* of the existing truffle market. One of the key characteristics, which is also a major issue, of the white truffle market is that the product *supply chain* has been, since long ago, highly *fragmented,* and *informal*. Some product features (underground growth, limited production, high market value) certainly favored this lack of information sharing among rivalrous harvesters, which directly reflected on market structure. The *truffle supply chain* in Piedmont thus comprises of *several* sparse appropriators, organized in small/medium scale *associations* that sell their products to different *small detailers* or directly to *consumers*. Aside from these small realities, the other important existence is the *International Fair of Alba*, which attracts many consumers and tourists every year. Here however *fraud* on truffle *origin* is frequent, favored by the significantly *higher price* offered for *Piedmont* white truffles. Since white truffle cultivation has yet to reach satisfactory levels, most of the *production* comes from *natural truffle grounds*. These *forest* area, which can be either *public*, *private*, or *community-owned*, need some specific *maintenance procedures* to foster production and avoid depletion of the resources. The *Region*, coordinating with *provinces* and *municipalities*, have thus set up *incentives* for the *preservation* and *maintenance* of truffle ground under private ownership. These procedures, however, were inevitably affected by an *information deficiency* at the bureaucratic level, as well as the *difficulty* to identify those areas which could potentially produce truffles.

All in all, such incentives have been only partially successful and did not really avoid phenomena of *abandon*, *production transformation* or *land conversion*. Aside from overexploitation, currently the biggest threat to truffles is the *conversion* of forests into *vineyards* and the diffusion

of some harmful cultivation practices (i.e. use of *fungicides* in production). This situation is favoured by several factors: *soil composition* and *morphology* of truffle grounds are highly *favorable* towards grapes too; there is a well-established *tradition* concerning *vineyards* in Piedmont; local *wines* are *highly valued* on the market and demand is rising; vineyards guarantee more *stable* and *immediate incomes* than truffle grounds management; the cost of existing vineyard plots is higher than the costs of forest conversion, and finally there are clearer *property rights* over the product benefits. All these conditions make *wine* a more favorable option than truffles when elaborating private forest management strategies. This conflictuality in the management of resource represent much more than an *economic matter*, as different *management strategies* deeply influence the "*shape*" of the *landscape*.

As a matter of fact, the landscape becomes a direct result of a *conflictual* management of different commons. Given that *truffles* are *common-pool resources*, *winemaking* (and the local traditions) represents a *cultural common*. The disparity of consideration between these two commons is what shaped the *iconic landscape* of these areas, which have been recently elected *World Heritage Site* by UNESCO. This nomination is centered on *vineyards*, neglecting the role of truffles for local communities. However, this *nomination* did not bring disadvantages to truffles as some might expect, on the contrary, it produced *benefits* for the entire supply chain. The most relevant one has been the creation of an *embryonic network* of local realities, composed of *institutions*, *associations*, *inhabitants,* and *landowners*. These different figures have been grouped by the *common interest* for the *valorization* of local excellencies. This network of collaborating users, which have made possible the UNESCO nomination, constitute the foremost ingredient for the *design* of institutions aimed at the *sustainable management* of local truffle resources.

To frame what existing institutions are doing to pursue this goal, the author interviewed the *technical coordinator* of Piedmont Forest sector on truffle production, *Flavia Righi*. Her kind availability aided in the formulation of a personal interpretative framework of the *internal dynamics* of the institution and the market, which would otherwise be hard to grasp. Thanks to a direct interview with her, it has been possible to clarify how the Region is currently involved in many national and international *research programs*, as well as being a direct *promoter* of a detailed effort for the *mapping* and analysis of *regional truffle production*. This effort has already produced an *open-access map* of areas with a *vocation to truffle production*, and it's expected to generate in the *future* a detailed *spatial database* of existing *truffle grounds*. This information will boost future *monitoring* and *management* initiatives, currently disadvantaged by harvesting practices and diffused informality of the supply chain. The other game-changing line which institutions are recently following is to increase *community participation* to truffle preservation efforts. All associations, with different degrees, are already collaborating, but *individual initiatives* and *improved organizations* among association would bring significant benefits to the entire system. A *strengthened collaboration* with local entities would ensure a better preservation of *traditions*, *social identities*, and *landscape*. One of the main goals of the Region is to *avoid* phenomena of *landscape disruptions* influenced by market interests, avoiding the creation of *monocultures* and impoverishment of the environment. It can be said that institutions are now passing through a crucial *phase* of change, in order to effectively respond to current and future conditions. This thesis concludes on an analysis of three future *risks/opportunities* which might arise in the *white truffle market*. The first possible change is the successful development of *cultivation practices*, which so far have been too unreliable to be effective.

Many efforts are being made to analyze and replicate *Tuber magnatum* reproduction in open-grounds, and *innovative technologies* offer reasonable possibilities to *achieve the result*. This new condition would offer great opportunities for implementing sustainable *multiple-use forest management strategies* in the forests. Since truffles are symbiotic fungi with many different hosting plants, their production could be carried out *simultaneously* with *other products* of the forests, thus generating several advantages for landowners. The second most probable condition which could incur is a *progressive privatization of truffle grounds*, carried out to ensure clear *property rights* over *production*. This *privatization* might be favored by developing successful *cultivation methods*, but it can also result from a "*private*" solution to the *commons dilemma*. *Privatization* or any other type of *pure* strategy (*state intervention* and *community*) of forest commons producing truffles would generate *disadvantages* in the *long-run*, further increasing the detrimental *fragmentation* of the market. This will also affect the *landscape* functions, as many forests could become *limited-access* for the population to *ensure truffle production*. The adoption of "*mixed*" solutions, comprehending *institutions*, *privates,* and *communities*, could possibly avoid these risks while ensuring the "*right to the landscape*" as well as *forests* (and landscape) *resources sustainable management*. The last prospect is a *market restructuration*, as current trends are threating to deplete truffle resources in Piedmont. Assuming the *depletion* would not occur, a *change* in market dynamics is *unavoidable*, and it could be triggered both from the development of truffle cultivation or by the improved institutional management of natural resources. Both options would somehow *stabilize* and help to *regulate* the *production*, giving rise to opportunities to *restructure* the markets. The development of more *structured market dynamics*, avoiding the proliferation of informality and exploitation, would benefit all the actors. In the future, it could also open possibilities to *certify* the Piedmont white truffles, which will bring not only protect the *products* and the *consumers*, but it could also act as a further assurance of *correct management* of the forest resources, and of the landscape they belong to.

The structure of this thesis will follow a *hierarchical order* according to the "*scale*" of the concepts. The second chapter expounds on *forests* and *commons*, first by clarifying *semantic* confusions around these notions, then develop a *detailed analysis* of them and their ramification, and it will conclude with a general perspective on what *links* forests and commons. The third chapter deals with *forest products* and *institutions* starting from defining *what* they are, then it will frame forest products *current conditions*, the *role* of institutions in *forest governance* and finally why *planners* should deal with these concepts. The fourth chapter presents the case study of *Alba's white truffle*, first by explaining the *characteristics* of these products and their *tradition* in Piedmont; then it will give an overview of the current *normative framework*, followed by an analysis of the current *local conditions* and *dynamics* of the *supply chain* thanks to the interview of institutional representative, concluding with *future prospects* and *opportunities*. The fifth chapter is the reference *bibliography* and the last chapter is the author's personal thanks.

2. Forests and Commons

In this first chapter, it will be given the starting framework for this thesis, expounding the two major topics of interest: forests and commons. To lay a solid foundation for successive elaborations, these two subjects will be addressed according to several disciplines, making references to different fields and competences. This multidisciplinary analysis is mandatory to give an as wide as possible perspective of what, where and how forest and commons have been, are and will be. The final goal of this chapter is to transmit the importance and relationship these two realities have among themselves and for humans at the global scale.

2.1 For a correct terminology

Before carrying out an analysis of how "forests" and "commons" interact and relate, the first issue to address is to define these two terms. Both are often used by many different speakers, and sometimes they can be interpreted and used in different fields and under different meanings. For example, forests are both biological systems and economic resources, and the interpretation adopted greatly affects any successive elaboration. This is even more true for commons, which are way too often not well defined or understood in their "canonic" definition. Therefore, this work will start by clarifying what talking about forests and commons means and what other concepts (such as property, externalities and more) are connected to them.

2.1.1 The concept of property and its ambiguity

Before focusing on the specificities of "forests" and "commons", it is important to take a step back in point of view and explore a vast and complex concept that underlies both these notions: property rights. When discussing forests and commons, it's a fact that they, as physical entities, exist independently from any legislative agreement concerning the principles concerning resource allocation. Property is thus not an inherent characteristic of an object, but it is a "*feature*" determined by society towards the various fitting entities. The property, when applied to natural resources, can be defined as a "primary" social institution[1], as many other "secondary" institutions are derived from it, such as taxation and credit (Ciriacy-Wantrup S. V., 1963; Ciriacy-Wantrup & Bishop, 1975). As simplified in the words of Demsetz (1974, p. 347), "*property rights are an instrument of society and derive their significance from the fact that they help a man form those expectations which he can reasonably hold in his dealings with others*". It is, therefore, an artificial construct independent by the nature of the goods or services it's attached to, but strongly related to the society in which it's devised and applied. The need of this social institutions lays in the detachment from a "state of nature" into an economically structured society, where individuals act to gain benefits for themselves, raising the need to have their benefits guaranteed and protected by the community they belong to. This transition is related to the concept of *externality*, which can be defined as the effects, being pecuniary as well as nonpecuniary costs and benefits, that any good or service in itself can grant. Demsetz (1974, p. 348) says "*no effect is external to the world*", meaning that anything has an impact on someone, which can be a positive or negative one. One of the most relevant functions of property rights is to "*guide incentives to achieve a greater internalization of externalities*" (Demsetz, 1974, p. 348). The need to internalize externalities, and in correlation the definition of property rights, arise with the emergence of new or different effects, which can develop with any change in knowledge that makes available new possibilities.

Once defined what is the key role of property in society, let's focus on how it works. Property is commonly defined as *a right*, but it cannot be easily limited to a single principle. That is why it's commonly referred to as property *rights*, meaning that it includes more than one right. Indeed, the most widely accepted formulation defines property as a "*bundle of rights*" (Ciriacy-Wantrup & Bishop, 1975, p. 714), which jointly work in defining this social institution. When discussing which rights make up this bundle, many divergences appear. During the 20th century, most scholars focused on private property, assessing that the right to exclude was the "*sine qua non* of property" (Merril, 1998), but this cannot be equally extended to all existing property regimes and it cannot be the unique feature of the property. A first proposal made by Tony Honoré (1961) identified 11 "*standard incidents of ownership*" (composed by 9 rights and 2 duties) regarding full ownership of land: (1) the right to exclusive possession; (2) the right to use; (3) the right to manage; (4) the right to the income; (5) the right to the capital; (6) the right to security; (7) transmissibility; (8) absence of term; (9) the prohibition of harmful use; (10) liability to execution; and (11) the right of residuary character. The combination of all 11 or fewer incidents could be helpful in categorizing

1 The term "institutions" can be confusing since it commonly used to address a plethora of subjects. Ciriacy-Wantrup define them as "*social decision systems that provide decision rules for adjusting and accommodating, over time, conflicting demands (using the word in its more general sense) from different interest groups in a society*" (Ciriacy-Wantrup S. V., 1969).

property interests when applied to many resources, but when discussing common-pool resources (namely resources based on commons), i.e. water basin or fishing grounds, it displays some shortcomings, as most property systems fail to comply to Honoré set of rights. Common-pool resources can be large enough to be costly to exclude potential beneficiaries, therefore making private rights insufficient to CPR. A more fitting set for common-pool resources has been proposed by E. Schlager and E. Ostrom (1992), which defined five rights:

- *Access*: The right to enter a defined physical property.
- *Withdrawal*: The right to obtain the "products" of a resource (e.g., catch fish, appropriate water, etc.)
- *Management*: the right to change the physical structures in a resource system.
- *Exclusion*: the right to determine who else could use the resource and what their specific rights would be.
- *Alienation*: The right to sell or lease of the above collective-choice rights

This list of rights evidently overlaps with Honoré proposal, but the differences cannot be disregarded, even more so accounting for the lack of standard, cross-disciplinary agreement on a common set of names, contents, and meanings of "property rights" (Cole & Grossman, 2002; Cole & Ostrom, 2010).

Once defined why property exists (to interiorize externalities) and how it can be described (i.e. a *bundle of rights* with different criteria), let's briefly discuss the different way property can be translated into. As mentioned before, property is not intrinsic to the object it's applied to, but it's a social instrument, hence, different *property regimes* can be chosen for particular or specific purposes (Bromley, 1992). Among scholars, there are different and opposing positions on which property regime is the most efficient for resources management. Harold Demsetz in his article "*Towards a theory of Property Rights*" (1974) argued that private property was the natural and evolutionary response to the demand for scarce and valuable natural resources. The opposing line of thought looked up at institutional intervention for the regulation of the resource allocation, proposing Hobbes's model of the *Leviathan* as driving force of society. Both models, even if diametrically opposed, claimed that resources had to be either under private or public regime to avoid over-exploitation and deterioration. Neither of them considered common property as a feasible solution, therefore failing to frame and recognize consistent part of regimes around the globe, as well as underestimating that markets (intended as private ownership representative) and governments can fail, both separately and together. At the same time, it's important to highlight that distinction between private, public and common property is not so easy to distinguish, as it hardly (if not at all) exists a *purely* private o *purely* public property (Cole, 2002, p. 13). Ultimately, it cannot be assumed that a specific property regime is fundamentally superior to another in every case, but any regime can be effective in regulating resource allocation. The key factor is the relationship between the property regime and the society in which it's applied; the compatibility with social norms, traditions, and local economies eventually determine if a property regime is apt or not to a specific good or services, be it a forest or a flower.

2.1.2 Defining what is a "forest"

When asking any individual on Earth if he knows what a forest is, the answer will most probably be affirmative. This is because forests are the dominant terrestrial ecosystem on Earth, and they are diffused on the entire surface of the globe, amounting to the 30.6 percent of the global land area in 2015 (FAO, 2015). However, when asking for a *definition* of forest, meaning describing its physical, biological and geographical characteristics, different people will give totally different answers. This variation is due to many factors: first, forest types greatly differ by aspects such as latitudes, temperature, rainfall patterns soil composition and human activities (Achard, 2009). At the same time, the definition of "what is a forest" depends on *who* (biologist, economist, architect, but also inhabitants, governments and so on) is saying it, varying according to the individual final purpose or discipline of specialization. This gives rise to a plethora of different interpretations about forests. To give an idea, when researching what definitions can be associated with the term "*forest*", a recent work listed more than 800 (Lund, 2012). Such numbers are easily explained due to the different finalities defining individuals must address, as well as the differences due to countries, vegetation types, species, goods, and services that characterize them. Moreover, countries may adopt several definitions at times, making the interpretation of such term extremely difficult. In such confusion, a reliable and generally accepted definition is the one adopted by Food and Agriculture Organization (FAO), which define forests as "*land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ; it does not include land that is predominantly under agricultural or urban use*" (FAO, 2015). Such definition is commonly accepted in many countries, such as Italy, even if more specialized formulations may be given. The only lacking aspect in this definition is that it does not consider trees *outside* forests, which may not mean much in rural settings but provide multiple benefits in terms of urban landscape and inhabitants' livelihoods. Moreover, when considering forest products, even a single tree can have a market value, even if such value is considerably lower than more structured ecological systems. Therefore, when talking about the forest, other important related terms that are:

- *Urban and peri-urban forests* (UPFs), defined as "*networks or systems comprising all woodlands, groups of trees, and individual trees located in and around urban areas*" (FAO, 2016b).
- *Protected areas* (PAs), which International Union for Conservation of Nature (IUCN) describe as follows: "*A protected area is a clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values*". This may refer to a plethora of entities, such as national parks, community conserved areas, and many others, and it has clear relationships with World Heritage sites (WHS).

Once explained how many different definitions of forest are in the world, the next level of analysis must be to understand what kinds of forests exist. The foremost categorization can be between *natural* and *planted* forests. Natural forests are the majority of world's forests, amounting to 93 percent of global forest area in 2015, i.e. 3.7 billion ha. Natural forests can be further divided into "*other naturally regenerate forest*" and primary forest, respectively amounting to 74 and 26 percent. Planted forest amount to 219 million ha, with an increase of over 105 million ha since 1990 (FAO, 2015).

More detailed categories can be adopted starting from forest more specific characteristics. First, the latitudinal gradient, which corresponds to the geographical distributions of climate (Woodward, 1987), deeply affects the length of the growing season, from the full year in the wet tropics to only 7 to 10 weeks in the boreal region. Forest life forms and growth forms, i.e. broad-leaved, deciduous, evergreen and needle-leaved trees, are correlated to the seasonality of temperature and rainfall in their geographical region. (Woodward, Lomas, & Kelly, 2004). At smaller scales, both regional and local, factors such as topography, soil type, and others can shape microclimates (Littell, Peterson, & Tjoelker, 2008), just like mountains influence local climates by modifying temperature, wind circulation, and precipitation. The correlation between geographical patterns of forests and climate highlight some major distinguishing variables, such temperature, and precipitation, which have been used as major variables to classify global biomes (Pan, Birdsey, & Phillips, 2013). Among the established classification schemes, two must be cited:

- *Holdridge's life-zone system* (1967), one of the most widely used and a quantitative system. It classifies biomes based on three bioclimatic variables: long-term average annual precipitation, mean annual bio temperature, and potential evapotranspiration ratio.
- *Whittaker's model* (1975), a simplification of Holdridge's scheme. It uses two climate variable, temperature, and precipitation, to represent the aggregate effects of gradients associated with community structure and environment.

Forest classification can, of course, differ from these models, especially with the advent of satellite remote sensing technology, which offers greater reliability thanks to being not "static" and allowing to develop *dynamic global vegetation models* (DGVMs)[2]. A shared and reliable scheme of forest classification is the one developed by FAO (2001) on *global ecological zones* (GEZ) for forest reporting (Table 1).

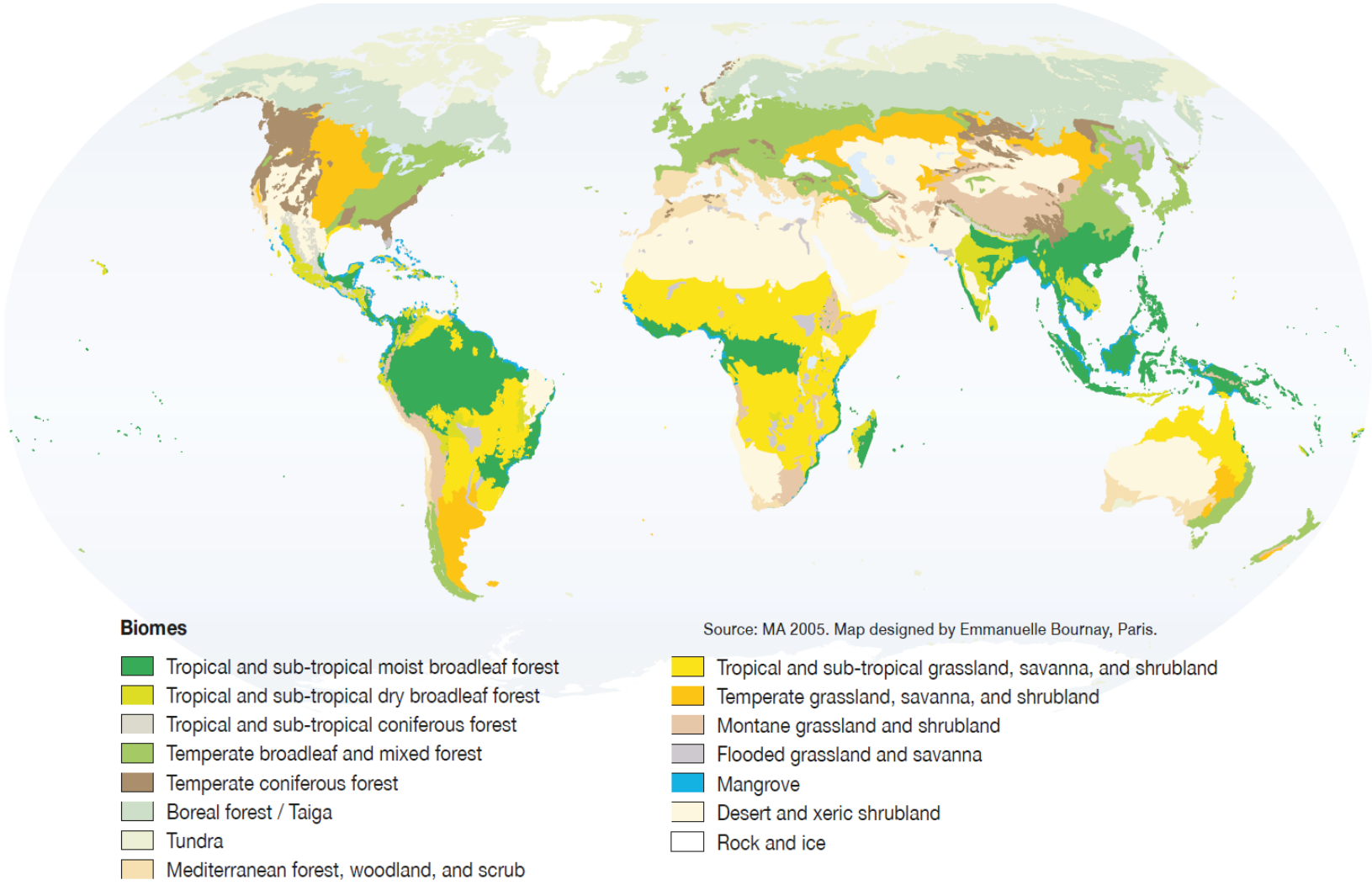
[2] Dynamic global vegetation models (DGVMs): computer simulations of large-scale vegetation and its interactions with biogeochemical and hydrological cycles as a response to climate

Table 1. Distribution and structure of the world's forests (and other woodlands)
Sources: (Pan, Birdsey, & Phillips, 2013; FAO, 2001)

Domain	Forest biomes	Annual mean temperature (°C)	Total annual precipitation (mm)	Seasonality	Canopy height (m)	FAO ecological zone (M ha)	Existing forest (M ha)
Tropical *23.5°N – 23.5°S* *All months without frost*	Tropical rainforest	~ 20 – 25°C	>1500	No dry season	25 – 50	1458	1354
	Tropical moist deciduous (monsoon)	>15°C	1000 – 2000	3 – 5 dry months in winter	15 – 30	1105	795
	Tropical dry forest	>15°C	500 – 1500	5 – 8 dry months in winter	5 – 20	747	645
	Tropical shrublands	>15°C	200 – 500	8 – 11 dry months	3 – 15	831	701
	Tropical mountain systems	<18°C	700 – 2000	0 – 11 dry months	3 – 35	453	351
	Mangrove	>18°C	700 – 2000+	Highly variable	3 – 30	-	14
	Peat swamp	>18°C	1500 – 2000+	<5 dry months	12 – 50	-	44
Subtropical *25°N – 40°N, 25°S – 40°S* *8+ months over 10°C*	Humid forest	14 – 22°C	600 – 1000+	No dry season	10 – 35	468	375
	Dry forest (Mediterranean)	>7°C	300 – 1000	Winter rains, dry summer	6 – 30	159	199
	Subtropical mountain system	<12°C	500 – 2000	C 0–8 dry months	10 – 30	486	408

Domain	Forest biomes	Annual mean temperature (°C)	Total annual precipitation (mm)	Seasonality	Canopy height (m)	FAO ecological zone (M ha)	Existing forest (M ha)
Temperate *~40◦N – 54◦N, 40◦S – 54◦S* *4–8 months over 10◦C*	Oceanic forest	5 – 11◦C; Coldest month >0◦C	600 – 3500+	All year growing season	50 – 100+	181	127
	Continental	~10◦C; coldest month <0◦C	750 – 1500+	120–250 days growing season	25 – 40	695	473
	Mountain systems	<10◦C	1000 – 2500	Variable	10 – 75+	723	497
Boreal *50◦N – 55◦N to 65◦N – 70 °N* *Up to 3 months over 10◦C*	Coniferous	−12–6◦C; 3 months >10◦C	<500	<100 days growing season	<15	865	697
	Tundra woodland	−15–0◦C Summer 6–14◦C	150–250	35–65 days growing season	<15	395	496
	Boreal mountain system	−14–5◦C Summer 6–16◦C	400+	50–80 days growing season	<15	630	582

Figure 1. Biomes of the world. Source: (Achard, 2009)



2.1.3 What's the meaning of "commons"?

For the term "*commons"*, the correct adoption of a terminology is pivotal. This is due to the misconception about what "*commons*" really means, which dates to the etymology itself. What is often interpreted as "*commons*" derive from traditional English (13th century), and it was used when referring to the common land system adopted in medieval England for the use of land by commoners. Such correlation was first introduced by Hardin's work (1968), which made the example of "*pasture open to all*", where herdsmen would be individually motivated to increase their own profit to the detriment of others, thus destroying the equilibrium of the resource. If, however, we track back the origin of the word to Latin, its origins are from the word "*communis*", meaning "public, general, common". Such word was not used for resources which were limited and therefore at risk of depletion by overuse, but it related to areas and goods which were open to the public and not necessarily exhaustible, in opposition to "*res publica*", meaning things managed by the government. When discussing what we currently refer to as commons, Romans used to adopt the definition of "*res nullius*", which means "nobody's property" (Ekback, 2009). This makes obvious that an enormous difference exists between the Latin and traditional English words for such entities, which is also reflected in the difference between Roman law and English "*common law*". In the English sense, the Commons were pieces of land whose owner's rights were restricted and to which other people (namely the commoners) had certain rights over. This was a confusing and often conflictual definition, and it gave rise to many issues still nowadays affecting modern society. Instead, the Roman interpretation was a more ideologically imprinted one, since when affirming the non-ownership of such pieces of lands and goods, it gave them a somehow religious meaning, as they were perceived as *unalienable* to every individual and therefore to be preserved for the common wellbeing. Such interpretation is surely a more philosophically interesting one, but historically it was not predominant.

Therefore, when referring to commons, the general reference is to English-based commons, which can be described as "*belonging to or shared by two or more individuals or things or by all members of a group*" (Merriam-Webster, 2018). This is, of course, a very generic definition, and it doesn't give a clear idea of the relevance of such a concept to the public and for academical researches. But the implications of this term and its role will be better defined later. Other related terms often used are:

- Common-pool resources (CPRs): "a resource made available to all by consumption and to which access can be limited only at a high cost" (Encyclopædia Britannica, 2015)[3].
- The *Tragedy* of the Commons: the iconic title of Hardin's paper (Hardin, 1968), meant as the "degradation of the environment to be expected whenever many individuals use a scarce resource in common" (Ostrom, 1990).

[3] Alternative but more detailed description list CPRs as "natural or human-made resources where one person's use subtracts from another's use and where it is often necessary, but difficult and costly, to exclude other users outside the group from using the resource" (Hess, Research on the Commons, Common-Pool Resources, and Common Property, 2006).

- Common property: "formal or informal property regime that allocates a bundle of rights to a group. Such rights may include ownership, management, use, exclusion, access to a shared resource" (Hess, 2006).

The terminology mentioned (to be met in successive chapters), even if not explained in depth[4], will help the readers to get familiar with the uses of these iconic but not-well-understood themes.

4 When deemed necessary for the correct interpretation of the context or of specific references, further information will be provided in the related chapters.

2.2 Forests: present and future role on a global scale

Forests have always had a role in human history since antiquity. From a source of materials and food for subsistence to biological ecosystems, their function and importance to humankind have varied across millennia. Modern technologies, mutated social systems, and environmental conditions are currently a huge threat to forest prosperity across the globe. Understanding entirely what forests represent for human societies would be too wide of a topic, especially as nowadays their functions are many and complex ones. Therefore, this chapter will briefly introduce why forests have been fundamental for human development in the past, why they should still greatly matter in modern times, and how actively preserving them would be of great support to humans worldwide.

2.2.1 Past and present

Forests have been fundamental presences for human societies since time immemorial. Tracking back to the Pre-History period, humans were fundamentally populations of hunters and gatherer, to whom the rich and various resources offered by forests represented key factors for their wellbeing. Forests provided not only food sources (such as animals living therein and wild harvestable flora), but they were also the source of wood, a fundamental resource for a very long part of human history and still of great importance nowadays. The relationship between humans and forests in the early periods of history was quite balanced, especially when compared to later ages. Forests were, in fact, not only a source of goods, but they played an important role in many religions and customs, as places of communion between humans and Nature. The first major shift happened in the Middle East during the 3rd millennium BCE, where the local vast cedar forests were largely and indiscriminately destroyed under the will of kingdoms' rulers, all in order to acquire timber for their massive building programs. The construction of temples and palaces in the Fertile Crescent and their impact on the forests is documented in the oldest known written story of humanity, "*The epic of Gilgamesh*", in particular in the second episode, known as " *The Forest Journey*" (Perlin, 1989). In this episode, it is narrated how, after overcoming the divine guard Humbaba, nothing could stop humans from cutting down all the trees, which Gilgamesh and Enkidu would employ to build the cedar gate of Uruk. After that, the exploitation of forest in the Middle East continued with Phoenicians, which required timber for their ships, to find which they turned to the nearby forests of Lebanon. Similar events are recorded for the construction of the first temple in Jerusalem under King Solomon. These events are recorded in many ancient texts, from the Bible to poems of Homer, Plato, and Pliny. Later on, the effects of prolonged unscrupulous deforestation partially contributed to a shift of the center of trade from the Middle East to the Greek world (Perlin, 1989), which was advantaged by long coastlines and many islands, as well as availability of timber in the inland. These factors turned civilizations in Greece and Asia Minor into maritime and trading powers, which were later suppressed by the emerging Rome. Romans were greatly reliant on wood and forests for many motives, as narrated by Pliny's "*Natural History*" books XII to XVI, specifically dedicated to trees. The extensive and tumultuous expansion of the empire seriously damaged forest areas inside of it, which coupled with the always increasing demand of wood and resources for industries gave an ulterior impulse toward the colonization of territories, especially in northern Europe, so abundant in forests. Afterward the Mediaeval Age, which saw the diffusion of a widespread subsistence economy among populations, thus lacking extensive deforestation[5], another period of extensive reliance on forests occurred. The development of naval trading route started in the Mediterranean basin, with Venice at the forefront of the era. Timber demand, for vessels and development alike, increased exponentially, with forest under their influence unable to effectively comply it, thus producing a grave shortage by the end of 15th century. Later, Venice and the Mediterranean lost their role, substituted by the North Sea and even more by the increasing overseas colonial trade, with countries like Spain and

[5] This is true mostly for Europe, as China, due to population growth and increasing timber demand, in the 13th century experienced grave wood shortage, resulting from the overharvesting of forest resources. Other countries or regions may possibly have had similar occurrences in the period, but there are less documents ascertaining those events.

Portugal experiencing meteoric power rise power in the 15th-16th centuries. The development of such assets put much pressure on forests, especially in Spain, which resulted in grave consequences, especially after the construction (and destruction) of *The Armada* to attack England. The latest historical event which deeply affected forest took place firstly exactly in England (and later similarly occurred across Europe), and it's related to the advent of Industrialization in the 18th century, which saw wood as the main energy source. This reliance, aggravated by the increasing demand of industries and growing population, caused a shortage of wood, especially in great cities which already exhausted their forest resources in the race for industrial development. The solution was found in the shift to coal as the main fuel, even if this produced more complex aftereffects on the environment in the long term.

This brief paragraph expounded mostly the role of the forest as sources of wood, which can be attributed to the major role timber played in global history for many years. Nonetheless, other forest products also had a key role throughout human history, even if it may have been somehow less relevant than timber in recorded history. The availability of foods such as roots, mushrooms, and berries, contributed immensely to the wellness of population across the globe, acting as supplements to the diet or as the main source of food. In modern times, even if the paradigm of living and industries changed greatly, from a rural lifestyle to an urban and metropolitan one, the role of forests, as means of subsistence and possibly improvement, is still great. To better understand forests worldwide relevance in recent years, let's first point out some data.

The global rural population, which has been recently surpassed by the urban one, accounts for nearly 3.4 billion, with the majority being in developing countries, especially Africa and Asia representing around 90% of it (UNDESA, 2018). Studies suggest that around 820 million rural people on the tropics live in forests and savannah areas (Chomitz, Buys, De Luca, Thomas, & Wertz-Kanounnikoff, 2007), of which around 250 million in the condition of extreme poverty (accounting for 40% of extreme rural poor) (IFAD, 2016). Moreover, forest products are essential for many: one-third of world population (2.4 billion) use majorly wood to provide energy services, while 1/5th of the population, especially vulnerable strata such as children, women and elderly, depends on products of the forest for food, income and nutritional diversity (FAO, 2018). These first data give just a superficial insight into the direct and immediate effects of forests globally. To frame what forests signify for populations, there are two perspectives that can be useful: viewing forests as *goods providers* or viewing them as *services providers*. These two categories are non-independent but strongly related as both are based on the same system. When seeing the forest as a source of goods, income or resources, the reference is mostly to Non-Wood Forest Products (NWFPs, also Non-Timber Forest Products NTFPs) and wood related resources (Timber and wood-based products). The former refers to every product of forests which can be harvested without greatly damaging the trees and includes nuts, berries, leaves etc., while the latter usually involves the partial or complete destruction of a tree, usually negating other uses of the resource (especially NWFPs). While the timber market has a quantified bigger economic impact, NWFPs have been estimated to produce a worldwide income of USD 88 billion, even if such number is thought to be "substantially underestimated" (FAO, 2014). If this is the relevance of resources exploited directly from the forests, the benefits they grant are much wider than it may appear. Forests have an essential role in providing, thanks to their

complex characteristics, what are commonly identified as *ecosystem services*. The terminology includes a variety of different feats such as food and water supplying systems, flood and disease control, cultural services and supporting services to human settlements (Millennium Ecosystem Assessment, 2005). Forest have, therefore, always influenced the dynamics of settlements and populations residing around them (or even further off depending on the territorial system). During the entire human history, modifications of any kind of forest systems, being them either willed or natural, have, sometimes subtly, sometimes openly, affected the course of action of human activities in the area. For example, the loss of tree due to deforestation have often altered hydrologic regulation of the soil, thus possibly affecting other apparently unrelated activities such as agriculture and water management. The different "values" population attached to forest inevitably changed the way they treated and managed such resources. To understand what "values" forest might have for human settlements and population worldwide, implementing an economic framework might be helpful to reach a generally shared understanding. Therefore, the next chapter will explore how the economic frames the different "values" of global forests, starting from their duality as good and service providers.

2.2.2 Forest economic duality: goods source and services provider

The economics of forest is part of a wider topic which is environmental economics. This current of economic has experienced an increasing interest in recent decades, in conjunction with growing concerns about the environment. One of the main goals of environmental economics is to understand how to preserve the environment, not driven by a moral conception but according to the need to allocate resources in an efficient way.

When discussing what economic functions environment provides, Pearce and Turner (1994) identified four basic ones:

- *Amenity values*, intended as the pleasure the environment supplies directly to humans, such as landscape and species observation.
- *Resource base*, when acting as the basic input for the economic system, as it holds both renewable and non-renewable resources which make up the starting point of the market.
- *Waste sink*, meaning the assimilative capacity of digesting residuals from the economic system and process such residuals into new usable resources.
- *Life-support system*, accounting for the fundamental role in the preservation of global biology, for both humans and non-humans.

These four functions have a very distinct area of action and, apart from the role of the resource base, have been mostly poorly considered by economic theories for a long time. This can be motivated by a simple consideration, that is the difficulty in defining a clear value to the other functions, either because they have a complex range of factors affecting their actions, or because their effects are clearer on a broader perspective than that of common market approaches. Nonetheless, they all depend on the well-being of the environment and its ecosystems, such as forests, rivers, seas and so on. The disruption of the integrity of these entities, either due to over-exploitation or pollution, negatively affects the overall system capacity to generate resources (and its other values, too). If the environment can be interpreted as a global network of different entities composing an interdependent system, the strategies to promote a sustainable management of such entities must address both global and local issues, as well as being calibrated according to single entities characteristic. Therefore, when discussing forest management, a tailored approach will be needed, considering the specificity of forest settings and communities.

As aforementioned, forests in term of market economy can be framed as providers of goods and services, both of great importance for humankind. The most basic example of this is the role of timber, obtained by the deforestation, and oxygen, a by-product of photosynthesis which is essential to life. Both these two goods are commonly provided by forest and can most certainly be regarded as fundamental to humankind. Even if both goods have a clear importance, they originate from distinct and opposing behavior towards forests: timber originates from the loss, which can be controlled or not, of forests, while oxygen requires for the maintenance of forests well-being. Theoretically speaking, the importance of oxygen is vastly superior compared to timber, being the basis gas for sustaining carbon-based organisms, from micro bacteria to humans. And yet, this fundamental role is not evident when analyzing the forest condition worldwide. From 1990 to 2015, the global land area

occupied by forest decreased from 31.6 percent to 30.6 percent, quantifiable to around 129 million ha of forest net loss, representing an annual net loss rate of 0.13 percent (FAO, 2015). Of course, these data must be interpreted, since the net loss rate has not been constant, but it decreased from 0.18 percent in the 1990s to 0.08 percent in recent years. This can be seen as a positive trend, even if the balance remains negative. The loss of forest area is not uniquely caused by human activity since events such as natural disasters could affect it too, but deforestation plays a vital role in the destruction of forest ecosystems. The causes of deforestation are complex and varied, as they include factors such as population change, with consequent increased demand for land mostly for food production. This kind of processes can be explained by a relatively simple concept: economic incentives. In fact, inefficient logging and land conversion do not occur due to some morally "vicious cycle" perpetrated by rural populations, but simply because "*when conservation competes with conversion, conversion wins because its values have markets, whereas conservation values appear to be low or zero*" (Pearce, 2001, p. 285). This trend is mostly related to a simple yet contradictory principle: most of the ecological functions of the forests do not have a clear market value. The absence of a clearly defined or otherwise relevant market value, which can be identified as a price, must not mislead into thinking that such functions have no economic value.

Before discussing how to assign an overall market value, let's discuss which kind of values can be adopted in the analysis of forests. Pearce (2001) classifies forest values into four categories:

- *Direct use values*: it includes all the values arising from consumptive and non-consumptive uses of the forests, e.g. the extraction of timber and wood fuel, the gathering of genetic material and tourism.
- *Indirect use values*: based on various forest services, such as protection of watersheds, climate regulation, and carbon storage
- *Option values*: they express the willingness to pay to conserve the option of making use of the forest even though no current use is made of it.
- *Non-use values* (also existence or passive use values): the willingness to pay for the forest in a conserved or sustainable use state, unrelated to a planned use of the forest themselves

Each of these categories has different evaluation depending from factors such as location, traditions, and welfare, but studies suggest that the dominant values worldwide have been mostly for timber extraction and carbon storage (see Table 2)

Table 2. Summary of economic values ($/ha if not otherwise stated). Source: (Pearce, 2001, p. 293)

Forest good/services	*Tropical forests*	*Temperate forests*
Timber conventional logging	200-4400 (NPV)	-4000 to +700 (NPV)
Timber sustainable logging	300-2660 (NPV)	
Fuelwood	40	-
NTFPs	0-100	small
Genetic information	0-3000	-
Recreation	2-470 (general) 750 (near towns) 1000 (unique forests)	80
Watershed benefits	15-850	-10 to +50
Climate benefits	360-2200 (GPV)	90-400 (afforestation)
Biodiversity (other than genetics)	n.d.	n.d.
Amenity	n.d.	small
Non-use values		
option values	n.a.	70?
existence values	2-12	12-45
	4400 (unique areas)	

The interpretation of this table can at least rise two interesting reflections: first, these values are non-additive, as many functions are in contrast with each other; second, the uniqueness of forests have a great influence on values, especially with high non-use value. The values on this table reflect a pressing matter in many countries, which is the difficulty or inadequacy in the assessment of forest values, especially for non-direct ones. The evaluation of forest services faces a major obstacle in the market confrontation since they have no commonly shared market value and its assessment is made harder by the different nature of services. One solution to determine a price for life-supporting systems provided by forests has been the evaluation of the value of the marginal change in their availability. These approaches have some clear deficiencies, as in many settings forest services cannot be easily quantified and evaluated in term of quality; therefore, giving an assessment based on the marginal variation of the services could prove to be impossible or highly ineffective for determining a reliable economic value. In fact, if the evaluation of forest benefits is too burdensome for involved stakeholders, this might decrease the interest in promoting conservative actions. The point of evaluating the economic value of forest benefits is to determine the right incentives towards conservation, especially in critical forest areas where forest services are substantial and financial incentive could shift the balance between conversion and conservation, favoring the latter.

Finally, when discussing the economic values and role of forest for population, one of the main features to be considered is the role of the discount rate of the resource. This is deeply connected with local population consideration upon forest perceived future values: if the forest sustainable maintenance is considered less relevant than its conversion or exploitation, than it will have a higher discount rate, meaning it will be less likely for the forest to be preserved and efficiently managed. Discount rates are not univocally defined, but they highly depend on local conditions. It has been observed how in developing countries, where the population has less secured rights to land or lower basic incomes, that forest faces higher discount rates than in developed countries. More than a cultural fact, this is strongly related to the economic conditions of such countries, where population often lack reliable sources of income and therefore recur to forest resource exploitation or conversion to increase their living conditions. This ultimately involves the adoption of different management strategies by governing institutions, thus resulting in different possible outcomes for forest resources, which in many countries devolved into overharvesting and consequently depletion. To address such issues, a global effort must be directed towards the improvement of developing countries living conditions hand in hand with sustainable natural resources management strategies. One of most commendable on-going efforts has been the 2030 Agenda of the United Nations, which offers a new framework for forest roles in global settings, emphasizing the transversal role they can have in global development (interpreted as a contribution to Sustainable Development Goals and Targets).

2.2.3 Towards the 2030 Agenda: forest benefits to SDGs

When discussing what will be forests' role in future human development, a valid method, adopted by FAO in its 2018 report, is to frame it according to the United Nations 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals (SDGs), a common framework for guiding development policies throughout the world (UN, 2015). The Agenda has four main objectives, eradicate poverty, heal the planet, secure prosperity for all and foster peace and justice, and it was further reinforced through the Paris Agreement. The 17 SDGs are problem-oriented and not sector specific, meaning they are not specifically addressed by single independent action, but there is the need to identify interlinkages between SDGs and actions. To express it simply, when implementing a solution designed for a specific problem, it affects different SDGs in an interconnected system, therefore there is a need to evaluate the effectiveness of it accordingly to a wider framework. Here is the 17 SDGs list (UN General Assembly, 2015):

[1] End poverty in all its forms everywhere
[2] End hunger, achieve food security and improved nutrition and promote sustainable agriculture
[3] Ensure healthy lives and promote well-being for all at all ages
[4] Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
[5] Achieve gender equality and empower all women and girls
[6] Ensure availability and sustainable management of water and sanitation for all
[7] Ensure access to affordable, reliable, sustainable and modern energy for all
[8] Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
[9] Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
[10] Reduce inequality within and among countries
[11] Make cities and human settlements inclusive, safe, resilient and sustainable
[12] Ensure sustainable consumption and production patterns
[13] Take urgent action to combat climate change and its impacts
[14] Conserve and sustainably use the oceans, seas and marine resources for sustainable development
[15] Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
[16] Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
[17] Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development

Figure 2. Sustainable Development Goals developed for 2030 UN Agenda

On a first read, each goal has a wide range of implications, and therefore it must be addressed with a cross-sectoral approach, which must foster positive interactions between actors on a local, national and global scale. Each goal has specific targets, amounting to a total of 169 associated targets which are integrated and indivisible from their related goals.

Regarding forests, FAO *State of World Forest 2018* focuses on addressing 10 SDGs (specifically SDG1, SDG2, SDG5, SDG6, SDG7, SDG8, SDG11, SDG12, SDG13, and SDG15) and 28 selected targets. They, however, highlight that "forest and trees contribute to all 17 SDGs, as well as to Aichi Biodiversity Targets of the Convention on Biological Diversity, and the Paris Agreement on Climate Change" (FAO, 2018). Such width of applications is possible thanks to the multiplicity of factors and relationship that forests inherently have. Forests and trees, in fact, make a vital contribution "both to people and the planet, bolstering livelihoods, providing clean air and water, conserving biodiversity and responding to climate change", as well as providing "products and services that contribute to socio-economic development". Let's express these linkages in more detail, following the SDGs framework according to FAO.[6] [7]

SDG1 – No Poverty. As mentioned above, around 40% of rural poor (defined as living on less than USD 1.25 per day) lives in or around tropical forest and savannah areas, with different distribution between and inside countries (Table 3). Studies suggest a strong association between areas of high forest cover and high poverty rates, as well as low poverty density (Sunderlin, Dewi, & Puntodewo, 2007). In these conditions, forests represent a source of income, subsistence goods, as well as a safety net for population relying on agriculture as a primary activity. In fact, a study suggests that on average, environmental income[8] accounted for 28% of total household earnings, nearly as much as crop income (Angelsen, et al., 2014). This reliability towards forest and forest products is influenced by some characteristics of the resources themselves. First, biomass stocks, such as trees, do not depend on biomass growth as much as non-perennial crops, making them less susceptible to weather shocks. Second, natural ecosystems are more diverse than agricultural ones, making them more stable (Noack, Wunder, Angelsen, & Borner, 2015). Lastly, forest products are often available when other income sources are not, making them useful for making up household incomes in many regions.

[6] In the next paragraphs, the linkages are analyzed not considering the superstructures existing on the referred goods and services (such as resource management choices, agreements between actors etc.). Such relationship will be addressed on later chapters.

[7] Forest impact on SDG5 have been omitted in this chapter because it's related to policy making more than forest characteristics. It will be mentioned on later chapters.

[8] The term environmental income is used to reflect "the hidden harvest" — the diversity of goods provided freely from the environment, i.e. from non-cultivated ecosystems such as natural forests, woodlands, wetlands, lakes, rivers and grasslands (Angelsen, et al., 2014)

Table 3. Rural people living on less than 1.25 USD/day living in or around tropical forests and savannahs. Sources: (Chomitz, Buys, De Luca, Thomas, & Wertz-Kanounnikoff, 2007; IFAD, 2013)

	Africa	*Latin America*	*Asia*	*Total Tropics*
Forest population (millions)	284	85	451	820
Forest population living on under USD 1.25/day (millions)	159	8	84	251
Forest population living on under USD 1.25/day as a percentage of total rural population living on under USD 1.25/day	50%	82%	27%	40%

SDG2 – Zero Hunger. Forests improve food security in many areas by "providing food and dietary diversity, supplying wood energy for cooking food, and enhancing the resilience of the ecological and social systems surrounding agriculture" (Wheeler & von Braun, 2013). As mentioned above, forest, in fact, does not only provide products to be directly consumed or sold for an income (NWFP & timber), but they also create important habitats which host animal and insects, useful for pollination and consumption. Moreover, the presence of trees in agroforestry system has proved to improve agricultural crops, thanks to contribution such as soil protection, nutrient circulation and water regulation (FAO, 2010). Lastly, wood fuel is estimated to be a mean for cooking meals, sterilizing water and heating homes for 2.4 billion people worldwide, with 765 million depending on it for water safety measure (FAO, 2017a).

