Chapter 12
Truffle Cultivation in the South of France: Socioeconomic Characteristic

Pierre Sourzat

12.1 Introduction

The aim of this chapter is to present the conditions for development of truffle cultivation in its natural and agricultural environment and its socioeconomic context in the south of France. The first section presents the ancestral know-how, the truffle's place in its natural environment, the relationships between truffle fungi and agriculture, agroforestry and truffle sylviculture, agroecology, and truffle cultivation. The second section is devoted to the roles of the truffle in the territory, the sociology of truffle growers, the development of truffle cultivation in the southwest of France, and the lessons learned from truffle cultivation abroad. Finally, the third section analyzes the reasons why one becomes a truffle grower and how truffle growers become involved in the environment and contribute to its maintenance and evolution.

12.2 Truffle Cultivation from the Perspective of Agroecology and Agroforestry

12.2.1 The Ancestral Know-How

When Joseph Talon invented truffle cultivation by sowing acorns in 1810 (Chatin 1892), he initiated a method of indirect cultivation of the truffle adapted to the environmental conditions of his time. In the absence of controlled mycorrhizal plants, the abundance of black truffle spores in situ was sufficient to optimally inoculate the roots of oak seedlings. "He had noticed that truffles were generally found in dry, stony quarters at the foot of certain trees; that where they were, the ground was

P. Sourzat (✉)
Truffle Expert, Bel Air, Ussel, France

J. Pérez-Moreno et al. (eds.), *Mushrooms, Humans and Nature in a Changing World*, https://doi.org/10.1007/978-3-030-37378-8_12

generally devoid of vegetation, and placed under the direct action of the sun" (Lucas De Montigny 1862). Knowledge of the ecological requirements of the truffle was a matter of empiricism but was sufficient in a context that was clearly very favorable.

From the experience of Joseph Talon, the peasants of Provence and the south of France developed a know-how over the ensuing decades. This know-how was recorded by various authors, the best known of whom were Chatin (1892), Ferry de la Bellone (1888), De Bosredon (1887), and Pradel (1914). Taking the example of the "Manual of Trufficulture" (Pradel 1914), the titles of the most significant chapters are eloquent: considerations on truffles and truffle production; conditions favorable to truffle production; sowing in the nursery, choice of acorns, and time of seeding; planting of truffle trees, creation of natural truffle trees; formation of the "truffière," their maintenance, fertilization, reconstitution of exhausted "truffières," watering; harvesting products; evaluation of the cost of creating artificial "truffières"; some insights into the characters of taste and perfume which distinguish the best truffles; and shipping fresh truffles, culinary recipes.

In short, nearly all the extant knowledge on the truffle and known methods for its cultivation as of the beginning of the twentieth century are presented in this book. Nevertheless, production fell rapidly after the publication of the "Manual of Trufficulture" (Pradel 1914). In reflection, the Great War and its human, social, and economic consequences were important factors in the decline of truffle production. But what additional ancestral know-how was it possible to collect after Doctor Pradel's "Manual of Trufficulture"? Jean Rebière in "La Truffe du Périgord" (Rebière 1981), proposed a method of culture associated with various more modern analyses. Nevertheless, truffle production continued to decline after this publication and those of additional authors. However, the works of Grente and Delmas (1974) and Delmas (1976) have fed many hopes based in particular on the popularization of greenhouse production of seedlings inoculated under controlled conditions with truffle fungi.

A 1997 survey carried out in the Department of the Lot at the request of the Midi-Pyrénées Region (Sourzat et al. 1997) made it possible to collect and/or confirm additional know-how that contributed to the local history of the truffle as it contributed to an independent way of life. Pruning for the collection of leaves at the end of August sometimes led to the appearance of natural "truffières" in old alfalfa meadows at the edges of woods. These practices were linked to a very frugal animal husbandry. The energy for cooking food, baking bread, and heating was primarily wood-based. Peasants returned to the soil the organic matter resulting from their activities. It can be said that the cycles of carbon (energy) and nitrogen (organic matter) were perfectly regulated, without excesses that could induce unnecessary losses. Truffle cultivation was integrated into these cycles because, in the vineyards, where the truffle trees were planted, manure was brought directly to the feet of the vines where truffles were often harvested.

12.2.2 The Truffle and the Natural Environment

After the devastating phylloxera infestations of 1870–1880, the destroyed vineyards located on the hillsides were recolonized by the native oak forest (*Quercus pubescens*). They were excellent sites for development of natural "truffières" (Olivier et al. 2018). The unproductive or hard-to-reach limestone lands, the first to be abandoned due to agricultural degradation, were also suitable places for the development of natural "truffières." The maintenance of these sites was accomplished, thanks to pastoralism, which delayed and diminished the encroachment of brush and woodland. The black truffle, because of its pioneering character, had no difficulty in colonizing the abandoned limestone environments. But, in the absence of passage of the small flocks of sheep, the forest encroached on these limestone moors, and the truffle gave way to secondary stage mycorrhizal fungi.