SDG6 – Clean Water and Sanitation. The forest-water relationship is a very close and complicated one. It might be obvious to say that water availability and quality is fundamental for the well-being of forests and trees, but it's often overlooked that forests as a system play a vital role in maintaining and preserving water sources. In fact, forests are an active and important part of the water cycle: they regulate stream flow, support groundwater recharge, and through evapotranspiration contribute to cloud generation and precipitation (FAO, 2018). To express it with some data, over 75% of world accessible freshwater comes from forest watershed, with half of Earth population dependent on these areas for water supplying (Millennium Ecosystem Assessment, 2005). This applies to the urban population as well, since over 1/3 of world metropolis (accounting for 366 million inhabitants) take a great share of their drinking water from protected forests (Dudley & Stolton, 2003), with this number rising if non-protected or recognized water-providing forests are accounted. When considering the urbanization trends, which project urban population to make up 68% of world's (UNDESA, 2018), the role of forest become pivotal as natural infrastructure that supports water supply.

SDG7 – Affordable and Clean Energy. Wood fuel is considered one of the most affordable and reliable energy sources, used both for heating homes and electricity generation or co-generation of heat and power. It's differentiated in many products available on the market, mainly as woodchips, wood pellets, and wood charcoal, with potential developing wood-derived liquid fuels, such as biodiesel or ethanol, for transportation purposes. The main

feature that makes wood fuel sustainable, aside from its cheapness and availability, it's it represents a major renewable energy supply, which accordingly to FAO is equivalent to 40% percent of world's renewable energy supply (FAO, 2017b), which translate to about 6% of global primary energy supply. An important factor is that wood fuel is widely exploited in developing countries, but it constitutes a relevant portion of energy use in developed countries too. Since it's based on a renewable and growing stock, namely the forests, when considering a sustainable use of this resource, this represents 142 billion tonnes of oil equivalent, equaling to around 10 times annual global primary energy consumption (FAO, 2016a). Even if not considering a complete shift towards wood fuel, such abundant resources are considered a great asset towards a sustainable energy production.

SDG8 – Decent Work and Economic Growth. Forestry and forest-related industries are widespread activities, whose characteristics greatly differ between regions. The main division we can highlight is between formal and informal activities. The formal sector incomes, direct and indirect, employs around 45.15 million jobs globally, and produce USD 580 billion per year (FAO, 2014), while informal employees are estimated between 40 to 60 million (Agrawal, et al., 2013). Given the relationship between poverty and forests, the market relevance of this sector potentials is a big incentive for its development, especially in developing areas where other possibilities are limited. Another possible income provided by the forests is related to ecotourism, among the fastest-growing market's segment around the world (Conservation International, undated). Protected areas (PAs) are estimated to have totaled USD 611 billion globally in 2014, with significant regional variations (Balmford, et al., 2009), making it a feasible and remunerative solution for sustainable development.

SDG11 – Sustainable Cities and Communities. Green spaces such as urban and peri-urban forests have an asserted positive impact on citizen livelihood and wellbeing, which can be quantified with several tools[9]. Specifically, FAO asses that "urban forests and trees can contribute to the protection of cities' local cultural and natural heritage by enhancing communities' sense of place, providing settings for recreational and physical activities, increasing aesthetic appreciation of the surrounding environment, inspiring artistic expression, and fostering local tourism" (FAO, 2018). Two key parameters about forests and trees in urban settlements are the extension of urban tree canopy cover[10], which measures the quality of open spaces; and accessibility, influenced by factors like distance, distribution, typology, and quality[11]. A

[9] (FAO, 2018) refer to I-Tee Eco, a tool developed by the US Forest Service, which express tree systems' benefits in monetary terms given information on trees (such as species, diameter and health condition) and cross-referencing them with local hourly air pollution and meteorological information. References on application studies:

> Rogers, K., Sacre, K., Goodenough, J. & Doick, K. (2015). *Valuing London's Urban Forest: Results of the London i-Tree Eco Project*. Treeconomics London. 84 p.

> Nowak, D.J., Hoehn, R. E.III., Crane, D.E., Stevens, J.C. & Walton, J.T. 2007. *Assessing urban forest effects and values: New York City's urban forest*. USDA Forest Service, Northern Research Station Resource Bulletin NRS-9. Newtown Square, PA, USA. 24 p.

[10] Intergovernmental Panel on Climate Change (IPCC) defines it as "the percentage of the ground covered by a vertical projection of the outermost perimeter of the natural spread of the foliage of plants". Reference: IPCC. 2003. *Good practice guidance for land use, land-use change and forestry*. Institute for Global Environmental Strategies (IGES), Kanagawa, Japan.

[11] The definition of accessibility varies greatly from legislation agencies. The European Environment Agency (EEA) adopt a 15 minutes walking distance (approx. 900-1000 mt.) from living areas, in United States the

special mention must be done about forests and tree contributions to urban UNESCO World Heritage Sites (WHS), which can be measured (Table 4) by the use of related terms (trees, forest, gardens, park, man-nature) in WHS selection criteria and WHS description and management information. The relationship between forests, culture, and wellness is, therefore, a proved one, making the planning and management of urban forests a central topic in future urban planning.

Table 4. Percentage of urban World Heritage Sites (WHS) that include natural elements as a key component (calculated as related terms presence in documents). Source: UNESCO. 2017. World Heritage Centre – World Heritage list

	WHS selection criteria	*WHS description and management information*	*Total urban WHS*
Africa (sub-Saharan)	12	18	15
Asia Pacific	12	16	54
Europe	11	13	224
Latin America and the Caribbean	8	11	54
North America	0	0	6
Near East and North Africa	13	13	31
World	11	13	384

SDG12 – Responsible Consumption and Production. Considering the rising global population, which correlate to rising product demands, especially in developing countries where forest are a major source of income and resources, the technical improvements in wood products have strong positive effects towards resource productivity. An example is an increasing shift from roundwood production to sawnwood and wood-based panels, with the latter demanding 10-20% less raw material input per unit of output[12]. Another positive initiative is the increasing paper recycling rate in the paper industry, which increased from 24.6% in 1970 to 56.1% in 2015, even though such rates differ greatly among regions (FAO, 2017c). Another important issue concern forest product certification, but it will be discussed later in this thesis.

average distance inhabitants are willing to walk is ¼ of a mile (approx. 400 mt.), while in the United Kingdom recommendations is that "no person should live more than 300 metres from their nearest area of accessible natural green space of at least 2 hectares in size". Sources:

- Ambiente Italia Research Institute. 2003. *European Common Indicators: Towards a Local Sustainability Profile*. Final Report. Milano, Italy.
- Boone, C.G., Buckley, G.L., Grove, J.M., & Sister, C. 2009. Parks and people: An environmental justice inquiry in Baltimore, Maryland. *Annals of the Association of American Geographers*, 99(4), 767–787.
- Natural England. 2008. *Understanding the relevance and application of the Access to Natural Green Space Standard*. Natural England, London.

[12] 1 m^3 of sawnwood need 1.9 m^3 of roundwood, while 1 m^3 of wood-based panels (ex. Fibreboard and particleboard) need 1.5-1.7 m^3 of roundwood. Source: UNECE-FAO, 2010. *Forest product conversion factors for the UNECE region*. Geneva Timber and forest discussion paper 49, UNECE Timber Section, Geneva, Switzerland.

SDG13 – Climate Action. The Paris Climate Agreement in 2015, just like many other studies, assess that forests and trees are essential for the accumulation of greenhouse gases (GHGs) in the atmosphere, working as carbon sinks which sequester carbon dioxide during their lifecycle. The approximate quantification of this effect is 2 billion tonnes of CO_2 equivalent, but it's currently threatened by deforestation (which also contribute to nearly 20% of GHGs global emissions) and natural disasters (with 800+ million hectares of the forested area destroyed/affected between 1996-2015 (FAO, 2015)). The major concern is enhancing the resilience of forestry systems, involving interventions on natural resources, land-uses, and people's livelihoods, following a landscape approach to improve the stability and vitality of ecosystems (FAO, 2018).

SDG15 – Life on Land. As obvious as it might seem, the role of forests in the preservation and improvement of life on Earth is crucial, since they have a complex network of relationship involving other living organisms, soil, water, and atmosphere, to which they provide a wide range of contribution in terms of services and goods. The global forest area amounted to 4 billion hectares in 2015, and host 2/3 of terrestrial species on tropical forests alone (Gardner, et al., 2009), as well as being species-rich ecosystems in their context (Millennium Ecosystem Assessment, 2005). Despite these contributions, the world is still losing forests, decreasing from 31.6% to 30.6% of the global land area between 1990 and 2015 (FAO, 2015), even if the pace of such loss is decreasing recently. It comes with little surprise that the losses occur mainly in developing countries, where forest area are converted for agricultural and other purposes, whereas in some area of Asia, North America and Europe many afforestation programs and natural reversion into forests are occurring. The Global Forest Goals of the UN Strategic Plan have among its aims to reverse the loss of forest cover and increase forest area by 3% worldwide by 2030, to be achieved through forest and landscape restoration (FLR) initiatives, monitored by FAO Forest and Landscape Restoration Mechanism (FLRM) since 2014. These objectives are relevant not only to maintain the forest presence on a sustainable level, but they enhance the preservation of biodiversity in many different settings, from mountainous to tropical regions, whose species are often enlisted on the Red List Index (RLI)[13].

This list of actions and guidelines elaborated by FAO represent a proposed institutional framework for forest management goals across the world. As stated before, forest resources are many and their effects touch different aspects of human society. How different forest resources are managed by various institutions to achieve specific goals can give an insight into how social and economic interests can "shape" the resources future. Commons, which are resources possessing specific risks and opportunities deeply associated with their management, deeply reflect the relationship between management strategies and resources conditions. Analyzing how commons works and comparing them with forests resources represent an interesting and helpful way to understand how interests (social, economic, …) of governing institution could shape forests futures.

[13] RLI measures changes in aggregate extinction risk across groups of species, based on changes in the number of species in each category of extinction risk on the IUCN Red List of Threatened Species. A specific indicator (Red List Index [forest-specialist species]) has been developed due to the relevance of this category. Source: IUCN. 2015. IUCN Red List of Threatened Species. Version 2015.1. International Union for Conservation of Nature, Gland, Switzerland.

2.3 Commons: how they work, *tragedies* and potentials[14]

Commons are quite a popular topic among scholars of different disciplines, as they "embrace" several and disparate situations which can be included in this definition. When discussing what commons really are and how they work, however, most fail to give a clear (or correct) answer. This chapter will thus present a brief introduction on Commons, expounding how they were born, explaining why there exists a so-called "*Tragedy of Commons*", and why dealing with commons represent an important global challenge that experts are facing nowadays.

[14] Since describing in a single chapter, or even a single book, the entire corpus of knowledge about commons would be a vain effort, this section wants to simply highlight some general information about commons, which might prove to be useful for readers who approach for the first time this theme and could maybe offer new linkages to experts working on these topics.

2.3.1 The emerging of the commons' dilemma and their characteristics

As mentioned in chapter 2.1.3, the term "*common*" has been used since the 13th century in England, and it was associated with the legislation and regulation concerning grazing and exploitation rights of forest and pasture not privately owned, which were therefore open to locals. Even if such wording has been in use from a long time ago, the relevance of Commons has been increasing with an exponential rhythm ever since the publication of Garrett Hardin's (1968) article, titled "*The Tragedy of the Commons*". The frequency of use of such term in successive scientific papers has been monumental for the widespread interest it has piqued, and many experts of different fields have been and still nowadays do challenge and study upon. But what exactly are commons and how they differ from another type of entities?

When researching about commons, one of the major figures that can be mentioned surely is Elinor Ostrom. Ostrom's work, which earned her a Nobel Prize in Economics Sciences in 2009, focused on how commons can be "governed" successfully, giving a wide range of examples, fruit of long-term field studies. She also reorganized and structured the knowledge about commons in her book "*Governing the Commons*" (1990), which had a major impact on successive works on the argument. Before elaborating on what problems and what solutions Ostrom and others formulated for the commons, let's frame their object of discussion.

The description given before, interpreting commons as "*belonging to or shared by two or more individuals or things or by all members of a group*" (Merriam-Webster, 2018), may seem too wide to be reliable at first, but it actually serves to illustrate how far and different commons can be. A more sectorial definition could be written as *Commons* being a general term for "shared resources in which each stakeholder has an equal interest", making clear the intrinsic complexity of relationship involved in these resources. Currently, research focuses on different topics related or somehow included into "*Commons*", which can be divided into Agriculture, Fisheries, Forest Resources, General and Multiple-use Commons, Global Commons, Grazing Areas, History, Information, and Knowledge Commons, Land Tenure and Use, New Commons (or Non-traditional CPRs), Social Organization, Theory & Experimental, Urban Commons, Water Resources and Wildlife (Hess, 2006). Commons represent a wide range of resources, which apparently seem unrelated to each other for their characteristics. They all, however, represent a complex system of interrelation involved in the exploitation of a specific resource, be it either a pasture, fisheries, or indeed some forest resource too. All these different realities can, therefore, be framed and analyzed according to the analytical model adopted for Commons.

The pivotal element of any analysis can be identified as the common-pool resources (CPRs), which are the most evident and conflictual result of commons. Ostrom's (1990) definition of common-pool resources, "*natural or man-made resource system that is sufficiently large a to make it costly (but not impossible) to exclude potential beneficiaries from obtaining benefits from its use*" highlights some key characteristic. As resource systems, CPRs can be thought as "*stock variables that are capable, under favorable conditions, of producing a maximum quantity of a flow (namely resource units) variable without harming the stock or the resource system itself*" (Ostrom, 1990); the use of terms like "*flow*" and "*stock*" puts a clear linkage towards renewable resources, which can be considered sustainable if the withdrawal rate is lower than the average replenishment rate over time.

Meaning, many commons could potentially be supported for long periods of time if correct strategies and solutions are applied. Excepted for exogenous disruptions, such as natural disasters, global-scale phenomena or hazards, the key factors of CPR are the individuals, groups or firms entitled to their exploitation. Those who withdraw resource units from commons can be called "*appropriators*", those who arrange for the provision of CPR are "*providers*", while those who ensure the long-term sustenance of CPR can be named "*producer*" (Ostrom, 1990). This might seem like a simple subdivision of roles among people involved with commons, but it's the basis of the problem. A resource system can have multiple appropriators, providers, and producers, whose roles can sometimes overlap or not, operating simultaneously, but the resource units granted by the system cannot be jointly used or appropriated. Therefore, improvements to the system are jointly benefitted from every participant, which united with the difficulty in excluding appropriators from the system itself makes such structure extremely fragile. To make a comparison (Table 3), public or collective goods have a similar structure of participants, but they are based on non-subtractive goods/services, meaning their usage by actors does not affect others' possibilities; it a situation of shared benefits as well as shared goods. Therefore, public goods, very often confused with commons, lack the conflictual nature of goods/services they grant, making related theories inadequate.

Table 5. Resource types according to excludability and rivalry to consumption

	Excludable appropriators	Non-excludable appropriators
Rivalrous benefits	*Private Goods*	*Common-pool resources*
Non-rivalrous benefits	*Club-goods*	*Public Goods*

2.3.2 The "Tragedy" of commons

All Commons are subject to conflictuality for the appropriation of resources, since an erroneous actors' disposition or extreme disequilibrium in the allocation of benefits may incur at any time. Such mistakes are not immediately recognizable, and their aftereffects very often require long times to be absorbed and solved naturally by the system, if the system capability is not irreparably compromised by such behaviors. Even if preventing such courses of action may seem an obvious priority, it's not as simple as it might sound to tackle the multiple factors affecting it.

Let's make a simple example, following Hardin's article: an open to all pasture benefits each herder in relation to the number of animals which can graze, and they are damaged from the deterioration of the commons due to overgrazing. To impede such deterioration, the rate of resource units' withdrawal should be maintained below the optimal economic level of withdrawal, making necessary a cooperation among herders to succeed. This represents the setting which many kinds of commons may be related to. There are appropriators, a jointly benefitted resource system and a conflictual resource good. Let's give a formalization of Hardin's example according to a normal-form game, as stated in Gibbons (1992): there are *n* farmers in a village, which each summer graze their goats on the village green. Defined the number of goats the i^{th} farmer owns by g_i, the total number of goats in the village will be:

$$G = g_1 + g_2 + \cdots + g_n.$$

The cost of buying and caring for a goat is *c*, independent of how many goats a farmer owns. The value to a farmer of grazing a goat on the green when a total of G goats are grazing is $v(G)$ per goat. A goat needs a certain amount of grass in order to survive, therefore there is a maximum number of goats that can be grazed on the green, expressed by

$$G_{max}: v(G) > 0 \text{ for } G > G_{max} \text{ but } v(G) = 0 \text{ for } G \geq G_{max}$$

The first few goats have plenty of room to graze, so adding one more does little harm to those already grazing, but when so many goats are grazing that they are barely surviving (i.e. G is just below G_{max}), then adding one more dramatically harms the rest, which formalized means: for $G < G_{max}$ and $v'(G) < 0$. In spring, the farmers simultaneously choose how many goats to own. Goats are assumed to be continuously divisible. A strategy for farmer I is the choice of the number of goats to graze on the village green, g_i. The strategy space $[0, \infty)$ covers all the choices that could be of interest to the farmer; $[0, G_{max})$ would also suffice. The payoff to the i^{th} farmer from grazing g_i goats when the numbers of goats grazed by the other farmers are $(g_1 + \cdots + g_{i-1} + g_{i+1} + \cdots + g_n)$ is:

[1] $$g_i v\,(g_1 + \cdots + g_{i-1} + g_i + g_{i+1} + \cdots + g_n) - c g_i$$

Thus, if $(g_1^* + \cdots + g_n^*)$is the Nash equilibrium[15], then, for each I, g_I^*must maximize [1] given that the other farmers choose $(g_1^* + \cdots + g_{i-1}^* + g_{i+1}^* + \cdots + g_n^*)$. The first-order condition for this optimization problem is:

[2] $$v(g_i + g_{-i}^*) + g_i v(g_i + g_{-i}^*) - c = 0$$

where g_{-i}^* stay for $(g_1^* + \cdots + g_{i-1}^* + g_{i+1}^* + \cdots + g_n^*)$, namely the other farmers Nash-equilibrium compatible choice. Substituting g_i^* into [2], summing all n farmers first-order conditions and then dividing by n yields, the Nash equilibrium formula becomes:

[3] $$v(G^*) + \frac{1}{n} G^* v'(G^*) - c = 0$$

with G^* standing as $g_1^* + \cdots + g_n^*$. However, the social optimum, denoted by G^{**}, solves for:

$$max_{(0 \le G < \infty)} Gv(G) - Gc$$

with the first-order condition being

[4] $$v(G^{**}) + G^{**} v'(G^{**}) - c = 0$$

Comparing [3] and [4], it appears that $G^* > G^{**}$, meaning that in the Nash equilibrium too many goats area grazed compared to the social optimum. This result can bring up some considerations:

First, the strategies adopted by actors are strongly related to their level of information, which include not only the information about other actors' actions, but it often refers to a specific knowledge on the resource system they are exploiting. Very often appropriators do not have an in-depth knowledge of the commons they are using. This might not necessarily be due to a lack of interest, but it may be because they have not been granted adequate education (such as in developing countries, where access to knowledge for the population is still an issue), or the complexity of the system has made retrieving information too demanding or difficult, or again actors may have precedent personal opinions and experiences which can discourage them to accept new notions. It's also an issue to determine which information should be considered correct since alongside scientific results it's of great importance to consider the know-how coming from experience. Therefore, one of the basic assumptions of the model, which every game player can accurately predict other players strategies, is fundamentally unreliable, since there is no guarantee that players operate with the same level of information and consequently the same capacity to make predictions. A simple example might be the comparison between global level firms and local rural producers; the disparity of assets, manpower, and competences obviously affect the players' ability to predict the best strategy. Moreover, the commons complexity could be an obstacle to data gathering from the player's side. In fact, many effects that have repercussions in the common's boundaries could originate from outside of it, reducing the possibility of intervention by the players.

[15] Nash equilibrium is a concept of game theory where the optimal outcome of a game is one where no player has an incentive to deviate from his chosen strategy after considering an opponent's choice. This is based on the assumption that every player adopts a rational and stable strategy and therefore other players' strategies can be predicted and accounted when elaborating single players strategies.

Second, assuming a shared level of information by all actors, a relevant factor is whether and how cooperation among them can be achieved and enforced. This deals with human behavior itself and it's based on the assumption that a rational individual will take rational solutions for their own benefit. Nonetheless, this seems feasible to be applied on the individual scale, but when dealing with multiple individuals, many theories formulated that individually rational strategies, when combined, may result in collective irrational outcomes[16].

This is the core of the "tragedy" Hardin (1968) suggested in his work: "*Ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the common*". This assumption was further supported by some studies suggesting that "where a number of users have access to a resource common-pool resource, the total of resource units withdrawn from the resource will be greater than the optimal economic level of withdrawing" (Dasgupta & Heal, 1979; Clark C. , 1979). The presence of free-riders is one of the main problems affecting the commons since whether a person cannot be excluded from benefits others provide, they are not motivated to contribute to the joint effort. And when all participants choose to free-ride, the benefits will not be provided anymore, to anyone (Ostrom, 1990). To solve such pending issues, several institutional arrangements have been formulated, which can be summarized into three categories:

- *Theory of state*: the maintenance of the resource system and the cooperation among actors is to be achieved thanks to the government's "*overwhelming power of coercion*" (Ophuls, 1973), which is identified with Hobbes' figure of the "*Leviathan*". Such support towards central government control of natural resources has seen a widespread adoption especially in developing countries, but results have been variable. In fact, public governance of CPRs have been successful for some commons, but it has been greatly detrimental to others, even when dealing with the same kind of resource[17]. Such failure to meet expectations can be explained with the assumptions it was based upon: to correctly manage a common, an external authority must be able to "*accurately determine the capacity of a common pool resource, unambiguously assigns this capacity, monitors actions, and unfailingly sanctions noncompliance*" (Ostrom, 1990), while not considering the cost of implementing such system. It's no wonder that achieving optimal equilibrium under such conditions is a very hard task, especially in countries when central authority is lacking or not efficient.
- *Theory of firm*: in stark contrast with a state-based control system, some policy analyst suggested that privatization of common resources was to be implemented to correctly manage these kinds of systems. It's, therefore, the application of a market-based approach towards public goods, that was based on the assumption that "the only way to avoid the tragedy of the commons in natural resources and wildlife is to

[16] Such theories are related to Prisoner's dilemma game, a model which served to elaborate actors' interactions and outputs in adequately simplified situations based on well-defined assumption. Such theoretical models have had a great following, and they served as basis for a number of theories. Ostrom (1990) offers a partial overview of a series of case studies, which are based on economic theories mostly opposing the success probability of commons cooperative management.

[17] It's the case of fishing *quotas*, which have been developed as a solution to over-fishing in many countries, with different efficacy within countries themselves. The failures to develop successful quota systems can be linked to a series of different factors, such as social composition, geographical characteristics and local market existing conditions. More on this point in: Wilson, Yan & Wilson (2007) and Berkes et al. (2006).

end the common-property system by creating a system of private property rights" (Smith, 1981). Such theory was based on the development of private property rights in order to internalize externalities of CPRs, but such action was more feasible for stationary resources such as land (dividing the land into parcels and assigning individual right of exploitation according to general regulations). When dealing with non-stationary resources like water and fisheries the establishment of private rights is highly difficult to succeed, also for the political complexity involved. (Clark C. W., 1980; Ostrom, 2008a).

- *Theory of community*: It represents Ostrom's point of view, it debated that no institution can be successful without a mixed presence of market and state. It also refutes the impossibility that CPRs could be managed by a collective effort based on collaboration between actors. She argued that, when developing management systems for CPR, the consideration of pre-existing social dynamics was of fundamental importance. Discussing how to develop set of rules and institutions entrusted to monitor, enforce and maintain a common resource, the existence of a commitment among actors themselves, even if not explicitly formalized but still sufficiently binding, can be adopted as a strong foundation for further developments. The main issue was the recognition of such commitments by governing institution and their correct enforcement. Ostrom suggests that in many cases the incapacity of the government to recognize such forms of cooperation has led to believe them as not lawful. This, in turn, led to implementing strategies unrelated to existing practices – solutions which very often led to failure and degradation of the common. Therefore, Ostrom main contribution, (which was worth the Nobel Prize) was the study of commons where self-governance and organization were adopted, sometimes with successful outputs and other times with failure, depending on a series of factors and strategies adopted by institutions in charge of CPRs.

These two issues, information availability, and effective cooperation are affecting commons globally, and they equally contribute to the potential failure of management systems adopted. Nonetheless, talking about a "Tragedy" of the commons is misleading. Contrary to Hardin's early assumption, in the many years passed since the publication of the article, not every common have met a tragic end. On the contrary, some very successful examples have been observed in many different settings where self-governance has led to maintenance of CPRs well-being (McCay & Acheson, 1990; Ostrom, 2005). Therefore, what has been deemed as most relevant, namely the property rights arrangements, has been proved to be substantially overestimated, partially confuting Hardin's conclusion (Ostrom, 2008b). There still exist many risks that may potentially lead to tragedies in common pool resources, but such an ending is not fixed, nor it must be perceived as an issue to tackle with a one-cure-all solution. On the contrary, the great variety of common pool resources settings should be perceived as a stimulus to elaborate new solutions (or empower traditional ones) into sustainable paradigms, for the local and global scale.

2.3.3 Commons' opportunities in global settings

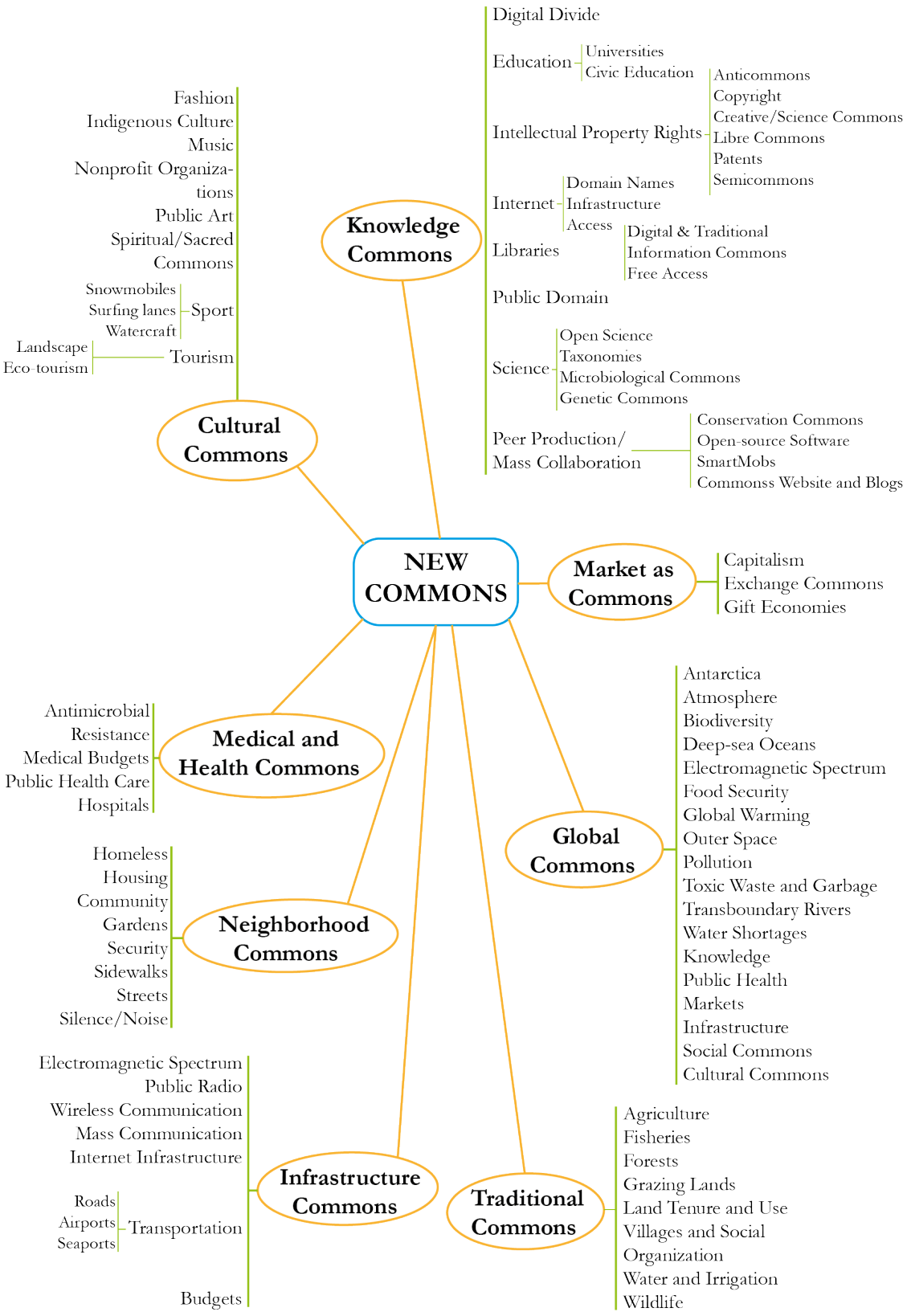
Once described what commons are, how they work and what solutions have been devised to respond to these dilemmas, the next obvious question should be "what future awaits the commons?". This is by no mean a simple question, nor can it be addressed by a simple answer. When speaking about commons, a key feature which has been identified is the role of property rights, intended as a social institution devised to internalize emerging externalities (Demsetz, 1974). The birth of property is therefore connected to the development of externalities, phenomenon caused by technological, social and economic progress. Which is to say, when "something" new disrupts the existing system, externalities will arise, and the system will respond with evolving property rights and more generally institutions receptive of these disruptions' effects. However, how this response will be configured, what theory will it follow (state, firm or community), and what results will it bring cannot be univocally predicted. As previously stated, there are no fixed answers to the common's dilemma, but every institutional strategy and arrangements can be proved to be effective if well-designed (Ostrom, 1990). So, finding a unique answer to what commons will become could potentially be misleading, if not damaging, for future development, as it would inevitably narrow the scope of research and development towards the most fitting solution. Moreover, it will strongly contrast with the proved fact that it cannot exists a "panacea" solution towards commons (Ostrom, 2008a), as any one-fit-all solution will inevitably ignore any local diversity, being its traditions, social, economic or environmental values. At the same time, it cannot be expected to find effective solutions in short time, nor it should be rushed, as it has been proved that quick fixes may be more damaging than positive (Sterner, et al., 2006). The development of solutions must be supported by reliable and extensive data, gathered in accordance with the scales and the types of resources involved, so to avoid the incompatibility between solutions and reality.

An underlying issue affecting commons, which most literature fails to highlight, is the "*scale problem*" (Harvey, 2011). This specific problem is, in fact, fundamental to any planner dealing with commons, as it concerns the capacity of devising solution which works on multiple scales. If a solution, namely an institution governing the local commons, is effective in solving the dilemma, this does not mean that it will be equally effective at another scale. It's the case that applies to many of Ostrom's case studies (Ostrom, 1990), which were mostly on a small scale (involving a few hundred of appropriators); even if solutions devised by small communities proved to be feasible and successful in the long term, the same solution, when applied to much larger communities, has been proved to be not as effective or easily applicable. Therefore, "jumping scales" with solutions designed on the local scale cannot be done, as the nature of the common-property problem dramatically change with scale. Also, it's not a given good solutions at one scale aggregate up (or cascade down) to form good solutions at another scale (Harvey, 2011). Put it in other words, any solution devised in a specific scale would not necessarily work at another, negating the possibility to once again assume a "one-cure-all" mindset. In fact, when Ostrom described successful larger scale commons (a few thousand appropriators), they inevitably needed a nested hierarchical structure, diminishing the direct negotiations between individual which has been proved so effective at the local scale. There is another vital problem which appears when discussing

commons on multiple scales, which is the conflictuality among differently valued commons. Let's make an example, as reported in (Harvey, 2011): to ensure the preservation of biodiversity and at the same time protect the culture of indigenous populations in Amazonia would prove to be extremely hard to achieve. Both can be considered commons, biodiversity is part of natural commons while indigenous culture is part of cultural ones. To protect biodiversity, institutions will inevitably prohibit the exploitation and conversion of the forest in favor of agriculture and ranching activities, which holds higher market interest than forest preservation, especially to the indigenous population. Inevitably, the interest of preserving the forest will clash with indigenous interest to convert land use; in extreme, it could become inevitable to expel the local population from the forestland to ensure its preservation. This will mean that one common may need to be protected at the expense of another, inevitably highlighting the existence of conflicting social interest in the "commons' dilemma".

So far, there has been more argument about the latent issues of the commons, rather than their opportunities. This should not convey the idea that commons inevitably generate problems; on the contrary, they possess high potential for innovative initiatives in terms of social and economic institutions. A misconception, or let's say an old perspective, about commons, is that they only correspond to specific natural resources affected by scarcity and exclusionary uses. This is not completely true. In fact, natural scares resources can be, depending on the characteristics of the resource, be considered commons, and many scholars confronted with this specific category (from Hardin to Ostrom etc.). But there is more than that, in fact much more. In recent years many studies on the topic highlighted the emergence, or it would be better say recognized as such, a wide variety of entities which respond to the commons feature. They have been labeled as "new commons" (Hess, 2008), and consists of commons without pre-existing rules or clear institutional arrangements. These new commons most notable feature is their limitless diversity, especially when compared to traditional ones (such as land and watersheds). Their origin can be attributed to evolving technologies enabling to capture previously elusive open-access goods (it's the case of the Internet, genetic data or the electromagnetic spectrum) or they can be commonly shared resources reconceptualized as commons (i.e. sidewalks, urban gardens, and playgrounds). Altogether they form a complex new field of work for many disciplines, as they embrace and include new and developing multidisciplinary themes, addressing almost entirely the corpus of human knowledge. Therefore, such variety of new commons means numerous challenges for scholars and researcher, but also for managers and institutions alike. Commons are still, if not more than before, a hot topic of discussion on the global scale.

Figure 3. Map of the "new commons ". Source (Hess, 2008)



Let's briefly discuss one of these new categories, the so-called "neighborhood commons". These are surely interesting from the perspective of planners and architects alike, as they involve people living in close proximity which together care for a local resource. This new category defines as commons the social bonds shared by a community, including the need for trust, cooperation, and human relationships. The existence of such bonds it's what differentiates a "community" from a group of individuals living close to each other. This field of study has mostly focused on shared public space and their protection, opening a whole new field of study for urban planners and managers. Quoting Foster (2006), "*only through a rethinking of the city commons can we begin to take social capital seriously in land use policy and law. Instead of conceptualizing the city as an aggregation of private property rights, we should instead seek to identify and protect common resources and interests in the city commons through limited access rights and collaborative governance strategies that preserve and draw upon existing social networks to manage common city resources.".* This category of commons shouldn't escape planners careful consideration, as it deeply linked with the urban and rural planning, as it includes themes such as community gardens (Linn, 2007), local streets and public spaces (Cooper, 2006), sidewalks (Anjaria, 2006) and even street trees (Steed & Burnell, 2007). In fact, neighborhood commons are strongly related to cultural commons, which are defined as "*not only the earth we share but also the languages we create, the social practices we establish, the modes of sociality that define our relationships*" (Hardt & Negri, 2009). Following this line of thought, it can be affirmed that "*the metropolis is a factory for the production of the common*" (Hardt & Negri, 2009). Such considerations, even if originally elaborated under socio-economic analysis by scholars, cannot be neglected by any planners approaching urban settings and metropolitan planning, as they constitute both the substratum and the coronation of planners' action, influencing urban dynamics at every scale and also being the subsidiary product of every design action on the cities we live. Therefore, commons dilemma and implication can and should effectively take part in every planning strategy process, being it about rural land or urban public spaces, affirming once more the important role commons in everyday life.

2.4 Meeting points: a first conclusion on forest and commons

So far, this work has given an overview of what forests are, why they matter to us and how they could contribute to a better future. At the same time, the concepts of commons and common-pool resources have been introduced, it has been explained their relevance in global settings and their influence in modern society. Both for Forests and Commons, property rights constitute a pivotal concept, as they deeply affect the way they "work" and possibly their futures. Before going further on with the analysis, one main underlying question remains: can Forests be considered as Commons? And if yes, what does it imply? Giving a plain answer to the question Is not as easy as it might seem. An answer which might be quite reliable and accepted should be: yes, but a "special" kind. Let's try to analyze why such ambiguity exists.

As said before, commons are strongly affected by the different property regimes they are subject to, and forests share the same fate. This, however, does not imply that all commons are totally depending on property regimes to be defined as such, rather, many common pool resources are so independently by the property regimes they are subjected to. Things like the air we breathe, the tradition of a place or even Internet are not subject to property rights of the sort (even if such condition should never be assumed as immutable). However, they can still be depleted, they are somehow rivalrous and often generate externalities to be internalized by someone. They are, thus, assimilable to common-pool resources, even if no clear property regime is applied to them. In fact, resources which somewhere are commons, in another setting might be either private or public goods. The institutional arrangements (such as property rights) applied to common-pool resources in many cases simply overlap with the intrinsic characteristic of the resources themselves but do uniquely define commons. In fact, such arrangements depend on the context they exist and develop. Factor such as social, economic and environmental conditions deeply affect which regimes are applied to local resources. That being said, what might qualify forests as special kind of commons? First, can they be excluded from others? One might correctly say that yes, the forest can (and in many cases are) be excluded from undesired users. It's not rare that forests are subject to limited access for their specific governing regimes. Forests, however, supply a wide range of products and services to the public, such as timber, hydrological stability, water supply, and even life-support systems (such as oxygen production). All these are resources forests produce, but not all of them can be considered common-pool resources, and even if they are commons, not all of them share the same boundaries. For example, timber can generally be considered a common-pool resource, as it's rivalrous in nature (if harvested by someone it won't be available to others), exhaustible (it usually takes long period of time to regenerate the resource), hard to exclude (it's hardly difficult to completely isolate forests from outside), can generate externalities for some users (profits go to their harvesters) and ultimately it can be subject to property regimes (either public, private or community). Water supply granted by forests are common-based resources too, but their characteristics are, obviously, different from timber. A simple reference is that timber (meant as trees) can be quite accurately monitored as they are stationary and in plain sight, while water supplies have larger (and often unclear) boundaries, thus are harder to monitor. To exemplify this reasoning, it's enough to think that oxygen, which can be considered a "global common" everyone enjoys,

can be counted as one of the forest products. In the opposite line of reasoning, some forest products, such as nuts from trees, are not real common-pool resources, as they can be clearly be excluded from other users without much difficulty or modification of the resource. To sum up, forests components (products and services) are subject to different conditions and characteristics, making them difficult to include in a single, comprehensive classification. Therefore, forests in their entirety cannot be considered completely as commons, since they possess some features (products or services) which are different from each other, either completely (commons and non-commons) or just for some characteristic (the *scale* of the resources, their features, and characteristics, …). Thus, defining the institutional arrangements for forests become a difficult matter. To make an example, we all breath air to survive, therefore the destruction of a globally relevant forest, such as Amazonia rainforest, is a fact which inevitably affects all of us, and it cannot (and shouldn't) be solely managed by local institutions. Following this line of reason, any reduction in world forests extension could be considered as concerning all the global population. But it's obvious that if all of us might still be concerned by the loss of Amazonia forest, the logging of a small patch of trees in a rural village in Africa does not really afflict our daily life, much less the felling of some trees in our neighbor backyard. The same line of reasoning might be applied, with the opportune adjustments, to every other forest product which can be considered a common. Thus, even if theoretically speaking forests could be considered a matter of global interest, in reality, forest management is left to respective countries policies. International agencies have put the effort in the development of a common framework towards sustainability (i.e. UN Agenda 2030 and previous initiatives), but ultimately the most effective matter remains the institutional arrangements which forests are subject to across the globe. That is to say, forests (in their entirety as entities) can be considered *particular* commons, but ultimately the management regimes they are subject to play the vital role in determining their actual condition.

Looking up at the global conditions, the data show an interesting picture. Observing the major statics on forest ownership (FAO and RRI), the situation is clearly favoring public regimes over other forms of management, even if in recent years public and community-owned forests have decreased in favor of private ownership (FAO, 2015).

Table 6. Forest ownership regimes. Source: (FAO, 2015; RRI, 2014)[18]

FAO estimates – 2010 figures

Forest ownership modality	*Hectares (millions)*	*Share of global forest area*
Public forests	2969	76%
Individually-owned forests	433	11%
Community-owned forests	116	3%
Community + individually owned forests	559	14%

Rights and Resources Initiative (RRI) estimates

Forest ownership modality	*Hectares (millions)*	*Share of global forest area*
Public forests (administered by govt.)	2410	73%
Forests owned by individuals and firms	397	11%
Community-owned forests	416	13%
Forests designated for community control	96	3%
Community-owned, community-controlled + forests owned by individuals and firms	909	27%

Looking at the statics, we can say that, even if not all forests are specifically treated as commons, a great majority of them are under regimes which are either public or community-owned, thus resembling commons setting (many actors take part to the use of the resource). In fact, when using the terminology "public forests" it's not better specified what kind of management system is enforced. For example, both a protected area and a regional park are under the public regime, but they have an obvious difference in access regimes. Therefore, if a public forest is open to all and possibly under a low monitoring regime, it could somehow relate to the commons condition, and be equally subject to a "tragedy" if over-exploitation occurs. This is a frequent case in developing countries, where forest under public regimes, because of lacking monitoring and enforcement capacity, are in fact open-access resources, which are often relied upon by local population for supplementary goods or even as the first source of income. Another important possibility is that, even if a forest is under a public regime, there are existing informal agreements for the exploitation of its resources, agreements which might not be recognized by public institutions for a series of reasons. The informality of these conditions is not a surprising fact, as in many countries these kinds of regimes are widespread realities, mostly associated with poverty and lack of opportunities for formal employment. To sum up, even if not all forests follow the definition of Commons, a big part of them globally could be, formally or informally, considered under such condition.

[18] There are important differences between datasets. FAO estimates are based on data from 234 countries and territories. RRI estimates are based on data from 52 countries, covering nearly 90 percent of the global forest area. Also, RRI data do not distinguish between individuals and business entities in categorizing privately-owned forest.

Therefore, if global forests can be considered as commons, going forward, what does this imply?

We already discussed what solutions have been devised so far to solve the "commons' dilemma". Many (Hardin et al.) supported the "state" solution, which assumes that governments can effectively assess and enforce sustainable strategies. Others (Demsetz et al.) supported the "firm" model, which favored the adoption of market logic, inevitably somehow reducing communitarian social and cultural values of forests. The last and more "recent" is the community model supported by Ostrom. This last approach can offer some interesting advantages, even if it's not without faults as it fails to effectively address commons of large dimension unless recurring to nested hierarchical structures (Ostrom, 1990; Harvey, 2011). As we said before, none of these models is always *right* or *wrong*, as they must be adapted to the context and conditions. A matter of interest is that community models, more than the other two, imply a wider social inclusion in designing strategies and management. This could be a point of interest in global settings, since even if a wider group of participants exponentially increase the complexity of cooperative action, this same cooperation, if successful, greatly increase system resilience in unstable settings. This affirmation deserves a better explanation to be correctly interpreted. "Classical" commons[19] are fundamentally based on natural resources, which make up, by themselves or concurrently with other resources, complex ecological systems. As it has been observed, ecological systems and socioeconomic systems are linked in their dynamics, as they must equally be addressed to obtain both environmental protection and economic growth (Levin, 2006). This case deeply applies to the case of forests, as they are fundamental ecosystems supporting life, but at the same time represent an irreplaceable economic system for many populations, as well as a social reality for local inhabitants (and visitors too). The reasons why forest can potentially be powerful mediums towards sustainable development have already been said. The underlying principle of this process is the effective cooperation among actors at a different level (as stated in SDG 17: Partnerships for the goals). This cooperation is in the first place among different experts and scholars; quoting Levin (2006, p. 328), "*Ecologists, economists and other social scientists have much incentive for interaction*" when developing strategies aiming to sustainable development. It's a fact that dealing with commons require an in-depth knowledge of local conditions and characteristics, to ensure this a multidisciplinary collaboration must be established among experts of different fields and applied in field studies. Of course, cooperation cannot be limited at the academic level, but it must strongly involve local populations and officials, who need to "*craft institution built on at multiple levels built on accurate data gathered at appropriate scales given the type of resource involved*" (Ostrom, 2008a, p. 17). Ultimately, cooperation among commons participants is fundamental to ensure commons survival and prosperity, not only in terms of resources but especially of its population welfare. As it has been studied, cooperation in biological ecosystems can be enhanced in two ways: repeated interaction over time (Fehr, Fischbacher, & Gachter, 2002) or spatial localization

[19] "Classical" commons refer to the research line carried out by authors such as Hardin and Ostrom, which mostly focused on natural resources and their product. "Classical" commons are therefore intended as opposed to "new commons" which are differently based on more abstract and not always natural resources systems. More on this point in Hess (2006; 2008).

of interactions (Nowak, Bonhoeffer, & May, 1994; Nakamaru & Iwasa, 2005). Both ways in human society (and in other animals) have a similar objective, which is to create social norms[20] to support and enforce behaviors supportive of the communal interest (Ehrlich & Levin, 2005). The role of social norms is to develop widely accepted and supported behaviors in commons participants, with the implied purpose of diffusing such practices at larger scales. It has been proved that a few strongly motivated individuals can arrange larger groups to imitate their actions by a transitive process of imitation (Levin, 2006). This is one of the bases for collective action[21], which is recognized as one of the main approaches to overcome rural poverty and achieve sustainability.

To sum up, how all of this applies to forests? Forests are sources of various goods and services, some of which can be classified as common-pool resources, for local populations, making their management essential for ensuring a correct and sustainable exploitation. However, governing institutions may lack required knowledge of these resources' characteristics, either due to the (physical, economic or social) complexity of the resources or because they are not enough "in touch" with local dynamics and populations. Too often, the population conditions do not facilitate their involvement in management processes, as a result making them adopt a passive (and possibly harmful) stance towards forest resources, i.e. by exploiting forest products over their regeneration capacity. To ensure that these population won't act against their own (not always easily perceived) collective interests, building up a collective action approach will lay the foundation for the emergence of marketing and value addition initiatives, which could take the shape of more inclusive market chains for forest products. The adoption of a participatory market chain approach (PMCA) or similarly inclusive market models would not only tackle economic issues, but it will foster processes of social learning, increase collective cognition and facilitate collaboration with agencies and governments towards sustainable development strategies. This will ultimately culminate in the design of institutions and policies fitting the context and responsive to global objectives, all while safeguarding forests ecosystems and local socioeconomic conditions.

[20] From Levin (2006, p. 331): "*Social norms and conventions are culturally influenced structures that constrain and otherwise influence individual behaviors. They include simple acts and customs such as forms of dress and greeting, as well as rules that restrict antisocial activities such as theft and murder, and that encourage communally beneficial acts such as charitable giving. They may be purely informal, though relatively robust because of common acceptance, or may become rigidified as religious or societal laws.*"

[21] Collective action refers to voluntary action taken by a group to pursue common interests or achieve common objectives. In collective action, members may act on their own, but more commonly they act through a group or an organization; they may act independently or with the encouragement or support of external agents from governmental bodies, non-governmental organizations (NGOs) or development projects (Devaux, et al., 2009). More on this point in Olson (2009).

3. Forest products and their management

So far it has been explained why forests can be considered a *special* kind of commons and are thus subject to similar risks. All commons imply the existence of a resource which can be exploited but inherently involve complexity in their management (non-excludable and rivalrous). For the purpose of this work, forests have been mainly considered in their role as good sources, thus focusing on the so-called "*forest products*" and the system which governs them, namely the "*institutions*". These two terms, even if commonly used by many, are not equally understood and interpreted by all, as they include many different facets to their working. Therefore, this chapter will try to clarify the confusion concerning forest products, their governing institutions (including how they can change), showing how they tangle with each other (with the example of certification processes) and ultimately why forest governance greatly matters for planners.

3.1 Understanding the terminology

Once again, before discussing in detail what kind of contributions resources from the forest provide to the public and how can they be governed, it's important to make a brief excursus on what these two terms, "*forest products*" and "*institutions*" means. Because they are so often and commonly used in many different contexts, a shared or universally valid definition of them is not clear, as individuals' backgrounds, both cultural and social ones, inevitably influence their own understanding of these two terms. Therefore, the explanation of used terminology will not be a strict semantic effort, but it will also help to frame successive analysis.

3.1.1 Forest products: not simply wood

Humankind has always relied upon natural resources for its survival, and later for its development. Forests have been among the first and most reliable sources of products, and they are still nowadays strongly exploited to retrieve goods of various genre. The differences in forests typology, geographical conditions, and historical development produced different consumption patterns and therefore different traditions associated with forest products. A first division, even if considered overly simplistic by field experts, can be among timber and non-timber products (Ahenkan & Boon, 2011). These two categories are not very useful when discussing market dynamics, as they are too wide and vague to be clearly documented. However, they can already highlight a major difference among forest products, which is the resource collection method, which can be either destructive or non-destructive. Destructive processes, such as logging, inevitably affect the condition of the sources, i.e. to collect wood trees must be broke down, compromising the other biological and physical functions otherwise provided by an intact tree, such as growing fruits and producing oxygen. On the other hand, non-destructive processes preserve the integrity of the source and therefore do not affect the production of other resources; the harvest of fruits most of the times do not compromise the health status of the tree, and it can be repeated multiple times during the plant lifecycle without major aftereffects. However, differentiating timber and non-timber products solely on the process, either destructive or non-destructive, is an understatement and might be misleading in many settings. For example, when evaluating the usage of woodfuel in developing countries, simply stating that all the resources come from destructive processes might not reflect the reality. In many cases, woodfuel might comprise of wood obtained by the clean-up of undergrowth, a process which brings benefits to the forest as a whole. At the same time, non-destructive processes can greatly affect trees and plants conditions if carried out without proper techniques or without clear consideration of the resource regeneration ability. Both destructive and non-destructive processes could equally harm or not the resource bases, depending on the specific characteristics of the resources itself and of the techniques adopted for harvesting/management. For example, selective logging of forest trees (which can be considered *common-pool resources*) could be sustained for a long period of time without affecting the forest if correctly carried out. On the other hand, erroneous harvesting technique of mushrooms (another forest *common-pool resources*), that should be non-destructive for the resource base, could potentially damage the source and thus deplete the resource. Therefore, the collection process cannot be the sole discerning criterion, but separating timber from other non-timber forest resources can be done as a first step in defining forest products.

Once defined that forests supply timber and non-timber forest products (NTFPs), it's necessary to further analyze the term NTFPs, since it has generated much controversy in field literature (Belcher, 2003; Shiva & Verma, 2002). The term NTFPs has been coined in the early 1980s by authors such as Posey, Peters, de Beer and McDermott (Belcher, 2003; Ahenkan & Boon, 2011), and ever since there has been an exceeding number of interchangeable terminologies adopted by various authors and organizations. Among the various terms there are: "*non-wood forest products*", "*minor forest products*", "*forest biological resources*", "*special forest products*", "*non-wood forest benefits*", "*non-wood goods and services*", "*forest garden products*",

"*wild products*", "*natural products*", "*non-timber forest products*", "*by-products of forests*", "*secondary forest products*" "*minor forest products*", and "*hidden harvest*". (FAO, 2006; Ahenkan & Boon, 2011). Still, nowadays there is no universally accepted terminology about NTFPs. The main issues are first the division between NTFPs from natural forests and those from human-influenced systems, second the multidisciplinarity of studies on NTFPs which inevitably complicate the problem (Ahenkan & Boon, 2010; 2011). In fact, the definition of NTFPs has evolved greatly from when it has been coined, by the work of different authors with various backgrounds.

Table 7. Definitions of NTFPs. Sources (Rajchal, 2008; Ahenkan & Boon, 2011)

Authors	*Definitions*
(de Beer & McDermott, 1989)	The term "Non-Timber Forest Products" (NTFPs) encompasses all biological materials other than timber, which is extracted from forests for human use.
(Chandrasekharan, 1995)	Non-wood forest products include all goods of biological origin, as well as services, derived from forest or any land under similar use, and exclude wood in all its forms
(Ros, Dijkman, & van Bueren, 1995)	"*all tangible animal and plant products from the forest, other than industrial wood*" In 1998, they slightly modified this definition to include: *".... all tangible animal and plant forest products other than industrial wood, coming from natural forests, including managed secondary forests and enriched forests*"
(Mathur & Shiva, 1996)	All products obtained from plants of forest origin and host plant species yielding products in association with insects and animals or their parts and items of mineral origin except timber may be defined as Minor Forest Products (MFP) or Non-Wood Forest Products (NWFP) or Non-Timber Forest Products (NTFP).
(Shiva, 1998)	All usufructs/utility products of plant, animal and mineral origins except timber obtainable from forests or afforested/domesticated land areas are termed as Non- Timber Forest Products (NTFP) or Non-Wood Forest Products (NWFP)/Minor Forest Products (MFP).
(FAO, 1999)	Non-wood forest products (NWFP) are defined as "goods of biological origin other than wood derived from forests, other wooded lands, and trees outside forests"
(Wong, 2000)	"*...all products derived from biological resources found on forest land but not including timber, fuelwood, or medicinal plants harvested as whole plants"*

Discussions about NTFPs concept are related to the interests and priorities of authors, therefore addressing different issues and fields, but they can be summed up into five main distinctive features (Belcher, 2003; Ahenkan & Boon, 2011):

- *The nature of the product*: whether to include or exclude non-industrial timber and other wood products.
- *The source of the product*: whether to include or exclude tree plantations, managed forest, grassland and managed agroforestry systems within agricultural land.

- *The nature of production of the product*: if gathered only from the wild or also domesticated products.
- *The scale of production*: if they involve capital intensive labor on an industrial scale or rather small-scale mixed systems
- *The ownership and distribution of benefits*

All these topics deeply affect NTFPs, not only in the side of terminology but also and most importantly in term of strategies employed. In fact, one big concern is whether a forest product can be classified as NTFP if it's *cultivated* or *domesticated*. This is not only a dispute of semantic, but it also affects market decisions in global settings. Whether products such as honey, mushrooms, and fruits, which are harvested in the wild as well as domesticated or under management regimes, are to be included in a single comprehensive definition is a crucial point. Many products, which have an origin either wild or domesticated, when sold on the market are often lacking a label clarifying their origin, thus potentially affecting the market value. In global settings, many products which have economic success are domesticated, as communities, when they detain control over forest resources, tend to manage forest products which are the most valuable to them (Belcher, 2003). Even if such practice is diffused, it could mislead to think that timber, which has clear and usually higher market value, is for the rich while NTFPs, which have different and usually lower market values, are for the poor. This might wrongly direct efforts from planners and governments into supporting policies which negatively affect local populations, for example by defining a forest area as logging area, inevitably destroying the collection of other products from that forest. The correct interpretation of what (and what not) are forest products is thus not simply a matter for scholars, statistical organization, or market agents, but it strongly addresses the perception of the forest role by population and institution. And it's precisely for these last entities, the institutions, that having a different interpretation of forest products inside the markets greatly matter. According to the theories of institutionalist political economics, the market itself should be viewed as an institution which is politically constructed. In a more general way, economics shouldn't be separated from their social and political contexts, as they inevitably reflect such conditions. This means that well-designed institutions, as varied as they can be, could effectively "shape" the individuals and their behavior towards forest resources management. Therefore, the way forest products are defined (thus perceived and managed) inevitably reflect the institutions governing such resources. Understanding what "*institutions*" are, how they are "*born*", and eventually how can they "*change*" becomes then a fundamental step towards achieving sustainable management of forest resources (especially for common-pool ones).

3.1.2 What are *institutions*

In this complex and globalized modern era, the role of so-called "*institutions*" and "*organization*" as key figures in society has been long established. They are those who people entrusted with the management of resources, the enforcement of rules and in general, rely upon to ensure their well-being. But terms like "*institution*", "*organization*" or even "*rules*", are they clearly understood and interpreted by the public, or even by scholars? The disappointing answer would be no. Even if the use of the term "*institution*" in social sciences dates to 18th century[22], still nowadays there are disputes over a unique definition of this term (as well as others related). It might prove useful to give some insights into the complexity that defining "*institutions*" implied so far, as it relates to the different institutional arrangements that exist worldwide.

First, it must be clarified why institutions are such a hot topic in modern society. It all stems from the fact that most human interactions and activities are carried out in compliance to either plain or implicit rules. A non-conflictual definition of "*institutions*", as proposed by Hodgson (2006), might be that they are systems based on social rules (both defined and implicit) that govern social interactions (comprised resources management strategies). Following this definition, language, money, laws, behavioral manners and organizations are all included under the term "*institutions*". In real life, it is clear enough that language works differently from money and laws, that social behaviors can be the more disparate, and that there is a wide range of organizations with different purposes and structures. This definition, due to its wideness, opens several other questions, like what can be defined as "*rule*" and how do institutions as systems really work. Let's compare some major definitions of institutions developed by social economic scholars in different years (Table 8):

Table 8. Definitions of "institutions" by author (in alphabetical order)

Author	*Definitions of the institution (and source)*
Thorstein B. Veblen	"settled habits of thought common to the generality of men" (1899, p. 626)
Walter Hamilton	"a way of thought or action of some prevalence and permanence, which is embedded in the habits of a group or the customs of a people" (1932, p. 84)
John Fagg Foster	"prescribed patterns of correlated behavior" (1981, p. 908)
Douglass North	"[…] are the rules of the game in a society or, more formally, are the humanly devised constraints that shape human interaction" (1990, p. 3)
Jack Knight	"a set of rules that structure social interactions in particular ways" (1992, p. 2)
Geoffrey M. Hodgson	"durable systems of established and embedded social rules that structure social interactions" (2006, p. 13)

[22] Among the first mentions of the term "institution" it can be found in *Scienza Nuova*, work of Giambattista Vico published back in 1725.

Looking at these definitions, there are a number of terms which might need to be further analyzed: "*behavior*", "*rules*" and "*habits*" deserve special attention among others.

Let's start with "*behavior*". As institutions are deeply related to people responses and actions, their durability relies on the ability to accurately predict the behaviors of others. However, this does not imply that institutions are dependent on people behaviors. Rather, Hodgson (2006) write that "*Institutions both constrain and enable behavior*". As rules (as a form of institution) inevitably impede or prohibit some actions, they also open new possibilities which were absent or not accessible before. One example might be the ban on car circulation in the weekends enforced during the oil crisis in the 70s by many governments. Even if it was a limitation imposed under pressing market conditions, it also (somehow forcibly) encouraged the adoption of more sustainable behaviors in the general public, which might have been later maintained and promoted by some individual. Unfortunately, or maybe luckily (depending on who you ask), such actions were mostly ineffective in establishing durable behaviors in many countries, simply being abandoned once the laws imposing the ban were lifted. This has clearly been a case of laws (another form of institution) not becoming "rules". Similar conditions were faced in many developing countries, where the imposition of bans on forest product harvesting did not always have success, failing to establish environmentally virtuous behavior in the population. Of course, the reasons for these failures are complex and connected to the local conditions. However, they also relate to the institutional inability to trigger and support behavioral changes which could transform imposed laws into shared rules.

This brings to the second term, "*rules*". A commonly accepted definition of "*rule*" could be "*socially transmitted and customary normative injunction or immanently normative disposition, that in circumstances X do Y*" (Hodgson, 2006, p. 3). This definition includes some interesting words which merit a bit of focus. First, rules are *socially transmitted*, meaning that they depend on the social culture and language they develop into. No rule is codified in the DNA of an individual or population. Nonetheless, social rules must abide by laws of nature, thus are somehow constrained in their possibilities. The only way rules can evolve into new forms is through technological or institutional development. Another important issue is the relationship between *rules* and *laws*. The first subtle difference is the specific knowledge required to the population on these topics. A famous legal principle from Latin states "*Ignorantia juris non excusat*", translating into "ignorance of law excuses no one". The lack of knowledge in the law is potentially harmful, as it could lead to inadvertently breaking it, thus committing a crime. An everyday example might be the signs for parking lots. If a person is not knowledgeable on the current normative about whether it's permitted or not to park somewhere, it might wrongly assume that is permitted where it's not, thus possibly taking a fine, or even worse having its vehicle removed. Rules, however, do not strictly abide by this principle. For example, not many could recite precisely grammars rules of their native language. This does not impede them from adhering to them in every detail. According to Hayek (1967, p. 67), "*rule is used for a statement by which a regularity of the conduct of individuals can be described, irrespective of whether such a rule is 'known' to the individuals in any other sense than they normally act in accordance with it*". Even if a bit wide for a definition, it clearly gives the idea that rules can be followed even if their formulation is ignored, while laws require precise

knowledge. Interestingly, this strongly relates to the management of forest products in local communities. Past traditions of silviculture have in many cases ensured the well-being of forests without the need of formalized laws governing them. Later, when external institutions have devised specific laws negating such practices, these laws have been largely unreceived by locals. The further these laws have been from existing rules, the harder has been to successfully implement them. Thus, the second and even more important matter is the manner of enforcement adopted. Laws, especially new or controversial ones (which are "far" from population behaviors and traditions), where transgressions allow to obtain greater benefits (much like in many commons), require to be effectively and strongly enforced by authorities. Rules, however, might not necessarily need enforcement, as the population could comply with them without requiring external enforcement or excessive fines to do so (it's the case of many of Ostrom (1990) successful cases). To sum up, ignored laws are not rules, and rules should not require coercive enforcement to be complied with. The key for allowing laws, especially new ones, to become rules is that they must become customary, in other words, "*habits*" (Hodgson, 2006).

Some institutional economist, such as Veblen (1899), supported the idea that institutions work only because the rules involved are embedded in shared habits of thought and behavior. But when defining what "*habits*" are, some incongruences emerge. According to Thomas and Znaniecki (1920, p. 1851) "*A habit . . . is the tendency to repeat the same act in similar material conditions*". On how they originate, John Dewey (1922, p. 42) write "*[t]he essence of habit is an acquired predisposition to ways or modes of response*"; they might be unconscious in their origin, but could be reinforced or even triggered by an appropriate stimulus or context (Hodgson, 2006, p. 6). Habits can be considered the basis of rule-following behaviors, thus acting as a key factor in the successful establishment of rules and, consequently, institutions. Such a path has been followed by many local communities in the past for the definition of harvesting periods of forest resources. However, habits do no comprise laws, as they require a normative content, should be codifiable and of course be well-established between members of a group. Habits are, much like rules, not genetically transmitted, but they are acquired in a specific social context. The presence (and development) of traditions, customs, and history in local settings have often ensured forests resources preservation over the years. Having established (or successfully developing) habits promoting compliance with specific rules might solve the need to enforce strong constraints upon population, thus facilitating the establishment of successful institutions. In the words of Hodgson (2006, p. 7), "*habits are the constitutive material of institutions, providing them with enhanced durability, power, and normative authority*".

So far, it has been expounded about the main components of some definition of "*institution*". Another important point of analysis is whether there is a difference between "*institutions*" and "*organizations*". These two terms are often interchangeable in their mainstream use, but it should be clear that once comparing existing organizations with institution definitions above, they appear to possess additional characterizing features. One of the most relevant scholars in institutional economics, Douglass North, have apparently characterized institutions and organization in a different way, thus leading to the misconception that organizations are not a type of institutions. On the contrary, Hodgson (2006, p. 8), proposed that "*organizations are*

special institutions that involve (a) criteria to establish their boundaries and to distinguish their members from non-members, (b) principles of sovereignty concerning who is in charge, and (c) chains of command delineating responsibilities within the organization". This formulation has been also the result of the extensive exchange of letters among Hodgson and North on the topic. Let's briefly explain how such a definition might reconcile the concept of "*organizations*" and "*institutions*". North (1990, p. 3-5) definition of institutions as "*rules of the game*" include that rules "*must be clearly differentiated […] from the players*". It's this definition which might wrongly lead into distinguishing institutions (i.e. rules of the game/structures of the system) from organizations (i.e. players of the game/agents of the system). The solution Hodgson finds to this discrepancy is the interpretation given to organizations socio-economic characteristics. Assuming organizations as single actors is not wrong, as long as "*they have means of reaching decisions and of acting on some of them*" (Hindess, 1989, p. 89). However, most organizations, such as political parties or trade unions," *are structures made up of individual actors, often with conflicting objectives*" (Hodgson, 2006, p. 10). In fact, to follow North (1994, p. 361) own definition of organizations, which he wrote as "*made up of groups of individuals bound together by some common purpose*", an organization must possess rules governing the matter of communication, membership or decision-making. By this own principle, organizations can be generally treated as a kind of institution with special features. Organizations can, therefore, be treated as actors in other institutional systems while being themselves formed by individual agents operating within the boundary of the organizational systems. It can, therefore, be regarded as a nested hierarchical institutional framework, where the role of organizations (and their consequent features) vary in relation to the socio-economic level of study.

One last consideration should be about "*formal*" and "*informal*" institutions. This separation has plagued a great number of scholars and institutionalist, as "informal" institutions have been wrongly interpreted as illegal rather than nonlegal (not expressed in law) or tacit rules. Another interesting perspective is interpreting *formal* with designed institutions and *informal* with spontaneous ones (Hodgson, 2006, p. 11). All these distinctions are based on several points of view, but all of them are starting from the essential assumption that there exist purely "*formal*" and purely "*informal*" institutions. However, this statement is inherently lacking in framing the role of institutions as rules, which can both constrain and enable actions. As expounded before, rules are interlinked with laws, but they ultimately rely on developing habits to effectively be enforced and complied with. In other words, any institution, either defined as "*formal*" or "*informal*", deeply relies on informal rules and habits to work and succeed. Therefore, any formal institutions require strong informal supports, unless devolving into "*unsupported legislative declaration rather than real institutions*" (Hodgson, 2006, p. 18), thus inevitably calling for a *change* of institutions. As a matter of fact, all the aforementioned concepts should not be perceived as products of "static" systems. Rather, all of them are the result of dynamic and constant evolution and modification of the systems themselves. New events, technologies or opportunities could possibly generate a shift in the behavior of the population, make existing rules obsolete and modify habits. Such was the case of electricity or industry, which greatly modified human societies and consequently their rules, habits, and behaviors, ultimately leading to new institutional arrangements. As times pass and societies evolve, so must do any institution which expects to effectively govern them.

3.1.3 Defining institutional change

Change is an omnipresent dynamic, being it in physics, biology and in economics. Institutions are deeply interconnected with all these fields, as they are the rules governing interactions, both between human-human and human-nature. However, institutions do not always effectively respond to current conditions, either because they are based on rules no longer valid, or because they are less apt to confront these changes than other institutional systems. There are various reasons for this apparent stability of institutions. First, rules do not change overnight. Even if a law is issued in small time before it gets completely integrated into the existing institutional arrangements and corpus it requires time. This is not necessarily influenced by the characteristic of the law, even if laws which are more similar or linked to existing ones will inevitably require less time to be implemented. The capacity of transforming laws into rules, as explained before, require creating a behavioral deviation in the rule takers, i.e. the population/resources governed by institutions. This clearly cannot be done in small time, as no propaganda tool is strong enough to completely reverse human habits and believes in the short-term. Even so-called "*revolutions*", which are intended as sudden and unexpected transformations are not as violent and immediate as it might seem. The diffusion and adherence to new believe across different population strata and conditions surely require external stimuli but also and foremost call for an internal will towards change. To put it bluntly, no great change in history have been born from nothing, they have been either originated from underlying and unrecognized flows or have been slowly nurtured until strong enough to overcome, even with violence, existing institutions. Moreover, institutional change faces a major obstacle towards its achievement, which is usually defined as "*path-dependency*". In general, path-dependency in institutional settings means that governing institution might not be the best possible ones at every instant in time. This would contradict the neoclassical economics' assumption that rational actors take rational (thus the best) decisions at every instant. Such assumption is obviously not true in real life, as institutions would possibly change only because of unpredictable events (like technological discoveries or natural disasters), and not for predictable and temporary shifts (like the passing of seasons). This argument has been studied in particular by two scholars in political economics, Hall and Soskice (2001), which have been strong supporters of cross-national divergence. They argued that actors operating in organized market economies, who have poured efforts and organized their strategies according to "*indigenous*" institutions, will not be willing to abandon these arrangements (i.e. institutions) even in face of new market pressures (i.e. the emergence of new externalities). In other words, actors will not change their system if they have been supportive and reliant on such a system for their own organization. Once again, mindsets do not change overnight. This is even truer considering that, in theory, a system will inevitably generate feedbacks supporting the maintenance of the system itself (Thelen & Kume, 2004a). This condition is also depending on the timing of institutions, as "*Path-dependency suggests that the institutional legacies of the past limit the range of current possibilities and/or options in institutional innovation*" (Nielson & Jessop, 1995, p. 6). Aside from a matter of "innate conservatism" of human, other important factors could lead to institutional path-dependency. First, the change of institutions inevitably involves some kind of *switching cost*, which could be economic (necessity to buy new assets or make investments), temporal (time

needed to adjust to new arrangements) or of any other type. Very often, for users/institution the estimated costs of switch could exceed the expected benefits, or at least make them appear not advantageous enough, thus discouraging any change. Second, there is a base fallacy in neoclassical economics' assumption, as not all the actors are always rational in their choice. There is, in fact, a matter of *limited rationality* of users, which might impede them to perceive or take the most correct choice/path when offered the possibility. Finally, the existence of an information asymmetry greatly influences users' attitude. Especially for risk-averse subjects, when no clear (or considered reliable) assurance is given about the results of any institutional change, changing existing (and reputed known, safe) institutions for new (thus foreign, risky) ones would be greatly unfavored, if not totally deterred. All these conditions (individually or together) could potentially hinder institutional change in human societies.

All being said, institutions *can* (and often *do*) change in global settings. Understanding how this process come to be is less than simple or univocal. In fact, there are several way institutions might change, without however overtly showing such changes. There has been a commonplace tendency to interpret such *major* changes as caused by exogenous factors, which are mostly observable by all. *Minor* changes, who could be endogenous and not apparent to the population, are instead usually not considered in the framework of institutional change. To better frame and highlight the different ways institutions can change, it's quite useful to "*distinguish between processes of change, which may be incremental or abrupt, and results of change, which may amount to either continuity or discontinuity*" (Streeck & Thelen, 2005, p. 8). This has been summed up in the following Table 9:

Table 9. Types of institutional change classified by processes and results. Source (Streeck & Thelen, 2005, p. 9)

		Result of change	
		Continuity	*Discontinuity*
Process of change	*Incremental*	Reproduction by adaptation	Gradual transformation
	Abrupt	Survival and return	Breakdown and replacement

Looking at this table, it seems clear that apparent transformation in institutions, which might be done by revolutions, is only one ("*Breakdown and replacement*") of the possible ways an institution can change. This analytical framework by Streeck and Thelen has been developed according to the discipline of political economies, thus it might be slightly affected by a political point of view. But since organizations like political parties are nothing more than different and specific forms of institutions, this analytical frame still holds wide validity in the general analysis of institutional change.

Let's leave aside processes of "*breakdown and replacement*" or "*survival and return*", which are more related to exogenous and abrupt transformation, whose cause could be unrelated to internal dynamics and thus difficult to confront. Much more interesting topic of study is those transformations which are "covered", based on gradual but still effective internal transformative processes. Streeck and Thelen (2005) suggested that there five modes through which such transformation can happen, and they are:

1. *Displacement*. In any society or context, no matter if a dominant logic of action is in place and strongly enforced by some institution, there are no completely coherent institutional frameworks. To put it bluntly, there is always dissensus towards governing institutions in any society, which is usually supported and promoted by other institutions, which have different origins, histories and possibly contradictory ideas from the mainstream institutional arrangements (Orren & Skowronek, 2004). When the traditions, habits, and behaviors (that constitute the backbone of any dominant institution) change or disappear, the latent dissents, those "*left aside*", may possibly be rediscovered, activated and (always) cultivated, thereby eroding the foundations of the existing system, their actors. The more actors defect to the "new" system, the weaker the previously dominant institution become, empowering those "*deviant, aberrant, anachronistic or foreign practices*" (Streeck & Thelen, 2005, p. 20). This process might seem unusual from the perspective of an actor/institution, as logic suggests that no one sane of mind would keep risk factors which might negatively affect close enough to be harmful. In reality, as institutions are an expression of the society they refer to, that same society often include multiple, contrasting logics among its members, as *per se* human nature require. Institutions are therefore bound to accept (or even need) other logics and behaviors (i.e. other institutions) whose principles are supposedly incompatible with their own. At the same time, societies have usually texture "*loose enough*" to allow the coexistence and development of conflicting institutions. The compresence of a different institution, both indigenous (the ones *cultivated* by the local population) and invasive ones (those *imposed* by exogenous actors by victory or coercion) makes societies, with different magnitudes, *hybrids* (Herrigel, 2000). These changes are more likely to succeed the more actors are willing to pay a price to enforce that change, as it will require the expenditure of resources and power to establish the "substitute" institutions. Even when transformations are caused by exogenous forces, they might result from a cooperation of endogenous forces aligned in their intent but needing external supports to act. To sum up, displacement happens when institutions which are already inside a "system" are substituted by different ones, without explicit revision of existing arrangements (Streeck & Thelen, 2005).
2. *Layering*. Changing an institution is by no mean an easy feat. As some authors highlight, "*the older the system, the costlier it becomes to dismantle it*" (Myles & Pierson, 2001). To overcome this limitation and therefore limit the relative costs of change, "*reformers learn to work around those elements of an institution that have become unchangeable*" (Streeck & Thelen, 2005, p. 23). This process, rather than proposing a disruptive path alteration, it stress over a differential growth mechanism, where a gradual transformation does not frontally attack traditional institutions, but it slowly amends, alters and refines them, adding new "*layers*". This kind of transformation does not fundamentally shake existing institutions; thus, it's not perceived as a menace by defenders of dominant institutions. However, over time, those new *layers* might growth exponentially and alter, or even supplant, old institutions/systems, thus effectively becoming the dominant ones.
3. *Drift*. When discussing institutional stability, there is nothing to be taken for granted. When standing still, institutions do not survive, neither positive feedbacks and returns can ensure their stability (Thelen, 2004b). Institutions can be subject to erosion or atrophy, a process which might happen covered by stability on the façade. Drift,

however, does not just happen (Hacker, 2005), but it can be cultivated by endogenous forces of the systems itself. So far it might seem that drift it's quite similar to *layering*, but there is a fundamental difference to be considered. Adding layers is the result of decisions taken by actors inside the system, while drift occurs as a result of "*non-decisions*" by dominant institutions. This atrophy of action could result in the failure to include new groups in shared benefits, thus gradually provoking the demise of the existing system itself.

4. *Conversion*. In this mode, institutions are neither amended nor abandoned, but they are "*redirected to new goals, functions, or purposes*" (Streeck & Thelen, 2005, p. 26), without however disturbing their continuity on the surface. Conversion happens because existing institutions are called to respond to new goals or address the interest of new actors. These conversions are possible thanks to the gaps which already exist or emerge in the relationship between institutions and their local enactment. Those gaps may arise from different sources, which Pierson (2004) sum up in four: First, institution establishment may arise *unintended consequences*, as they cannot address a single issue in their working. Second, institutions often involve *compromise* in their creation, as they must interpret different interests. Third, actors, both supporters and opposers, will do their utmost for their own interest, to the point of *circumventing* or *subvert* those rules going against them. Fourth, *time matter* (Pierson, 2004), as institutions may outlive both their designer and their supporters, thus becoming obsolete.
5. *Exhaustion*. In this last method, institutions experience a *breakdown*, but rather than an abrupt collapse it's a gradual one. To paraphrase Marx's words, institutions may enforce dynamics which sow the seeds of their own destruction. When institutions operate in conflictual settings, if they cannot positively solve those conflict but rather exacerbate them or leave them unsolved, they trigger mechanisms which are self-harming over time. Moreover, the "*age*" of the institution may affect their continuity. As they exist over a long period of time, their values and practicability may be reduced if not annihilated.

To sum up, institutions can change in many ways, not all of them destructive or abrupt (see summary Table 10). Any institution which wants to pass the proof of time must be conscious that many factors could undermine its existence. These factors could be endogenous (i.e. invaders) as well as exogenous (i.e. the internal transformation of society). As no institutions can be so perfect and so precisely planned from the beginning, as the risks and conditions which might happen are too far and wide in range, the most feasible strategy is not to oppose change, but to include it in the design process. Therefore, institutional resiliency is not about the strength of enforcement and support, but rather its capacity to adapt and work under mutable conditions. The capacity of institutions to adapt to mutable conditions inevitably constitute a requirement to be achieved in order to ensure sustainable management of resources such as forest commons. Considering current global and local factors (climate change, market interests, technologic advancements, and so on) which might negatively, or if well-directed even positively, affect common-pool resources (such as forest products), institutions' adaptability and design become key aspects to ensure to such resources a future.

Table 10. Institutional gradual transformation types. Source (Streeck & Thelen, 2005, p. 31)

	Displacement	***Layering***	***Drift***	***Conversion***	***Exhaustion***
Definition	Slowly rising salience of subordinate relative to dominant institutions	New elements attached to existing institutions gradually change their status and structure	Neglect of institutional maintenance in spite of external change resulting in slippage in institutional practice on the ground	Redeployment of old institutions to a new purpose; new purpose attached to old structures	Gradual breakdown (withering away) of institutions over time
Mechanism	Defection	Differential growth	Deliberate change	Redirection, reinterpretation	Depletion
Elaboration	Institutional incoherence opening space of deviant behavior Active cultivation of a new logic of action inside an existing institutional setting Rediscovery and activation of dormant or latent institutional resources Invasion and assimilation of foreign practices	Faster growth of new institutions created on the edges of old ones New fringe eats into old core New institutional layer siphons off support for old layer Presumed fix destabilizing existing institutions Compromise between old and new slowly turning into the defeat of the old	Change in institutional outcomes affected by (strategically) neglecting adaptation to changing circumstances Enactment of the institution changed not by reform of rules, but by rules remaining unchanged in the face of evolving external conditions	Gaps between rules and enactment due to: 1. Lack of foresight limits to (unintended consequences of) institutional design 2. Intended ambiguity of institutional rules: institutions are compromises 3. Subversion: rules reinterpreted from below 4. Time: changing contextual conditions and coalitions open space for redeployment	Self-consumption: the normal working of an institution undermines its external preconditions Decreasing returns: generalization changes cost-benefits relations Overextension: limits to growth

3.2 The products of the forest

When discussing forest products, as explained before, there are many goods to considered, each of them with distinctive characteristics and complexities. Managing such a wide range of goods, most of them having their own markets, pose a difficult problem to governing institutions. The first step should be the development of a comprehensive knowledge of goods, considering their physical, biological, and economic features. After that, such knowledge should be applied by institutions to positively influence the goods wellbeing. This chapter will thus start from analyzing the product of the forest, dividing them into conventionally adopted categories of Timber and Non-Timber Forest Products (NTFPs), focusing on their market value and management strategies. Later, it will show how forest products certification works, as they represent one (among many others) institutional tools for the forest resources management.

3.2.1 Timber and wood products

3.2.1.1 Characteristics

Timber is the most commonplace, most used and among the most valued products that can be harvest from forests. The uses of timber are innumerable, with the foremost being as construction material, implemented worldwide by rich and poor people alike, even if applications and techniques differ greatly. This material has been fundamental for the development of humankind in several fields, such as for building assets (i.e. ships, shelters, homes, etc.) but also to shape tools, create artworks and produce paper. At the same time, timber can be used in totally different applications, such as woodfuel, which globally provide basic energy services to about 2.4 billion people (about one-third of world population) (FAO, 2014). Regardless of the applications, timber is a product derived from trees (or other woody plants), generally yielded from their trunks. Timber (wood) is an organic composite material, made of cellulose fibers in tension embedded in a lignin matrix. Even if the chemical composition is approximately the same[23], there exists two commonly recognized categories of wood/tree types: hardwood and softwood. Hardwood is produced by angiosperm trees, which reproduce by flowering, they are mostly deciduous in nature and characterized by a slower growth rate and more complex internal structure. Softwood originates from gymnosperm trees, generally consisting of conifers, which remain evergreen. Talking about the terminology, hardness (or rather density) is not always a discriminating factor, as there exist hardwoods which are less dense than softwoods, even if generally hardwoods tend to be denser than softwoods. A much more important factor is the reproduction system these plants employ. Hardwoods produce seeds with a covering, thus producing fruits or nuts which possibly grows into new plants. Softwoods reproduce by emitting pollen to be spread by the wind to other trees, dispersing naked seeds from which new plants grow. This division deeply affects the various *by-products* of trees species, products that would be lost as a result of timber harvesting. Different reproduction systems influence the management strategies ought to be employed to ensure the regeneration of resources (as required by common-pool resources). To ensure resource continuity over time, timber harvesting should be carried out only according to specific selective logging strategies, considering the unique characteristics of the tree species and their site-specific features. However, in many settings, due to pressing market pressures and social conditions, logging is carried out indiscriminately, thus threatening or even destroying the resource base (producing a real *Tragedy of the Commons*)

The variety of trees species sold in the market (Table 11) must not surprise, as different types of constructions/products call for different kinds of timber since they will offer better performances. At the same time, different climates will favor some species instead of others; softwoods, which are mostly evergreen, will be more common in temperate and boreal climates, while hardwoods will be more frequent in tropical and sub-tropical climates. The variety and distribution of wood products market are some of the characteristics which make

[23] Wood as a composite material is approximately composed of 50% carbon, 44% oxygen, 6% hydrogen, and traces of several metal ions, which comprise two major chemical components: lignin (18-35%) and carbohydrate (65-75%). Source (Pettersen, 1984).

this sector one of the most diffused and differentiated one globally, thus making its analysis a challenging and interesting one.

Examples of wood applications in architecture

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Figure 4. City of Yawnghwe in the Inle Lake, Myanmar

Figure 5. Borgund Stave Church in Norway

Figure 6. Metropol Parasol wooden sculpture at La Encarnación square, in Sevilla, Spain. Designed by architect Jürgen Mayer.

Table 11. List of woods commonly used in timber trade (classified as softwoods or hardwoods)

Softwoods	Hardwoods
Araucaria	Acacia (*Acacia sp.*)
Cedar (*Cedrus*)	Alder (*Alnus*)
Cypress (*Chamaecyparis, Cupressus, Taxodium*)	Ash (*Fraxinus*)
Douglas-fir (*Pseudotsuga menziesii*)	Aspen (*Populus*)
European yew (*Taxus baccata*)	Birch (*Betula*)
Fir (*Abies*)	Cherry (*Prunus*)
Hemlock (*Tsuga*)	Elm (*Ulmus*)
Larch (*Larix*)	*Eucalyptus*
Pine (*Pinus*)	European crabapple (*Malus sylvestris*)
Spruce (*Picea*)	European pear (*Pyrus communis*)
	Hickory (*Carya*)
	Maple (*Acer*)
	Oak (*Quercus*)
	Olive (*Olea europaea*)
	Walnut (*Juglans*)
	Willow (*Salix*)

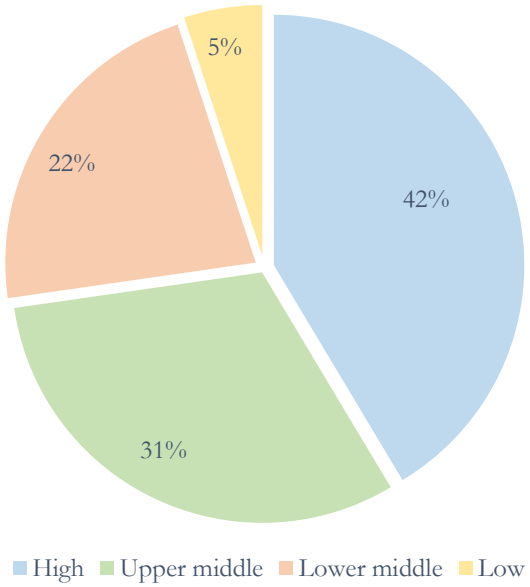
These different species will have different market values and therefore there will be different interests for their exploitation. In general, timber and wood products remain highly sought forest products, especially since their appropriation is hardly excludable (it's not easy to limit forests access) and highly rivalrous in nature (many trees species take long times to regrowth), making them in fact common-pool resources at risk of depletion in many social settings.

3.2.1.2 Global value of the market

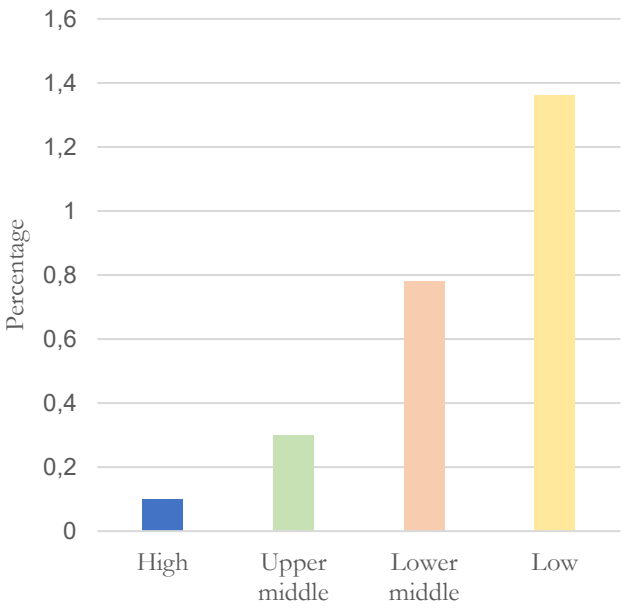
Once introduced the variety of timber qualities globally, it's useful to give some figures to interpret how much wood and timber impacts on the global market and forest use. The first important datum to highlight is that of the overall 3999 million ha of global forests in 2015, around 1187 million were destined to production purpose (FAO, 2015), meaning that were substantially destined to be exploited for the harvesting of wood products. It notable that more than half of this area is distributed in high-income countries, with only 8% in low-income countries. These figures, which are already impressive, should be compared with the second category of forest designation, called multiple-use as they are used both for wood removal and NTFPs harvesting, which in 2015 globally amounted to 1049 million ha. Of these, two-thirds of them are in high-income countries, while only one-tenth in low-income countries (FAO, 2015). At the same time, even if compared to 1990 productive forest area decreased of around 13 million ha, in the same time-frame, multiple-use forest area decreased by 38 million ha, especially in high-income countries. These data clearly show that wood

production plays a dominant role in the global market and often take the lion share of forest areas designation. Comparing these data on Table 6 information on forest ownership, it seems obvious that a consistent part of productive and multiple-use forests is under some kind of public ownership (as the sum of documented privately and community-owned forest do not reach the total forest area). This means that, in many cases, the externalities generated are to be allocated among various, possibly rivalrous, users, making governing local institutions the key figures ensuring the correct management of resources.

The forest sector contribution to global GDP has been estimated in 2011 at USD600 billion (around 0.9% of global GDP), with USD117 billion from forestry and logging only (according to FRA data on 148 countries) (FAO, 2015). Once again, the distribution of this amount is not equal, with high-income countries accounting for 41% and low-income ones only for 5% of it. However, even if high-income countries have a bigger contribution, the contribution to their GDP, amounting to 0.1%, is much lower to the 1.4% to low-income countries GDP.



Graphic 1. Value added by forestry and logging by income category. Source (FAO, 2015)



Graphic 2. Contribution of forestry and logging to GDP. Source (FAO, 2015)

After describing in general what are contributions of wood products to the market, let's briefly consider how this contribution is generated, specifically what kind of products and their quantities. According to 2016 data of FAOSTAT-Forestry database, the main forest wood product in the market is roundwood (both industrial and as woodfuel), which accounted for around 3.8 billion m^3 worldwide, much more than all the other products combined. These are almost evenly divided between woodfuel (1863 million m^3) and industrial roundwood (1874 million m^3), but their distribution is significantly different (see Table 12). Woodfuel is mostly produced in the Asia-Pacific region (39%), then Africa (36%), Latin America and the Caribbean (14%), Europe (8%) and Northern America (3%), with an overall slight increase from the past (2015-2012) (less than 1%), especially in the Northern America (+20%), Europe (+5%) and Africa (+5%), in contrast to Asia-Pacific (-3%) and Latin America and the Caribbean (-5%). A stark contrast is the industrial roundwood market, which sees Europe (32%) and Northern America (27%) as global leaders, followed by Asia-Pacific (24%), Latin America and the Caribbean (13%) and finally Africa (4%). The global production of industrial roundwood has also greatly increased compared to 2015 (2.6%) and 2012 (5.9%), with Asia-Pacific, Europe, and Northern America jointly producing 7% more than 2012, with Africa and Latin America and the Caribbean not experiencing significative changes (FAO, 2017d). These analyses clearly depict a total opposite tendency in forest usage in the world, which should be deeply related to the income levels in these countries. It can be assumed that such discrepancy would gradually decrease, as woodfuel is getting increasingly popular as a sustainable energy source in many high-income countries, while slightly decreasing in low-income countries[24].

Table 12. Global industrial roundwood and woodfuel production by region. Source (FAO, 2017d).

	Europe	*Northern America*	*Asia-Pacific*	*Latin America and the Caribbean*	*Africa*
Industrial roundwood (in million m³)	590	514	459	237	73
Industrial roundwood (as % percentage)	32	27	24	13	4
Woodfuel (in million m³)	157	64	733	257	673
Woodfuel (as % percentage)	8	3	39	14	36

Finally, let's compare and analyze other wood products on the market which also require deforestation be processed (Table 13). Other major products that can be obtained by trees are wood pellets, sawnwood, wood-based panels, wood pulp, and paper. These products, together with roundwood, according to FAOSTAT, globally accounted for USD227 billion dollar in 2016, representing a decrease of 1% from 2015, but actually a massive increase of 57% from 2000 and an astonishing 301% from 1980. This clearly shows how the market

[24] This decrease in consumption is not solely attributed to decreasing wood harvesting, but it can be expected thanks to the diffusion of more efficient devices and systems to produce energy.

value of forest products have steadily increased from past years, with comforting perspectives for the future. Of all products, even if the major contributors in terms of exports quantities are still lowly processed ones, i.e. roundwood and sawnwood, the highest increase has been in more complex and technologically advanced products, such as wood-based panels and paper (especially recovered). This clearly shows that there is a tendency towards technological development in the usage of wood, supporting the prospects of a market shift towards more advanced wood products. While technological advancement would probably not directly reduce tree logging, the current loss of material (wood residues like chips) caused by basic processing (logging and shaping) would be sensibly reduced, thus increasing the efficiency of resource usage. Another important reality, which could make timber harvesting more sustainable worldwide, is the widespread diffusion of forest certification requirements by industries and consumers. Forest certifications, institutional tools which will be better explained later in this work, could (with the adjustments needed for the different contexts) possibly be one of the effective ways to foster better forest management practice in many otherwise threatened settings.

Table 13. Global production and trade of forest products in 2016. Source FAOSTAT-Forestry database

		Production				***Exports***			
			Change (%) compared to				*Change (%) compared to*		
	Unit	*2016*	*2015*	*2000*	*1980*	*2016*	*2015*	*2000*	*1980*
Roundwood	*million m³*	3737	1%	8%	19%	132	2%	11%	40%
➢ *Woodfuel*	*million m³*	1863	0%	5%	11%	9	-4%	153%	
➢ *Industrial roundwood*	*million m³*	1874	3%	11%	30%	122	3%	7%	31%
Wood pellets	*million tonnes*	29	6%			17	8%		
Sawnwood	*million m³*	468	3%	21%	11%	147	7%	28%	109%
Wood-based panels	*million m³*	416	4%	123%	310%	91	7%	60%	457%
➢ *Veneer and plywood*	*million m³*	174	3%	161%	296%	34	5%	56%	326%
➢ *Particleboard, OSB and fiberboard*	*million m³*	242	5%	102%	321%	57	8%	62%	585%
Wood pulp	*million tonnes*	180	2%	5%	43%	64	6%	66%	201%
Other fiber pulp	*million tonnes*	12	-7%	-19%	70%	0.4	-7%	20%	88%
Recovered paper	*million tonnes*	230	1%	60%	354%	58	2%	135%	953%
Paper and paperboard	*million tonnes*	409	0%	26%	142%	111	0%	13%	218%

Figure 7. Timber and wood products
©FAO

Industrial roundwood

Sawnwood

Wood pellets

Woodfuel

Wood fibre

Wood-based panels

3.2.2 Non-Timber Forest Product (NTFPs)

3.2.2.1 Characteristic

Non-timber forest products (NTFPs) have experienced a great boost in their fame in recent years, as they have become a hot topic in global agendas. The main motive supporting such interest has been the belief that the sustainable use and management of NTFPs could produce a win-win situation, addressing at the same time poverty reduction and biodiversity conservation (FAO, 1995; Rasul, Karki, & Sah, 2008). They been recognized to contribute to many fields and have been studied by many scholars. The main recognized contributions include:

- Improving the *livelihoods* of *forest-dependent communities* (FAO, 2006)
- Increase *employment* and income (Marshall, Newton, & Schreckenberg, 2003)
- Grant new opportunities for *NTFPs based enterprises* (Shackleton & Shackleton, 2004)
- Improve *foreign exchange* earnings (Shiva & Verma, 2002)
- Support *biodiversity* and *conservation* efforts (FAO, 1995)

The major difference between NTFPs and timber products it's the former relatively small impact on forest ecosystem and environment. This could be explained by the non-destruction of the resource base during harvest that many allow (i.e. harvest of chestnuts do not harm the tree). This does not mean that erroneous harvesting techniques couldn't be harmful to the source (i.e. mushroom wrong picking can destroy the substratum). Since they represent a great opportunity for many areas, many international agencies[25] have focused their efforts in the direction of NTFP-based development to address rural poverty synergistically with environment protection. NTFPs are currently providing a green social security to billions of people, who depend on them as secondary (cheaper and reliable) source of material for building, fuel, food supplements, medicines, and income; for some population NTFPs revenue can even be the only source of income (Marshall, Newton, & Schreckenberg, 2003).

When discussing NTFPs, the first consideration to be done is the great existing variety (Table 14). Since the definition of NTFPs has not yet reached a common understanding in the academic world[26], they include a great number of different products which can be commonly found in forests. The two main categories could be between *plant-based* products and *animal-based* ones. This first divide has some important differences between scholars and planners. Animal products have their origin from living animals, either from their killing as a source of food and material or from their work (i.e. bees provide honey). This kind of resource is variable in number and not spatially fixed, as many species tend to move around for feeding or other purpose. At this category belongs many common-pool resources, such as those Ostrom (1990) has analyzed (like the lobsters in Maine or the fishery in Alanya, Turkey). This

[25] The leading agency in NTFP development strategies could be identified as Food and Agriculture Organization (FAO), while other international agencies currently involved include: World Bank (WB), International Development Research Centre (IDRC), Center for International Forestry (CIFOR) and Biodiversity Support Programme (BSP).
[26] See the dedicated chapter (Forest products: not simply wood) about the discussion on NTFPs terminology.

potentially hinders local population to secure a stable flow of products and at the same time, it's a great obstacle for monitoring and preservation efforts, as monitoring a moving (and often elusive) animal population is costly. In market perspective, the monitoring of forest animal species directly affects their reliability as a source of income, as well as their derived product price (the rarer a species is, the more expensive its products will be). From planners and policy makers viewpoint, the major concern is the spatialization of information, as any preservation initiatives must consider the species flow inside the forest ecosystem (and possibly outside of it). A different story applies to plant-based products, as they mostly rely on unmovable (or at least seasonally stable) sources, shifting the major concern on monitoring the wellbeing of interesting plants. The preservation of plant-based resources is generally connected to the definition of sustainable yield flows, as well as the adoption of suitable collection techniques which do no damage the plant. For example, the harvest of leaves by logging entire tree branches, even if easier than collection leaf by leaf, could potentially reduce future yields from the tree, as it will require time to regrow its branches. Even if trees have a clear spatial location and can be easily monitored, they often reflect the condition of locals and global ecosystems; large-scale issues, such as pollution, climate changes and loss of biodiversity negatively affect also small-scale forests, which inevitably reflect on trees. Many plant-based resources have a further level of complexity, as even if they grow into defined forest ecosystem, they are subject to seasonal variation in the location of growth (i.e. mushrooms and truffles). This increase the difficulty in their management, being resources potentially open to all and at risk of depletion (in other words, *commons*). The same conditions do not apply to resources who have fixed and spatially localized resources base, making them more prone to be attributed clear property rights (like bananas, coffee and other NTFPs). Overall, even if at the local scale the monitoring and preservation of plants-based resources can be carried out with positive results (assumed that managing institutions have enough power and willingness to enforce the rules), many problems harming plant ecosystems have horizons of action too wide to be addressed solely by local efforts.

A standard classification system for NTFPs at global scale does not quite exist (Shiva & Verma, 2002), some models developed from major international agencies can be adopted. Here it's reported an elaboration of the Harmonized Community Description and Coding System (HS)[27] developed in by (Shiva & Verma, 2002):

[27] The Harmonized System is an international nomenclature for the classification of products. It allows participating countries to classify traded goods on a common basis for customs purposes. At the international level, the Harmonized System (HS) for classifying goods is a six-digit code system. It was introduced in 1988 and has been adopted by most of the countries worldwide, and it's a major asset for World Customs Organization (WCO) mission of enhancing the effectiveness and efficiency of Customs administrations. Sources: WCO, United Nations Commodity Trade Statistics Database (UN Comtrade)

Table 14. Categories of non-timber forest products. Sources (Shiva & Verma, 2002; Ahenkan & Boon, 2011)

Plant products		*Animals and animal products*	
Categories	*Description*	*Categories*	*Description*
Food	Vegetal foodstuff and beverages provided by fruits, nuts, seeds, roots	*Living animals*	Mainly vertebrates such as mammals, birds, reptiles etc.
Fodder	Animal and bee fodder provided by leaves, fruits etc.	*Honey, beeswax*	Products provided by bees
Medicines	Medicinal plants (e.g. leaves, bark, roots) used in traditional medicine and/or by pharmaceutical companies	*Bushmeat*	Meat provided by vertebrates, mainly mammals
Perfumes and cosmetics	Aromatic plants providing essential (volatile) oils and other products used for cosmetic purposes	*Other edible animal products*	Mainly edible invertebrates such as insects (e.g. caterpillars), crabs and other "secondary" products of animals (e.g. eggs, nests)
Dying and tanning	Plant material (mainly bark and leaves) providing tannins and other plant parts (especially leaves and fruits) used as colorants	*Hides, skins*	Hide and skin of animals used for various purposes
Utensils, handicrafts	A heterogeneous group of products including thatch, bamboo, rattan, wrapping leaves, fibers (e.g. Arouma, Bwa Flo, Silk cotton floss, Screwpine)	*Medicine*	Entire animals or parts of animals such as various organs used for medicinal purposes (e.g. caterpillars, crab legs, snake oil)
Construction material	Thatch, bamboo, fibers	*Colorants*	Entire animals or parts of animals such as various organs used as colorants
Ornamentals	Entire plants (e.g. orchids, ferns, philodendron) and parts of the plants (e.g. pots made from roots) used for ornamental purposes	*Other non-edible animal products*	e.g. bones used as tools
Exudates	Substances such as gums (water soluble), resins (water-insoluble) and latex (milky or clear juice), released from plants by exudation		

Once outlined a classification system, there is another important feature which deeply affect NTFPs assessment criteria, which is the management regimes they are subject to: wild, managed and cultivated. Such differentiation is not product-specific, as the same product might be wild, managed or cultivated depending on where it's located (i.e. honey, which on the market can be found from wild or managed beehives). However, depending on the management regime resources are subject to, it's easier to define clear property rights over those same resources. To make an example, many medicinal plants exists in all three regimes: they can be found on the wild, can be part of public gardens or can be cultivated for specific purposes. If a medicinal plant with recognized market value which have always only growth in nature becomes cultivable through a new technique, the efforts to internalize those externalities would possibly lead to a modification of the property rights over the resource (like by privatizing the forest area they grow into,). Therefore, management regimes are not necessarily bound by the product's nature, but they are mostly related to product specific conditions, such as terrains, traditions and market pressure. This last factor plays a great role in the definition of prices for NTFPs, which in turns affect the regimes governing such resources. When a product is highly demanded or there is a scarcity of supply, its price will inevitably rise. If such condition is to be maintained long enough, it will trigger a modification of management regimes, which will adapt (or will be adapted if external forces intervene) to maximize the profit of beneficiaries (which might not include local population). This might happen also for the appearance of new technologies, which will thus induce the emergence of externalities; as property theories teach, when new externalities appear, the property regimes will change to internalize these externalities (Demsetz, 1974). Therefore, analyzing whether a product is subject to a specific regime could offer many clues about local conditions, both social and economic ones, especially to planners dealing with developing rural areas. The shift in management regimes is thus inevitably related to the market interest on specific products; let's get an idea of what figures NTFPs market deals with.

3.2.2.2 Assessing their global value

Before discussing how NTFPs contribute to market and livelihoods of the population around the globe, let's first highlight that one of the major issues in this kind of analysis is the absence of a clear and reliable widespread dataset of information on consumptions patterns. To put it in other words, the high variety of NTFPs and the different settings they grow into, coupled with the institutional confusion (and consequent different interpretation) on which products "*NTFPs*" definition includes, makes data gathering and assessment a challenging task. In fact, as FAO "*State of world's forests 2018*" report, data on NTFP (i.e. production, consumption, trade and resource availability) are greatly incomplete, with the main motive being that a predominant part of any activity related to NTFPs in many countries is undertaken in the informal sector, thus making the data collection unreliable. Therefore, any figure which might be provided inevitably suffer from such opaque market conditions.

It has already been expounded which products can be labeled as NTFPs, and among those, the ones which surely have a clearer market value (at least in term of utility to the consumer at every income level) are food products. It has been deeply studied how forest-based food products ensure household resilience, especially in developing countries, acting as a safety net in time of crisis (either for direct consumption or as secondary income when other

sources get damaged). Worldwide, it has been estimated that NTFPs generate USD88 billion of income (FAO, 2014), but for the aforementioned reasons, this figure can be considered a "*substantial underestimate*" (FAO, 2018). As for how these incomes are distributed on global markets, it's another difficult question. To get a picture, a review of the literature on case studies can give a general idea. When considering NTFPs major role as a safety net, it's clear that the focus of many studies is on developing countries, where households greatly rely on NTFPs both as a supplement to their diets and as a source of income. Nonetheless, before evaluating this bulk of literature, let's briefly discuss the condition in developed countries. In 2015 a survey, conducted over 17000 households across 28 European countries, showed that as far as 91.5% of them had consumed wild forest products. Of these, 82% have purchased some of them from a shop, thus operating inside the (supposedly) formal market, but another 25% were obtained through direct gathering (Lovrić, 2016), therefore being outside the scope of official analysis. This datum does not mean that directly gathered NTFPs contribute to informal market, but it shows how even in developed countries the practice of harvesting NTFPs is still going strong, as part of local traditions or familiar heritages.

Returning to developing countries condition, let's try to give some data on how household relies on NTFPs as a source of income. The situation is shown in Table 15. The data shown must be interpreted to be of a real relevance. All these countries can be considered at low to lower-middle income (South Africa most notable outlier), therefore perfectly fit the adoption of NTFPs as a safety net and poverty mitigators. In the Sahel, which notably stands out with its 80%, the production of shea nut is one of the key activities; in Ghana, Mozambique, Zambia, and Congo basin the proportion is also very high, which can be related to the fact that natural forest is the predominant type of land use (FAO, 2018).

Once described how NTFPs act as safety nets essential for developing countries, gives some figures of estimated size and value of NTFP trade in those countries, according to Shackleton, Shackleton, & Shanley (2011) and reported studies (Table 16):

Table 15. Percentage of household income from NTFPs. Source (Vira, Wildbuger, & Mansourian, 2015) and

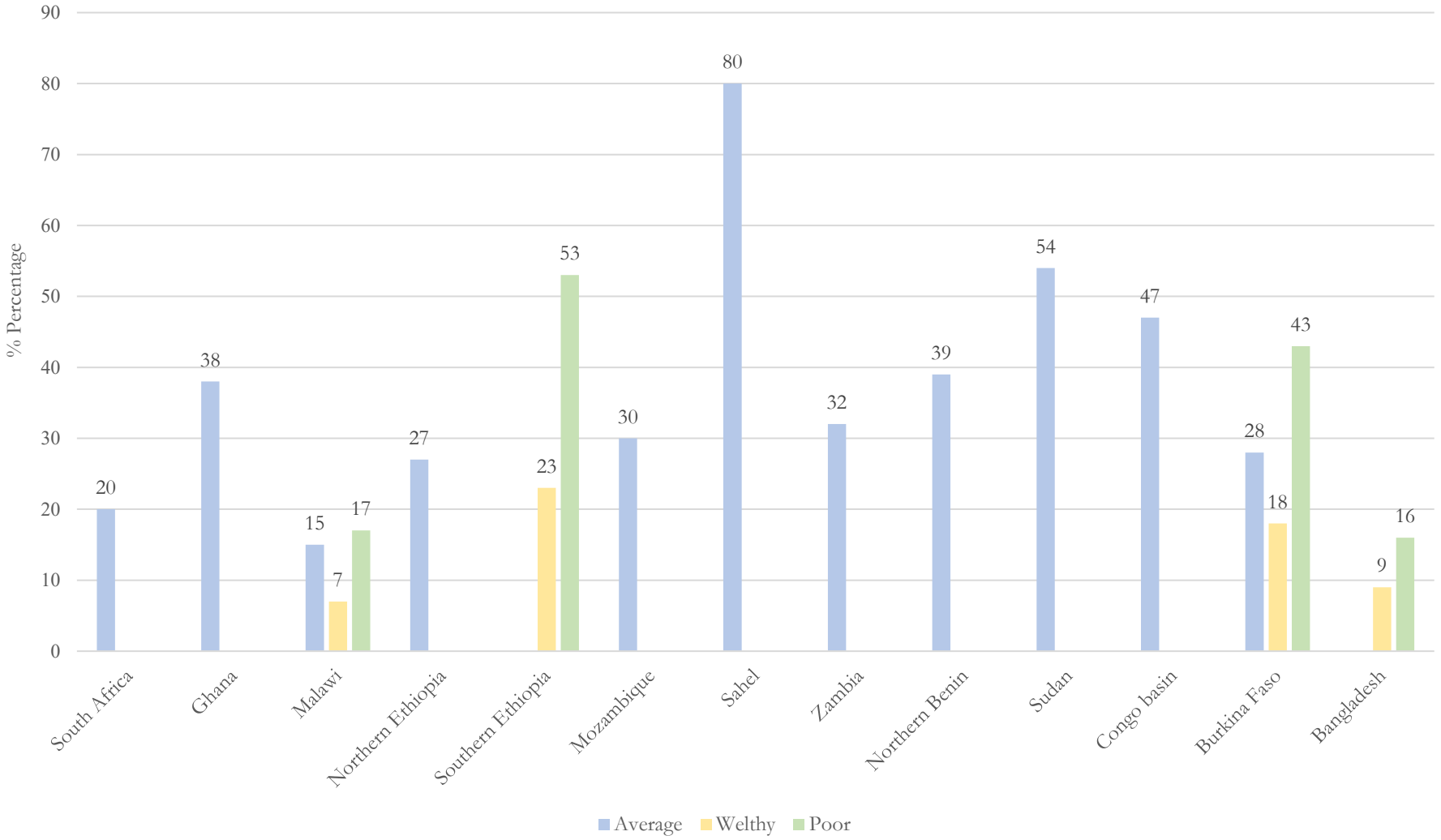


Table 16. Estimated size and value of NTFP trade in different countries. Source (Shackleton, Shackleton, & Shanley, 2011)

Product	*Country estimates*
Medicinal plants	Bangladesh: around 12,000 tons of dried medicinal plants worth around USD4.5 million are sold annually from rural areas Southern Africa: trade in medicinal plants is valued at USD 75–150 million per annum with around 35,000–70,000 tons of plant material traded each year
Baskets	Botswana: commercial buying started in early 1970 in Ngamiland District. In that first year USD 500 worth of baskets was bought from a handful of women, by 1990 this increased to USD 115,000 per year to more than 2,000 women. By 2000 the value of the trade was some USD 350,000 per year
Gums and resins	Ethiopia: the value of gum and resin exports from 2001 to 2003 amounted to USD 2.8 million, 3.3 million, and 4.1 million respectively. Natural gum tapping and collection activities create seasonal employment opportunities for 20,000–30,000 people
Woodcarvings	Kenya: the woodcarving industry is worth over USD 20 million annually in export products and employs some 60,000–80,000 carvers supporting over 400,000 dependents
Honey	Zambia and Tanzania are two dry forest countries exporting the largest volumes of honey. In Zambia in 2005, 219 tons of honey were exported with a value of USD 491,000, while Tanzania exported 466 tons with a value of USD 674,000. Volumes exported have risen by 20–30% since 2001
Oils – Shea butter	Burkina Faso: shea butter provides income to about 300,000–400,000 women, with imports of shea butter to Europe from Sahelian countries, were estimated at USD 13 million in 1999
Insects	Botswana: the trade in mopane worms was valued at UK£4.42 million in 1995 and employed as many as 10,000 local people

These are some data from developing countries, which have been obtained through on-site studies and publications. Therefore, they are referred to specific and different time-frames, with different purposes and possibly different standards of evaluation. When addressing the official statics, the conditions are far more obscure. According to Global Forest Resource Assessment, carried out by FAO in 2015, most NTFPs do not enter the commercial marketplace, so data on them are unreliable or absent (FAO, 2015). In this last data gathering, only 74 countries have reported data, with most of them incomplete or missing, but those who have provided clear and detailed information can give an overview of NTFPs yield in different countries around the world, characterized by different climates, social conditions and kind of products obtained. Nonetheless, this can give the first key of lecture of how different setting perform in NTFPs market (Table 17).

Table 17. Top ten countries by value of NTFP removals per hectare in 2010. Source (FAO, 2015).

Country	Value of NTFP removal (USD/ha)
1. *Republic of Korea*	169
2. *Portugal*	124
3. *Czech Republic*	101
4. *Tunisia*	98
5. *China*	50
6. *Latvia*	44
7. *Austria*	43
8. *Poland*	42
9. *India*	35
10. *Spain*	34

3.2.2.3 NTFPs management: a pending question

Once given an account on the global share of NTFP market, let's discuss how these incomes are generated and how resource management may possibly influence these figures. As mentioned in chapter 3.2.1 on timber market, of the existing forests (3999 million ha), "only" 1049 million ha are managed as multiple use forests. Joined with the existing 1187 million ha of productive forests, it clearly shows that NTFPs, even when they have clear and high market value, still play a secondary role in the forest management strategies. This should not surprise, as the well-established market value of timber, when compared to existing NTFPs markets, surely plays a big role in the adoption of timber-oriented forest management rather than multiple-use management. Still, a great part of literature proclaims the advantages of multiple-use forest management (MFM) towards the achievement of sustainable forest management practices (Hiremath, 2004; Zhang, 2005), even if a shared methodology is still no defined. One of the most interesting possibilities that multiple-use forest management offers over product-specific strategies is that is can satisfy multiple stakeholders demands for different products and services (Kant, 2004). Even if this model clearly grants some benefits, its adoption so far has been relatively low, especially in developing countries where, for some sort of irony, the availability of NTFPs along with timber resources is of great importance to

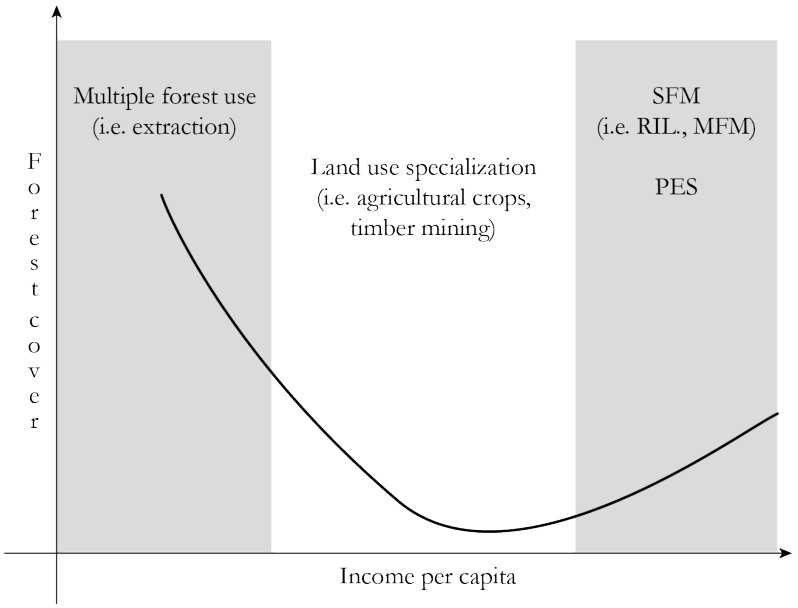
the local population, especially to the poor. The initial refusal toward MFM adoption have been caused by the discrepancy between conventional logging, with high-intensive and focused extraction, and initial multiple uses, which were low-intensive, broad-based and applied to large areas (García-Fernández, Ruiz-Perez, & Wunder, 2008). Currently, MFM is becoming more intensive and remunerative, thus overcoming this initial distance from intensive logging. When discussing the feasibility of multiple use management, the core question is the relationship, or compatibility, existing among NTFPs and timber extraction strategies. Especially in tropical forests, where the pressure towards land conversion or intensive logging is high, the adoption of actions favoring NTFPs can stem from two kind of compatibility conditions: passive (or opportunistic) compatibility, where management action indirectly benefit NTFPs, or active compatibility, where they are explicitly adopted to improve NTFPs and timber values (Guariguata, et al., 2010). A series of factors can have different effects on the feasibility and efficacy of such compatibility, as listed in Table 18.

Except for these listed factors, another important matter to be considered is that the feasibility of multiple-use forest management models is closely related to the stage of forest transition process (García-Fernández, Ruiz-Perez, & Wunder, 2008). In other words, the changes to forest use and management strategies adopted are related to a country (or region) development phase (Cubbage, Harou, & Sills, 2007). As a matter of fact, in poor countries with low market development, forests play the role of safety nets and thus forest resources are exploited in their entirety. With the gradual development of societies and countries toward more market-driven paradigms, the pressing need for more specialized land use, such as agricultural activities, produce a decrease in forest cover and the shift towards more capital-intensive forest use. At some point, this tendency backtrack, whereas the demand for more products and services provided by forest increase, which coupled with technological advancement and higher wages favors the regeneration of secondary forests, which are thus managed for granting multiple resources (Sayer, Vanclay, & Byron, 1997). This analytical model can also explain why the adoption of sustainable forest management models, especially of MFM ones, is predominantly present and effective in countries of the Northern Hemisphere (Poore, 2003).

Table 18. List of factors affecting extraction and management of timber and NTFPs in tropical settings. Source (Guariguata, et al., 2010)

Factors	*Issues influencing compatibility*
Seasonality	➢ Production peaks for a given NTFP ➢ How it influences labor availability for harvesting timber and/or NTFPs
Habitat overlap	➢ Extent of spatial segregation of timber and NTFPs due to edaphic/disturbance factors
Growth habit and product type	➢ Lianas, shrubs, epiphytes, palms; or fruits, foliage, resin, bark, vis a vis timber ➢ Relative timber/NTFP values
Silvicultural practices	➢ Application thinning, liana removal, reduced impact logging norms, enrichment planting, site preparation ➢ Whether the NTFP benefits from felling gaps
Length of timber rotation cycles	➢ Time to recover to pre-harvest levels
Pre-harvest timber inventories and marking of future crop trees	➢ NTFP growth habit (if it is an arborescent palm or a tree, rather than understory plants)
Access to NTFP resources	➢ Extent of protection of NTFPs from logging and/or logging damage
Local knowledge	➢ Interaction between loggers and NTFP harvesters
Gender	➢ Who is involved in collecting NTFPs and local decision-making during sales
Property rights	➢ Modes of access (legal vs. customary, cooperative members vs. open access, determined by gender) ➢ Extent to which some users are excluded ➢ How management plans for timber respect property boundaries
Local governance	➢ Degree of organization among producers ➢ Extent of differences between established mechanisms to distribute revenues from timber and NTFPs
Training and education	➢ Degree to which NTFPs are incorporated into forestry curricula, and loggers and forest managers are aware of NTFP values
Legal frameworks	➢ Extent to which government-designed management plans for timber harmonize NTFP issues or vice versa ➢ Enforcement of hunting bans or NTFP theft
Income diversification	➢ Extent to which timber and NTFP diversify income sources
Market chains	➢ Extent to which market chains for timber and NTFPs are complementary or divergent

Figure 8. Country development relationship to forest transitions[28]. Source (García-Fernández, Ruiz-Perez, & Wunder, 2008)



However, the adoption of multi-use management strategy cannot solely be attributed to the development phase of countries, but it has deeply rooted issues that can either favor or obstruct the integration of timber and NTFPs management. A wide number of studies on successful management integration have highlighted some characteristics which affect integration efforts (García-Fernández, Ruiz-Perez, & Wunder, 2008):

- Presence of regulations to control the extraction of resources
- Definition of tenure and use rights among stakeholders (public, private and community)
- "Solidity" of the market, both import and export
- Integration of communities in the market
- Presence and strength of institutions (as communities support, law enforcement and economic incentives)

Excluding market conditions, which are inherently variable according to several factors, it appears obvious that the relevance of institutions, in the specific their policy and regulatory activities, is of paramount importance to the adoption of multi-use forest management. One of the main problems which greatly undermine the development of long-term forest management is the establishment of forest tenure rights (Cubbage, Harou, & Sills, 2007). This is true especially for developing countries, where the lack of institutional support and enforcement have produced disincentive in the adoption of sustainable strategies. It's important to highlight that the predominant forest tenure worldwide is public ownership (Table 6), (RRI, 2014; FAO, 2015) and that the community-owned/administered forests comprise another important part, especially in developing countries. This share of community forest tenure has seen a steady increase in recent years, with increasing demands for participation and accountability in public planning and decision-making on forest

[28] Shade areas represent stages with favorable conditions to implement forest management regimes and other conservation schemes that make use of the wide array of goods and services provided by forests

management. Devolution and decentralization of forest tenure rights to communities and landowners, however, do not have always led towards forest conservation strategies (Tacconi, 2007). This has been attributed to a few reasons: First, decentralization may have been faulted, like having an only partial delegation of power or local elite capture. Second, in many developing countries, the safest and most lucrative long-term strategies might involve agricultural conversion rather than multi-use forest management (Kaimowitz, Byron, & Sunderlin, 1998). Nonetheless, devolution policies coupled with institutional incentives and adoption of multi-agent management models have been deemed favoring the implementation of multi-use forest management regimes (García-Fernández, Ruiz-Perez, & Wunder, 2008; Guariguata, et al., 2010).

Lastly, another relevant issue (especially for planners) has been the scale of action of MFM strategies. How to achieve this goal on the ground have been the object of debate among scholars and planners (Zhang, 2005). A first way has seen the spatial segregation of demands at the landscape level, delimiting forest units with a single dominant use (either timber, NTFPs or ecosystem services). Others support the adoption of the same management unit covering multiple goods and services production, thus working at forest-stand level (García-Fernández, Ruiz-Perez, & Wunder, 2008). It has been observed that the integrated production of forest outputs is a feasible and efficient solution when the complexity of multiple-use forest management techniques is low, thus maintaining the cost-benefit ratio to acceptable levels. In many cases, especially in developing countries, this requirement is unattainable, due to the high fixed costs of forestry operations and lack of expertise on multiple-use management regimes adoption. Therefore, where these factors are strong, specialization will prevail over multiple uses at both landscape and stand level. Where these conditions are otherwise mitigated, such as in community forestry in smaller scales, multiple uses may become a profitable strategy. The spatial separation of management will nonetheless depend not only on economic factors but also on the nature of NTFPs and its biological and biophysical demands. Institutions have thus developed some tools that should allow to overcome the information gap that many products are subjects to: forest certifications.

3.2.3 Forest resources certification as a way towards sustainability

When discussing forest products and their management, an interesting point could be the presence of specific labels indicating the quality of these products, a *certification* somehow proving the value(s) of products. Evaluating and attesting the quality of some products could sound as simple matters, but certifications do not only concern the quality (intended as aptness to their purpose) of products. They operate on a much wider range of criteria and requirements, and in general can be applied to several things. Balances, production processes, products and much more can all be certified, making certification a topic of great interests for economists. In general, certification can be defined as a useful tool to overcome an existing information asymmetry between users of a system which can analytically formalized as a game with incomplete information. Depending on the object of analysis, certifications will face different and generally complex issues. When dealing with forest products, for example honey, it could be assessed if it's edible or not, what are its components, where they originate from and so on. As much as all these data might be interesting for other disciplines and goals, not all of them are relevant for commons management. However, some certification might asses if the resource bases are managed according to sustainable criteria, which would be of central interests regarding commons.

The general idea behind modern eco-labeling is "*to provide an indicator of how well a product is environmentally adapted*" (Perera & Vlosky, 2006, p. 2). To reach this goal, certifications over the years have followed three main approaches: *top-down*, where policies are formulated at high levels of governments and enforced per authority; *bottom-up*, where the public agrees to form policies and implements them through cooperative actions; lastly, the third approach (born from previous approaches experiences of ineffectiveness) which make *commercial power* (rather than central or local) the driver of policy changes, using market acceptance rather than regulation as enforcement mechanism (Naka, Hammett, & Stuart, 2000). Overall, certifications are configured not much differently from institutions. This should not surprise, as forest certifications are nothing more than one of the tools adopted by different institutions to answers problems of information asymmetry in the market of these products. As such, certification programs and methods have been developed in accordance to the context and the characteristics of the society they were born into. It's thus no surprise that there are currently several different certification programs operating in the global market. All of them have been developed according to specific goals and have established their own regulations. Later in their history, some programs have diffused into settings different from their original contexts, gaining global relevance but also encountering different ideas on certification goals. When using certifications on common-pool resources, there are two main issues affecting forest certification. The first was how to address the difference between certifying the forests and certifying the products of the forests. This is no small matter for commons management, as certifying only the products might omit some essential information on the resource base, i.e. the forest. However, certifying only the forest might be too wide and leave aside the differences between different products management practices. The second main issue is how can a general set of criteria encompass the wide variety of products forests can offer. Clearly, certifying mushrooms, nuts, and timber following the same criteria would be quite hard, and it would also inevitably affect the

completeness and relevance of data monitored. Even if such issues are still affecting the certification programs, they have nonetheless been widely applied to forest resources worldwide, constituting a diffused institutional tool to aid in the management of commons. To understand how certifications have been applied to forest products, it will be presented a brief description of the history of forest certification and an overview of the currently most diffused certification programs worldwide.

Forest certification, in most modern settings, can be defined as "*a process which results in a written certification being issued by an independent third party, attesting to the location and management status of a forest which is producing timber*" (Baharuddin & Simula, 1994; Perera & Vlosky, 2006). Hence, forest certifications should act as a credible guarantee to consumers that labeled product comes from environmentally conscious, socially positive and economically feasible sustainably managed forest, thus fostering the creation economic, environmental and social benefits (Perera & Vlosky, 2006). These processes were developed as a response to increasing concern over tropical deforestation in the 1980s and 1990s (Merry & Carter, 1996). The first steps in this direction have been done by the International Tropical Timber Organization (ITTO), which under pressure from environmental groups in 1988 proposed to implement a labeling program to identify sustainably produced tropical timber. Later on, in 1992, while the Earth Summit (i.e. United Nations Conference on Environment and Development), held in Rio de Janeiro, reunited global countries which led to the formulation of Agenda 21 Forestry Principles, a parallel NGO Rio summit developed the concept of a system for certifying and labelling forest and forest products (Perera & Vlosky, 2006). These non-governmental efforts resulted into the founding in 1993 of a voluntary non-profit organization, Forest Stewardship Council (FSC), with the coalition of Worldwide Fund for Nature (WWF) and other environmental organizations. After this, many different certifications have emerged in the market, all with their own specific features. To be classified as proper certification scheme, the ITTO identifies three key characteristics to be present: first, *clear standards* used as a basis for assessment; second, *well-defined certification processes and rules* regulating the use of labels; thirdly, *adequate institutional arrangements* with qualified human resources (Perera & Vlosky, 2006). Certification schemes can be classified in two groups: *performance based*, which define specific performance levels for aspects of forest management; and *process based*, aiming to develop, implement, monitor and evaluate environmental policies within a systematic approach, without adopting performance standards. A key point for any certification system is the credibility of its program, which is determined by the "*quality of forest management and chain of custody assessment, the absence of conflicts of interests, acceptability of key elements of certification schemes to all the main stakeholders and the positive impact of certification in improving forest management*" (Bass & Simula, 1999; Perera & Vlosky, 2006).

Before going on with the technical description and list of certification programs, it might be interesting to highlight some links between institutions and certifications. First, both are based on *rules*, that can be informal for institutions but must be formally expressed for certification. Second, certifications rely on effective institutions to be carried out. This clearly show that certification by themselves cannot be the main solution to commons dilemma, but they can be a successive assurance of correct resource management. Thirdly, certification, much like institutions, need an extensive and accurate knowledge of the resources, but differently from institutions are based on formalized and systemic approaches to get them.

That is to say, the sources of information reputed reliable are potentially narrower than those available to institutions. Lastly, certifications, much like institutions, face a problem of credibility, in other words can be subject to change. Differently from institutions, that can be responsive to changes and adapts themselves (as seen in chapter 3.1.3), certification programs have been generally more fixed and stable in their forms, most of them experiencing few and laborious revisions of their forms. Overall, when interpreting certifications as a kind of institutions, they seem more fragile and demanding, further reinforcing the idea that they should be implemented only after other interventions.

Returning to their description, certification schemes have two major components: *forest managements certification*, which asses on-the ground operations (i.e. planning, inventory, silvicultural practices, timber harvesting and others), and *product certification* (also named *chain of custody*), which include the tracking of products from forest to final consumers through the production phases of the supply chain, known as "*chain of custody*". Once summarized the general features of certification programs, let's present a brief overview of most diffused and famous certification programs worldwide.

- *Forest Stewardship Council* (FSC): Born in 1993 in Toronto, with 130 participants from 26 countries, it has become the largest voluntary program for independent third-party forest certification in the world (Humphries, 1999; Perera & Vlosky, 2006). It's a two-pronged process, including both a performance and a chain of custody audit. FSC does not actually certify forests, but it accredits certification bodies (qualified independent organizations) which carry out inspections and certifications. To be granted the FSC logo, a set percentage of products must come from certified forests and follow a monitored chain of custody. At September 2018, FSC-certified forest areas amount to more than 200 million ha under 1595 certificates, distributed in 86 countries with the majority being in Europe (49.4%) and North America (34.5%), with minor diffusion in South America and the Caribbean (6.9%), Asia (4.9%), Africa (3.5%) and Oceania (1.3%). Chain of custody certifications amount to 34968 and are present in 123 countries, with Europe leading (52%), followed by Asia (32.5%), North America (9.4%), South America and the Caribbean (4.3%), Oceania (1.2%) and Africa (0.6%) (FSC, 2018).
- *Pan European Forest Certification* (PEFC): Founded in 1999, it works as an umbrella organization, facilitating mutual recognition among national certification standards developed in a multi-stakeholder process (Perera & Vlosky, 2006). The unique feature of PEFC is the encouragement of bottom-up approaches to multi-stakeholder development of certification standards while respecting regional political processes. PEFC is, therefore, a certifier of certification processes, granting its logo to products confirming to accredited national certifications which ensure a monitored chain of custody. At December 2017, worldwide, 313 million ha of forest are PEFC-certified, with 49 countries being members, 20 countries currently with ongoing procedures and 750000 forest owners certified. The chain of custody certificates amount to 11484, with more than 20000 companies benefitting from PEFC's Chain of Custody (PEFC, 2018).
- *International Organization for Standardization* (ISO): Non-profit organization which establishes global standards for various products, production processes and services

to ensure that they meet an acceptable level of quality. In 1996 it introduced ISO 14000 series, concerning environmental management, with ISO 14001 for Environmental Management Systems (EMS) being the only standard against which it is currently possible to be certified by an external third-party certification authority (Perera & Vlosky, 2006). This is a process-based certification system, applied at the level of entire enterprises, without specific, on-the-ground standards for forest management, mostly focused on improved environmental planning. The recognition of ISO system facilitates this system diffusion, with forests certified under dual programs often opting for ISO standards.

- *Sustainable Forestry Initiative* (SFI): Established by American Forest and Paper Association (AF&PA) in 1994 to promote sustainable forestry in the USA. It includes a system of principles, objectives and performance measures, integrating environmental and business practice. Membership requires compliance, with verification including first, second and even independent third-party certification of conformance to SFI standards.
- *Canadian Standards Association* (CSA): Established in 1996 based on a set of internationally recognized sustainable forestry criteria consistent with ISO 14001. It's composed of 6 criteria (including environmental, economic and social values) and +80 indicators. The certification includes a process and a performance system.

These listed so far are some of the major certification programs worldwide, either because they are the most diffused (FSC and PEFC at the front), the most comprehensive (ISO), or are specific of some of the most relevant countries in forest production (SFI and CSA). Other countries have developed their own certification programs, such as *Malaysian Timber Certification Council* (MTCC) and *Lembaga Ekolabel Indonesia* (LEI) which have experienced great success, also thanks to the leading role these countries have in forest market.

These programs have several strong and weak points which could possibly clarify the potential and the limits of forest certification as a management tool. As diffusion data of FSC and PEFC programs shows, forest certification is severely lacking in developing countries. This can be attributed to a series of reasons, including inflexibility of certification standards, incompatibility between legal settings and standards, or uncertainties over expected market benefits. In fact, for many countries, certifications are requirements imposed by commercial partners that are difficult to comply with. They in fact become trade barriers instead of aids in fostering positive economic growth (i.e. exports with more reliable prices). In fact, since certification are mostly based on market-driven mechanisms, some current dynamics are affecting certification diffusion and efficacy on global scale: the lack of market share of certification in many markets (such as Asian and African ones); the additional costs of certification, which can increase the production costs by 5-25% (Gan, 2005); and the proliferation of certification schemes are some of the main issues.

A more specific matter relevant for this thesis is the current product coverage of forest certification. As mentioned above, there are many and different certification schemes, however, most of them are strongly wood-oriented, scarcely considering the NTFPs market. Recently, there has been a proliferation of standards and certification programs for some NTFPs which have further complexified the existing framework. Moreover, most of these

programs have been specifically developed for some products (such as medicinal plants), being therefore not adoptable, if not possibly detrimental, for other products.

As it can be noted in Table 19, certification programs have a plethora of promoters and objectives, thus creating great confusion in the NTFPs certification market. This condition can be reconnected to the differences between wood and NTFPs markets. Certified timber and wood-products have a long-established demand in many countries, supported by the diffused consciousness regarding unsustainable forest management effects on the environment. For NTFPs, currently, little is known among the public about their unsustainable management effects. Contemporarily, while certified wood products have become a commonplace market reality, the demand for certified NTFPs is still not affirmed and thus not perceived as a priority. Excluding the unripe market conditions, there are more stringent technical barriers to the establishment of NTFPs guidelines in certification schemes. The design of guidelines for timber can rely on detailed, species-specific knowledge about density, distribution, regeneration, harvesting and management practices which are well proved almost on a global scale (Shanley, Pierce, Laird, & Robinson, 2008). The same conditions are totally missing for NTFPs since their wide array of products and complexity of end uses of different parts make the formation of this knowledge base exponentially more challenging than for timber. There are also more complex and specific issues with NTFP certification compared with timber, as they are summed up in the following Table 20.

Table 19. Comparison among main certification programs for NTFPs

	Wildcrafter Standards	*Organic Certification*	*FairTrade Certification*	*Forest Management Certification (FSC)*	*Good Agricultural and Collection Practices – GACP (WHO)*	*Good Manufacturing Practices (GMP)*	*Methods Validation Programs*
Emphasis	Guidelines for harvesters	Pesticide-free standards; organic processing guidance	Assures fair wages and good working conditions	Assessment of forest management, including management and monitoring of ecological and social impacts	Guidelines covering planting, harvesting and handling of both agricultural and wild harvested products	Standards for appropriate facilities and trained personnel	Standards for proper preparation of botanical remedies
Weakness when applied to NTFPs	Difficult to implement; relies on harvesters to be organized or accept organization	Single species orientation; weak forestry and ecosystem standards	Requires individual product endorsement and standards; weak environmental components	No attention to processing or manufacturing stages of production	Little to no ecological or social criteria for sourcing	No attention to sourcing issues	Overlooks sourcing issues, variable standards, and applications
Main Message	Trained or certified ecologically sensitive harvesters	Products are virtually free of artificial chemical fertilizers and pesticides and good for the environment and for health	Equitable trade with producers, fair labor conditions	Sustainable forestry and harvesting, healthy forest ecosystems	Contaminant-free (and increasingly 'sustainably harvested') starter materials	Clean and safe manufacturing	Botanical medicines produced by standardized methods

Mechanisms	Voluntary or mandatory guidance	Independent, third party certification to independent standards or government standards	Independent verification by third-party certifiers	Independent Verification through third-parties	Second- or third-party oversight	Second- or third-party oversight – usually a government regulation	First- or third-party companies and laboratories
Agents	Private companies, associations, and NGOs (e.g., Canadian Ethical Wildcrafting Association, United Plant Savers)	Independent voluntary schemes established by NGOs (e.g., Soil Association, Organic Crop Improvement Association –OICA) or government programs (e.g., U.S., National Organic Program)	National schemes affiliated with the FairTrade Labeling Organization (e.g., Max Havelaar)	Certifiers accredited by an accreditation body such as the Forest Stewardship Council (e.g., SCS, SGS, SmartWood, Soil Association)	Governments, trade associations and international organizations (e.g., the European Agency for the Evaluation of Medicinal Products, the World Health Organization)	Governments and trade Associations (in the USA for herbal products) (e.g., NSF International, National Nutritional Foods Association)	Internal company programs, independent laboratories (e.g., Indena, Institute for Nutraceutical Advancement, Shuster Labs)

Table 20. Main issues in the certification of timber and NTFPs

	Timber	*Non-Timber Forest Products (NTFPs)*
Technical issues involved in assessments	➢ A less complex chain of custody ➢ Relatively well-established guidelines ➢ Clear procedures ➢ Ecological standards widely accepted (FSC, PEFC, SFI) ➢ Timber and derivatives are not ingested, therefore no hygiene and quality control issues	➢ Complicated, lengthy chain of custody ➢ Incipient, ad hoc guidelines ➢ Uncertain procedures ➢ Multiple standards apply (i.e., organic, fair trade, ecological) ➢ Site-specific standards difficult to apply to some NTFPs ➢ Quality control issues are paramount for edible and medicinal plants, adding an extra layer of complexity
Ecological issues	➢ Considerable data for developing management plans (less for lesser-known tropical species) ➢ Predictable production/yield ➢ Moderately variable quality	➢ Lack of ecological data to design management plans (except for a few highly valued species) ➢ Highly irregular and unpredictable production ➢ Highly variable quality
Economic/ markets issues	➢ Moderate to high economic return (except for lesser-known tropical species) ➢ Stable to growing national and international markets ➢ Gradually emerging demand for certified wood, especially in Europe and N. America ➢ Certification affordable to larger industries (more challenging for smaller operations and communities) ➢ Incipient consumer demand	➢ Low economic return ➢ Local markets and direct use predominate ➢ Unpredictable, niche markets; international NTFP markets subject to 'boom-bust' and substitution ➢ Certification generally unaffordable without subsidies, unless carried out as part of a forest management certification that includes timber ➢ Low consumer demand, confusion over labeling of NTFPs

Social issues	➢ Social issues range from simple to complex (depends on context) ➢ Some cases of local incentives in temperate forests triggered by consumer demand ➢ Industries possess the organizational capacity, ➢ Capital and information (not so for community forestry and small operations) ➢ Tenure less of an issue for timber extraction than nontimber harvest	➢ Social issues usually exceedingly complex (especially in developing countries) ➢ Little to no local incentives for NTFP certification ➢ Low-intensity producers lack organizational capacity, capital, information, and power ➢ Many gatherers have insecure tenure or access to NTFP resources ➢ Poor wages/prices for goods and difficult working conditions

Considering all these matters and adding the great degree of overlap between NTFPs certification schemes and other products (timber in front, but also fair trade, organic or quality control ones), the *collaboration* between schemes becomes an important goal to achieve. It could be interesting to analyze the approach *Forest Stewardship Council* (FSC) program has undertaken regarding NTFPs certification. FSC has established a NTFPs Working Group since 1996, which proposed the addition of a NTFPs-specific principle to the ten already existing *Principles and Criteria for forest management* (Brown, Robinson, & Karmann, 2002; Shanley, Pierce, Laird, & Robinson, 2008). This initiative has been rejected by the *Board of directors*, opting for authorizing certification on a "*case by case basis*", leaving to individual certification bodies to develop their own NTFP standards, provided they follow the existing chain of custody guidelines for timber-based products. This produced some NTFP certification, listed in Table 21.

The efforts aimed to integrate and promote collaboration on NTFPs certification with existing timber and forest certifications, well-established in global settings, could offer great opportunities for the public recognition of NTFPs values. This integration would also reflect the interrelationship between forest products and their impossibility to be addressed as single matters referring to different regulations and standards. These matters should instead be jointly discussed and confronted by both third-party certification agencies and institutions involved in NTFPs management. The strategy of FSC, to entrust the definition of product-specific certification standards to other agencies while only demanding the compliance to general standards, can be considered a conscious and positive move in this sense. Since NTFPs certification address highly complex issues that reflect site-specific conditions, they face even bigger barrier in the formulation of standards and procedure than forest certification. Not only the establishment of tenure rights is consistently harder, but also the enforcement of monitoring and quality control activities pose major barriers to the development of NTFP certification (see Table 22).

To sum up, forest certifications are institutional tools which have been devised to overcome an information gap among users of a systems, thus supposedly facilitating management of resources. Even if certifications offer some interesting possibilities for forest resources in general and could be effective actions for some developed settings, they fall short to directly address some important issues of forest common-pool resources. The need for detailed information, extensive monitoring and well-established collaboration are not immediately compatible with many commons, characterized by informality and lack of information on the system. To successfully implement and adapt certification programs to commons (with forests as one of them), they must be preceded by an extensive analysis of the system, carried out by well-designed institutions allowing for effective collaboration and participation of actors to the resource system. Therefore, rather than effective solutions by themselves, the successful adoption of a certification program should be a proof of the correct management (inevitably the consequence of a correct design) carried out by the governing institutions.

Table 21. NTFPs included in the scope of FSC certification. Source (Shanley, Pierce, Laird, & Robinson, 2008).

Non-Timber Forest Product	*Product Description*	*Scientific Name*	*Date Certificate Issued*	*Country or State*	*FM/ CoC*	*CoC Only*
Cork	Bark for bottle stoppers, flooring etc.	*Quercus suber*	2005–2007	Portugal, Spain, Oregon (CoC)	4	4
Mate	Leaf for making mate tea	*Ilex paraguariensis*	2003	Brazil	1	2
Breu resin	Cosmetic (perfume)	*Protium spp.*	2004, 2005	Brazil	2	
Chicle (latex)	Ingredient in chewing gum	*Manilkara zapota*	1999, 2005	Mexico	1	
Brazil nuts	Edible nut, and oil derived from nut (food and cosmetic use)	*Bertholletia excelsa*	(2000) 2006, 2007	Brazil (previously also Peru)	2	2
Maple syrup	Food product (sweet syrup)	*Acer saccharum*	(1999) 2000	USA	1	
Acai juice Palm hearts	Beverage and food product	*Euterpe oleraceae*	(2000) 2005	Brazil	1	
Rubber	'Vegetable leather' sheets (for handcrafts, bags etc.)	*Hevea brasiliensis*	2005	Brazil	1	1
Pine resin	Input to chemical industry	*Pinus spp.*	2006	Belarus	3	

Dried bark	Handmade paper	*Daphne bholua, Edgeworthia gardeneri*	2005	Nepal		
Multiple species of plants (>16)	Essential oils, Ayurvedic medicines and supplements, herbal teas, crude herbs	16+ spp.	2005	Nepal	1	
Buriti	Fruit (food product) and oil for cosmetic product	*Mauritia flexuosa*	2005	Brazil	1	2
Jarina seed	Seeds for handicrafts	Vegetable ivory	2004	Brazil	1	
Copaiba oil	Medicine and cosmetics	*Copaifera spp.*	2002, 2004	Brazil	2	1
Multiple species of plants (>30)	Ingredients for cosmetics and herbal medicine	30 spp.	1998	Brazil	1	1
Venison	Meat (food product)	*Cervus elaphus*	n/a	CoC		2
Bed logs	For mushroom production	n/a	n/a	Japan	1	
Mushrooms, herbs, fruits, game	Food products	n/a	n/a	Poland	1	
Small evergreen trees	Christmas trees	*Various spp.*		Germany, UK, Switzerland, Denmark, Lithuania, USA	13	1

Table 22. NTFPs certification framework of analysis. Source (Walter, Cole, Kathe, Lovett, & Soldan, 2003)

Requirement	*Opportunities*	*Challenges*	*Issues needing further clarification*
➢ Establishment of a limited and monitored permitting system ➢ Development of tenure rights ➢ Limitation of access to harvesting site in order to maintain sustainable harvesting level ➢ Development of niche market for high-quality products ➢ Implementation of quality control measures	➢ Establishment of the monitoring system to ensure compliance according to given standards ➢ Traceability of products from the source to consumers (chain of custody) ➢ Clarification of tenure (both, land and user) rights ➢ Environmentally friendly exploitation through sound exploitation techniques and limited access to harvesting sites ➢ Improved income generation through higher market prices ➢ Value addition, since high-quality products might have better access to markets and gain higher prices	➢ Dispersion of collectors, who are often located in rural and isolated areas ➢ Definition of sustainable harvesting levels difficult due to limited ecological knowledge ➢ Creation of user conflicts due to the limitation of access to harvesting sites and unclear land tenure/ownership, especially in open access or communal land areas; ➢ Unclear market potential for certified NWFP ➢ Insufficient product definition and classification, since many NWFP are not included in international classification or standardization systems	➢ Suitability of different certification programs ➢ Collaboration opportunities among different certification programs ➢ Standard quality and complementarity; ➢ Costs of certification procedures ➢ Monetary and nonmonetary benefits for stakeholders ➢ Replicability and mainstreaming of certification and the impact on noncertified products

3.3 Institutions and forest governance

Hitherto a comprehensive list of the actors and factors involved in forest management have been presented. What is still missing is understanding and framing the system of interactions and relationships linking them. In other words, how institutions "*govern*" forest products. Taking up the reasoning of the previous chapter, this thesis proposes that forests can be considered as *special* kind of commons. This assumption is not without reason, as forests benefits are not exclusive by intrinsic nature (no one can deprive people of the oxygen they produce), but they are exhaustible and rivalrous (the number of mushrooms in a forest is limited and variable, thus "*first come first serve*"). Therefore, if forest acts as commons, many forest products are in fact common-pool resources. This makes their management a problem of allocation and governance of resources the kind of which has been extensively studied by many scholars (such as Hardin, Demsetz, and Ostrom, to cite a distinguished few). Among these authors, Elinor Ostrom has been a prolific and influent voice advocating for the consideration of what she referred as "*a third way*" (i.e. the *community*) aside from state and private regimes on commons governance. It's not the purpose of this thesis to support one regime over another, as it has been clearly stated that no management regime "*fits all*" (Ostrom, Janssen, & Anderies, 2007). However, the compliance with some strategic principles and feature might surely benefit both the population and the institutions involved in forest resources. In Ostrom's major work, "*Governing the Commons*", the analysis of different case studies around the globe have shown some common traits in successful institutional regimes. Ostrom (1990, p. 90) list them as follow:

- *Clearly defined boundaries*. The boundaries of the resource system, such as irrigation systems or fisheries, and the individuals or households with rights to harvest resource units are clearly defined.
- *Proportional equivalence between benefits and costs*. Rules specifying the amount of resource products that a user is allocated are related to local conditions and rules requiring labor, materials, and/or money inputs.
- *Collective-choice arrangements*. Many of the individuals affected by harvesting and protection rules are included in the group who can modify these rules.
- *Monitoring*. Monitors, who actively audit biophysical conditions and user behavior, are at least partially accountable to users and/or are users themselves.
- *Graduated sanctions*. Users who violate rules-in-use are likely to receive graduated sanctions (depending on the seriousness and context of the offense) from other users, officials accountable to these users, or both.
- *Conflict-resolution mechanisms*. Users and their officials have rapid access to low-cost, local arenas to resolve conflicts among users or between users and officials.
- *Minimal recognition of rights to organize*. The rights of users to devise their own institutions are not challenged by external governmental authorities, and users have long-term tenure rights to the resource.
- *Nested enterprises (for resources that are parts of larger systems)*. Appropriation, provision, monitoring, enforcement, conflict resolution, and governance activities are organized in multiple layers of nested enterprises.

There have been some challenges to these assumptions, especially about the need for nested enterprises (Harvey, 2011) and on the matter of enforcement (Chhatre & Agrawal, 2008) in the management of forest resources. These discussions surely hold some interest among scholars, but they do not deny the general validity of Ostrom principles in many settings.

If these principles are the final goal, then the struggle to achieve them is the key process towards devising sustainable and resilient institution governing commons (and consequently applicable for forests, too). Let's now discuss which factors favour the governance of commons, or in other words, that generate the "ideal conditions" for governance (Dietz, Ostrom, & C., 2003), taking in consideration their application to forests. First of all, the monitoring process should be feasible and carried out at relatively low cost, meaning that resources must be easily accessible and their use should not be "hidden" (Schlager, Blomquist, & Tang, 1994). This condition is rather problematic when dealing with forest products. Forests and trees are quite easy to be monitored since they are stationary goods. Monitoring forest products and services exploitation, however, is no easy feat, since they vary in numbers and characteristics, with specific and often conflictual nature for their use. To put it in other words, it might be easy to monitor the rate of extraction of tree logs done by a big firm on a hill, but it's enormously different to monitor the gathering of a fixed quota of mushrooms by local households in a similar hill. The nature of products makes the adoption of cost-effective monitoring process a pernicious issue for institutions. Another factor is that the system should be characterized by a moderate variation rate in its features (resources state, users' populations, technologies, and socio-economic conditions) (Gunderson, 2001; Jannsen, 2002). For forests, this factor can often be achieved, as trees and their products have no strong disruption on their life-cycle in the short to medium-term, except cases of natural disasters or strongly aggressive actions. The same could be said for users, technologies and socio-economic conditions, which are usually slow to change. However, they are inherently riskier for the system, as they often depend on agents and events external to the system itself. To make an example, the market prices of mushrooms, berries or nuts is often unrelated to the will of the gatherers, their communities, single firms or even states. They are mostly affected by global market dynamics of supply and demand, which are not in the scope of action of most governing institutions. The third factor, the communication and networking among users (especially communities) should be highly developed to allow the build-up of social capital. This would imply increased trust, as well as more responsive and empowered reaction to non-compliance, ultimately leading to lowered monitoring costs (Frank, 1988; Pretty, 2003). Global forests have great variety, as various settings and traditions can differently influence the formation of networks among users. For example, in Latin America there are consummate traditions of social participation and community actions, which might possibly facilitate the increment of social capital. However, other regions might not be equally favorable grounds to promote these processes. And even if communication among communities is facilitated, in settings where public or private institutions are among the actors, communication might be greatly obstructed by mutual non-recognition. It's the case of many settings in Latin America, where networks among actors are present and usually effective in their action. Nonetheless, they are often labeled as "*informal*" and thus not recognized by public policy makers or private firms, thus being excluded from their decision-making processes. The mutual recognition and communication

among actors depending on forest resources become a major issue for the design of durable institutions. The fourth factor, the cost of excluding outsiders from exploiting the resource should be relatively low, as they could potentially harm it due to lacking knowledge and increased pressure on existing actors. This requirement, which sounds obvious if related to the limited availability of forest resources, brings around a complex question: how could forest be "closed" to outsiders without affecting their values? If it's true that excluding outsiders from gathering medicinal plants which sustain local markets means to protect the direct use values of the forest (i.e. forest as resource base), doing so will inevitably affect some indirect use values (i.e. forest as amenity and life support system). To clarify it, let's make an example of a forest stretching across various hills, hosting different species of animals and plants and supporting some downhill communities. The forest act as a diversified but comprehensive unitarian biological system, where organisms and resources are all interconnected and depend on each other according to a natural equilibrium, with communities exploiting these resources without disrupting such equilibrium. At some point of time, evolved market conditions highly encourage the extraction of an herb which grows only on a small portion of these hills due to the specific geophysical characteristic. The new market conditions will grant increased benefits through the harvesting of this herb, a situation which is highly valued by communities settled in the proximity of the resource. To achieve the complete internalization of these externalities, a group of communities mutually agree to create a fence delimiting a portion of the forest where the herb grows. This will surely ensure that no outsider can enter, at least without the explicit consent of the governing communities, thus preserving the resource. But the fence does not only keep outsiders from entering, but it also greatly disrupts the natural equilibrium existing in the forest. Animals would probably be unable to enter the area, experiencing a reduction in their living space and increasing the competition for nutrients and resources. This will primally damage other plants, which will diminish in the population at a faster rate than in the past, and it will also reflect on other communities, some of which might be reliant on those same plants or animals as means of subsistence, which will inevitably face lowered yields and thus income. As a matter of fact, the exclusion of some "outsiders", even if they are also actors benefitting from (sometimes different) forest resources, when carried out without a comprehensive knowledge of the boundaries and dynamics insisting in the entire forest system, could generate a destructive chain reaction to the entire system. When confronting this case of forest management with Ostrom (1990, p. 90) list of successful regimes, a few considerations emerge.

- The *boundaries* of the entire forest system are wider than the common-pool resource ones, and their misidentification has been one on the wrong moves. This could have been avoided with a more in-depth analysis of the forest systems itself.
- The *rules* defined by some communities could be effective in ensuring the single resource correct management (*benefits* and *costs* are equally shared), but they are not as effective with the entire system of resources. This is deeply related to the *collective arrangements* done, which have excluded other users which are not directly related to the resource but are nonetheless part of the forest system. Expanding the scope of inclusion could potentially resolve this issue.
- *Monitoring* done by communities is probably more effective than imposed or external ones, as all appropriators are also monitoring, and social dynamics strengthen rule

compliance. *Sanctions* could be, if not even absent, reasonably more well-devised, as users/monitors are clearer of the context and the situations of offenders.

- The presence of a spontaneous network of interactions among forest users could be a positive stimulus for the creation of local arenas to *resolve conflicts*. The main issue with these networks is whether they are *recognized* by superior governing institutions. Informal arrangements over forests are quite common worldwide, but they are usually not considered by governments as trustworthy or relevant. Overcoming such judgment in many cases would greatly influence the success of communitarian forest management.
- Forests complexity demand the creation of a *nested* management system, since many overlapping interests are present in these settings. The possible "failure" of most settings is the lack of adequate consideration towards some local resources in favor of other (for example, strongly caring for timber production may damage overlapping commons such as mushrooms or animals). To avoid this, any institution be well informed and carefully consider forests resources interlinkage when elaborating management strategies.

In general, it emerges that communitarian management of forests offers some interesting possibilities, but at the same time is deeply affected by the intrinsic complexity of these systems. Forests, thanks to their holistic impact on society and environment, cannot be solely interpreted as a matter of economic resources, rather, they must be considered for their characteristics as biological, physical and social realities. In consideration of this fact, the limitation of access (as any other physical modification) to the forests should be deeply considered by governing institutions. Ideally, drastic interventions causing great and extensive impact on the forest system should be avoided, instead working more on social mechanisms to prevent the exploitation of resource by external actors, without modifying physical accessibility to the resource itself. The last factor, which somehow underlies many of the previous ones, is that users should support effective monitoring and promote the enforcement of rules (Costanza, et al., 1998). This is by no mean an easy feat, as it involves the generation of a positive (and proactive) response in population towards the application of constraints on their actions. As discussed in chapter 3.1.2, the capacity to develop such a mechanism is deeply rooted in the formation of habits influencing the behavior of both single individuals and entire communities. The sphere of action thus shifts to social economics and behavioral psychology, thus increasing the complexity of institutional designing.

The above-listed conditions are rarely present in commons settings. Usually, they need to be built up by those same institutions whose creation they were supposed to support and facilitate. Therefore, institution governing the commons (i.e. forests) should be designed to be adaptive towards complex systems. Ostrom et al (Dietz, Ostrom, & C., 2003; Ostrom, 2008a). have stated a list of five requirements to generate such conditions and at the same time design resilient institutions.

1. *Achieve accurate and relevant information*. The trustworthiness and accuracy of information about the characteristics of forest systems (stocks, flows, processes and interaction with actors) are fundamental steps in designing institutions governing

those same resources. One of the key issues when discussing information is the level of aggregation they are compiled with. A too high level of aggregation (i.e. generalization of data) may leave out some important local facts which could potentially identify future risks and help to design preventive solutions. The opposite condition is also detrimental, as high fragmentation (i.e. highly specific) could possibly lead to designing institutions which negatively affect the system on a wider scale than the one adopted from a single group of users. Information must, therefore, be scale-conscious, as well as time-, content- and form-congruent with decisionmakers needs (National Research Council, 1989), while not exceeding users' capacity to assimilate them. Another important task is that information must be able to balance between local (more concrete) values, such as market values of products, and global (more intangible) values, like ecosystem capacity of adaptation to variations.

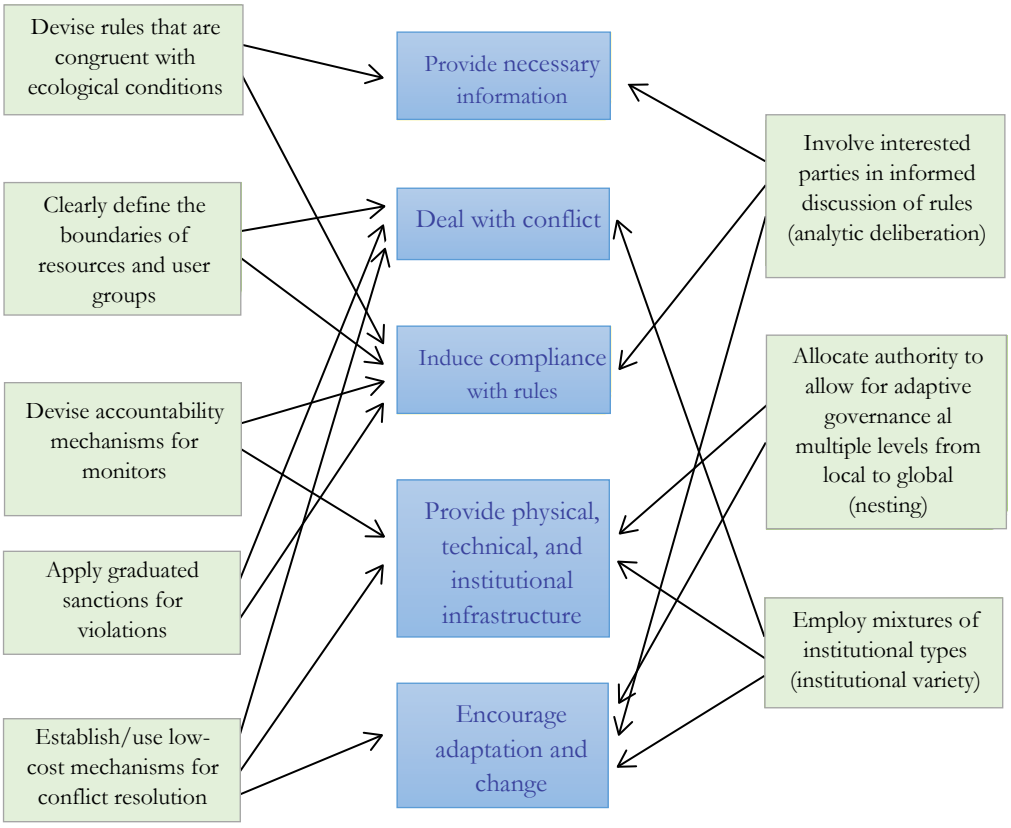
2. *Dealing with conflict*. The presence of conflict is inevitable in the governance of resources. As resources are usually shared among several users, who have different perspectives, interests and mental frameworks regarding problem-solving, the adoption of a strategy/course of action could potentially lead to dysfunction if not carried out correctly. However, conflicts, if not escalated to the extreme, also represent a trigger for learning and change (Stern, 1991). The key to avoid this trap is to design institutions not as a delegation of authority, process which might not satisfactorily resolve conflicts, but rather as structured participatory processes for conflicting parties. (Renn, Webler, & Wiedemann, 1995; Beierle, 2002)
3. *Enhancing rule compliance*. To ensure the continuity of an institution, actors must recognize its values and follow its rules. The process to achieve such a condition is, however, a non-linear one. Community-based institutions usually rely upon informal strategies, such as social norms and ostracization of wrongdoers, while most of the private and public institutions have been based on "command and control" actions, where laws are issued and enforced, punishing non-compliance with fines or worse. Both strategies have their strong and weak points, but usually requires sufficient resources (i.e. people acting on behalf of institutions) to be effective, otherwise they generate poor results, while also been economically inefficient in many cases (public and private institutions more than community ones) (Berkes, Folke, & Colding, 1998). A key tool to overcome such limitations seems to be financial incentives[29], proving to hold substantial advantages compared to "command and control" strategies (Libecap, 1990). The most relevant factor ensuring the success of any type of strategy enhancing rule compliance is to successfully promote the users' voluntary compliance, either through financial incentives or social pressure.
4. *Providing infrastructure*. Infrastructure is the major factor ensuring the degree a common can be exploited, its use optimized and the level at which existing resources and users are monitored by any institution. These infrastructures are physical (i.e. highways, irrigation systems, etc.), technological (i.e. transportations, communications, …) and institutional (i.e. researches, social capital and multi-scalar

[29] Tradable environmental allowances (TEAs) have experienced popularity and have been one of the bases for Kyoto Agreement on climate change. (Yandle & Dewees, 2003)

rules), all of them facilitating the linkage between local systems and larger (i.e. regional, national or global) levels of governance and systems (i.e. markets) (Princen, 2003).

5. *Encourage adaptation and change.* As sustainable and resilient institutions must be responsive to ever-changing settings and conditions, they must avoid the imposition of fixed rules, favoring more flexible ones and allows for change to happen. Devising this kind of institutional arrangements might be suboptimal in the short run, but it will possibly ensure continuity in the long-run, as learned by research on adaptive management (Gunderson, 2001).

Figure 9. Principles for robust governance of environmental resources (on the sides) and their requirements (in the middle). Source (Dietz, Ostrom, & C., 2003)



This list of principles can be considered as commonly established and proved through empirical studies (Hagedorn, 2002), thus framing reliable guidelines for the design of institutions who can ensure resilient and sustainable governance of forest resources. The value of these principles is their adaptability to a wide spectrum of institutions (i.e. governments, communities, organizations, etc) dealing with commons management. Such principles should also and above all be implemented to institutions at every scale because citing Ostrom et al. (2003, p. 1910) closing words:

"*As the human footprint on the Earth enlarges, humanity is challenged to develop and deploy understanding of large-scale commons governance quickly enough to avoid the large-scale tragedies that will otherwise ensue.*"

3.4 A planner's perspective on forests governance

So far in this thesis, a lot of knowledge, concepts, and theories have been introduced, briefly explained and sometimes interpreted. This has been done to give a framework and background as wide as possible to readers of different disciplines. All these tools, disciplines and theories should constitute the basis for implementing multidisciplinary analysis of the existing dynamics and of the solutions designed to ensure the best future possibilities, for both resources (forests and their products) and users (all of us). There has been a strong emphasis on institutions: what are they, how they are born, what do they imply, and how they change. There has been an overview of forest products: what are they, why they matter and how their management can be improved through technologies or other tools (certifications). The previous chapter has tried to understand how institutions can respond to global and local change and challenges to their best, promoting a sustainable use of resources and at the same time social and economic benefits to all. It might seem that all the tools have been put on the table, and now the case study can start. But before doing so, let's take a moment to discuss a further, inclusive, and fundamental interpretation of this already complex and interlinked framework.

It has been said that institutions are "*the rules of the game*" (North, 1990) that mold the way actors think and operate in specific settings. At the same time, it has been explained that forests are complex biological ecosystems which operate in equilibrium and influence their surroundings and in larger scales the entire Earth's ecosystem. It has been clearly expounded how instructions can govern and affects these ecosystems by altering their biological, physical, and economic characteristics. Different institutions produce different results to forests, that's a fact. These results can be expressed and compared through different indicators (SDGs are proof of that), and scholars, decisionmakers, and planners can act in accordance to them to adjust, improve or eventually remedy to these conditions. There is nothing wrong with this workflow. On the contrary, it might be wider in its scope than others which are carried out by many existing institutions, which by reason of their specialization in one sector often put aside unwanted complexity and focus on a single core aspect of the matter. Once again, this selection of focus is not a crime, rather, it's precisely the attention to specific details which increase the overall validity of wider strategies (so far that data are in quantities which users can process, as Ostrom et al. (2003; 2008a) teach). And yet, even if institutions may put aside some set of information in favor of others more practical to their goals, this complexity, this huge and comprehensive mass of information, notions and (way too often unspoken) emotions, do not simply disappear. It just remains there, unmoved, (supposedly) free and accessible to all. So how can we call this underlying entity, this untold database, this visible yet incorporeal concept? It's not easy to name it. Not because there is no concept which might correctly describe it, rather, each discipline has their own precise and specific term, or possibly more than one. It might be called "setting", "context", "environment" and so on. Each definition is functional to the discipline that adopts it. To discuss all these possible interpretations is not the goal of this work, nor it might provide great benefit to the narrative. It must be however understood that each definition underlies a precise background, whose understanding might facilitate to frame the information and purpose of different authors. Therefore, this work too shall give a personal definition of this

"space of complexity". Inevitably, the author's background will strongly influence such choice, but even if biased by personal (but somehow universal) experiences, this terminological choice should be understood by all, thus meaning no harm to more sectorial definitions. Hence, let's call this place with a simple yet powerful name: *Landscape*.

Using this term might make things more complex rather than simplify them, opening a Pandora's box of discussions on the validity, interpretation and correctness of this choice. There is no universally valid definition of this term, as its characteristics are too dependent on the society that express them. The vision and idea of "landscape" of a European citizen would be most certainly greatly different from the one of an African or Asian citizen. Therefore, any use of this term must be contextualized and interpret in accordance to the society which originate from. Nonetheless, even if with different interpretation, almost all population have an idea of "*landscape*". Everyone have different ideas of landscape, which are based on the subjective perception of it. However, there are also objective and inter-subjective ideas of this concept. To make it simple, even if a healthy man and a blind one both experience the same landscape, they will have personal subjective perceptions (i.e. the image they associate with the idea), but they will have also objective judgements (the presence of ongoing precipitations) and possibly inter-subjective ideas (the feelings this landscape transmit to them). Therefore, even if not everyone have the same idea of landscape, no one is privy of one. Then again, why the landscape should be considered the place where institutions operate, forests management is carried out and actors interact with each other? There are several reasons for that. First, there is not a single landscape, rather, there are landscapes with different scales which enclose themselves by hierarchical and dimensional order. A hill will be a local landscape, which together with other hills will form a "regional" landscape, which will be included in a wider one, and so on. When discussing hierarchical order of the landscape, the adoption of an environmental framework could be helpful (Table 23).

Table 23. Hierarchy of environmental systems

Spatial scale	*Definition*	*Determining factors*
Macro scale	Climate zones Climate regions	Climate Climate and human activities
Mesoscale	Landscape systems Landscape areas	Geomorphology Geomorphology and human activities
Micro scale	Landscape unit Ecotopes	Local environmental system Homogeneous environmental card

There is a strong affinity with the classification systems of forests typologies, thus adding one more point of validity for this choice of words. Going forth, the landscape can be expressed under different values, which can be summed up into five categories:

- *Aesthetic value*: the view, the feelings it conveys to the observer (subjective and hard to quantify, but still relevant in specific market dynamics)

- *Environmental value*: ecologic quality and biodiversity (objective and quantifiable)
- *Social value*: the "identities" of places influence the populations living there (in factors like behavior, habits and mental framework)
- *Economic value*: the economic potential of places (in term of resources and tourism)
- *Historical-cultural value*: in its role as the heritage of traditions, values, and knowledge specific of a place

These set of values most perfectly align with considerations done about forests and their products, in term of social, economic and environmental characteristics. Now, let's try to make a consideration: is landscape a common? Following the general and wide definition of "non-excludable and exhaustible resource", landscape could fit in the description. Certainly, speaking of "exhausted" landscapes might sound unconventional, but if "exhaustion" is considered as complete transformation and loss of existing values, then it sounds dramatically commonplace of a situation, especially in situations of extreme and uncontrolled human development (like wild deforestation). As per the non-excludable characteristic, it's quite a philosophical matter, but considering the simplest case of a flowerbed, the only way to exclude others for experiencing this landscape it's to radically alter the physical characteristic of the object (for example by tightly fencing the area, blocking the sight). However, landscape is not a "standard" common, but it often represents the "space of inference" among several commons, and it's a direct expression of the management regimes these commons are subject to. To make an example with forest commons, the landscape value of a production forest (for timber harvest) and a multiple-use forest (for timber and NTFPs) are two totally different things. It's not a matter of "quality" of the landscape (both settings can be, if correctly managed, equally valuable), rather it's about the "shape" of the landscape. A sustainable production forest would be composed by young trees, few species and generally with a not-too dense canopy. A multiple-use instead would have a dense canopy, older trees, and more variety in the ecosystem. Both settings are still forests and form landscape of their own, but the difference in management regimes of the resources is what makes them different. Another important question is, when is landscape a common and when it's a public good? This becomes a tricky question which is outside the scope of this thesis. To give a personal interpretation, landscape should be considered more as a special common rather than a public good, as this categorization better shows the intrinsic complexity of dynamics and interests which shape the landscape at every scale. Ultimately, the landscape is the results of something more than the action from the "public". Rather, it's the result of the inference between different resources and their respective management strategies. When interpreting the landscape as such, rather than limiting the design to the physical environment, the planners should aim to "shape" the landscape by designing those who govern and are the interpreter of its dynamics, i.e. the institutions.

This leads to what's the linkage between institutions and landscape. Institutions have a wide range of definitions and forms (see chapter 3.1.2), therefore it's quite a demanding task to define how all of them are linked to the landscape. The first and simplest link is that landscape, as physical space of interactions, is where institutions work in every form. Therefore, institutional influence should be perceived in the spatial forms, and vice versa spatial entities should have some relation with institutions. For example, the presence of

Roman Stadium in cities clearly shows the past existence of Roman institutions in those areas, while the currency adopted is related to the spatial location of users. But the relationship is deeper than just spatial. Following the definitions of European Landscape Convention of Florence (2000), landscape management is defined as "*action, from a perspective of sustainable development, to ensure the regular upkeep of a landscape, so as to guide and harmonize changes which are brought about by social, economic and environmental processes*". Looking at the goals of adaptive institutions, it's clear that similitudes and point of contact abound. Landscape is then not only the location, but also an object to be managed by institutions. Surely, it's already quite a strong relationship between these two concepts. But let's focus on one last point. Among the different definitions of landscape, one which is quite interesting for its formulation (and global recognition), is the one by European Landscape Convention (2000):

> *"Landscape" means an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors;*

Now, when juxtaposing this with Hodgson's (2006) definition of institutions:

> *Durable systems of established and embedded social rules that structure social interactions.*

some clear affinities appear. Both are, even if differently, social constructions based on human perceptions and actions, which in turn affect the ways actors act and behave. It might not sound too-farfetched or absurd to say that landscape is a special kind of institution. It might be argued that landscape as a physical entity exists independently from human presence, differently from institutions which one way or another are based and shaped on humans. However, saying so might arise a dilemma: if no human experience a landscape, does it still qualify as a landscape? According to the general convention about the landscape, and following the definitions, the landscape is inevitably related to human perception, thus is non-existent (at least semantically) when humans are not there. Which is the same as institutions. Thus, under theoretical reasoning, considering landscape a kind of institutions is not completely baseless. But then again, why introducing only now this reasoning? Once defined landscape as a results of commons management and institutions as those responsible for the management, this creates a biunivocal correlation between the two. Following the framework of commons, the way to preserve and develop a sustainable use of a common-pool resource (in this case the landscape) is only through the correct design of its governing institutions. Tu support this thesis, the case study will try to show how to shape the landscape and to design its governing institutions are two deeply connected, if not the same, concepts. In the case study the main landscape will be a result of a commons (a cultural one, to be exact), which differs from the forest common-pool resource take into exam. The goal of the case study is to understand which and how should institutions deal with a forest common which is not predominant in the landscape management strategies to ensure its prosperity. Here the landscape will thus become a constraint rather than a facilitator for management, taking a predominant role in the design process of institutions governing the commons. To confront this complexity, the chosen case study has been Alba's White Truffle (*Tuber magnatum*) and its management in the Piedmont region.

4. Case study: Alba's White Truffle (*Tuber magnatum*)

The case study presented concern a typical product of Piedmont, Italy, namely the Alba's White Truffle. Contrary to his name, such species of fungi is not exclusive to Piedmont but has been historically linked to the Region since long ago. Truffles are peculiar common-pool resources which grow in forests, needing careful management processes to be successfully harvested. Generally they are highly valued as market goods, especially *Tuber magnatum*. As a matter of fact, in Piedmont, considered the putative birthplace of white truffle, *Tuber magnatum* is slowly disappearing due to overharvesting and lacking forest management practices. Understanding and arresting this dynamic represent a challenge, not only for institutions but for many other actors at different levels. *Tuber magnatum* can thus represent an interesting case among forest commons in relation both to the market needs and the territorial landscape management.

4.1 Concerning the White Truffle

Truffles are quite unique products of nature, as they are dependent on several variables and factors for their development, while also being strongly interlinked with the entire ecosystem they live into. Overall, truffles represent an interesting object of study for many fields, since they possess remarkable social, biologic and economic values wherever they grow, making them a feasible centerpiece of sustainable development. Even among these unique products, the *Tuber magnatum* represent a stand-alone case, being the most valued and most demanding between the *Tuber* genus in nature. Understanding the uniqueness of this product is fundamental to frame why protecting and developing it should concern so deeply not only those who profit from its market value, but all the institutions, organizations and population touched by the truffle heritage.

4.1.1 What is a truffle: denominations and characteristics

Truffles, more than other forest products, present a high complexity and variation in their taxonomy. There exist several *genus* and species collectively called "truffle", but since their characteristics differs greatly from each other, clarifying what can be defined as truffle becomes important. Adopting a general definition of truffles, they "*are fungi that sequester their spores within differentiated fruiting structures that are produced below the soil*" (Bonito & Smith, 2016, p. 3). However, this definition includes many different products, which have a consistent difference in their market value and in the importance attached by local populations. When mentioning truffles which are most relevant and valued, most probably it's in reference to "*true truffles*", which are included in the genus *Tuber*. Truffles mostly fruit below the undergrowth, in the rotting zone of plants or eventually in the mineral horizon. Leaving aside microscopical and biological characteristics, at the macroscopic level truffles present a great variability in characteristics, such as shape and size, as well as color, aroma, and texture. At the microscopic level, the differences only broaden, with still many missing details about the natural ecology of many truffles' species. The difference in speciation and function in ecosystems of truffles is strongly related to their ectomycorrhizal (ECMs) ecology and their correlated diversification in respect to major plant families (Bonito & Smith, 2016). The role of truffles in ecosystems is not to be underestimated, as through the formation of ECMs correlating them with plants, truffles exchange nutrients with the latter, mostly providing nitrogen and phosphorous while taking carbohydrates. This symbiotic system plays an important role in the functioning of soils and forest ecosystems, which coupled with their relevance as a food source for forest mammals contribute to the maintenance of Earth ecosystems and food webs. Differently, from other fungi, which actively discharge their spores in the environment to reproduce, many truffles have taken a more "passive" mechanism to ensure the dispersal of their spores. They rely on animals, which are appealed through olfactory or visual attractants (Beever & Lebel, 2014) to consume truffles fruiting body and consequently release and disperse their sequestrated spores. There is, in fact, a strong correlation and coevolution between truffles and mammals and animals living in the undergrowth worldwide. Truffles are quite a complex forest product, as they do not only support and improve the ecosystem with their existence, but they are also highly dependent on the well-being of the ecosystems themselves. To say it otherwise, a loss of animal population, especially small mammals and other animals (like boars), can negatively influence the reproduction of truffles, while the excessive extraction of them could directly impact the biodiversity of the undergrowth. Not to mention that deforestation processes privy of consequent reforestation initiatives negatively impacts their nutrient chains, thus impeding their growth and reproduction. Overall, truffles are strongly interconnected pieces of forests ecosystems dependent from various factors and elements for their development.

As mentioned before, truffles have a complex phylogeny. The family of Tuberaceae comprises six genera: *Tuber* and *Choiromyces*, which are diffused in the Northern Hemisphere; *Reddellomyces*, *Labyrinthomyces*, *Dingleya* and *Nothojafnea* which are mostly in the Southern Hemisphere. The most valued ones are *Tuber* and *Choiromyces*, but even though *Choiromyces* genus present rare but widespread species, the *Tuber* genus include way more studied species, with different characteristic and highly variable market value. The other genus, even if highly

diffused, have received low interest in term of economic or gastronomic value for humans, even if they still play their roles in hosting ecosystems. Analyzing the genus *Tuber* using ITS rDNA[30], Bonito et al. (2013) distinguished 11 *clades* (Table 24), with around 180-220 species,.

Table 24. Tuber clade and notable species

Tuber clade	*Notable species and information*
Aestivum	*Tuber aestivum* Vittad. *Tuber mesentericum* Vittad. *Tuber magnatum* (the species of the famous white truffle) *Aestivum* clade species are associated with angiosperms, gymnosperms, and orchids.
Excavatum	*Tuber excavatum* Vittad. *Tuber fulgens* Quél *Excavatum* clade have a strong aroma but are usually not consumed by humans
Gennadii	*Tuber gennadii* (Chatin) Pat. *Tuber lacunosum* Mattir. *Gennadii* are rare and not much distributed, thus rarely consumed
Gibbosum	*Tuber gibbosum* Harkn. *Tuber oregonense* Trappe, Bonito, and Rawl. Highly diffused in Pacific Northwest of USA, they are associated exclusively with *Pinaceae* and have recognized market value
Japonicum	Only recently discovered, still not officially described. No information on human consumption of this clade.
Macrosporum	*Tuber macrosporum* Vittad. – found across Italy and Eastern Europe, currently cultivated in Austria and Hungary (Benucci, et al., 2012) *Tuber canaliculatum* Gilkey – widespread from Eastern USA to Canada
Maculatum	*Tuber maculatum* Vittad. – in New Zealand has been marketed Elsewhere are considered contaminants
Melanosporum	*Tuber melanosporum* – the black truffle, possibly the most cultivated truffle species in the world. It has economic significance in many continents *Tuber indicum* Cooke and Massee – Asian species, harvested in high number for human consumption
Multimaculatum	*Tuber multimaculatum* Parladé, Trappe, and Alvarez – is the only known species, not well analyzed.
Puberulum	*Tuber borchii* Vittad. – most relevant edible species of the clade Most *Puberulum* species are considered weedy associates of other truffles, often disturbing their cultivation
Rufum	*Tuber melosporum* Moreno, Diez, and Manjon They usually have an unpleasant aroma, thus are not apt for consumption. The only notable exception is *Tuber lyonii* Butters (known as pecan truffle), which is harvested and sold in the USA, with efforts for cultivating it underway.

[30] Internal transcribed spacer (ITS) is the spacer DNA between a sub-unit of ribosomal DNA (rDNA) and larger sub-unit of rDNA genes. The comparison of sequences of ITS region is a reliable and diffused practice adopted in taxonomy and molecular phylogeny to map *taxa*.

This overview of *clade* gives an insight on how wide and complex is the philology of truffles in correlation to market and social values across the globe.

Explained how truffles are classified according to their phylogeny and clade, the next step is to classify their species according to morphologic and physical characteristics. As mentioned before, truffles grow below ground, at a variable height between just below the rotting foliage and bit more than a meter. Once excavated, there are some key characteristics which can be used to identify the species of truffles that help to distinguish them from other fruiting bodies which grow underground (i.e. edible roots or some wild vegetables). Truffles have an irregular or globose shape, like many other tubers, variations in their size, and dimensions of few centimeters (<10 cm) depending on the species, even if bigger specimens have been occasionally found (and highly valued on markets). The outer wall of the fruit is called *peridium*, and it's one of the main distinguishing features among species without the need to cut (thus spoil) the truffle. The peridium varies according to the species of the truffle, both in color and surface roughness and shape. For example, the white truffle (*Tuber magnatum* Pico) has a smooth surface with a light or yellowish color; the black truffle (*Tuber melanosporum*) has a brown or black peridium, with significative protuberances on the surface, usually with a pyramidal shape. The internal part of the truffle is called *gleba*, which protects the alveoli containing structures (in Italian "*asci*") hosting the spores. The color of the gleba yet again varies according to the species and their maturity. White truffle (*Tuber magnatum* Pico) have a light colored gleba, turning hazelnut with occasional pinkish elements, while black truffle (*Tuber melanosporum*) have an initially white gleba, which gets progressively reddish-black with small white veins. Aside from this visual indicators, one important feature to distinguish truffles is their characteristic *aroma*, which besides helping for their reproduction (by attracting animals which diffuse their spores) is one of the most appreciated features for humans.

Besides their physical characteristics, truffles can be identified and characterized by two other features: their *soil preferences* and their *hosting plants*. Concerning the soils, the physical and chemical composition of them greatly influences the truffles growth capacity and distribution. Different truffles need different soils, but they all share a general attitude favoring *calcareous* soils that can often be found in prehistoric see regions, which produced soils rich in calcium carbonate ($CaCO_3$). These conditions can also be found in riparian areas, which have often the right equilibrium of soil granulometry. Another important factor influencing successful truffles growth is the *altitude* of the terrain, with variations according to species. Generally, in Italy white truffles grow up to 600 m a.s.l., while black truffles are found between 250 mt. and 900 m a.s.l. The pH level can also influence the attitude of soil, with many species favoring soils with pH grossly between 7 and 9 (white truffle: 7.4-8.4; black truffle: 7.5-8.5) (Regione Piemonte, 2001). A detailed analysis of soil composition can be considered fundamental in the study of truffles, both for their biological characteristic and their diffusion patterns. An interesting consideration is that these kind of soil compositions are also strongly favorable towards viticulture activities, as many varieties of grapes privilege calcareous soils with good nutrients and not too high altitude. In Italy this might prove to be a potentially conflictual condition, as both products are highly valued and sought, while sharing the same demands in term of soils composition.

Another major condition for truffles growth and diffusion is the distribution of hosting plants. Being symbiotic in nature, truffles strongly relies on other plants for gathering nutrients, while at the same helping the plants by giving other material (*nitrogen* and *phosphorous* mostly). The creation of ECMs with plant roots is, therefore, the main factor influencing the successful implantation and growth of truffles in the environment. Many studies on hosting attitude have been conducted along the years, thus producing a notable amount of scientific proofs about this argument. Table 25 shows the host plants for some of the most relevant truffles species in Italy. As shown in the table, different species have some variations across their host plants, especially the white truffle, which is one of the most demanding species. On the other hand, *Tuber aestivum* and *Tuber melanosporum* have greater compatibility with different plants. Both species have a strong affinity with genus *Quercus* and *Pinus*, while *Tuber magnatum* is more related to genus *Populus*, *Salix,* and *Tilia.* The distribution and conditions of hosting plants is thus a key parameter to ensure the well-being of symbiotic being like truffles.

Truffles are quite fascinating products, as they are dependent on many factors while also influencing the ecosystems they live into. The study of the characteristics, either physical, biological or environmental of these products has been and still is of great interest for scholars and institutions governing forests. Among all these different species of truffles, the focus of this work has been the *Tuber magnatum* Pico, named the white truffle of Alba, that even among unique products such as truffles, possess characteristics and history making it one of the most relevant and interesting species to study.

Table 25. Hosting plants of Tuber species according to studies. Source (Gryndler, 2016)

Tuber species		*Hosts (scientific name)*	*Studies*
Tuber aestivum		*Abies alba* *Alnus cordata* *Betula pendula, B. verrucose* *Carpinus betulus* *Castanea sativa* *Cedrus atlantica, C. deodara* *Cistus spp.* *Corylus avellane, C. colurna* *Fagus sylvatica* *Fumana procumbens* *Ostrya carpinifolia* *Picea abies, P. excelsa,* *Pinus brutia, P. halepensis, P. nigra P. pinaster, P. pinea, P. strobus, P. sylvestris* *Populus spp., P. nigra* *Quercus boissieri, Q. calliprinos, Q. cerris, Q. ilex, Q. ithaburensis, Q. libani, Q. petraea, Q. pubescens, Q. robur* *Tilia spp.* *Ulmus spp.*	(Hall, Brown, & Zambonelli, 2007) (Stobbe, et al., 2012) (Turgeman, et al., 2012)

Tuber magnatum (White truffle)		*Abies alba* *Alnus cordata* *Cedrus atlantica, C. deodara* *Corylus avellana* *Ostrya carpinifolia* *Pinus pinea* *Populus spp., P. alba, P. nigra, P. tremula,* *Quercus cerris, Q. ilex, Q. petraea, Q. pubescens, Q. robur* *Salix alba, S. caprea* *Tilia spp., T. cordata, Tilia x europaea, T. platyphyllos*	(Granetti, De Angelis, & Materozzi, 2005) (Hall, Brown, & Zambonelli, 2007)
Tuber melanosporum (Black truffle)		*Abies alba* *Alnus cordata* *Betula spp.* *Carpinus betulus, C. orientalis* *Castanea sativa* *Cedrus spp., C. atlantica, C. deodara* *Cistus spp., C. incanus* *Corylus avellana, C. colurna, C. heterophylla* *Pinus nigra, P. pinaster, P. pinea, P. strobus, P. sylvestris* *Ostrya carpinifolia* *Populus spp., P. alba* *Quercus cerris, Q. coccifera, Q. faginea, Q. ilex, Q. petraea,* *Q. pubescens, Q. robur, Q. sessiliflora, Q. suber* *Salix caprea* *Tilia spp., T. cordata, Tilia x europaea, T. platyphyllos*	(Riousset, Riousset, Chevalier, & Bardet, 2001) (Granetti, De Angelis, & Materozzi, 2005) (Hall, Brown, & Zambonelli, 2007)

4.1.2 What about the white truffle of Alba (*Tuber magnatum* Pico)?

Tuber magnatum Pico, named also white truffle of Alba or in local dialect *Trifola d'Alba,* has not been the first truffle to be consumed by men. There are documents and texts (for example Juvenal in the book I of "*Satires*" cite *Tubera*) testifying that Romans enjoyed eating truffles, probably black ones. At that time truffles probably came from North Africa and they were of the species *Terfezia* rather than *Tuber magnatum* or *Tuber melanosporum*. Truffles use on the table was diffused among the population in the Medieval Age, but it was excluded from the nobles' tables, as it was considered "immoral" since it could grow from decaying undergrowth. The first official documents on the use of white truffle go back to 1380, an archive of the *Savoy* dynasty which explicitly stated that Princes of Acaja send white truffle to Bona di Borbone as royal gifts (Ceruti, 1968). Truffle was later widely used as a diplomatic gift in foreign relations by the princes of Savoy (Nowak Z. , 2015), and among their estimators can be found figures such as French kings Louis XV and Louis XVIII, as well as the Queen of Austria Maria Teresa (Ceruti, 1968). The white truffle got so famous in the Kingdom of Sardinia that Giovanni Bernardo Vigo published in 1726 a small poem titled "*Tubera terrae*", edited by the Typografia regia. This poem intended to magnify a regional excellence, supporting the custom of the kings Vittorio Amedeo II and Carlo Emanuele III to send them to kings and princes as gifts. This use of white truffles as a diplomatic gift spread their name across Europe, improving their popularity and originating what Rittersma (2011) defined as a "*truffle mania*" across Europe. The first description of Alba white truffle comes from Italian physician Vittorio Pico (or Picco) in 1788, which in his degree thesis wrote:

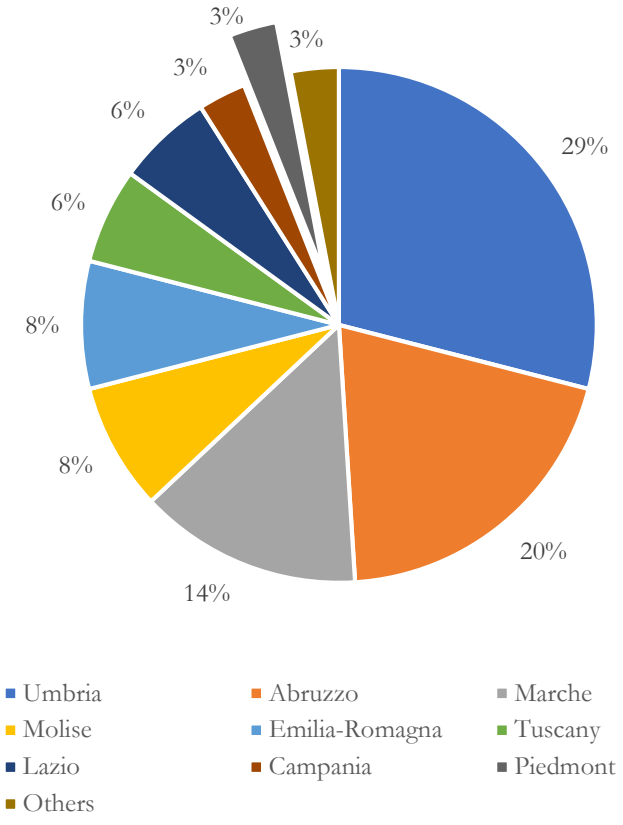
> *"Tuber magnatum - T. formae irregularis externe luteo griseum, attactu molli, pulpa ex albo-grisea subflava, venulis decoloribus serpentinis eleganter intertexa, maculis rubentibus hinc illinc saepe notata. Naribus, et palato deliciosissimum. Autumni productum peculiare Montisferrati, Astensibus et Liguris collinis. Vernac. Trilole generico nomine insigniuntur, cui addunt alli Synonimum Crise"*
>
> (Pico, 1788, p. 79)

Here the author, even if not completely, described the species of *Tuber magnatum* which bore his name. The name itself, *magnatum*, referred to its diffusion among the nobles, the *Magni* of Europe. This wave of interest towards this regional specialty has persisted during successive centuries, bringing to the establishment of the first truffle market in Alba in 1930, action which further reinforced the linkage between the white truffle and Piedmont. Later studies found that *Tuber magnatum* can also be found in other Italian territories (particularly Umbria and Abruzzo), as well as in the Balkan Peninsula (Marjanovic, Saljnikov, Milenkovic, & Grebenc, 2010), southeast of France and sometimes Switzerland (Riccioni, Rubini, Belfiori, Gregori, & Paolocci, 2016). Even if these regions effectively produce *Tuber magnatum*, the popularity of Alba white truffles have not diminished in the years, rather it's recently on the rise, supported by the promotion of its global "brand" and the public interest in gourmet cuisine.

When searching for historical records about gross production of white truffles, reliable information is practically non-existent. This might be attributed to several factors influencing white truffle production. First, they were mostly goods consumed by nobles for pleasure,

without any strong strategical value, and by poor hunters, mostly as a secondary source of income (possibly even illegal). Therefore, no strong or exact record of harvesting was carried out. Secondly, even if this practice was diffused among the population, the hunt of truffles remained sort of a taboo. The economic value of white truffles has always been quite high, enough to discourage hunters to diffuse clear information on their harvest, to avoid making trouble for themselves in any way. Lastly, as their main role was still that of diplomatic gifts, the most accurate tables of quantities were those related to truffles sent to foreign kingdoms. Estimating the internal consumption and total production would be quite a difficult task, as no precise and diffused records were kept by any control organ about this good consumption among the population. The only possible source of data might be records of noble families hunting activities, which were sporadically accounted for by their accountants or housekeepers. This lack of data should not be interpreted as an age-related issue, as still nowadays, even if data on production and selling of truffles have reached quite higher precision, there is still inaccuracy in their estimation, as disinterestedness to register harvests among hunters (or farmers) is still a well-established habit. Still, some studies have tried to estimate the world production in previous years, such as Hall et al. (2003) that estimated *Tuber magnatum* worldwide production between 50-200 t. Another study of Brun and Mosso (2010) quantified *Tuber magnatum* production across Italy: 124 t in 2002, 19 t in 2006 and 12 t in 2007. Putting aside the stunning decrease in production, it's even more interesting to analyze the distribution of such production across Italian regions (Graphic 3).

Graphic 3. Tuber magnatum production per region (medium 2002, 2006 and 2007). Source ISTAT



Brun and Mosso (2010) compared ISTAT data and found out that even if *Tuber magnatum* is particularly famous in Piedmont, officially only 3% of its production comes from this region. Even considering that such estimations might be significantly inaccurate and thus unreliable, it's a fact that even if most white truffles do not come from Piedmont, this "product label" remain predominant compared to other regions.

Another important feature of white truffles is their price. Truffles, like many other mycorrhizas, are highly valued by chefs and gourmets for their distinctive flavor and their organoleptic properties. This has made such category of products among the most expensive one, and among all the white truffles stands at the top of the list for the price (Table 26)

Table 26. Market information on edible mycorrhizal mushrooms. Source (Hall, Yun, & Amicucci, 2003)

Scientific name	*Common name*	*In-season retail market US$ (estimated)*	*Wholesale prices US$/kg for first grade (estimated)*	*References*
Boletus edulis	Porcini	>250 million	13-198	(Hall, Lyon, Wang, & Sinclair, 1998)
Cantharellus cibarius	Chanterelle	1.62 billion	8-19	(Baker, 1997)
Tricholoma matsutake	Matsutake	500 million	40-500	(Wang, Hall, & Evans, 1997)
Tuber melanosporum	Périgord black truffle	>150 million	250-1200	(Olivier, 2000)
Tuber magnatum	Italian white truffle	>150 million	1000-13000	(Hall, Zambonelli, & Primavera, 1998)

White truffles high market value should not surprise, as differently from other mycorrhizal mushrooms or other truffles species such as *Tuber melanosporum* Vittad. and *Tuber aestivum* Vittad., there are still pitifully few successful cultivations of this products, with a negligible impact on overall production. This factor, coupled with rising global demand in contrast with unstable production, results in high variability for this product value. For example, in 2007 a drought deeply impacted production, resulting in low volumes, which spiked the prices up to 7000 €/kg; in 2014, however, the harvest went quite well, with higher volumes in the market, thus price ranges decreased to 600-700 €/kg. Even if market prices have experienced oscillations, the prices paid to the hunter for *Tuber magnatum* in the last 10 years have been around 1000-1500 €/kg. (Riccioni, Rubini, Belfiori, Gregori, & Paolocci, 2016).

Favored by such widespread popularity, in Italy the studies about *Tuber magnatum* Pico have been extensive and highly detailed, even if due to their publication mostly on Italian journals they have been difficult to access by foreign researchers. From a biological point of view, *Tuber magnatum* is the "pickiest" of the Tuber species regarding hosts and soils composition, especially for the formation of *ascomata* (the fruiting body). Therefore, many studies have been carried out to identify the most suitable soils for this product. In particular, the work

of Montacchini and Caramiello (1968) analyzed the soil composition of 23 truffle grounds in the region of Langhe and Monferrato, identifying the key elements present (Table 27).

Table 27. Topsoil components in Langhe-Monferrato truffle areas. Source (Montacchini & Caramiello, 1968)

Chemical components	*Mean*	*Standard deviation*	*Minimum value*	*Maximum value*
C_{org} (%)	1.9	1	0.5	3.8
$CaCO_3$ (%)	25	17	1	68
Ca_{ex} $(cmol(+)\ kg^{-1})$	19	7.7	10.6	35.1
Mg_{ex} $(cmol(+)\ kg^{-1})$	2.1	0.85	0.73	3.71
NO_3^- $(mg\ kg^{-1})$	56.4	37	18.8	187.5
$Total\ P$ $(mg\ kg^{-1})$	0.64	0.31	0.26	1.26

These analyses determined that white truffles grow in soils with the presence of *calcium carbonates* ($\mathrm{CaCO_3}$) and *exchangeable magnesium* ($\mathrm{Mg_{ex}}$), coupled with rich content of *exchangeable calcium* ($\mathrm{Ca_{ex}}$) and variable range of *organic carbonium* ($\mathrm{C_{org}}$). These data, as detailed as they might be, had not too high of an impact, since they are common to many Italian soils which have not experienced white truffles colonization. The characteristic which has been proved to be more relevant has been the structure of soils, i.e. their *granulometry*, which highlighted specific attitudes towards higher, interconnected macro-porosity which allows the truffle to "breath" and do not hinder the growth of the *ascomata*. The many years of studies allowed to comply a list of criteria, effectively synthesized by Bragato and Marjanovic (2016, p. 206-207), which soils and locations must have to facilitate *Tuber magnatum* growth (and possibly its cultivation):

- Environments must be *moist* and *drained*, within tectonically active areas
- Soils must be continuously *rejuvenated* by solid materials (through floods or mass movements, depending on the *geomorphology*)
- Soils must be strongly *porous*, highly aerated and soft, which is facilitated aggregates accumulation
- The *microhabitat* must be nor excessively dry nor moist, thanks to water from the surrounding environment
- The most relevant landscapes are *floodplains*, as they act as water storage which can sustain dense tree cover, that in turn generate cool environment at soil surface level
    - Colonization on slopes is affected by changes in the angle which attract water and thus a cool environment
- Soil chemical characteristics are not stringent
    - pH must be neutral to alkaline
    - Prevalence of calcium and magnesium cations in surfaces can be influencing factor
    - Favorable soil classes are *Calcaric Fluvisols, Colluvic Calcaric Regosols, Calcaric Cambisols,* and *Fluvic Eutric Cambisols.*
- Non-variation in nearby soil-formed areas negatively influence finding probability

All these criteria are quite specific and presuppose an in-depth knowledge of the territory, which can originate only from continuous research and work on the field. There are several

other forest products which would require the same effort of analysis for their development, but they are very often not subject to the desirable deepening. *Tuber magnatum*, however, possibly due to its high market value, comparatively low area of diffusion and, especially for Piedmont, its strong relationship with local traditions and history, have experienced and it's still having high attention by researchers and institutions alike. This strenuous effort can be exemplified by the drafting, done by the Piedmont region with the support of the Institute for Wood Plants and Environment (IPLA spa), of a Charter of the potential for truffle production (*Carta della potenzialità alla produzione del tartufo pregiato*, in the Annex). Such effort has been possible thanks to the special relationship, not only economic but also social and cultural, that exists since long ago between Piedmont and its prized "*Trifola d'Alba*".

All these characteristics of the *Tuber magnatum* make it among one of the most interesting forest products which can be found in nature. Especially Piedmont white truffle is subject to quite unique conditions and history, which makes it an interesting object of study. In fact, even if the common name evokes the regional provenience, it has been shown how most of the white truffle produced comes from somewhere else. This can be explained by a simple and yet harsh reality, which is that (like many other common-pool resources) the white truffle in Piedmont is being slowly depleted by years of overharvesting and lacking management strategies. Such loss, even if it might be not particularly significant in the bigger picture (*Tuber magnatum* will keep on existing in other areas), will have a large-scale effect at the regional level. Because the white truffles in Piedmont not only means economic value: they imply the well-being of the ecosystem, bus also the *corpus* of techniques, knowledge, and heritage of many local realities, a long tradition which since a long time ago have inextricably linked, and will keep tied, Piedmont and the *Tuber magnatum* histories

4.1.3 Truffles between tradition and modernity in Italy and Piedmont

Before introducing the laws and regulations concerning truffles at a different scale, let's try to briefly expound why truffles, especially the white ones, are so highly valued and considered in Piedmont and what this implies. To fully understand this relationship only by using economic factors (which nonetheless have an undeniable influence) would be incomplete and possibly detrimental. To understand this long-lasting interest in truffles, any analysis must begin from quite a long time ago, before the first mentions on official documents. It has already been said that truffles consumption was already a habit at the time of the Romans nobility, later going into disuse during the Medieval Age. Yet, even if no clear records have reference to the use of truffles among the population in those years, it cannot be excluded that among the poor and farmers the harvest of these products was diffused. In fact, it should be reasonable to assume that it was quite common especially in Langhe-Monferrato area, and for several reasons. The relationship between farmers and forests in the Medieval Age was quite stronger than in many other periods since forests were not the only source of wood for construction and heating, but they also supplied plenty of products which could sustain farmers during droughts or harsh winters. This process is not different from conditions in many developing countries nowadays, only missing factor the modern economic and industrial pressure for development. Without strong external pressure for exploitation, truffles have been successfully harvested for many years without major repercussions on the environment and the population. The method truffle hunt was carried out was quite similar to now, but with some important differences. It has been said that truffles release the distinctive strong flavor to attract animals and thus release their spores. Among the most responsive animals to this smell, aside from small mammals, boars (and their cousins the pigs) were the best by nature, while dogs were quite as good but required training and had to be taken care of. For poor or farmers, the upkeep of animals only for hunting truffles was an economic burden which most could not afford; pigs, however, were entirely compatible with their lifestyle (it also became a common practice in France). As they were naturally attracted to truffles, using them as hunting partners during harvest seasons, while butchering them when they were grown up, was quite a positive cycle. Their feeding was already to be accounted for their raising, thus any other use of these animals brought only benefits to their owner. Therefore, the first harvester were probably local farmers who had animals capable to smell out truffles and used truffles and other forest products as a supplement to their diet (and possibly income). These interactions between locals and forests created a positive cycle, both economically and environmentally speaking. The action of harvesting several resources from forests, that naturally involve taking care of them, brought benefits to the truffles' growth, which require forests maintenance practices to flourish. The higher truffles harvest in turn favored those local which made use of them. This way, before any scientific study on truffles could be done, local practices were already favoring this product prosperity and contemporary improving local conditions.

Later, during the Renaissance, the ostracization of truffles from nobles table was lifted. This produced a diffused fascination for this product among the nobility, which fueled its popularity and the practice of hunting them. For noble, truffle hunting was more of an amusement rather than a pressing need. They did not strongly need forest products as

sustenance or income source, rather, the practice was appreciated for the enjoyment of the products as a delicacy and the action of exploring green areas. However, the nobles, given the dignity of their position, couldn't make use of common pigs as hunting partners. They thus opted for dogs, which were equally capable of hunting for truffle once correctly trained. And in fact, using dogs was quite an efficient choice. Many nobles already had packs of hounds and dogs, which they used for companionship or as hunting partners. Seen from an economic perspective, they already had the required assets, they simply needed to adjust these assets to perform different tasks. Of course, as dogs required care and truffles needed to be excavated, a new figure/task emerged, which in Piedmont was called "*trifolau"*, as related to the search of truffles, "*trifole"* in dialect. This figure would possibly be integrated into other existing figures, such as hunting masters or trackers, but later it would evolve into a separate figure and role of its own. The relationship between nobles and truffle hunting was not an interest-driven one, rather it responded to the need for entertainment which this class looked for. Therefore, they did not effectively contribute to the biological well-being of truffles, as they did not specifically clear out forests to gain resources, nor did they enforced stringent rules regulating their harvest. Nobles were thus simple appropriators, rather than actors directly involved in the upkeep of the forests. This does not mean that all nobles didn't care for the forest they governed/owned, but simply that among some of them forests were not a priority on the agenda. Some nobles acted as benevolent rulers in their territory, permitting their subjects to freely use forests and harvest the products, while others were more severe, prohibiting locals to make use of forests. It might be hard to assess how each of these attitudes affected local population behaviors regarding forests; if it stimulated them to care for the forests, or rather induced to transgress and covertly exploit the resources. A clearer consequence which nobles had on truffles is that they promote their diffusion and popularity across Europe and the world. The custom of Savoy royal household in XVIII century to send white truffles to foreign courts as diplomatic gifts certainly fostered their consumption among those rich segments of the population which held the wealth and influence needed to patronize the harvest of these products. Among the influencing figures that promoted the white truffle can be listed Gioachino Rossini and Camillo Benso of Cavour, both figure of great importance to the Italian (and Piedmontese) image in Europe and the world, as well as different foreign figure (Lord Byron and Alexandre Dumas to cite a few). In this period, hunting for truffles become a palace entertainment, a game which many royal visitors to Turin would undertake and enjoy, bringing with them this practice and applying it in their home countries. It was in this period that white truffle gained its great name as the "king of the truffles" and that acted as the base for its flourishing market.

Even if during the 1700-1800 the Piedmont white truffle gained widespread popularity, it's not until 1900 that its value was globally recognized and thus its market flourished. Possibly one of the most relevant figures which contributed to this development was Giacomo Morra, a hotel manager from Alba, which strongly promoted the white truffle worldwide, being the main culprit behind the establishment of the first truffle market in the world in 1930 and later of Alba's Truffle Fair in 1933. From this point onwards, the marketing of white truffle has experienced a nearly unstoppable growth, creating a market of incredibly high value. But with this exponential growth came also many issues. The production of truffles, which by its nature is not an assured one, under the effect of climate change and increasing market

demand, put much pressure on the product chain and negatively affected the local production in Langhe and Monferrato. The emergence of other white truffles across Italy and the Balkans exacerbated phenomena of counterfeit and alienation of products. This, however, did not strongly impact the flourishing market and the label of global renowned "*Trifole d'Alba*", as the market demands still haven't fallen short, nor it's expected to in short times. Increasing market pressure, coupled with the reformatted land governance, from kingdom to the modern Italian Republic, also deeply affected the organization of *trifolau*, which are no more workers for nobles or for landowners, but are now independent workers, maybe also amateurs or hobbyist which enjoy and can afford this practice. From people who depended on forests as supplements to workers employed by nobles to individual earning an income from harvesting these products and organizing themselves into unions and organization, the figure of the "*trifolau*" has changed much while always adhering to centuries-old traditions. The same can be said of the role of truffles; once a simple treat for nobles' tables, now a highly demanded good with high market value. From a supplement to the diet, to an expensive gourmet ingredient. The truffles and its actors have greatly changed from their origin, and they are still developing. While this global promotion surely brought several advantages, especially to the Alba region, it cannot be excluded that this positive paradigm could become a negative one, resulting in an overexploitation of the resources, or a deterioration of cultural and social values which this product carries. As many cases in history have taught, when a resource become of interest, when an externality emerges, the "market" acts to exploit and capture the benefits. However, how this process happens, what does it implies and what are the consequences are no easy questions. Even more, the consequences might be not univocally interpretable. They can greatly benefit the majority, or the main categories involved, but contemporary have long-lasting, more subtle effects on other oblivious actors and settings. Little is known to the poor valley farmers about what happened to the river's water along its route, but any action has one way or another, influenced the quality of the resource they rely upon. Once again, understanding the resources settings, their conditions, and their values become imperative for all those who must govern those resources and direct their future changes in the best direction. Alba's white truffles are a quite fitting example of this context complexity and pressure for development; on one side the traditions and social identities of the places and practices, on the other the high market demand for this prized good. What can be learned and predicted from the current conditions about future developments could represent a turning point for this small but significant Italian "excellence", and for many other similar cases across the globe.

Figure 10. The Truffle Fair of Alba: past and present

4.2 Normative framework

Truffles species have a widespread diffusion on Earth, as different species fruit and prosper on disparate areas and countries. Framing all these products under a uniform and international normative framework is hardly achievable. This is hindered by the product's different characteristic and related required procedures and cures. Also, truffles have widely variable price ranges among species, while countries have their own specific conditions derived from their historical and social values. In any case, the normative concerning truffles is mostly focused on national and regional level laws, while international normative mostly deals with commerce regulation and promotion of research about truffles. Here follows a summarized and scale-referred framework of the Italian normative disciplining truffles up to the Regional level.

4.2.1 International normative

The first step of the normative framework is the international scale, which for Alba white truffle involve United Nations and European Union.

Considering the United Nations, they norm the truffle according to the UNECE standard FFV-53, recently edited in 2017 (UNECE, 2017). This document does not actually concern the maintenance or development of the truffle industry, rather, it only establishes some generic definitions concerning the marketing and the commercial quality control of truffles. This can be attributed once again to the variety of conditions and setting truffles are harvested from, too far apart both geographically and socially to be included in a single normative encompassing all those factors and practice required for harvesting truffles. The content of the document cover six topics and can summarize as follow:

I. *Definition of the produce*: for the *Tuber magnatum* Pico (common name white Piedmont truffle), the accepted definition is the one from Ulloa and Hanlin (2012).
II. *Provisions concerning quality*: it defines the quality requirements for truffles after preparation and packaging. It's articulated in three sub-topics which have related sub-points.
    A. *Minimum requirements*: truffles must be
        - intact; however, a slight superficial cut is not regarded as a defect
        - firm
        - sound; produce affected by rotting or deterioration such as to make it unfit for
        - consumption is excluded
        - clean, practically free of any visible foreign matter; the residual soil rate must not
        - exceed 5 % by weight
        - positively identifiable
        - practically free from pests
        - practically free from damage caused by pests
        - free from damage caused by frost
        - free of abnormal external moisture
        - free of any foreign smell and/or taste
    B. *Maturity requirements*
    C. *Classification*: there are three classes of truffles
        i. *"Extra" class*: truffles of superior quality, with a rounded shape and free from defects in appearance, shape, and color affecting their general appearance
        ii. *Class I*: truffles of good quality, with allowed slight defects in shape, development, and coloring, and allowed slight superficial bruising if they do not alter the appearance, quality and keeping the quality of the product.
        iii. *Class II*: truffles which satisfy the minimum requirements, which allowed defects in shape, development, coloring, presenting

superficial bruising and slight superficial damages caused by pest (that must not be developing).

III. *Provisions concerning sizing*: determined by the weight of the truffles, with minimum requirements per class (20 g Extra class, 10 g Class I, 5 g Class II)

IV. *Provisions concerning tolerances*
   - *A. Quality tolerances*
     - i. *Extra class:* 2% tolerance by weight meeting only Class I requirements, with no more of 0.5% meeting only Class II requirements
     - ii. *Class I*: 5% tolerance by weight meeting only Class II requirements, with no more of 1% not meeting minimum requirements or decaying.
     - iii. *Class II*: 10% tolerance by weight not meeting minimum requirements, with no more of 2% of product affected by decay
   - *B. Size tolerances*: 10% tolerance by weight for all classes

V. *Provisions concerning presentation*
   - *A. Uniformity*: contents must have the same origin, species, quality, size (if sized), maturity, development, and coloring.
   - *B. Packaging*: protect the produce properly, done with clean and quality materials to avoid damage

VI. *Provisions concerning marking*
   - *A. Identification*
   - *B. Nature of produce*
   - *C. Origin of produce*
   - *D. Commercial specifications*
   - *E. Official control mark*

This document, therefore, does not provide any clear limitation or indication as to how the truffles ground or harvest must be managed, only defining some general indication for trade and distribution.

Going down in scale, the European Union normative include laws for truffles in different documents. The first and foremost document ruling the truffle inside the Union is the Common organization of agricultural markets (COM), which is normed by the European Parliament Regulation (EU) n° 1308/2013 art. 1 subsection 2, and more specifically in Annex I part X they are classified with the CN code 2003, which include "*Mushrooms and truffles, prepared or preserved otherwise than by vinegar or acetic acid*" (European Parliament and of the Council, 2013). Aside from regulating the trade of these products, the European Union also establish limitations for reasons of health protection, regulating the presence of dangerous substances inside products. In this category belong three documents [with corresponding codes and wordings]:

- *Commission Regulation (EU) No 318/2014 of 27 March 2014 amending Annexes II and III to Regulation (EC) No 396/2005 of the European Parliament and of the Council as regards maximum residue levels for fenarimol, metaflumizone and teflubenzuron in or on certain products Text with EEA relevance* [Code 0280020 Annex II and III]
- *Commission Regulation (EU) No 1096/2014 of 15 October 2014 amending Annexes II, III and V to Regulation (EC) No 396/2005 of the European Parliament and of the Council as*

regards maximum residue levels for carbaryl, procymidone and profenofos in or on certain products Text with EEA relevance [Code 0280020 Annex II and III]

- *Council Regulation (Euratom) 2016/52 of 15 January 2016 laying down maximum permitted levels of radioactive contamination of food and feed following a nuclear accident or any other case of radiological emergency, and repealing Regulation (Euratom) No 3954/87 and Commission Regulations (Euratom) No 944/89 and (Euratom) No 770/90* [CN 0709 59 50 for fresh or chilled truffles; ex 0712 39 00 for dried, whole, cut, sliced, broken or in powder, but not further prepared truffles; 2003 90 10 for prepared or preserved otherwise than by vinegar or acetic acid truffles]

The general idea of these sets of regulations is to possibly unify and legislate all the different segments of the truffles market, which has always been strongly plagued by irregularities and disequilibria. Excluded these kinds of regulations, European Union mostly acts as a mediator for the drafting of international agreements with other countries. The main advantage of establishing these agreements through the European Union (rather than as individual states) is that it provide a more solid background and thus more credibility, allowing to often sign more advantageous agreements. Asides from this trade regulation activities, the European Union represent a great promoter for researches about truffles and more in general forest products. Particularly relevant is the recently concluded STAR TREE project (from 11/2012 to 11/2016), which focused on multipurpose trees and non-wood forest products, that particularly for truffles financed socio-demographic studies about population and truffle harvesting. This and another financed project often constitute a great opportunity for national institutions to collaborate to analyze, design and test solutions for pressing matters, often too burdensome to be carried out by a single state. Even if Europe lay foundations for cooperation among its members, it's still usually only on research and trade topics, leaving the effective regulation of practices and modalities of harvest and management of truffles to each state sovereignty and initiative. Nonetheless, improving the existing cooperation and structuring new shared initiatives between international and national actors might provide substantial benefits to both parts.

4.2.2 National normative

The first national law governing the harvest and commercialization of truffles in Italy was the *Legge 568 del 17 Luglio 1970*, also known as "*Legge Salari*", which integrated the rights and duties of population introduced by articles 820 and 821 of the Civil Code about natural fruits generated by the property. This was the first law which established clear and complex rules for harvesting and transforming truffles, regarding in particular:

- list and definition of commercial truffles species (seven at the time)
- the duty of canning industries to report the Latin name of conserved truffles
- hunters' authorization to harvest
- the institutions responsible for governing truffle harvesting
- Timetable and method of harvesting, supporting the harvest of truffles in natural woods and unkempt grounds, but not in cultivated areas
- The possibility of owners to delimit truffle grounds for exclusive harvesting rights by affixing tables on the property

This was an important development for national regulations, as before this law there were many uncertainties and grey areas regarding truffle harvesting, inevitably putting at risk both ground owners and hunters. This law, however, contained a risky feature, as it entrusted the standardization of truffle hunting to many different municipal institutions, thus generating a normative fragmentation regarding the correct practices of truffle harvesting. This pending issue was (partially) solved by the new framework law at national level, *Legge 752 del 16 Dicembre 1985*, which is still nowadays used and whose articles can be summarized as follows:

1. Aim and legislative framework
2. List of commercial species and their characteristics
    - *Tuber magnatum* Pico, commonly called white truffle;
    - *Tuber melanosporum* Vitt., commonly known as a precious black truffle;
    - *Tuber brumale var. moschatum* De Ferry, commonly called moscato truffle;
    - *Tuber aestivum* Vitt., commonly called summer truffle or scorzone;
    - *Tuber uncinatum* Chatin, commonly called hooked truffle;
    - *Tuber brumale* Vitt., commonly called black truffle in winter or black trifola;
    - *Tuber borchii* Vitt. *or Tuber albidum* Pico, commonly called bianchetto or marzuolo;
    - *Tuber macrosporum* Vitt., commonly called smooth black truffle;
    - *Tuber mesentericum* Vitt., commonly called ordinary black truffle
3. Guaranteed property rights over truffles if provided correct fixing of tables along property limits; definition of controlled and cultivated truffle grounds and regions competence in their recognition; continuity with the existing laws
4. Creation of consortia and their rights
5. Introduction of qualifying exam of regional competence for truffle harvesting; national validity of qualification card; obligation of search with the dog and use of shovel for excavation; exemption of owners from examination if they harvest on their own grounds; general prohibitions:
    - the going processing of the land during the truffle harvesting period

- the collection of immature truffles
- the non-filling of open holes for collection
- the search and collection of truffles during the night hours from one hour after sunset to one hour before dawn, except for different regional provisions in relation to local customs

6. Regional competence and authority over preservation and development of truffles heritage; general definition of harvesting periods with a delegation of changing them to the regions, while prohibiting any form of trade around fresh truffle species outside harvesting periods

Table 28. Harvesting periods according to Framework Law 752/85

Truffle species	*Harvesting period*
Tuber magnatum	1st Oct. – 31st Dec.
Tuber melanosporum	15th Nov. – 15th Mar.
Tuber brumale var. *moschatum*	15th Nov. – 15th Mar.
Tuber aestivum	1st May – 30th Nov.
Tuber uncinatum	1st Oct. – 31st Dec
Tuber brumale	1st Jan. – 15th Mar.
Tuber albidum	15th Jan. – 30th Apr.
Tuber macrosporum	1st Sep. – 31st Dec.
Tuber mesentericum	1st Sep. – 31st Jan.

7. Marketing criteria for the category of truffle products (fresh, pieces and chopped)
8. Truffle processing authorization criteria
9. Trading criteria for conserved truffles
10. Classification of conserved truffles
11. Packaging methods for conserved truffles
12. Net weight
13. Packaging content
14. Prohibition of omitting labeling
15. Monitoring authority entrusted to *Corpo Forestale dello Stato*; enabling of provincial hunting guards, local police forces and voluntary security guards; guards' requirements
16. Payments of sanctions
17. Authorization of annual regional concession tax and its application criteria (exclusion of owners and members on unions grounds)
18. Violation implies confiscation of products and administrative fines; measures and methods of sanctioning entrusted to regional law on the following violations:
    - collection during the period of prohibition or without the aid of the trained dog or without suitable equipment or without the prescribed card

- the going processing of the ground and the opening of holes in excess or not filled with the earth first extracted for decara of worked soil and for every five holes or fraction of five open and not filled to perfection
- the collection in the reforested areas for a period of fifteen years
- the sale to the public market of truffles without observing the prescribed rules
- the collection of immature truffles
- the collection of truffles at night
- trade in fresh truffles outside the harvesting period
- the marketing of preserved truffles without observing the prescribed rules except that the fact does not constitute a crime pursuant to Articles 515 and 516 of the Penal Code
- the collection of truffles in the restricted areas pursuant to Article 3 and Article 4

19. Adequation of regions
20. Abrogation of Legge 568/70

Overall, this law established the role of Regions in the definition of strategies for truffle harvesting and preservation, entrusting them the hunter's qualification process, the monitoring, as well as management of the truffle resources and their promotion. This strong delegation of normative power, which could be explained by the specificity of the truffle market demanding product and area specific planning, it negatively affected the system overall coordination capacity. In fact, the extreme width of the framework law led many Italian Regions to develop their own legislation (listed in Table 29), which often came in contrast with a superior level of legislation (i.e. European).

To make an example, in the transposition of regional laws, cultivated truffle grounds became comparable to forests, thus subject to hydrogeological constraint (according to R.D.L 3267/23), thus limiting the management and making impossible to convert cultivation. Recently, however, after pressures from stakeholders, cultivated truffle grounds have been classified as non-forested areas (as determined by L. 35/12), but rather as agricultural grounds. Aside from this example, the law 752/85 was devised without coordinating with other national and European institutions, thus causing conflicts among truffle supply chain stakeholders. Moreover, recent social and market development strongly modified the figure and magnitude of the "*hunter*" figure in the preservation and management of the natural truffle heritage, conditions which are not efficiently captured by this legislation. For all these reasons, the current legislation appears unable to successfully achieve current market demand for truffles, but rather potentially clashing with European legislation. Aware of all these issues, in 2017 the Ministry for agricultural, alimentary and forestall politics (*Mipaaf*) organized a great working table with a representative from organizations, institutions, and groups operating in the truffle supply chain. This event constituted a major sectorial meeting of experts, operators, and participants in the truffle industry, and its final product has been the drafting of "*Piano nazionale della filiera del tartufo 2017-2020*". This document aims to respond to pressing issues affecting the market and to improve current conditions in hope of ensuring sustainable development of the truffles supply chain in all the national territory.

Table 29. Regional normative references (from north to south)

Region	*Type of law*	*Law n°*	*Date*
Piedmont	L.R.	16	25th June 2008
Valle d'Aosta	-	-	-
Lombardy	L.R.	24	8th July 1989
Alto Adige	L.R.	-	-
Trentino	L.R.	23	3rd September 1987
Veneto	L.R.	30	28th June 1988
Friuli Venezia Giulia	L.R.	23	16th August 1999
Liguria	L.R.	18	26th April 2007
Emilia Romagna	L.R.	24	2nd September 1991
Tuscany	L.R.	50	11th April 1995
Umbria	L.R.	6	28th February 1994
Marche	L.R.	5	3rd April 2013
Lazio	L.R.	82	16th December 1988
Abruzzo	L.R.	66	21st December 2012
Molise	L.R.	24	27th May 2005
Campania	L.R.	13	20th June 2006
Puglia	L.R.	8	23rd March 2015
Basilicata	L.R.	35	27th March 1995
Calabria	L.R.	30	26th November 2001
Sicilia	-	-	-
Sardinia	P.D.L.R	34	16th May 2014

4.2.3 Piano nazionale della filiera del tartufo 2017-2020

This Sectorial plan (Mipaaf, 2016) has been drafted with the conscious knowledge of inadequacy of the current law 752/85, thus acting as a propaedeutic work for future revisions of this law, especially in relation to current normative of European Union. The structural simplification of the sector it's a major concern requiring coordination among different *Ministries*, as well as a more harmonized participation and agreement among actors of the truffle supply chain, both institutional and economic ones. The successful establishment of an embryonal network among all the actors involved in the truffle harvesting, cultivation and commercialization would greatly facilitate and improve the efficacy of any future framework legislation on the sector. The drafting of this plan has been carried out thanks to the contributions of many actors and experts gathered in three *Working groups*. The final product has been transmitted to the *Permanent Conference between the State, the Regions and the Autonomous Provinces*, with the aim to devise and enhance shared authorization parameter for harvesting and cultivation, which would, in turn, make monitoring more efficient. The three groups have been divided according to specific topics and subtopics, which have been:

1. Harvesting and environmental management, qualification of the activity, calendar, environmental management, species list, the release of the card
    a. Search and harvesting of truffles
    b. Environmental protection and management
    c. Truffle cultivation
    d. Nursery and certification, instruments and methods of control
    e. Scientific research
2. Marketing, management of fresh products, processing, labeling, traceability, controls, and sanctions
3. Taxation and Statistics

All these Working groups have been established by departmental decree (n° 87134/2016) and composed by experts and consultants from different actors, which include (Table 30):

Table 30. Participants to drafting of Piano nazionale della filiera del tartufo 2017-2020 by categories

Governing institutions	*Research institutes*	*Organizations/Unions*
Central administrations Ministry of Agricultural, Food, and Forestry Policies Ministry of Economic Development Ministry of Economy and Finance Ministry of Health Ministry of the Environment of the territory and the sea Regions	Universities *CREA* *CNR* *ENEA* *Centro Sperimentale di Tartuficoltura S. Angelo in Vado*	*CONAF* Agricultural confederations *FITA Federazione Italiana Tartuficoltori* *Assotartufi* *F.N.A.T.I. - Federazione Nazionale Associazione Tartufai Italiani* *Associazione Nazionale Tartufai Italiani* *Associazione per il Centro Nazionale Studi Tartufo* *Associazione Nazionale TartufOK* *Associazione Nazionale Città del Tartufo* *Tuberass* *Consorzio Qualità Tipica Val Baganza*

This unprecedented participation to common discussions allowed *in primis* to frame the state of the art of the truffle supply chain in Italy as never before, while also facilitating the design of solutions and goals for development. The declared overall objective of this Plan is to increase the added value of spontaneous or cultivate truffles, either harvested or cultivated in Italy. This necessity has emerged from the realization that the actual truffle market normative framework has been detrimental to the national product, which has experienced increased origin costs which consequently favored import of foreign product. This sort of market condition, even if mitigated on the global markets thanks to the knowledge and technologies developed by national supply chain actors, have nonetheless damaged the Italian sector, which experienced a 20% fall in European export while also increasing the import by 95% in the last decade. The import of foreign truffles, characterized by lower prices, inevitably lowered sector prices, which in turn pushed truffles harvester to concentrate activities in few areas. The concentration of harvesting activities, coupled with scares or non-existent forests management, has triggered a gradual depletion of natural or spontaneous truffle resources on the territories, further affecting the resource production rate. These complex and diffused issues have been inefficiently confronted by a fragmented regional response, raising the need for a more coordinated and efficient national and regional politic, while also keeping in mind the value of the local know-how. The results of the Plan have been the definition of a list of goals and strategies for the truffle national sector. The list of goals has been expressly formalized and detailed in accordance with the interests of economic and institutional actors involved:

a. *National coordination for harvesting rules*. Need for the measure to be taken in response to regional normative fragmentation, which provoked phenomena of migrating harvesters and resources depletion.

b. *Planning of truffle production*. The build-up of knowledge and practices about truffles production would improve regional coordination and data-transfer, which in turn will help to devise guiding lines for chain actors aimed to improve local production.
c. *Increase the level of knowledge of the technicians who support the truffle producer*.
d. *Traceability of nursery propagation material*. Plagued by many frauds which deterred private investments, national-level certification procedures for mycorrhized plants might help to make truffle production more profitable, especially for rural under-developed areas.
e. *Definition of research lines on truffles*. The coordination of research on truffles salient topics (innovative silvicultural techniques, more efficient production systems, market data gathering, and analysis, new enterprise solutions and models) would improve the use of allocated resources.
f. *Coordination with European normative*. The obsolesce of national normative (752/85) compared to European legislation negatively affect the competitiveness of national enterprises on the market.
g. *Redefining the tax system applied to the truffle*. National tax system currently disadvantages Italian enterprises compared to other countries favorable conditions, generating much informal market and reducing resources available for improving production and consequently contrast decreasing market shares.
h. *Make controls efficient*. Introduction of new approaches or technologies for monitoring would improve supply chain overall conditions, especially combined with harmonization of sanctions at the national level.

The plan also indicated a list of political and economic actions to be taken to address these goals[31]:

a. Adoption of a new national normative harmonizing current regional fragmentation.
b. Use of incomes from qualification exams to draft a Multiannual plan at the regional level for the truffle, indicating area of intervention or of priority investment (particularly important for white truffle).
c. Creation of formative activities (according to DPR 137/2012) and new training courses supported by universities.
d. Introduction of new monitoring and certification protocols concerning mycorrhized plants to reduce producers risks and avoid input of contaminant substances detrimental to truffle grounds productivity.
e. Trigger political will to allocate new investments for research about the ecology and production of the truffles.
f. Update or abrogation of existing law (752/85).
g. The first phase of detaxation of non-professional harvester and facilitated tax system for the professional harvester, and a second phase of application to European Commission DG-TAXUD to introduce spontaneous products harvest into the category of agricultural activities subject to a flat-rate scheme.

[31] There is direct correspondence between list letters of goals and actions, except for point *i.* which stand out of the goals listed before.

h. Mapping of the harvesting grounds would improve monitoring efficacy in key areas, while the adoption of standard monitoring protocols would provide better clarity about procedures and protection against unfair competition.
i. Creation of a national germplasm bank.

Among this list of actions, the plan further highlights and elaborates four categories of priority intervention:

1. *Tax system*
    i. The modification of tax systems applied to spontaneous products' commercialization for the non-professional harvester, which constitutes the backbone of the national truffle supply chain;
    ii. The increment of exemption allowances and a decrease of direct and indirect taxation, solution proved effective in other countries to both improve production and increase tax revenue for the State.
2. *Rules for the harvest and protection of national and regional truffle heritage*
    i. Adoption of common norms at the national level, with Regions entrusted to plan and preserve truffle production inside their border;
    ii. Creation of a specific fund generated by revenues from the regional concession tax payments for harvesting;
    iii. Stimulate Regions into active initiatives for the maintenance of regional truffle resources thought targeted interventions coordinated by Regional plans for truffles.
3. *Nursing and truffle cultivation*
    i. Introduction of mandatory certification for mycorrhized plants;
    ii. Improvement of cultivation techniques.
4. *Commercialization normative*
    i. Harmonization of national legislation with European one and application for modification of some community norms to promote Italian enterprises

Altogether these lists constitute a positive line of development for truffle supply chain in Italy but also pose some important issues on how to achieve these goals and priorities. The plan also provides indications about what supportive tools and assets can be developed and adopted to achieve these goals:

- Tools
    a. Creation of a National Technical Table of permanent coordination on truffle in which supply chain actors must actively participate to:
        i. Monitor the interventions of the Regions in implementing future regulations for harvesting and marketing truffles and assessing the effectiveness.
        ii. Coordinate the players in the truffle supply chain to stimulate the political decision maker to update, where proper, the legislation that regulates the truffle sector according to European regulations.
    b. Creation of a web portal at CREA where to include

i. the main scientific evidence generated by the research and applicable in the truffles sector;
ii. the collection of "best-practices" of silvicultural management of truffle groves and other production habitats;
iii. theoretical and real management models of collectors in relation to local truffle resources;
iv. useful information to improve the efficiency of the truffle supply chain.

c. Creation of a data transfer portal at the MIPAAF in order to monitor:
i. The truffle market with the main socio-economic dynamics of the various players in the supply chain;
ii. Socio-economic dynamics linked to truffle pickers;
iii. Planning of the truffle sector in the various Regions;
iv. Regional referents who deal with the truffle;
v. List of future certified nurseries at the national level.

- Organizational resources: the Mipaaf responsible office will manage the data gathering while coordinating with CREA for the gathering of scientific and informative material useful to truffle producers and harvesters, as well as existing materials in the Regions
- Financial assets
  a. Direct assets generated by revenues from regional concession for harvesting
  b. Indirect resources:
  i. Activated within national funds aimed to support actions that are consistent and complementary to those of the Plan;
  ii. Made available by the Regions and P.A., also by way of co-financing using the community resources that transit through the Rural Development Programs (RDP);
  iii. Deriving from co-financing of private individuals/operators in the supply chain

Overall, this document represents an unprecedented and possibly game-changing initiative on the national level, which could turn the tables in the current nation truffle market and planning. Its value lies not only in the realization of the state of the art of the market and the designing of suitable and detailed strategies to improve it, but also and most notably in its capacity to include in the process many different actors of the truffle supply chain, which has been always characterized by high fragmentation and individuality. Hopefully, this initiative will set the course for a positive change in the national and international market, even if the core of action and intervention in the truffle market chain remains the regional planning and its effective coordination at a national scale.

4.2.4 Regional framework

Even if at national level ongoing initiative have defined new national development strategies for the truffle market chain, since the current framework law 752/85 remains in force, the main actors and legislators concerning truffles remain the Regions. Therefore, while waiting for the revision of the national law, the focus should be applied to regional laws.

As the object of analysis has been the *Tuber magnatum* Pico, commonly called Alba white truffle, even if not uniquely grow in Piedmont, it has been historically highly valued in this region, thus making quite interesting to analyze its ruling legislation. The framework law in Piedmont is the Regional Law 16/2008 (Consiglio Regionale del Piemonte, 2008), which have been subject to further revisioning in 2011 and 2012. Even if Piedmont white truffle detains a strong and widespread fame, this law is not as modern or updated as this fame might suggest. Even if it still proposes some interesting points of innovation compared to national law, mostly on the participation of supply chain actors, it does not solve the disrupting fragmentation and informality of the market itself. To better understand what it includes and how it differs from the national law (and from the *Piano 2017-2020*), a detailed overview of its content and articles is mandatory:

1. *Content and goals*. Promote protection and development of indigenous truffles and their natural environment, recognizing the role of truffle ecosystems in the socio-economic development of rural and mountainous Piedmontese areas. In particular, the Region delegate the drafting of an Activity plan and make use of the support of the Institute for Wood plant and Environment (*Istituto per le Piante da Legno e per l'Ambiente* – IPLA) to carry out some activities in place of the Region
2. *Definitions*. It differentiates between:
    a. Natural truffle grounds, as any natural vegetal formation spontaneously producing truffles, including single plants;
    b. Controlled truffle grounds, natural grounds subject to improvements and eventually implanted with mycorrhized plants;
    c. Cultivate truffle grounds, specialized areas newly implanted with mycorrhized plants which are subject to specific cultivation techniques.
3. *Interventions for the enhancement of the truffle heritage*. The Region, through IPLA and Centro Nazionale Studi Tartufo, enact;
    a. The study, research, and applied experimentation activities;
    b. Promotional, informative, cultural and development activities concerning truffles;
    c. Educational activities for harvesters, technicians, security officers and training courses for dogs
    d. Safeguard and strengthening of natural truffle grounds for *Tuber magnatum* Pico through specific cultivation interventions, preserving the existing natural environments.
    e. Development, increment, processing, and commercialization action for cultivable black truffle species through financing implants in fitting areas, assuring mycorrhized plants respond to requirements established by monitoring agencies.

The Regional council must also approve each year by January the Annual activity plan, which includes:

a. Interventions aiming towards the preservation and promotion of truffle heritage.
b. Interventions whose execution by other local authorities, organizations or unions can be subject of a contribution, as well as the available financial resources.
c. The contents of calls and the procedures for approving and financing these interventions, as well as the maximum payable contributions
d. As part of the truffle fairs recognized by the Region and limited to the duration of the same, in order to allow effective control over the sales activities of the fresh product and ensure traceability to protect consumers, municipal administrations can regulate with appropriate criteria and limitations the sale of fresh product throughout the municipal area.

4. *Indemnity for the conservation of the truffle heritage*. To protect the truffle heritage, an allowance is granted to owners of land, either private or unions, where there are planted treed of recognized truffle capacity. The allowance is given according to the number of plants subject to specific culture and conservation plan, while also allowing for the free harvesting of truffle. The identification of the truffle hosting plants is delegated to the Municipal advisory commission for agriculture and forests (according to art. 8 of regional law 63/78 - Regional interventions on agriculture and forests). It also establishes:
    a. The maximum annual amount that can be granted for each tree subject of recognized truffle capacity;
    b. The procedures for granting the indemnity;
    c. The technical contents of the culture and conservation plan, as well as the procedures for monitoring compliance with the commitments undertaken with the signing of the same.

4. bis *Consulta for the development of regional truffle heritage*. In order to coordinate the interventions and monitor their effectiveness, the Consulta for the valorization of the regional truffle heritage is established. The Consulta is coordinated by the Region and makes proposals, expresses opinions on the initiatives for the development of regional truffle heritage and prepares the activity plan to be transmitted to the Regional Council for approval. The Consulta, which holds office for the entire legislature and in each case until the new appointment, is composed according to the indications of the regional council after hearing the competent council committee. The members of the Consulta do not perceive any compensation or reimbursement.

5. *Recognition of controlled and cultivated truffle grounds*. The certificate of recognition of the controlled or cultivated truffle ground is issued by the territorially competent province and allows the affixion of delimiting tables and consequently the right of exclusive harvest within the borders. The certificate, which has a five years validity and can be renewed, also indicates the ancillary cultivation practices necessary for the maintenance of the natural ecosystem. The ascertained failure to execute these practices cause the revocation of the certificate and the obligation to remove the

tables. The list of the recognized grounds is transmitted annually by the provinces to the Region. It also indicates:

a. The procedures for issuing certificates of recognition by the provinces;
b. The planned cultivation practices;
c. The procedures for the compilation, updating, and communication of the lists.

6. *The discipline of harvesting rights*. The research and harvesting of truffles is free in the woods and uncultivated land, while in controlled or cultivated truffle grounds delimited by tables the harvesting rights are reserved to: the owner, to the usufructuary and to the farmer of the fund, to the members of the respective families, to the workers employed by them regularly hired for the cultivation of the fund, as well as, for the land conducted in associated form, to the members of the associations that lead the truffle and to their family members. The tables cannot be affixed by individuals in the riverbeds, in the plan and in the shoes of the banks of rivers, streams, rivers, public drafts owned by the state, even if bordering the property. It also identifies:
    a. The technical prescriptions to follow for the improvement of existing truffles and for the creation of new truffles;
    b. The characteristics of the tables and the methods for their affixing;
    c. The maximum territorial area of areas to be allocated to controlled truffle, balancing the rights of owners with those of free collectors.
7. *Search and harvesting methods*. The harvesting must be carried out in such a way as not to cause damage to the truffle grounds, the collection of immature truffles and during periods not allowed by the calendar is forbidden. The total individual daily collection allowed is within the maximum limit of two kilograms, while the hunting activities can be carried out during the night hours.
8. *Voluntary consortia*. Holders of agricultural and forestry businesses can set up voluntary consortia for the defense of truffles or for the installation of new truffle grounds.
9. *Qualification for the search and harvesting of truffles*. The collector must undergo an examination for the assessment of their suitability in the competent province for the territory of residence. The qualification exam is intended to ascertain in the candidate the knowledge: the species and varieties of truffles, the basic elements of biology and ecology of truffles, the methods of search, harvesting, and marketing provided for by the regulations in force, as well as general notions of mycology and forestry. The exam is carried out by commissions, constituted by the provinces territorially competent. These commissions, whose participation to work is free of charge, are composed of:
    a. An official designated by the Region;
    b. An official designated by the province;
    c. An expert appointed by the most representative association of harvesters at the provincial level constituted by notarial deed and comprising of at least fifty members.

    The owners of truffle grounds and hunters already possessing a qualification issued by other provinces or regions are exempted from the exam. The license is valid at

the national level for a period of ten years, it can be renewed without further exams and it establishes the minimum age to fourteen years. The Provinces gather data of the qualified subjects and carry out the updating and communication to the Region. The characteristics of the license, the categories of data and the updating and communication methods are further defined.

10. *Permit for the search and harvesting of truffles*. The permit for the search and harvesting of truffles is subject to the payment of the annual regional license fee, and it must be done before carrying out the research and collection activities, having value for the calendar year to which it refers. The permit has validity on the entire regional territory. It's also established:
    a. the amount of the concession fee, based on criteria of economy and convenience, for an amount not lower than that established by Legislative Decree 230/91 (Approval of the tariffs on regional concessions pursuant to Article 3 of Law 281 / 70, as replaced by Article 4 of Law 158/90);
    b. The procedures for attesting the permit

    The resources collected by the Region are transferred quarterly to the IPLA for the purposes of this law, following the verification by the regional offices of the fees paid in concession
11. *Search and harvesting calendar*. The calendar is defined by the Region, heard the provinces and the Consulta, and it's valid for the entire regional territory. It must include a period of absolute prohibition of harvesting not less than fifteen days differentiated by province. University and research institutes can, for scientific purposes and subject to a temporary authorization issued by the province, can undertake truffles harvesting outside the calendar period, while also been exempted from payment of the tax. The arrangements for consultation with the provinces, for the purposes of defining the timetable, and the data necessary for the issue of the temporary authorization are also defined
12. *Associations of harvesters*. Harvester can constitute associations to contribute to the safeguarding and improvement of local truffle ecosystems, as well as the careful management of controlled and cultivated truffles. Associations are authorized to carry out actions for the promotion, protection and commercial valorization of the truffle, supported by the Region or by other public bodies.
13. *Monitoring and administrative sanctions*. The vigilance on the application of this law is entrusted to the bodies and agents as devised by law. 752/85, whereas in protected national and regional areas, this operation is carried out with the coordination of managing institutions. Any violation involves the confiscation of the product, and it's punished with pecuniary administrative sanctions. The enforcer who confiscate the product also draws up a report containing the indications of the species, the number and the weight of the confiscated truffles, of which copy is issued to the offender. In view of the perishable nature of the product, the agents proceed to its sale to the highest bidder, upon attachment to the report (according to Article 17 of the Law 689/81 - Modifications to the penal system) of two purchase offers to be acquired from dealers or restaurateurs in the area. The amount obtained from the sale, net of payment costs, is paid to the territorial competent provincial treasury and is returned to the right holder if it is established that the violation does not exist.

Violations of the rules regarding the research, harvesting, processing, and marketing of truffles, the following administrative pecuniary sanctions are envisaged:

a. search and collection in the period of prohibition, the absence of the card or the permit in the cases prescribed: from € 516 to € 2582;
b. research and collection in the absence of the only certification of the permit: from € 52 to € 516;
c. research and harvesting in the reforested areas, before a period of fifteen years, has elapsed since the plants were planted: from € 258 to € 2582;
d. research and collection of unripe or damaged truffles: from € 258 to € 2582;
e. search and collection of truffles in ways that differ from those defined: from euro 52 to € 2582;
f. research and collection of truffles in the reserved areas: from € 516 to € 2582;
g. apposition or maintenance of reserve tables in the truffles not recognized as controlled or cultivated: from € 516 to € 5170;
h. trade of fresh truffles outside the harvesting period or belonging to species not admitted (not compliant with the methods prescribed by law. 752/85): from € 2582 to € 5170;
i. processing of truffles kept in compliance with the procedures prescribed by l. 752/85: from € 516 to € 2582;
j. trade in preserved truffles (as prescribed by l. 752/85), unless the fact does not constitute a crime pursuant to articles 515 and 516 of the penal code: from € 516 to € 5170.

The delayed payment of the regional concession tax is sanctioned according to article 6, comma 3 of the regional law 13/80 (Discipline of regional concession taxes). Violations of [a., c., d., e., f.] imply the simultaneous suspension and the withdrawal from one to two years of the card and the permission obtained, or the impossibility to obtain the authorization for the same period if not achieved. In the hypothesis of recidivism, the definitive revocation of the card can be arranged, while if harvesters incur two violations in a five-year period, the card is suspended and temporarily withdrawn for the period of one year. The competent authority is determined by the province, which also receives the revenues from the administrative sanctions, further investing them to carry out the activities of preservations and development of truffles.

14. *Notification of actions that can be configured as state aid.*
15. *Report to the Council.* Every two years, the Regional Council presents to the competent Council Committee a report illustrating the implementation of the law, in particular about:
    a. The methods for selecting interventions and the methods for allocating contributions and funding;
    b. The actions undertaken for the enhancement of truffle cultivation.
16. *Transitional and final rules.*
17. *Repeal of previous legislation.*
18. *Financial standard.*

Looking through this law, there are some interesting points which distinguish it from other regional laws. In general, there is a declared interest towards the protection and development of truffle ecosystems, with a plain interest especially for market-relevant indigenous species. It's quite interesting that article 3 explicitly says that natural truffle grounds hosting *Tuber magnatum* Pico are a priority, showing the high regard that this species holds in Piedmont, as well as its precarious conditions. The discipline regarding truffle harvest also might be a bit perplexing once interpreted. The harvesting of truffles is allowed everywhere except in truffle grounds with border tables delimiting controlled or cultivated grounds. It's also made explicit reference concerning the quantities, the conditions and an extensive list of sanctions which might affect the harvester. All these conditions pose a non-indifferent burden on the monitoring agents, which coupled with the state-of-fact difficulty in monitoring truffle harvesting, as well as the authorization for hunters to operate during the night, possibly create quite demanding conditions for the monitoring bodies. Moreover, the method through which the confiscated products are managed might arise some thoughts on the auctioning processes and the expenditure of resources required to implement it.

Quite interesting is also the structure of the qualification process, which even if nationally valid and regionally managed, it's further divided among provinces and region, effectively creating a redundant and territorially diffused system. On one hand, this surely increases the possibility of hunters to take the exam, but it could be interesting to consider the increased bureaucratic complexity and fragmentation this brings to the system. However, another quite interesting disposition is that inside the valuating commissions for the qualification exam, besides institutional officials, it's required the participation of an expert from the most representative harvester association in the province. This demonstrates an institutional intent to involve local actors in the regulation of the market itself, even if this participation is not strictly on a voluntary base. It can be quite peculiar that to manage the existing truffle heritage and to realize intervention of preservation and development the Region delegate to another organization, IPLA spa. This company is not uniquely managed by *Regione Piemonte*, which is the major shareholder, but it includes several actors (mostly public ones) and it acts as a mediator between the Region and other international agencies. The truffle normative system in Piedmont thus shows a great number of institutions and actors, which could potentially act as a weak point in the establishment of effective coordination among local and regional actors, as well as a substantial hinder to the coordination at national and international level.

Before passing to the analysis of the current market conditions of the white truffle in Piedmont, it's interesting to summarize the most recent interventions concerning the research initiatives in the Region. The most recently approved plan dates to September 2018, titled "*Indirizzi e criteri per il finanziamento delle attività di studio, ricerca e sperimentazione applicata nel settore del tartufo 2018-2020 […]*" (Giunta Regionale del Piemonte, 2018). This latest plan marks an interesting difference with previous initiatives, as it explicitly declares the adherence to European regulations (Commission Regulation (EU) No 702/2014) for its financing process, as well as the declaration that this plan does not require funds from the regional balance. The plan has been drafted in accordance with the priority guidelines of the aforementioned "*Piano nazionale della filiera del tartufo*", requiring research, experimental and informative projects to adhere to the following guidelines:

1. *Environmental protection and management of natural production environments*. To survey and characterize the productive environments, to experiment the cultivation modalities of the forest expressly aimed at the maintenance and improvement of the habitat and the productive increase of the truffle or the productive recovery (mycoselviculture), in particular for the protection of the productive environments of *T. magnatum* (the only truffle to have yet been successfully cultivated).
2. *Study and conservation of the biodiversity of the truffle and of the microbial associated*. The characterization of the associated biodiversity and microbial biodiversity and its spatiotemporal monitoring with statistical sampling methods.
3. *Qualitative-quantitative improvement of cultivated truffle production and development of forecasting models*. The production of cultivated truffles is more and more compensating for the natural production, even if not yet feasible for *Tuber magnatum*. To address this condition the focus of applied research should be:
    a. development of specific cultivation techniques for *Tuber magnatum*;
    b. improvement of mycelial inoculation techniques and genetic selection of strains in relation to the pedoclimatic characteristics of the implantation stations for an improvement of the production standards;
    c. application of the knowledge acquired with studies of microbial biodiversity in the natural environment to improve the quality of the product and favor the permanence of truffles in truffle environments.
4. *Development of innovative protocols for the certification of truffle products*. The high risk of fraud and erroneous identification required for a reliable trackability along the truffle supply chain. The effort should be focused on the creation of a unique identity card for each geographic area, including a deepening of the habitat of the truffle, the distinctive aromatic bouquet of the species and the geographical area of origin and the genetic diversity of the fungal strains. The study proposals are:
    a. Geographical traceability of valuable truffles by analysis of volatile compounds correlated with the analysis of genetic biodiversity, which might bring to the identification of qualitatively superior genotypes/ecotypes compared to existing products currently on the market;
    b. Characterization of the aromatic profiles in the phases of development and maturation of the carpophores of different species of Tuber by analysis of volatile compounds in order to be able to go back to the time elapsed from the collection of the fruiting bodies and an enhancement of the product in the optimal degree of ripeness;
    c. Production of approved models of molecular traceability for the protection of regional/national productions. Development of new molecular markers for the reliable identification of different *Tuber* species at each stage of the life cycle, in food preparations, in preserved and in mycorrhized seedlings

The plan also defines the priority actions to be developed:

- Census and characterization of the productive environments, and experimentation of the cultivation modalities of the forest expressly aimed at the maintenance and improvement of the habitat and the productive growth of the truffle or the

productive recovery (mycoselviculture), in particular for the protection of the productive environments of *Tuber magnatum*;

- Characterization of the microbial biodiversity of the truffle habitats and its monitoring in correlation with the management actions of the natural productive environments
- Improvement of certification protocols of mycorrhized plants, which should be shared at the inter-regional level
- Development of innovative protocols for the quality certification of truffle products

The main actors involved are divided into two typologies:

a. Research organizations, like universities and research institutes, expected to carry out basic research, industrial research or experimental development and disseminate the results by teaching, publishing or transferring technologies;
b. Technical organizations, including
    - Companies with regional participation that carry out research and experimentation in the field of truffles and truffles;
    - Forest and agricultural institutes and schools;
    - Associations of truffle hunters, truffle farmers, and their unions;
    - Consortia operating in the sector;
    - Service companies operating in the sector

To sum up, this latest initiative aims to more effectively integrate the research about truffles (notably with specific interest to *Tuber magnatum*) firstly with European regulations, secondly towards all the actors of the complex truffle supply chain in Piedmont, currently characterized by diverse and sparse realities operating in the territory.

4.3 Comprehending the local framework

The truffle supply chain represents a complex system of actors and interests coexisting in relatively small areas, which however host big economic interests and long-established traditions. Understanding and operating into such context would be quite hard for any "foreigner", since even among local actors no clear understanding of the system itself has been achieved. The high fragmentation, coupled with the variety of products, actors and interests at stake, make the analysis on the local socio-economic framework a mandatory step for designing effective solutions addressing current and future issues of the market. To get an overview of how this system works, it will be necessary to first frame the current conditions of the truffle supply chain, then to discuss on the relationship between truffles and other famous local products, and finally, it will be presented a technical point of view from the current governing institutions.

4.3.1 The white truffle supply chain in Piedmont

The white truffle market chain in Piedmont has, since long time ago, been riddled with uncertainty and fragmentation in its structure. In the early period (1700-1800) this was surely attributed to the organization structure of resource harvesting, which was mostly related to noble's hunting activities. Therefore, the structure of the market was mostly informal, deeply connected to the nobility and their entertainment. Once this product became widespread, the existing fragmentation has not been solved, rather, it has been somehow been validated by the legislation, which strongly delegated the administration and control of this supply chain to the Regions and provinces, giving them great margins of action to operate into. If on one hand this was aimed to preserve the local traditions and cultures, it also inevitably created asymmetries at the national level, which inevitably affected the local and regional levels too.

In Piedmont, in particular, this has affected the market both positively and negatively. As said before, in the white truffle production across Italy, Piedmont officially contribute for a small part, even if estimations of exact quantity must be taken purely as indications (Brun & Mosso, 2010). Considering the ISTAT official data on truffle production, it was estimated that on average between 2002, 2006 and 2007, Piedmont white truffle comprised only 3% of national production. However, even if such small (and most probably imprecise) quantities have been produced in Piedmont, among all the regions which produce white truffles, Piedmont has officially registered the highest prices on most of the measurement. Once again, any analysis meets with strong obstacles, which are the markets condition and informal dynamics. As said before, there are many laws concerning the way truffles must be treated to be sold, mostly concerning the packaging and the preservation method, as well as the timing and so on. Still, the way prices are to be quantified and estimated is not officially clear, as there are no defined criteria on which price is to be considered as "official". This is due to the market unique characteristics of white truffles and the way its market agents operate. The harvesting of white truffles in Alba is mostly done by *trifolau*, which act of their own accord or as members of small associations, mostly at the municipal level. The cases of white truffles farmers are still a minuscule minority, and there are no clear data on their operations, as they are loosely monitored regarding their market participation. It's estimated however that they contribute to a very small part of the overall production, so much that it can be considered a negligible fraction. Therefore, the most interesting actors are hunters and their dealings. Here most of the investigations meet with a serious complication. White truffles are considered a highly valued commodity, and yet most of them are not sold under structured channels. Rather, they are sold either directly by the hunters thanks to their own connections, or by associations which have agreements with market agents. Therefore, tracking the product chain become rather problematic, as it can diversify its path to the consumers in many different points. It's also unclear what price should be considered as representative of the whole market. White truffles, as luxury goods, are often sold in auctions or fairs, where prices can be quite inflated. Therefore, even if those are the plainest prices to be monitored, they are not indicative of the "real" market prices. Moreover, the prices of truffles greatly vary depending on the point of the supply chain which they are referred to: the quotation done among wholesalers, as rare as they are in Piedmont, would be quite

different from the prices practiced by restaurants, not to mention the one done by retailers. There is also great variation depending on the sources of the truffles, as agreements between hunters and middlemen would surely influence the prices. Or again, hunters might decide to sell truffles on their own directly to consumers they know, thus distorting the prices consumers might face. One last factor affecting white truffle prices is the moment of the season the transactions are carried out, as prices are influenced by the availability of products, which is related to the seasonality and other environmental conditions. All these factors inevitably affect the capacity of correctly and officially estimate prices of the white truffles in the market. Even if official estimations are quite ineffective, there are many online tools, generally managed by sectorial research centers and associations which monitor and record the prices of white truffles available on the local market. These tools, even they are effective in gathering data on the market, usually, do not follow a shared methodology in their estimations, thus hindering the confrontation among databases. They often do not assume a standard quality reference (i.e. *pezzatura*), nor they monitor the same points of the supply chain. Therefore, pricing white truffles come with many difficulties, showing the diffused lack of information and informality of the market among both officials and actors involved in the supply chain.

The first and foremost figure that must be analyzed in this supply chain is the hunter, i.e. the *trifolau*. They are the starting point of the chain, act both as harvester and sellers at any level, and they can be both professional or amateur. They are quite an interesting figure on an economic point of view, as they influence, implicitly or explicitly, every point of the supply chain. It's them which operate the harvest (excluding the sparse cases of farmers which, as said before, are few with poor influence for the white truffle). Most of the time they freely choose the client to sell to, and they are also greatly involved in preserving the stock of resource, which requires careful operations and knowledge to avoid damaging future harvests. As said before, in Piedmont any official hunter which operate within the Region must be in possession of a *license*, released by either the Region of the provinces, which can be achieved by passing an exam and by paying an annual contribution to the Region. However, these are just the institutional requirements hunters must have to operate in public (either natural or controlled) truffle areas. In reality, the "*instruments*" hunters must possess are essentially three. The first is the trained dogs, which concretely search for truffles and pinpoint their location to hunters. These are the most important companion and asset any truffle hunter must have, and they are also accounted for by the national and regional legislation (Legge 752/85), which decree that there must be no more than two dogs, included any training puppet, during the hunts. As these dogs are usually highly valued by hunters since they require training since an early age, it's practically unheard-of hunters not owning and caring for their own dogs. Of course, they constitute a fixed cost for any hunter, which is economically useless outside the season, excluding their value as household guards or companions, values which imply quite complex socio-economic accounts outside the scope of this work. Considering all the costs of maintenance that dogs imply, it has been estimated that hunters spend on average 700-800 €/year per dog. This is the thus the most onerous and obligatory fixed cost that hunters sustain in their activity, excluding the licensing costs, as they cannot operate without these aids. The second instrument is the spade ("*vanghetto*" in Italian legislation), which consist of the main tool for excavating the truffles and whose

dimensions are defined at the regional level. The cost of this tool can be considered as hardly relevant in the account of hunters, as it's relatively low compared to its lifecycle. Third, and possibly most hard to economically grasp, is the knowledge on production sites. If the first two instruments are physical instruments, the last one is a cultural one, which put it on another level of analysis. The knowledge of the sites and practices is slowly and gradually built one, and it requires experience and dedication, both to the activity and to the local traditions and territories. Therefore, estimating such value can be difficulty assessed in economic value, rather it constitutes the social and cultural value of a community. This is particularly true for the Alba white truffle, as its history and traditions are what give the local product, even if relatively diffused in other areas, the unique global recognition and fame, which in turn makes the *Trifola d'Alba* so highly valued. These three "instruments" and the figure of the *trifolau* are therefore the foundation of the entire white truffle supply chain, showing their enormous importance. And yet, even if highly recognized, they still operate in an informal way and are a quite varied group in its constituent, even if so few in number. It has been estimated that in 2014 Piedmont released 6350 licenses for truffle hunters, which compare to the regional population (around 4.4 million in 2014) account for no more than 0.143%. This percentage is not particularly relevant even when compared with other regions, especially to those with a marked interest in truffles (both white and dark ones), such as Molise, Abruzzo or Umbria (Table 31). Positively, however, the average age of hunters has overall decreased compared to the past, from a median age of 70-75 years in 1985 to 45-50 years in 2014 as a national average, with Piedmont just slightly over this value (around 50-55 years). This means that the corpus of local knowledge and traditions has been successfully transmitted and it's getting more interest from (relatively) younger people, signals that bode well for the future of this figure.

Figure 11. A "trifolau" harvesting truffles with guiding dog and "vanghetto"
© Jan Dahlqvist

Table 31. Number of truffle hunters and their population ratio in different regions. Source (Mipaaf, 2016).

Region	*Resident in 2014*	*N° of truffle hunters (* partial data)*	*%*
Abruzzo	1333939	7277*	0.546%
Basilicata	578391	1652	0.286%
Calabria	1014316	68	0.007%
Campania	5'869'965	1249*	0.021%
Emilia-Romagna	4446354	14945*	0.336%
Friuli Venezia Giulia	1229363	436	0.035%
Lazio	5870451	3284*	0.056%
Liguria	1591939	225	0.014%
Lombardy	9973397	3548	0.036%
Marche	1553138	12093	0.778%
Molise	314725	4601	1.462%
Piedmont	4436798	6350	0.143%
Puglia	4090266	309	0.008%
Tuscany	3750511	7198*	0.192%
Trentino-Alto Adige	1051951	416	0.040%
Umbria	896742	7422	0.828%
Veneto	4926818	2521*	0.051%

Going to the next level of the supply chain, in Piedmont, the transformation sector is represented by only two enterprises, which detain the majority of the market. Trading is instead mostly done by various operators dealing with small quantities, either with regular shops or within informal channels. Even if for the with truffle the transformation sector is comparatively of lower interest, as most white truffles are sold fresh and undamaged, it's interesting to analyze these realities as they are the only comparable and totally official companies which can be completely studied. Brun and Mosso (2010) studied that these companies are usually managed by young people assisted by their families, with around 12-15 employees and with a revenue of 3-4 million € per year, one-third related to truffles. The other traders, which are much smaller in size, deal with smaller quantities but are more widespread on the territory, usually with their revenue ranging around 150K € per year, with 90% of it from the selling of fresh truffles. Different from the two companies, smaller sellers have stronger rooting in the territory, having personal relationships with hunters or being hunters themselves, thus most of their product comes directly from Piedmont. These small sellers, however, are usually difficultly identifiable, as they are not really relevant outside their area of operation, thus limiting their capacity of mutual networking. To sum up, even if the white truffle is widely recognized and valued, its supply chain is scarcely clear, as there is no correlation between product and production structure since white truffle hardly requires

transformation. Therefore, among traders and actors involved in the supply chain individuality and lack of general coordination prevail at every level, a condition which reflects the peculiarities of the white truffles, characterized by diffused non-transparency in its system, negatively affecting the generation of systemic relationship across actors.

Before discussing the relation between truffles and the other major socio-economic reality of the Alba's area, the *wine*, a brief overview of natural truffle grounds management might be useful to make a comparison with vineyards. Natural truffle grounds are particularly important for white truffles, as currently there is no sure or reliable technique to cultivate it, thus leaving only the correct exploitation of existing productive areas as market choice. These grounds can be either private property, public forests or community-owned areas, but most of them operate as open-access commons for the truffles' harvesters (as prescribed by law). When discussing how natural truffle grounds can be preserved and developed, there are many different interventions to be done, which can be summarized into two different categories:

> *Ordinary maintenance*: all those operations apt to keep the truffle ground in optimal conditions, to be carried out with annual or infra-annual frequency. They usually involve activity like thinning of the shrubs and tree pruning, an action which can positively impact truffle production.
> *Extraordinary maintenance*: operations to be carried out *una tantum*, whose impact is long lasting and usually are made to concise with five years (cultivation plan duration in Piedmont). They include tree thinning and water regulation interventions, which serve to improve or restore truffle production.

Both kinds of operation can be carried out by the owner of the truffle grounds or of areas where existing plants which are apt to host truffle growth. Maintenance operations can be generally carried by the private owners themselves without generating external costs, as the instruments and labor required can be done manually with common-use tools, thus with low costs. When estimating the cost of such operations, the internal work must be interpreted as a "cost-opportunity" quantifiable in 12 €/h (full cost of an agricultural worker). Assuming one hour of work per plant per year for ordinary maintenance and one hour of work per plant per year of extraordinary maintenance (derived from the subdivision of five hours of work across a five-year cultivation plan), the maintenance cost of a natural truffle ground can be quantified as follows (Table 32).

Table 32. Costs estimation of maintenance operations for natural truffle grounds (per plant). Source (Brun & Mosso, 2010)

Operation	*Duration (total)*	*Duration (per year)*	*Cost per hour (€/h)*	*Total amount per year (€/year)*
Ordinary maintenance	-	1 hour	12	24
Extraordinary maintenance	5 hours	1 hour	12	

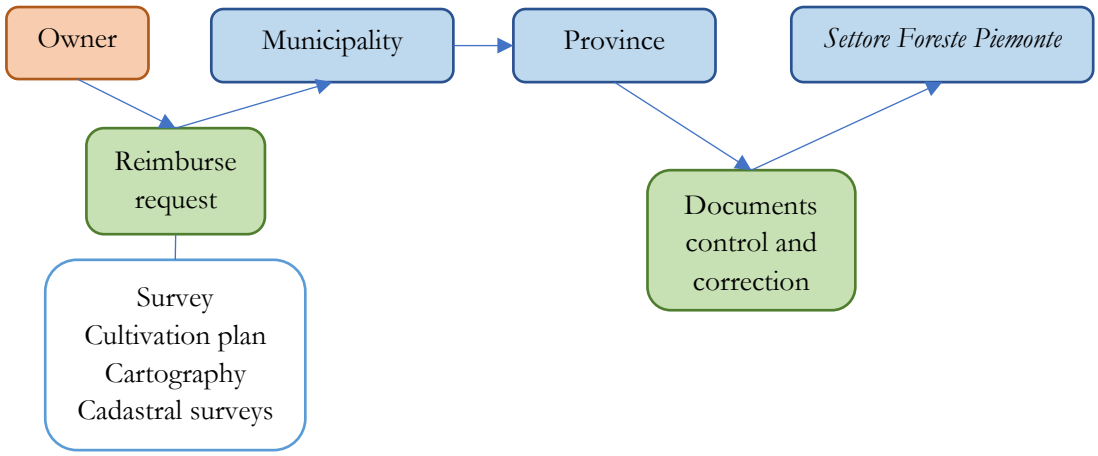
The estimation of 24 €/plant/year can be assumed as the maximum cost that owners can and should incur for maintenance operations. Such estimations have been quite useful for

regional and provincial administrators, as they have defined an incentive system to all those owners which operate action towards maintenance and development of truffle grounds or truffle hosting plant, in perspective of preservation of the truffle heritage in Piedmont. The incentives are coordinated both by the Region and the provinces and involve a series of passages and requirements which can slightly differ and be adjusted among provinces depending on the conditions. Taking for example of Cuneo province, which includes most of the most productive areas for the white truffle (including Alba itself), the province determined a maximum reimburse of 24 €/year per each tree which is maintained, while also limiting the number of plants to 25 per hectare. The procedure (schematized in Figure 12) implies a defined series of steps: first, the plants must be identified by the municipal advisory commission for agriculture and forests. After the correct recognition, the application for reimburse must be compiled by the owner, be either a single or an association/cooperative, and it must include a direct declaration attesting:

- A *survey* highlighting terrain characteristics of areas destined to truffle ground, compiled by a qualified expert, proving the vocation of those areas to truffle growth based on pedoclimatic, vegetational and topographical factors
- *Cultivation plan*, defining a detailed description of all the actions, planned and already carried out, for the maintenance and development of the truffle production in accordance to those identified by the region normative (Annex F for controlled truffle grounds)
- *Cartography* indicating the planimetric location of the grounds for which recognition is requested, approved by a qualified technician
- Updated *cadastral surveys*

All these documents must be delivered to the municipality where the areas belong to, which will provide to transmit them to the province, who will check and correct the documentation, then will further transmit them to the Regional competent sector.

Figure 12. Reimburse scheme for truffle ground maintenance in Cuneo province



This incentive system represents an important and partially successful effort by institutions to promote and develop the truffle sector and traditions, but it also calls for more stringent

monitoring and diffusion to effectively tackle pressing issues of the truffle grounds, such as abandon and land and resource conversion. These efforts supporting truffles production are now gaining increasing interest, especially in relation to white truffles, whose market is experiencing an apparently long-lasting interest. However, it's still confronted with the other characteristic supply chain of the Region, the wine, recently greatly aided and promoted by a global scale recognition: the nomination of Langhe-Roero as UNESCO World Heritage Site.

Annex F - Technical requirements for the execution of operations to improve the controlled truffle grounds

1. Drainage and management of surface waters to avoid water stagnation or erosion phenomena.
2. Preparation of containment works and implementation of suitable landings and workings of the land, allowed only in production areas, to contain surface erosion phenomena on sloping land.
3. Containment of the growth of vegetation, if infesting or excessive (herbaceous, shrubby and arboreal) through periodic mowing, brushing, pruning and thinning with functional methods for the different species of truffles.
4. The containment of herbaceous vegetation can be achieved by allowing grazing by rational techniques and reduced loads of animals. In order to avoid excessive compaction of the soil in the production areas, the establishment of water points and areas for the temporary parking of animals are not allowed.
5. Periodic working of the soil, near the productive plants, using rippers or harrows to counteract the phenomena of excessive compaction and felting.
6. Periodic aeration work on stable grassy shingles to counteract felting and compaction.
7. Possible planting of new truffle plants, with the aim of replacing subjects that are now depleted or dead or the strengthening of areas in light, compatible with the specific needs of truffle species and symbiotic plants. The insertion of new plants must not in any way damage the already present natural truffle.

4.3.2 Truffle vs Wine: Market rivalry and Langhe-Roero WHS nominee effects

Looking at the already complex market conditions of the truffle supply chain, there is an important consideration to do, especially regarding the white truffle. Contrary to other black truffle species, Tuber magnatum has not yet been cultivated successfully, or at least no reliable cultivation practices have been developed thus far. This inevitably implies that the white truffles are inevitably linked to the territory and its management more than any other truffle species, as they can be found uniquely in natural truffle grounds. Since these grounds can be threatened by many factors and yet are mostly open-access to users, white truffles represent a perfect example of common-pool resources. As seen before, this condition has been (apparently) strongly perceived by institutions and local organizations alike, as many regulations and initiative strongly aim towards the preservation and development of these natural grounds. Thus far, however, a significative factor has been (voluntarily) overlooked, which is that truffles are not the predominant market product of those areas. In fact, they do not even take the first place among the local forest products. The more pressing and dangerous "rival" truffles face on the local market is the wine.

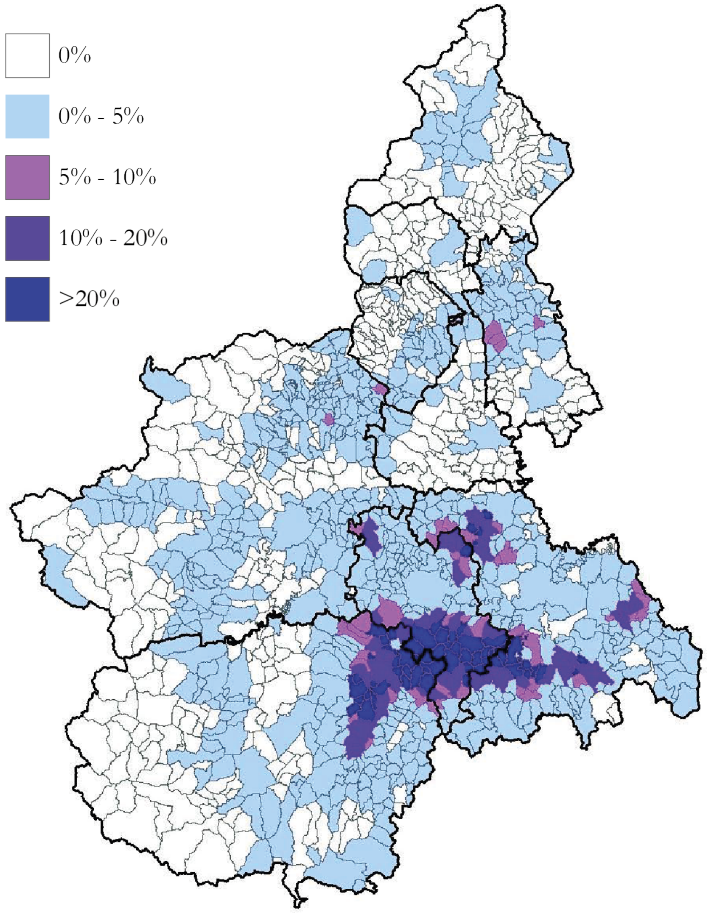
As stated before, truffles have very specific and harsh requirements for their growth, with soils being one of them, even if among the least stringent ones. The propensity to growth within calcareous soils (Montacchini & Caramiello, 1968) with the specific geomorphologic characteristic, in fact, do not strongly limit the truffle diffusion. At the same time however, this specific soil morphology strongly favors other cultivations, with wine being among the most remunerative and historically valued in Piedmont. Vinery is, in fact, one of the most long-lived agricultural activities carried out in Piedmont, with a strong diffusion and fame especially in the territory of Langhe-Roero and Monferrato. In these areas the cultivation of wine has been a long-lasting tradition for many centuries, receiving great credit during the years not only from locals but also from the world. There are in fact many wines in Piedmont which have been uniquely recognized as excellencies and have received important certifications of quality (42 DOC and 18 DOCG). This incredible variety and abundance of wines (listed in Table 33) have always been a marked characteristic of the territory of Piedmont (Figure 13), but it has been mostly and overwhelmingly conducted in the territories of Langhe-Roero The complex and stratified corpus of knowledge, tradition and history that winemaking has established in the limited territory of Langhe-Roero has in fact established a kind of *cultural common*. All these wines labels have been recognized and valued since they belonged to a specific local *identity*, which can be "enjoyed" by all but is threatened in its existence by things such as frauds (notable the ethanol wines scandal, which damaged the credibility of this cultural common). Interestingly, those same territories greatly overlap with the major areas dedicated to the white truffles (another commons), which coupled with the compatibility of soils and morphologic characteristics of vineyards, makes these two products/commons in a fundamental competition for the land(scape). There are various and complex reasons for this conflict, a conflict which is currently biased in favor of winemaking.

Table 33. List of certified (DOC and DOCG) wines of Langhe-Roero area

DOC (Denominazione di Origine Controllata) for grapevine variety	*DOCG (Denominazione di Origine Controllata e Garantita)*
1. *Arneis* 2. *Albugnano* 3. *Barbera* 4. *Bonarda* 5. *Brachetto* 6. *Cisterna d'Asti* 7. *Cortese* 8. *Dolcetto* 9. *Favorita* 10. *Freisa* 11. *Gabiano riserva* 12. *Grignolino* 13. *Langhe* 14. *Malvasia* 15. *Monferrato* 16. *Moscato* 17. *Nebbiolo* 18. *Rubino di Cantavenna* 19. *Pinot* 20. *Piemonte* 21. *Colline Saluzzesi Quagliano spumante* 22. *Rouché di Castagnole Monferrato* 23. *Verduno Pelaverga*	1. *Alta Langa spumante* 2. *Alta Langa spumante rosato* 3. *Roero Arneis* 4. *Barbera d'Asti* 5. *Barbaresco* 6. *Barolo* 7. *Brachetto d'Acqui passito* 8. *Cortese di Gavi* 9. *Dolcetto di Diano d'Alba* 10. *Moscato d'Asti vendemmia tardiva* 11. *Moscato d'Asti Canelli* 12. *Moscato d'Asti Santa Vittoria d'Alba* 13. *Moscato d'Asti Santa Vittoria d'Alba vendemmia tardiva* 14. *Moscato d'Asti Strevi* 15. *Nizza* 16. *Roero*

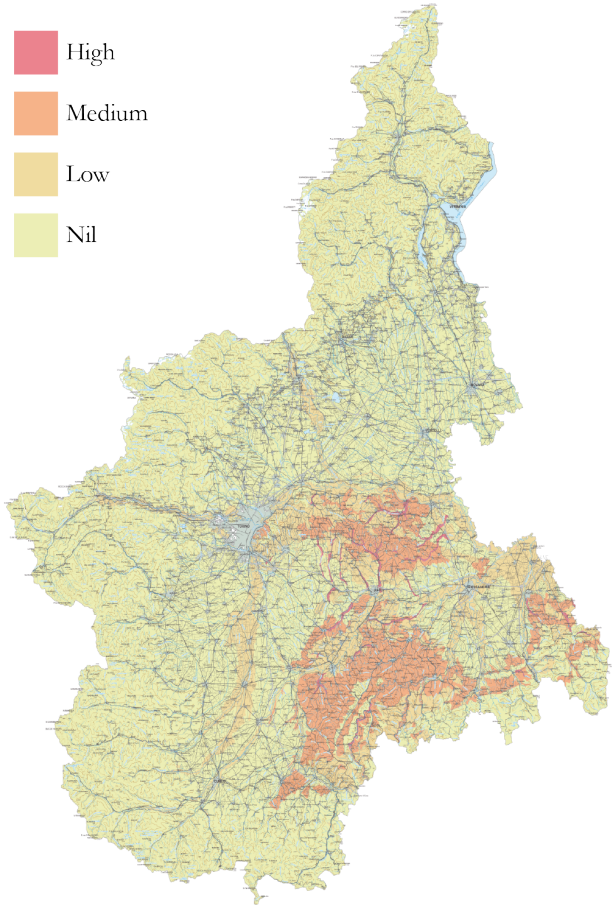
Figure 13. Distribution of vineyards across Piedmont and comparison with Tuber magnatum productive grounds distribution

Percentage of vineyards cultivated area on total surface of Piedmont



Source: UNESCO World Heritage Site nomination

Attitude of soils to white truffle (*Tuber magnatum* Pico) production



Source: Regione Piemonte (Annex)

First, vineyards are more reliable economic investments than truffles cultivation, and this only gets worse with natural truffle grounds management, which *Tuber magnatum* requires for its current unfitness to be cultivated. To understand why this convenience towards vineyards is so overwhelming, let's compare the economic lifecycles of a vineyard and a rarely "successful" cultivated truffle ground of *Tuber magnatum*. To do this, we consider an area of the same size, 1 ha, which is subject to the best climatic, biological and environmental conditions, thus maximizing the productivity of the fields. Both productions are considered as starting anew, thus possibly requiring initial capital to sustain startup costs. Now, assuming the productivity is maximized, the average production in a good year for *Tuber magnatum* has never exceeded 10-15 kg/ha, with the "real" average being 4-5 kg/ha (Riccioni, Rubini, Belfiori, Gregori, & Paolocci, 2016). Of course, this is obtained with relatively low costs to the farmers, as truffle requires only simply forest maintenance operation which can be done by the owners itself without the use of machines. The price for these operations has been estimated in no more than 24 €/year per plant, with the ideal number of plants per ha being 25 (Brun & Mosso, 2010). Usually there are no significative expenses to start the production, as the operations to eventually recover an abandoned truffle ground are mostly included in the overall cost per year per plant. The only other fixed cost is the maintenance of the hunting dog(s), which amount to around 800-900 €/year. On average, the time required for a truffle ground to bore fruit (which has no measure of guarantee in reality) is estimated in 20 years at best. Now, analyzing the conditions for vineyards, it has been that it can produce around 80-130 q of grapes, with a conversion of around 70% into wine, making it around 70 hectoliters per 100 q of grapes, with production starting in more or less 3 years (Fregoni, 2013). Considering the most onerous costs of extirpation and implant, the estimation of *Regione Piemonte* quantify in around 36000 € the total cost, while 30000 for the cost of the only implant in the case of a regular vineyard (Giunta Regionale del Piemonte, 2017). The missing income for at least two years (time required by the plants to become productive) can be estimated in 10000€, making the average cost of maintenance per year around 5000 €, figure which can be considered constant in the lifetime of the vineyard. When it comes to profitability of each product, there is great variability in numbers depending (for both) on the season general market trends as well as the time of the season. For wine the choices on grape variety (influenced by the aptitude of the soils and other complex factors) and the aging time (depending on the desired final product) are other fundamental factors. According to studies and statics, we can assume the prices can be quantified as follows in Table 34. Once formulated these data, the comparison can be done (in Table 35).

Table 34. Comparison between white truffles' and wines' prices in Piedmont

Product	*Minimum price*	*Maximum price*	*Average price*	*Source*
Tuber magnatum (averaged for hunters)	1000 €/kg	1500 €/kg	1250 €/kg	(Riccioni, Rubini, Belfiori, Gregori, & Paolocci, 2016)
Barolo DOCG (2014 data)	728 €/hl	780 €/hl	750 €/hl	Price surveys done by Cuneo Chamber of Commerce
Barbaresco DOCG (2015 data)	580 €/hl	640 €/hl	610 €/hl	
Barbera d'Alba DOC (2017 data)	211 €/hl	372 €/hl	290 €/hl	
Dolcetto d'Alba DOC (2016 data)	160 €/hl	182 €/hl	170 €/hl	

Of course, this model is mostly ideal and heavily simplified, as it doesn't take into account either fluctuation of the markets, no inflation adjustment and no account for eventual reimburses and development funds (which have been very aleatory in recent years for Piedmont). At the same time, it consistently assumes that production of both truffles and grape is consistent and assured, conditions which are hardly met for the truffle and are partially uncertain for vineyards too. Wine, however, have a 30-40 years life cycle, with variable productivity (in terms of quantity and quality) depending on its maturity. Generally, the older the grape, the better and the more wine it'll produce (Figure 14).

Figure 14. Vineyard lifecycle. Source (Fregoni, 2013)

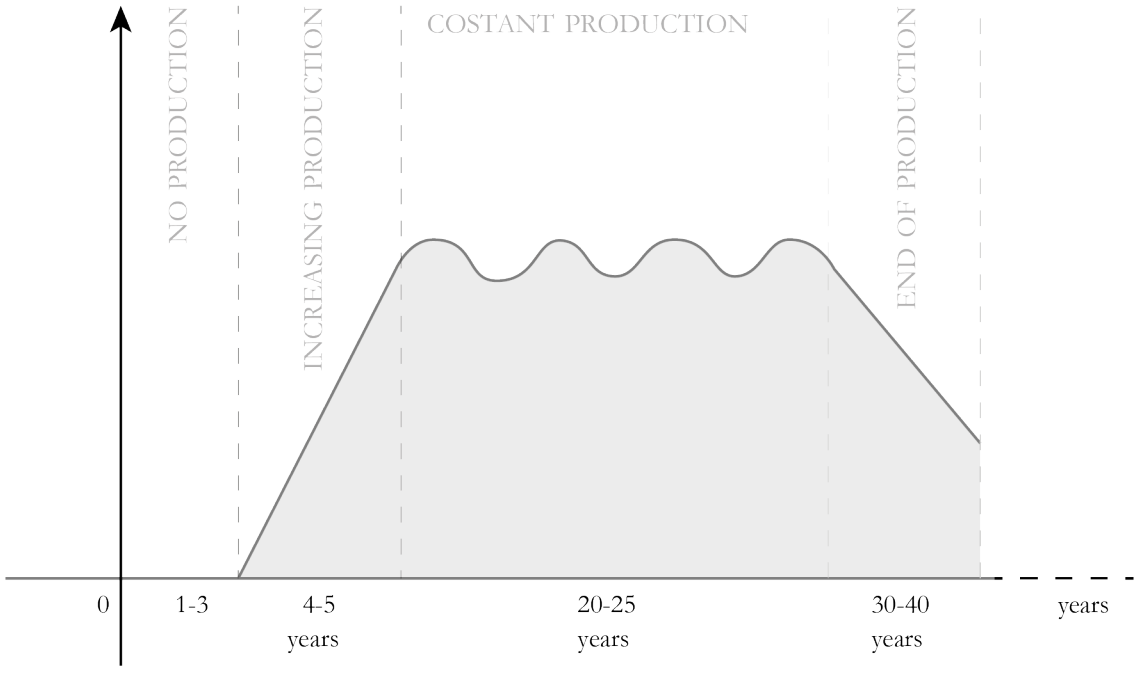


Table 35. Comparison between investments in vinery and in truffle ground

Product	*Launch costs*	*Maintenance costs (per year)*	*Productivity (raw product)*	*U.M.*	*Product (after processing)*	*U.M.*	*Prices per unit of measure*	*Estimated revenues (per year)*	*Yield time*	*Profits estimation 10 years*	*Profit estimation 20 years*	*Profit estimation 25 years*	*Variance of investment (%) in 25 years*
Tuber magnatum	€ 0	€ 1.450	12	kg	12	kg	€ 1.250	€ 15.000	20 years	-€ 14.500	-€ 14.000	€ 38.750	0,0%
Barolo DOCG	€ 30.000	€ 5.000	80	q	56	hl	€ 750	€ 42.000	6 years (3 yrs. plant + 38 months aging)	€ 88.000	€ 458.000	€ 727.000	1876,1%
Barbaresco DOCG	€ 30.000	€ 5.000	90	q	63	hl	€ 610	€ 38.430	5 years (3 yrs. plant+ 26 months aging)	€ 112.150	€ 446.450	€ 613.600	1583,5%
Barbera d'Alba DOC	€ 30.000	€ 5.000	100	q	70	hl	€ 290	€ 20.300	3 years (plant + 4 months aging)	€ 62.100	€ 215.100	€ 291.600	752,5%
Dolcetto d'Alba DOC	€ 30.000	€ 5.000	120	q	84	hl	€ 170	€ 14.280	3 years (no aging)	€ 19.960	€ 112.760	€ 159.160	410,7%

Truffle production, however, is much more aleatory, since there is no guarantee that any implant of mycorrhized plants or restoration of truffle grounds could effectively bore fruits to the farmers, while the costs they must sustain are mostly fixed and not always regional allowances are guaranteed to be given. What's more, the *property rights* over these resources differ greatly. Vineyards are mostly privately owned or run by a cooperative, as they require constant planning and resources to mature. Thus, the product ownership is usually defined in accordance to strict private agreements or regulations of the sort, thus impending others from gaining free benefits. For truffle, however, as expounded before, the conditions are quite variable. Owners can in fact either preserve and manage the operation of truffle grounds for their own use (only if they are recognized by the responsible commission) or they can ask a regional allowance for taking care of truffle-hosting plants in their property while leaving the areas open to public harvesting. Even if they are to be recognized as having exclusive harvesting rights on some grounds, thus being permitted to affix border table legally guaranteeing their rights, there is currently no absolute guarantee that trespasser will not come to poach truffles. This substantial uncertainty, coupled with the lower return on investment, usually acts as a decisive factor in choosing which land use to adopt. In fact, even when the land is not particularly apt for vineyards (either the wine produced would not be of the best quality or the environmental conditions are not the most favorable), many landowners would still opt for implanting the grapes, thus possibly removing space to the forest, and consequently the truffle.

This is one reason why wine and truffle can be considered rival products/commons in terms of land use investment and revenues, but it's not the only way these two products can be conflictual in their management practices. Considering the morphological and climatic requirements that vineyards and truffle grounds have when comparing them with the territory of Langhe-Roero, it's quite common to have vineyards on the hillsides and forests or small woods on the valley bottoms or in small plots dividing the property. This configuration could potentially favor both products, as white truffle favor valley bottoms with the right moisture and can be favored by the continuous irrigation of vineyards, especially in dry seasons. Unfortunately, the water coming from vineyards do not always (if not hardly ever) flows downstream without bringing with it some chemicals, which are very often implemented in normal vineyards. Not going into details, among the most commonly used category of chemicals in vineyards are *fungicides*, as they preserve the grapes from potentially dangerous fungi proliferation. Leaving aside if these fungicides are safe or not for human consumption[32], they nonetheless remain a huge threat to truffles, as they are hypogeal fungi. Thus, the choice, made by private owners, about taking specific cultivation plans for vineyards can directly affect the well-being of nearby truffle grounds, whose products can be or not be clearly owned. However, the conflictuality of the situation is not insolvable. Applying the right wastewater management systems to fungicide-user vineyards or shifting towards organic production techniques could potentially solve the issue completely. But both these solutions require investments from the owners of vineyards, which are usually not very likely to take solely upon themselves the entire cost of intervention, as they will usually gain

[32] Among the most diffused and cheap solutions for fungicide in vineyard there are copper pesticides, which constitute dangerous chemicals for human consumption too. In many vineyards, especially those "on the cheap side", the adoption of these solution is quite frequent for their efficacy.

nothing or barely anything in return. Once again, it's hard to make people invest to generate externalities which they do not perceive entirely and whose value do not assuredly surpass the cost of shifting. The only way this could possibly become a feasible solution would be if a counterpart would somehow guarantee that these added costs were partially covered and generate some benefits for all. Unfortunately, when looking for counterparts you stumble upon the already described truffles supply chain conditions, characterized by fragmentation, as well as variable cooperation and interest. This condition inevitably affects the possibilities that solid partnerships can be established between actors of the truffle supply chain and grape ones. What is needed would be shared platforms/initiatives allowing these diverse actors to interact with each other, and possibly leading to shared agreements and actions to tackle these issues.

Recently, the territory of Langhe-Roero and Monferrato have been affected by a major event, which has its root in the vineyards, but it spans across the entire territorial tradition and landscape: the nomination of "*Vineyard Landscape of Piedmont: Langhe-Roero and Monferrato*" as World Heritage Site by UNESCO in 2014. This nomination has come to be after many years and thanks to the efforts of many actors, both private and public ones, actively involved in the application process at every level. This nomination had a wide range of effects in almost every market sector, from vinery to tourism, and sure enough, it also affected the truffle market. However, quantifying these effects might be harder than expected. First of all, regarding the characteristic of the nomination, what has been elected as "heritage" is not actually the entire territory itself which is part of the site, but only a relatively small part of it, with a much wider buffer zone area including them (as illustrated in Table 36 and Figure 9).

Table 36. WHS Vineyard Landscape of Piedmont composition. Source (UNESCO, 2014)

# on Figure 15	*Name of component*	*Involved provinces*	*Municipalities included*	*Area of component (ha)*
1	Langa of Barolo	Cuneo	Barolo (CN); Serralunga d'Alba (CN); Castiglione Falletto (CN); La Morra (CN); Monforte d'Alba (CN); Novello (CN); Diano d'Alba (CN).	3051
2	Grinzane Cavour Castle	Cuneo	Grinzane Cavour (CN)	7
3	Hills of Barbaresco	Cuneo	Barbaresco (CN); Neive (CN)	891
4	Nizza Monferrato and Barbera	Asti	Montegrosso (AT); Mombercelli (AT); Agliano (AT); Castelnuovo Calcea (AT); Vinchio (AT); Vaglio Serra (AT); Nizza Monferrato (AT)	2307
5	Canelli and Asti Spumante	Asti, Cuneo	Santo Stefano Belbo (CN); Calosso (AT); Canelli (AT)	1971
6	Monferrato of the Infernot	Alessandria	Cella Monte (AL); Ozzano Monferrato (AL); Sala Monferrato (AL); Rosignano Monferrato (AL); Ottiglio (AL); Olivola (AL); Frassinello Monferrato (AL); Camagna Monferrato (AL); Vignale Monferrato (AL)	2561
The Vineyard Landscape of Piedmont: Langhe-Roero and Monferrato			**Total area (ha)**	**10789**
			Buffer zone (ha)	**76249**

Figure 15.Vineyard Landscape of Piedmont: Langhe-Roero and Monferrato. Source: UNESCO

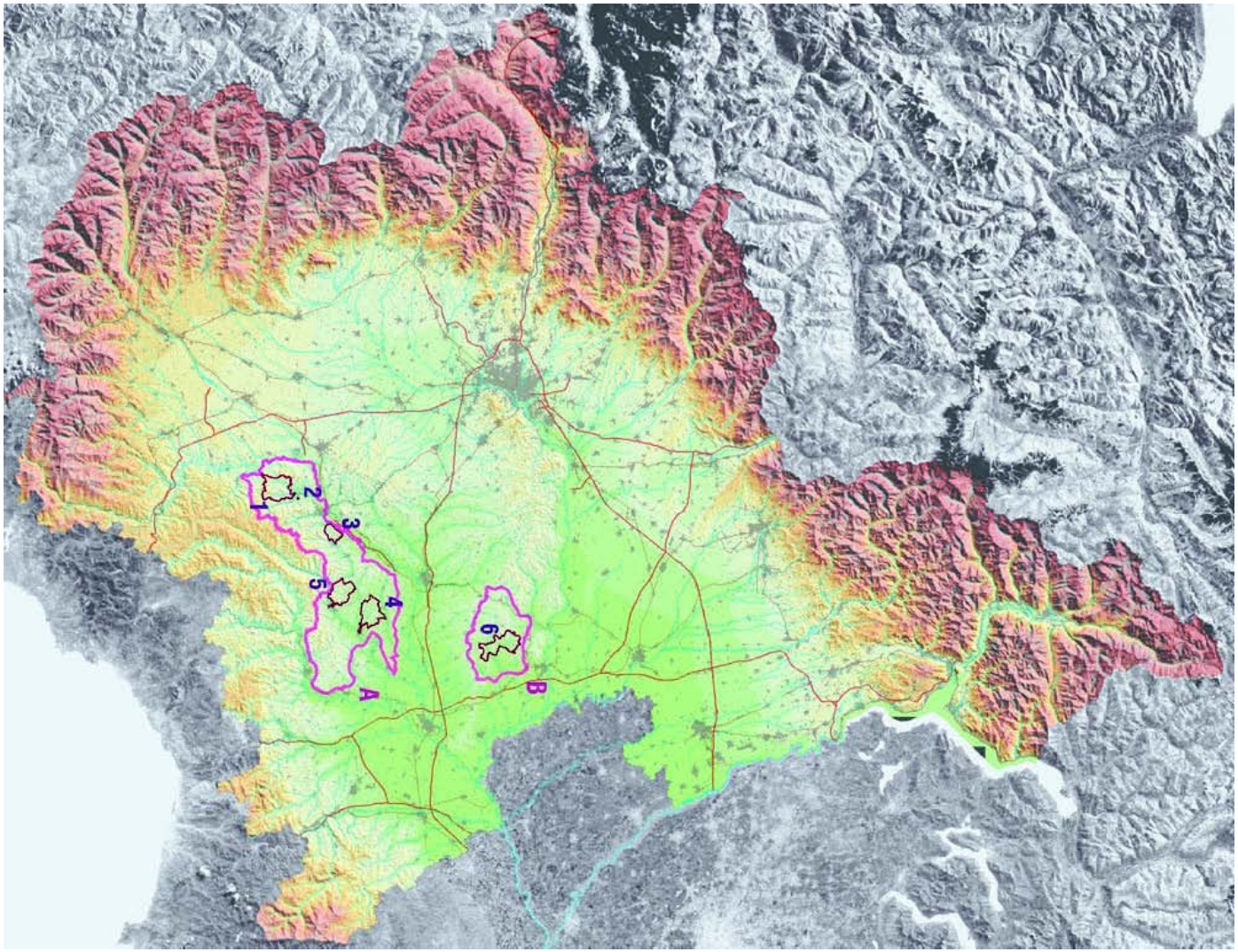


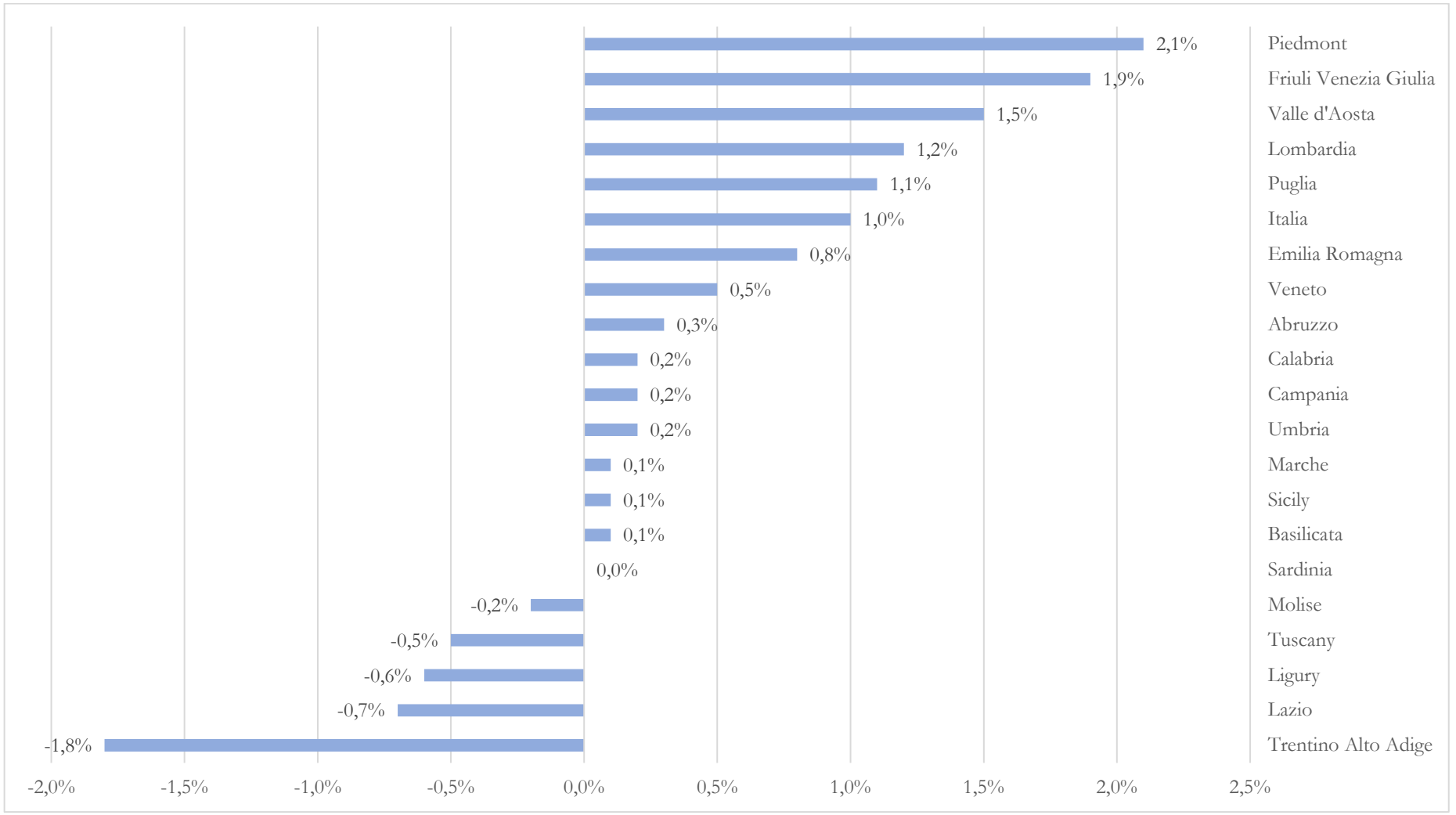
Figure 16. Vineyard Landscape of Piedmont: Langhe-Roero and Monferrato
© Touring Club

Inside the buffer zone, beside vineyards, there are also cities, streets, and forests in great measure. The nomination, however, does not explicitly extend to those areas (there are no overly strong limitations on planning interventions on human environment), if not the overall guidelines to preserve the vocation of the areas to grape cultivation. Asides from the limitations imposed on limiting the urban sprawl in the area, the role of forests and their protection is also analyzed, as they are included in article 142 of Code of the Cultural Heritage and Landscape ("*territories covered with forests or woods, even if marked and damaged by fire, and areas subject to reforestation constraints"*). This is done to favor the synergic and sustainable development of agricultural and forestry resources, a role which is entrusted to regional plans and initiatives. However, when looking for what are intended as forest resources, the main references are about the wood and hazelnuts, with many points also referring to the forest capacity to regulate the water cycle and the climate. White truffles are hardly ever mentioned in the application documents, if not as being gastronomic speciality of the place with moderate economic and touristic interest for the region. The fact that this nomination (and thus the promotion and protection efforts related) cover mostly the vineyard landscape and doesn't really influence forest conservation, even less about truffle development, is inevitably negative for the truffle market. In fact, considering the existing rivalry between the grapes and the truffle, this nomination could potentially unbalance the trend towards wine production even more. This nomination might have had an involuntary side effect in further rising the value per hectare of vineyards apt lands, which according to CREA data has been quite significative in Piedmont, especially for the Cuneo province (Graphic 4 and Table 37).

Table 37. Vineyards medium value per hectare (first five provinces). Source CREA

Province	*2006 €/ha*	*2011 €/ha*	*2015 €/ha*	*2016 €/ha*	*2016/15 %*	*2016/11 yearly %*	*2016/06 yearly %*
Bolzano	287.4	284.2	305.2	305.2	0%	1.4%	0.6%
Treviso	119.8	152.8	170.4	170.4	0%	2.2%	3.6%
Trento	252.6	202.8	163.9	162.1	-1.1%	-4.4%	-4.3%
Verona	165.3	158.4	145.1	149.9	3.3%	-1.1%	-1%
Cuneo	101.7	115.4	125.8	129.5	2.9%	2.3%	2.4%

Graphic 4. Vineyard land value yearly price variation between 2011 and 2016 (%). Source CREA



This phenomenon, even if not uniquely relatable to the candidature, has surely been favored by this special recognition of the value of those vineyards. And inevitably, with the increase in the value of fitting lands, there have been many cases of transformation of forests into vineyards, thus further threatening the environment of white truffles. To sum up, so far, the nomination has poorly confronted the theme of forest resources preservation and development, particularly when referred to the white truffle, and it has, more or less directly, influenced the already acting trend towards forest land conversion, thus reducing the truffle environment and further threatening other areas.

But these negative side effects have not been the sole effects which this nomination produced. There have been other, more underlying, side effects which have been (or could become) positive for the white truffle. First, this whole process has involved a great number of actors across these territories, who before this were mostly non-cooperative or hardly worked with strong coordination. The burdensome task of coordinating so many actors, institutions and organizations have laid down the foundation and the first visage of a sufficiently strong network in the territory. As these same areas are interested by a great presence of truffle grounds, the presence of such a network among local actors and institution could be a game-changing condition for the truffle supply chain. As currently this chain is mostly comprised of individualistic actors with scarce cooperation among larger institutions and local individuals or organizations, the existence of a previously tested and effective network of local actors might be of great help in improving coordination and participation. This need is further supported by the statements of *Piano nazionale Tartufi* and the regional recent initiatives, which highlight cooperation along the supply chain as a fundamental requisite for improving the system overall efficiency and sustainability. Secondly, this candidature has increased the public and touristic interest in the region of Langhe-Roero, leading to an increment in all the related sectors. If on one hand, this has possibly put even more pressure on the truffle market demand, it could also potentially raise the general awareness towards this product, especially on the *Tuber magnatum*, as a valued and endangered reality of the place. Ultimately, even if the candidature does not expressly focus on the forest, it still strongly orients the interest towards local landscape and environment, laying the bases for further initiatives and activities to protect, develop and promote the whole landscape, comprised the forests and their natural resources. Ultimately, all these potential positive externalities must find a way to be internalized in the truffle supply chain, and since the individual local actors (i.e. hunters) have generally been lacking in their efficacy of action, the most relevant role has currently been undertaken by the institutions. To better understand how those institutions are currently operating and what are their future plans of action, the author has interviewed the technical coordinator of the Regional institutions in the matter of truffle cultivation and related forest interventions: Flavia Righi.

4.3.3 The institutional side – Interview with Flavia Righi

When trying to understand the current conditions of the truffle market in Piedmont, the discussion with the existing governing institution become an essential step, especially whereas the role of these institutions in managing the resources is considerable. As in Italy a big part of truffle resource regulation is entrusted to Regions, when confronting the *Tuber magnatum* in Piedmont, having a response from the regional institution represented a great opportunity to better frame and comprehend the existing and future conditions of the market. The counterpart has been Flavia Righi, who currently holds the role of technical coordinator of the Regional Forest sector for the truffles supply chain and cultivation. Dr. Righi has worked in this sector for several years now, maturing wide experience on the subject. She has also been one of the representatives and members of the work groups which participated to the drafting of *Piano nazionale 2017-20*. Her role as a technician and coordinator has been one of the criteria for the proposal of the interview, as the questions have been mostly concerning technical and physical factors of the market, with less interest towards the political influences which might affect these conditions. Her kind collaboration in this work has been fundamental to predicts what future developments might await the truffle market in Piedmont and what actions are institutions taking to respond to or influence these developments. Here below follows a summary of some main topics covered during the interview.

4.3.3.1 The work of the institution

Overall, the entire Forest sector covers every aspect of agroforestry and forest management, with this specific sector concerning the management of the truffle resources in the Region. This sector exists from several years, but only recently has been actively integrated with the regional forest planning. The current planning make use of a series of documents: first, the Regional forest plan (*Piano Forestale Regionale*) which covers the entire regional planning at a larger scale; secondly, Territorial forest plans (*Piani forestali territoriali*) are smaller-scale, more detailed strategies on portion of territories; finally, for further detailed and precise planning it makes use of company forest plans (*Piani forestali aziendali*) which holds the most interest regarding the management of truffle resources in the territory. To design and actuate strategies on the regional territory, as well as collaborate to the analysis and research on specific topics, the Region established the Institute for wood plant and the environment (IPLA), a joint-stock company for which Regione Piemonte holds the majority, with minor participation of Valle d'Aosta region and Turin municipality. This agency operates by giving technical assistance and doing applied research. The Region also collaborated with many research institutes regarding the study of truffles biology and analysis; among the most successful collaborations, there have been the one with Italian Centro Nazionale delle Ricerche (CNR) and the French Institut national de la recherche agronomique (INRA). Piedmont, along with other Regions, has been co-financing many types of research at a high level, which otherwise could not be carried in the Region for lack of assets and technologies. The efforts of the Region in research and development of the truffle sector have always been clear, but since the availability of funds and assets has been insufficient to act independently, Piedmont has always promoted coordination among Regions and Ministry on truffle research. Piedmont also participated in the drafting of the *Piano nazionale per la filiera del tartufo*

2017-20, collaborating to the working tables and discussing with many other actors of the national truffle sector. The final text has been jointly agreed, with a clear indication of those who eventually opposed decisions and actions, with the final choices delegated to a later pollical decision. This opportunity for dialogue and confrontation has been important, as it allowed to recognize sectorial issues on the national level, thus giving the bases for future development of regulations and common strategies. Aside from cooperation on research, Piedmont is also autonomously carrying out intervention to map and analyzed the areas with a vocation to truffle productions, producing a regional map of the grounds with a vocation to natural truffle growth. This work of mapping and spatialize information of the territory has been only the beginning of the initiatives carried out by the Region; future plans, in fact, aim to develop a regional database on truffle grounds, with their exact location, their production, and their conditions. These major efforts are being brought forward in response to the current informal market conditions, largely affected by lack of data or incomplete information on production and condition of the regional truffle resources. The absence of reliable data on the entire supply chain and the resource bases currently stand as one of the major issues to which institutions are called to respond, especially in order to formulate effective strategies and regulations in the Region.

4.3.3.2 Establishing regulations and enforcement

The current normative framework in Piedmont has been officially updated in 2008, with successive changes done in 2011 and 2012. The regional normative have been drafted in accordance with the national frame law 752/85, whose legal constraints cannot be modified. The action of the Region regarding the regulations on truffles is just residual, as it can just operate in the limits that the national law permit. Since 1985 however the Region have taken a bit the lead in formulating regulations, since not every necessity was expressed in the law 752/85. The need of cogent constraints has been a necessity gradually perceived, since the production of truffles, especially *Tuber magnatum*, has been decreasing inversely from the demand, which is constantly rising, thus triggering overexploitation of the resources. There is a general agreement that the production of truffles, especially the white ones, has been declining due to climate and most notably social changes interesting the territory. Overall, the Region have enjoyed a great autonomy in its action, and recently it has promoted the recovery of techniques, traditions and practices specific of local territories, which, even if developed in past times, were more sustainable and positive for the truffle production and the agroforestry sector in general. The main instruments to promote such corpus of knowledges has been to make applicant for the qualification exam more conscious that truffles are not only an economic resource, but also a territorial and social one. However, Piedmont institutions alone cannot solve major issues such as who have the rights over truffles, where hunters can effectively harvest and what territories can be considered open or private. These major topics must be discussed with all the stakeholders of the truffle supply chain, to ensure that actors face no unreasonable constraint to their activity, while also protecting the well-being and development of the truffle heritage. The monitoring of all these activities and territories is a complex situation, as most of the truffle supply chain actors operate in the informality, thus making it harder to quantify and check all the products and actors involved. Of course, responding to this complexity, the monitoring system is multifaced and distributed in the territory. In the first place, the monitoring is done by what

used to be the *Corpo forestale dello Stato*, which have recently been incorporated into *Carabinieri*. This transition has not been a natural evolution, and it will probably take some time to make the situation settle down and restore their full capacity. The first level of control is during fairs, where the tracking of the products protects the consumers from fraud and other risks. On-field checks are carried out too, but they are more problematic, as they might have to be carried out during night, which imply several bureaucratic issues (overtime work, coordination, …), thus limiting their effectiveness. Aside from this national corps, other regional and local authorities (*Guardie ecologiche volontarie*, urban and provincial police) are qualified to monitor and sanction any breach of law, constituting a well diffused, even if limited in resources, monitoring system. In general, the most effective tool for checking the conditions is the *trust* of population in the institutions, which comes as a novelty to the sector. There are many more cases of people reporting violations of rules (harvesting in prohibited areas, use of harmful techniques and so on) to institutions that in the past, which obviously allows to improve the efficacy of controls and protection of the resources. This collaboration between locals and institutions is however still insufficient to completely eradicate violations, thus the Region set up harsh fines for rules infringement regarding truffle harvesting and commercialization. The harshness of these fines is not only to promote rule compliance by acting as deterrence, but they are specifically high because those activities are greatly harmful to the truffle and the environment they live into. In general, the Region purse to diffuse the consciousness of how harmful actions such as not closing pits or not stopping the dogs from excavating too hard really are. To promote a wider and more active participation of the local population to the truffle protection, the Region has allocated funds, derived from sanctioning and examining activities, to set up calls for preserving and developing the natural truffle grounds. Thanks to these calls, owners of truffle ground or truffle hosting plants can receive incentives to carry out cultural activities aimed to favor the growth of spontaneous truffles. These activities, which are coordinated by the Region with the participation of provinces and associations of hunters, have met many issues in their actuation, as the bureaucratic processes needed are often hindered by missing or unreliable data on the properties. Nonetheless, these initiatives might be an effective tool to tackle the preservation of natural truffle grounds, which are particularly important for the current *Tuber magnatum* conditions. The best way to ease these processes would be to promote projects involving the municipalities, the associations, and some landowners of a territory into innovative, more lean processes of preservation of these resources. Ultimately, the consciousness and involvement of communities into initiatives protecting the truffles, which are important territorial resources to be managed, constitute the best factors of success for future efforts.

4.3.3.3 The role of communities

As said before, the role communities have in the truffle sector in Piedmont could be the game-changing factor in any initiative to protect the truffles. In fact, communities already play some roles in the current system. For example, the associations have already asked to be more involved in the processes, but they already constitute the main inspectors when evaluating if a truffle ground or plant is productive or not. Given that the collaboration of all associations is assured, the levels and effectiveness of this collaboration vary. As a matter of fact, in areas more suited for truffle production, such as Alba or Asti regions, there is high presence of associations and hunters, but they often separate and reform into new forms.

On the contrary, other areas with less of a vocation for truffles, such as the Turin hill, have smaller but more stable associations. Maybe thanks to particularly favorable market conditions (the proximity to the city) or thanks to the leading of remarkable figures, these small realities have been since long time examples of managements and participation. To diffuse these models would surely facilitate the collaboration between institutions and these organizations, which would ultimately be positive for all the actors. About this, the recent Langhe-Roero UNESCO nomination have been a good occasion for many actors and association to discuss and promote collaboration in promoting and protecting the truffle heritage in Piedmont. In fact, the involvement of associations and local communities can bring countless benefits to the entire truffle sector. The local communities, especially in Piedmont, are depositary of a great corpus of knowledge, traditions ad practices which put them among the best in the world. These realities are the most competent, they disseminate culture, knowledge of the territory and have the primate concerning the gastronomic and wine culture. Rediscovering the old local practices, which have been born from the passing of time, the consciousness of the territories and their specificities is a step towards more sustainable practices ensuring a future for the Piedmont truffles. The institutions have been partially involved in this rediscovery of traditions, by promoting initiatives concerning didactic truffle grounds for children and more detailed examinations for the release of qualification card to hunters. Ultimately, however, the Region have limited resources and capacities to operate at every level and be equally effective everywhere. The main objective now is to stimulate the private initiatives into promoting and carry out projects, with the support of the region and other institutions and associations, constituting so a stepping stone for the sector. It's only thanks to such innovative forerunners that good practices and initiatives can become common to other actors, triggering the creation of positive synergies among the actors of the truffle supply chain. In the end, only common efforts by all parts can be effective in tackling the pending issues the truffle sector is facing. The goal must be to achieve sustainable development without disrupting the many unique characters and traditions that this practice represents, which are inextricably linked with their territories, their identities, and landscapes.

4.3.3.4 The relationship of truffle: local products and landscape

The role of truffle in the ecosystem they grew into has already been explained before: they are fundamental biologic indicators of equilibrium, a signal that represents the naturality and vitality of a forest. The establish a network of relationships with all the ecosystem and thus are the first to experience variation in case of disruption of the environmental conditions. The truffles are therefore common-pool resources with a strong linkage with the territories they grow into. This strong relationship is currently a disadvantage for the truffle production, as the current market dynamics are threatening the production pattern which previously characterized Italy and Piedmont. The global trends favoring more intensive, monocultural productions to the detriment of variety have clashed with the previously adopted traditional techniques and technologies. These old practices, which were based on less intensive and more varied cultivations, were much more effective in ensuring truffle production, in managing forest resources and in general in pursuing a sustainable use of forests. In fact, these same traditional and local practices are what shaped most of the landscape in our

territories. The plainest example of this effect is the area of Langhe-Roero and Monferrato, which have been globally recognized by UNESCO as World Heritage Site for its landscape characterization around the production of wines. It's the most iconic case of how our uniqueness in the adoption of traditional techniques constitutes one of our biggest riches, creating a so-called *cultural common*. And yet, even if these practices have shaped the landscape and contributed to local prosperity, they are substituted by foreign practice favored by market interests. One of the results of this shift is that many areas with a poor vocation for wine production are currently being transformed into vineyards, most of the time taking away areas from forests which very often are suitable for truffle productions. This process has been somehow favored by the release of constraints concerning areas where wines could acquire certifications (DOCG and DOC), expanding them in areas not considered before for truffle production. Such measure provoked the current expansion into new lands, even if they are not the most favorable for vineyards. The expansion into new areas, coupled with extensive use of chemicals such as fungicide for treatment of the grapes, have endangered the already weakened truffle grounds. Yet, all these phenomena will probably settle down with time, following a general increase in local consciousness about the values of the territories, which do not only concern wines but also other products like truffles or hazelnuts. Hazelnuts in particular have posed a different risk to the natural truffle grounds. Hazels are currently being implanted into many areas, since their products are highly demanded and, contrary to the truffle, need relatively low time to generate revenues. The implant of many *Corylus avellane* has not critically damaged the production of truffles since this plant can (even if less effectively than other tree species) host truffles, but the widespread of a single type of plant have been detrimental for the reproduction of *Tuber magnatum* in particular, which require more stringent environmental conditions. The production of hazelnuts would be more suitable coupled with the cultivation of *Tuber aestivum*, generating a varied output with an interesting revenue. But ultimately, the most endangered, with the highest market value, and the most strongly linked to the landscape of the truffle species remains the *Tuber magnatum*. This species is currently the only one not cultivable, relying only on natural grounds for its reproduction. In particular, the white truffle often grows around a single plant in the open field, or maybe at the border of tree rows. The fact that rows of trees might generate such a highly valued product might probably be a stimulus toward the safeguard and care of these rows, which generally constitute an element of diversification and valorization of the landscape. This is true for hills areas and even more for plains, where the presence of rows constitutes a strong sign of difference from the monotony of monocultures. Most of the times these rows are essentially marginal areas, often abandoned or unkempt, at the borders of more productive grounds. The possibility of making these unused areas to the regime, making them generate profit, would also stimulate owners to take better care of them, thus generating a more correctly planned and managed natural landscape. To sum up, *Tuber magnatum* (and truffles in general) might be decisive factors to foster the protection of landscape, the restoration of abandoned or unused areas, and overall contribute to a sustainable integrated management of the territories.

4.4 What future for the Piedmont white truffle?

So far, it has been described what characteristics the white truffle has, how it is regulated and how its supply chain works. It has been showed that this product involves a lot of complexity in every aspect, and that currently, even if major changes are still unseen, there are many indications that they might be "just around the corner". Of course, any change is related to new externalities and should be aimed to effectively internalize them. When considering what future hold for the *Tuber magnatum* in Piedmont, understanding where future developments might appear, how the actors may respond, and how these changes will affect the market are the great challenges that institutions face. Therefore, the end of this work will try to expound on how things might change, in order to predict what dangers and opportunities institutions might confront, and possibly it will give some tools to direct these changes towards positives, sustainable solutions.

4.4.1 Technological developments in cultivation

One of the major issues of the *Tuber magnatum* is that, differently from other species of truffles, it's the only one that so far has not been successfully cultivated in a reliable and repeatable way. In fact, there have been many studies, especially in Italy, of trial cultivation grounds, but the results have never been conclusive, as no clear factors or techniques have been proved absolutely able to guarantee the growth of *Tuber magnatum*. Moreover, even if in the end the cultivation has borne fruit, it has been a long-term investment with no significative returns, as the production has been sharply lower than other truffle species cultivation. The major concern has been the lack of guarantee of the reproduction and diffusion of ectomycorrhizas (ECMs) in nursery-inoculated host plants, as the formation of these fundamental parts of the fungi has been elusive for scientists. Even when this step has been successful, the on-field implantation has been rather inconclusive in many cases, with a lot of factors at plays which have been largely been misunderstood. Overall, the reproduction and fruitification dynamics of this truffle species have been non-completely understood by scientist, thus making practices unreliable. However, such conditions, which currently largely impede the cultivation of *Tuber magnatum*, are currently been largely studied, and the high emphasis that regional and national normative pose on the research and development of this sectors, and in particular of the *Tuber magnatum*, cannot be disregarded. It's highly predictable that with the increase of studies in the reproduction of this fungus, this last riddle will be cracked, and the currently ongoing development of molecular tools able to better monitor the spatial and temporal dynamics of *Tuber magnatum* is a promising research line (Riccioni, Rubini, Belfiori, Gregori, & Paolocci, 2016). The knowledge this research will bring will surely help institutions and organizations working in the market to elaborate more reliable guidelines for the cultivations, which are currently highly generalized and not entirely reliable to ensure productivity[33].

If it's predictable that it will become possible and efficient to cultivate truffles, then it makes one wonder how this will affect the market and the management of the resource base, i.e. the forests. It has already been said that currently, the truffles have a natural rival in the vineyards. But even excluding this rival product, inside the current agroforestry sector they are largely dismissed in favor of other product, mainly the hazelnuts and the wood pulp. It can be assumed however that, once such a highly valued product as the white truffle will become a sure (even if long) investment, these products would at least be side by side for the exploitation of the forests. It would become a precise choice how forests will be managed and operated, all in favor of one product of another, as they could be detrimental to one another full development. It's a fact that without trees, which are needed for making pulp or wood, truffles would not be able to prosper, as they need to be in symbiosis with live trees to survive. At the same time, hazelnuts represent a product with high market values, as they represent one of the typical products of the Alba area (along with wine and truffle). The trees which produce them, *Corylus avellana*, even if it's among the hosting plants which are favorable for truffle cultivation, is not among the most common and apted trees to implant ECMs. Thus, it seems that coordination among these supply chains is not easy. It is, however,

[33] The current guidelines for truffle cultivation in Piedmont have been recently standardized in a publication (Regione Piemonte - Settore Foreste, 2017).

feasible, and even sustainable and hopeful to achieve this goal. The possibility of establishing successful multi-cropping activities in the area would not only solve the issue from a market point of view, but it would also greatly benefit the farmers, thus further favoring the cultivation of truffles and their diffusion. Thinking about it from the perspective of farmers, even if truffles would become successfully cultivable, they would still represent a long-term investment (a minimum of 15-20 years at best) which not many would be willing to undertake, especially when compared with (relatively) much lower times required by hazelnuts (4-5 years) and wood (5-10 years depending on tree species). Furthermore, even if truffles become cultivable, they still nonetheless require harsh conditions to mature and become adult, with climate and environmental conditions being influential factors. This means that, even if cultivation is guaranteed to bore fruit, the actual quantity of product would be subject to variation depending on the conditions. This represents a factor of risk for any ideal farmer/investor, as it means a hardly predictable variation in revenue across the years, compared to a pure fixed cost for maintenance and harvest. Inserting one or more products in this production model will guarantee higher reliability on investments, as even when adverse conditions will damage truffle harvest, the production of hazelnuts or wood pulp would cover the losses at worst, while most probably increase the total revenues for the farmers. These conditions apply to a wide range of plants, as *Tuber magnatum* has been found compatible with different hosts which can be eventually used for different purposes (Table 38).

Table 38. List of hosting plant species of Tuber magnatum and potential for multi-cropping activities. Source (Benucci, Bonito, Falini, Bencivenga, & Donnini, 2012)

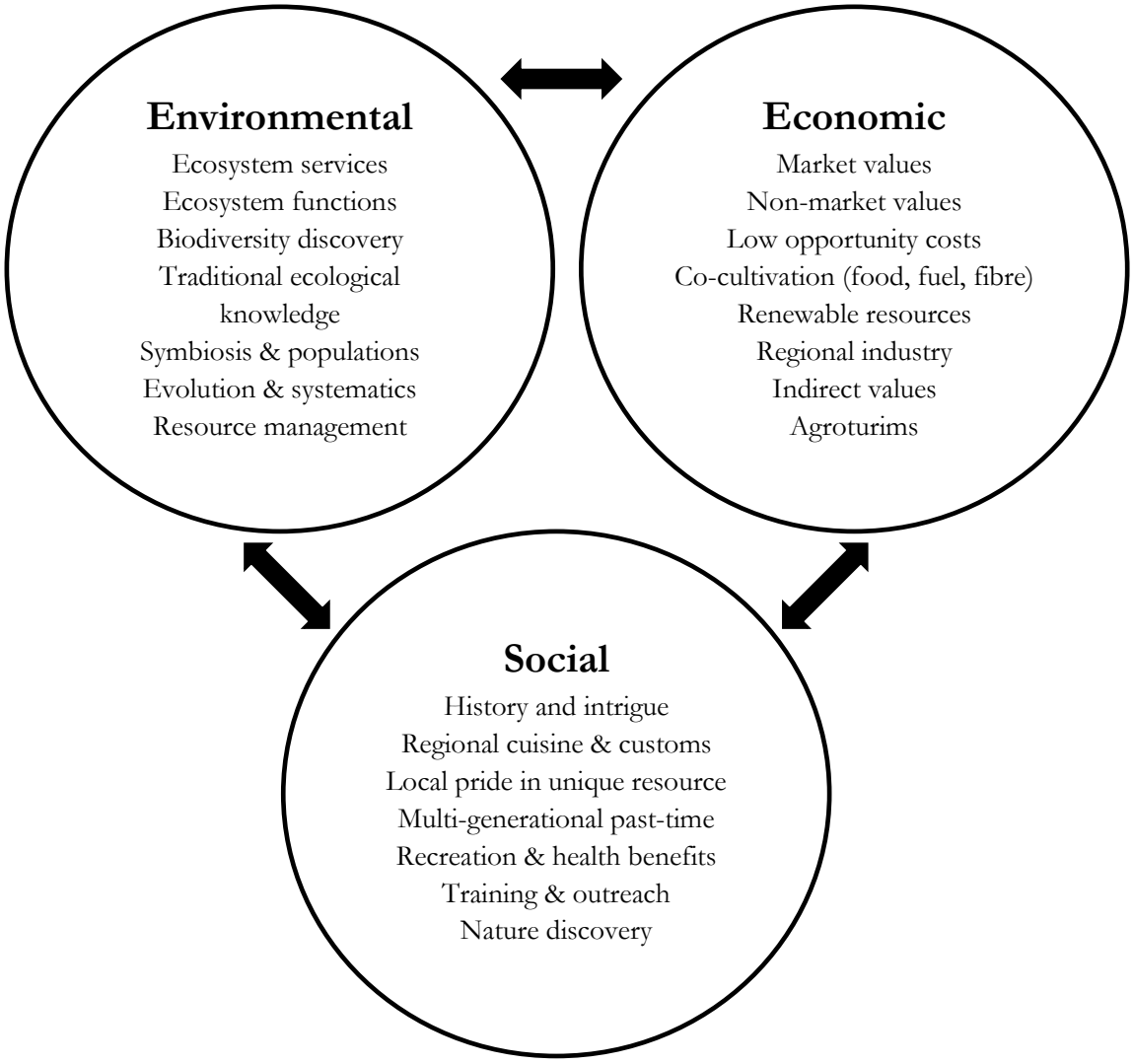
Plant species	*Fruits bearer*	*Used for fuel*	*Used for timber*
Cedrus species			X
Corylus avellana	X		
Ostrya carpinifolia		X	
Pinus pinea	X		X
Populus species		X	X
Quercus cerris , Q. petraea, Q. pubescens,		X	X
Quercus ilex		X	
Quercus robur			X
T. cordata, T. platyphyllos			X

It can be seen that many different plant species can be adopted as an alternative for multi-cropping activities, and in fact the differentiation of hosting plants, aside from favoring the formation of truffles, it has positive benefits bot for farmers and for the environment. For farmers, the presence of a different source of incomes (i.e. different products) which can possibly be harvested in different periods, constitute a great safety net, as the risk of failing one harvest is at least attenuated (if not solved) by the presence of the other products. At the same time, the presence of many tree species in the area constitute a positive indication for

the environment, as it means greater biodiversity and resilience, thus improving the environment capacity to sustain life and prosper.

Considering all these points, the implementation of multi-cropping activities involving truffles constitute a remarkable contribution to the overall sustainability of the system and diversification of the landscape. As it has been said many times before, *Tuber magnatum* is quite a complex product/common of the forests, as it needs specific conditions to grow, it is susceptible to changes in the environment and is strongly connected with the entire ecosystem it lives into. But even more, white truffles have been since a long time ago an important part of the traditions and social heritage in many areas, especially in Piedmont, where they have always been highly sought by population, riches and poor alike. Ultimately, it's a highly valued market product, with an established global demand, and it contributes greatly to the incomes of a considerable part of the population, either directly with its market or indirectly with the tourism and attention that it brings to these areas. To sum up, the presence and successful development of truffles in some areas represent a major indication of sustainability, thus effectively becoming one more indicator of the effectiveness of the existing governance practices and structure.

Figure 17. Truffles as "sustainability indicator"



4.4.2 Privatization of the landscape

Once analyzed what might be the consequence of successful truffle cultivation, another important matter is how the resources property rights could transform in the future. If cultivation would become a viable option, it quite safe to assume that most farmers would demand for private property rights over their lands, as it would be rather uncommon to have entrepreneur to work and invest to later have others take a portion of their products/incomes without gaining anything (or less than the expected revenues) in return. It quite easy to understand this condition when comparing these truffle farmers to any other farmer; no rational farmer would allow others to pluck their product, even less if these products have high market value. Therefore, the possibility of cultivating truffles would most probably push farmers to demand the privatization of these grounds. If this case comes true, we could actually observe the transformation of forest commons (since the access to truffle grounds is mostly free and open to all, even if truffles are an exhaustible resource) into private properties, thus somehow proving the theories of Hardin (1968) and Demsetz (1974) regarding the future of commons. Even discarding the possibility of cultivating the *Tuber magnatum* with success, the current conditions of the market pose a great risk to the continuity of this product, as the increasing demand and consequent overharvest badly damage the long-run capacity of truffles to regenerate. This trend, if continued without significative changes, would inevitably mark the doom of *Tuber magnatum* in Piedmont, and possibly mark the loss of this biodiversity, tradition and its market in the region. Now, considering the existent economic and social interests for the white truffles in Piedmont, it's quite unrealistic to think that the supply chain actors would not intervene to preserve this regional asset. As mentioned before, the "best" way to protect a resource is to establish clear property rights over this same resource, as this will supposedly lead the owners (or other recognized and authorized usufructuary) to do the utmost to preserve the resource itself, as any damage would be directly detrimental to their own good. Put it otherwise, nobody will care for the resources well-being more than the ones who will directly be affected by any damage to these resources. Thus, it's quite presumable that many actors of the truffle supply chain, once deeply aware of the risks, would do their utmost to avoid the disaster that otherwise would befall their own interests in the sector. Once again, to be assured to reap the benefits of their efforts, any actor would try to gain the most favorable conditions to protect their interests, that is to say, establish clearly defined rights over resources.

Now, assumed that the actors might be either private (landowners or hunters deciding to buy the lands), communities (associations of local hunters managing their own grounds) or public (the Region, the provinces or even the municipalities establishing protected areas for the truffle and monitoring them strictly), the results are all, one way or another, unfavorable for the overall truffle market and the local populations. Assuming the private solutions take the lead, we will have an even higher fragmentation of the supply chain and consequent complexification of the system, with owners caring for their own land and somehow disregarding the bigger picture, which for truffles play a big role. Even if the private would surely care deeply (or at least more than others) for the well-being of the truffle grounds, thus ensuring that no other nearby factors affect the production (for example vineyards water flows, overharvesting, wrong harvesting practices or poaching), this division would

ultimately be negative. Either the grounds are owned by many small owners, creating high fragmentation and relatively higher costs and difficulties for monitoring by institutions, or they are divided into bigger plots owned by few individuals, which will inevitably impede many local hunters to harvest truffles and thus create somehow of an oligarchy. In both cases someone loose somethings, and ultimately this will negate the fundamental nature of forests as commons open to all, as no one, hunters or inhabitants alike, will be completely free to access the area, neither to take a stroll into nature or to harvest resources for forests. To put it in a dramatic but easily understandable way, privatizing the truffle grounds, which are nothing else than forests, would be equivalent to put up barriers (not necessarily physical, but also legislative and social) to the access and use of these same forests to any aside from their owners. The second possibility, the community ownership, surely would partially solve the issues of the private ownership, as it will be a more inclusive model of resource management, which will probably limit the harvesting of truffles to the members of an association, organization or small community, model which has been proved successful for other products such as matsutake mushrooms in China and Japan (Saito & Gaku, 2008; He, 2010). This division in community-owned ground would however possibly disadvantage some communities with fewer grounds or those with more members, as the available truffle resource would be scarcer than in an open-access model. This lack of resource would not be supplied by simply changing hunting grounds, as the communities would probably be unwelcoming of outsiders harvesting their resources, or at least would demand compensation for this concession. Moreover, bigger grounds could have to be (administratively) divided among different communities/organizations, thus creating the issue of delimiting and monitoring these portions to avoid trespassers and poaching. In general, dividing the territory into many different community owned truffle grounds would probably generate more chaos in the monitoring efficacy by governing institutions, and it would put communities at risk in case of the bad season. It will also limit the capacity to implement large-scale initiatives encompassing large areas, as the coordination among many different actors would become difficult to manage and thus reduce the efficacy of many needed measures. The last model, public ownership and control, will have the positive effect of facilitating compliance with national and international guidelines. It will also possibly ensure the higher systemic impact of the decisions, as it will be directed towards a bigger picture than local decisions might aim to. As any good sides, it also has important risks and barriers. First, truffles have high differentiation in behaviors, even in nearby areas, which can be exemplified by their harvesting calendar, which might significative vary among provinces or areas, depending on whether or environmental conditions. A central, unified regulation would inevitably destroy the uniqueness of these conditions, possibly differently affecting the various actors/harvesters depending on where they work. Second, concentrating the management of these grounds under a single public institution will inevitably make the monitoring and enforcing costs skyrocket, and even if funds will come from the activity of sanctioning and regulating access (the current system is mostly financed by fines and qualification cards quota), ensuring the compliance on bigger areas would require for more assets, thus more investments. Sadly, the current and future financial prospects do not give much hope regarding the availability of funds to be destined for these activities. Even accounting for increased revenues from future fines, the current institutional system starts with a deficit in resources and assets, which would require many investments. To cover this

existing gap in monitoring, and then find more resources to enforce interventions to preserve and develop the truffle heritage, is realistically outside the most optimistic expectations.

Every aforementioned "*pure*" solution has their ups and downs, as it should be. Of course, limiting the possibilities to these three would be reductive, as many other "*mixed*" solutions have been successful in their action, somehow compensating for the weaknesses of each other. As for defining with absolute precision and certainty what is the most correct institutional arrangement, it's not possible, as there are no fixed or always right answers to institutional design (Ostrom, 2008a). Most of the time, the evolution of the society leads to the emergence and prevalence of a model over another, thus generating, if not the optimal solutions, a widely acceptable sub-optimal alternative. Of course, with time conditions might change, making institutions unfit to respond to the new conditions and becoming obsolete, and possibly be changed by others or transformed themselves into something else. Considering the current truffle market in Piedmont, it can be described as an overall mixed system, with different participation of either public, private or community actors, with a historically high fragmentation of the sector. Assuming that humans and institutions are somehow subject to a *path-dependency*, it can be presumed that this mixed and fragmented condition will be long-lasting for a while more, as no predominant actor or model of the sort has emerged thus far. This condition it's quite fitting of the specific characteristics of the truffles, as they themselves are complex and variable goods in nature. If no sure assumption can be made about the future institutional arrangements of the sectors, there are some important current trends which should be attentively considered that might led to success. First, nowadays too few is known on the real conditions of truffles grounds and productions, with a significative difference in information level among the supply chain actors. This lack of data directly impedes the efficacy of management strategies and should be tackled as soon as possible by all the actors involved. This brings to another issue/opportunity of the current condition: its fragmentation. As said before, the actors involved are far and wide in nature and conditions, but all of them have some roles in the truffle market. Overcoming this individuality, shifting from a "fragmentation" to a "*synergic cooperation*" of these actors, would surely benefit the entire system and lay the foundation for an adaptive governance model (Ostrom, 2008a). Ultimately, this social participation to the institutional design process on truffle grounds would ensure a wider consideration of what is commonly referred to as "*right to the landscape*". Even more, the sense of being part of the institutions governing the resources would, with time, possibly enhance rule compliance among the actors of the supply chain, thus reducing the monitoring efforts needed to safeguard truffles. The benefits which improved *cooperation* and *social consciousness* might bring are innumerable, and any future institutional arrangements should be based on these two principles and possibly follows the requirements to establish an adaptive and sustainable system.

4.4.3 Market restructuration

Lastly, let's look at the possible future developments of the truffle market in Piedmont. The future strategies to stop market trends that are leading to resources depletion in Piedmont can be exemplified into two: either *Tuber magnatum* become a cultivated good or a change in the current resource management strategies occur. For the first option, if the white truffle effectively becomes a cultivable product whose production rate is reasonable, this would probably make prices somehow decrease at first. As history and economic theories teach, the less a product is abundant or available, the higher the price it will fetch. If *Tuber* magnatum production reasonably stabilize and the farmers do not act unreasonably, then it can be expected that more truffles will reach the local market and thus make this good comparatively less *rare*. Of course, since global demand for truffles is sensibly higher than the current supply, this decrease in value would be negligible in the long run, and it actually might be an opportunity to capture market opportunities not reachable before because of the instability of the supply. Thus, it's not overly concerning what effects a successful cultivation method might bring to the supply chain actors. The second possibility, however, is another story. As said before, the demand for regional products is higher than the supply, and the market mostly solves this disparity by passing off *Tuber magnatum* of other areas as regional. When it's good they are at least from other Italian regions, but it's not uncommon that they come from other areas (Balkans particularly), thus plaguing the market and the consumers with fraud products. These products might not be greatly different from the original regional goods in term of characteristics, but they nonetheless fetch quite less in local markets, granting the wholesalers quite a higher revenue if sold as "original Piedmont white truffle". It has already been said how the current supply chain of the truffles is highly obscure in many steps, and no real monitoring from grounds to the consumers is employed. This informality is ultimately detrimental to the good name of the authentic Piedmont white truffle, especially for the hunters and harvesters, which are faced with illicit and notably cheaper concurrency from other regions. The introduction of foreign white truffle in the local market inevitably makes prices fall, which in contrast make exploitation more frenetic to overcome the gap in value. This is a vicious circle which negatively affect the resources well-being, possibly leading to irreversible over-harvesting levels, and later with the disappearance of the local products. This will probably do not deeply affect the overall truffle market since as stated by Brun and Mosso (2010) Piedmont could actually contribute (conservatively) less than 5% of the Italian production, which amount to a non-unreachable gap for other regions' future production. If this loss would not affect the global market, it would deeply damage the complex system of small actors and detail consumers reliant of local products, which will experience the disappearance of a source of income, and more personally the end of a long-established tradition and bond with the territory. Thus, the current dynamics of the truffle market cannot be excluded from the scope of action of any institution willing to protect the *Tuber magnatum* well-being.

Supposing this loss of local products do not happen, either because the production sharply increases following the successful cultivation, or because the institutions and actors manage to discipline the harvesting of these products and avoid their depletion, the market would face some interesting opportunities. Once again, let's consider the possibility of successful

cultivation. This will bring more products on the market, relatively reduce the prices, but more than ever, it will make a necessity the disposition of more reliable and structured monitoring activities, as like any other agricultural products are subject to strict controls regarding quality and quantities produced. This will potentially reduce the opacity of the current supply chain and give institutions more reliable data, essentials to take a decision and enforce development strategies in the sector. On the other hand, if cultivating the white truffle proved to be unreachable or not feasible in time for avoiding disaster, that most probably this will require for institutions to take a stronger lead in monitoring and managing the resources. If this process is carried out according to the aforementioned principles of adaptive governance (Ostrom, 2008a), the supply chain will inevitably be reformed and possibly straightened towards more transparent practices. Either way, a positive transformation of the market towards more open-data transfer among actors would be a key point to overcome the current and future risks of the sector. Finally, the achievement of a more reliable and known supply chain for the *Tuber magnatum*, even it might increase the costs for actors to be implemented, it will bring ulterior economic benefits in the long-run. Currently, fraud and forgery of products constitute a major concern in the white truffle market, as less valued products are sold as local of Piedmont, more valued by consumers. If the supply chain of the *Tuber magnatum* become more formalized, or at least if positive interactions among actors and share of data become common practice, this will actually strongly weaken the possibility of such episodes to happen. Moreover, the delineation of a precise supply chain in the truffle market will lay the foundations for the successful establishment of future certification procedures. These procedures will further act as institutional tools to ensure correct management of resources and possibly bring more benefits local actors. Such initiatives will contemporarily protect the consumers and the products, while possibly bringing more value to the to-be-certified Piedmont *Tuber magnatum*. In last analysis, restructuring the regional supply chain would foster the overall improvement of truffles production and future perspective, ensure more reliable data to governing institutions, and brings benefits to the current actors. If carried out correctly, it could harmonize the truffle supply chain with other important market products (wine and hazelnuts), thus bringing to a more cohesive and overall sustainable territorial (and landscape) management.

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