Today, natural "truffières" are formed mainly in natural grasslands (Fig. 12.1) along the edges of woods (Sourzat 2004a). They result from the presence of an open space where the roots of the border oaks thrive in an unfertilized lawn (no additions of nitrogen in nitric or ammoniacal form), usually a *Mesobromion* grassland. The black truffle's burnt areas ("brûlé") appear about 10 m from the oak woodland edge, in the *Mesobromion*. Under the edge trees, in or near the underbrush of the natural prairie, mostly basidiomycete fruiting is observed (*Hebeloma*, *Tricholoma*, *Boletus* and *Russula*) (Sourzat 2004a). Different species of these genera are known to become important late in the successional development of the natural

Fig. 12.1 Natural truffle burnt area ("brûlé") formed by *Tuber melanosporum* in a meadow at the edge of a woodland (Le Montat, Lot, France)

environment (Sourzat 2004a). It is also sometimes possible to harvest some small *Tuber brumale* truffles in the undergrowth. When *Tuber melanosporum* develops following afforestation, it is thanks to the open space that allows the truffle to express its pioneering character.

All these elements of the ecology of the black truffle suggest that, if one could establish plantations with the agronomic and ecological characteristics of the best natural "truffières," the difficulties of truffle production would be solved. It remains to be understood, however, that many of the natural "truffières" that have been discovered these last 30–40 years have a fleeting existence (2–3 years), whereas the longevity of natural "truffières" that were found at the start of the twentieth century was often 10–20 years. Certainly, pastoralism delayed the closure of clearings and the afforestation of the moors. But this does not explain everything, especially when they appear in natural grassland maintained mainly by one or two annual mowing. The absence of summer rainfall appears sometimes to explain their decline. The possibility of a historic decline in the dominance of the truffle over other competing fungus species raises the issue of the relative virulence (Sourzat 2010).

12.2.3 Truffle and Agriculture

Truffle arboriculture, which has developed with the availability of mycorrhized plants, has not yet solved the difficulty of normalizing truffle production in traditional truffle regions. In "The truffle environment: constraints and management" (Sourzat 2010), the analysis of the distribution of production according to the size of the plots and their wooded oak environment has made it possible to identify "truffle bastions" (Fig. 12.2). These are areas within plantations where *Tuber melanosporum* is dominant over competing fungal contaminants (e.g. *Tuber brumale*) associated with the edges of surrounding oak woodlands. The pressure of fungal contamination is apparently nonexistent (or nearly so) in these truffle bastions.

If in traditional areas, truffle arboriculture finds its limits according to the size of the plantations (and in the absence of watering), on the other hand, in the cereal and wine plains of Poitou-Charentes, Center or Provence Alpes Côte d'Azur, plantations of mycorrhized trees have rapid responses with relatively simple cultivation methods (including for example tillage, watering and tree pruning). This is also the case in Western Australia where the results of truffle arboriculture are remarkable though unexplained. In New Zealand, results seem poorer than in Western Australia, raising many questions. However, yields of 50 kg per ha are now also being reached in New Zealand plantations (Guerin-Laguette, pers. comm.).

In the Lot department (in south-western France), "trufficulture" experiments (truffle silviculture) have not yielded satisfactory results. However, a site not far from Lalbenque is renowned for its exceptional success (Sourzat 2004a). The original plantation (over 50 years old) has been heavily thinned, and the residual trees have been pruned. The soil was worked during the first years. Sheep have grazed a few days in the spring. "Brûlés" have formed outside the trees' canopies, in spaces not crowded by root systems of woody plants. The calcareous lawn (*Mesobromion*)

Fig. 12.2 The high production area (pink) constitutes a Périgord black truffle bastion within a 4 ha plantation (Masquières, Lot et Garonne, France)

has been gradually nibbled by the "brûlés" that produced *Tuber melanosporum*. Species such as *Tuber brumale* and *Tuber aestivum* are rare on this site. The owner of the site never wanted to start collecting truffles until January. It is possible that early rotting truffles provided natural inoculum for enhanced production. Aerial photography of the site (Fig. 12.3) shows the impact of thinning at this site in comparison with surrounding area.

If it is desirable to talk about truffle agroforestry, why not consider it in a process of reconquest of old truffle plantations, which are not in short supply (especially in the south of the Lot department)? The essential condition will be to create sufficiently open spaces inside the oak woodlands in order to favor expression of the pioneer character of the truffle. Root systems will have to be rejuvenated by tillage that cuts roots in the first 2 years, thus allowing the profusion of young roots. The practice of inoculation, either by "truffle traps" in the form of pits or trenches, in unshaded root zones just outside the canopy dripline, should favor the appearance of new truffle mycorrhizae.

On the plateau of Valensole or in the Tricastin (Vaucluse and Drôme departments in southeastern France), the association of lavender cultivation with the planting of truffle oaks is as common as that of vines with truffles in the Lot department (Fig. 12.4). In Lascabanes (Lot, France), a truffle farmer has opted on his organic

Fig. 12.3 Contrast of tree density between the thinning plantation and its surroundings at Lalbenque (Lot)

Fig. 12.4 Truffle plantation established with lavender (Drôme, southeastern France)

farm to sow cereals (wheat, spelt) between rows of truffle trees, until the trees have reached production age. On some plantations, horses valorize the grassland resource, possibly by providing manure. In Spain, the closure of the environment and the disappearance of the natural truffle trees followed the decline of the animal husbandry which is to say the grazing of underbrush by flocks of sheep, goats, and cows (Reyna Domenech 2000). Truffle agroforestry is not lacking in examples even before the concept became popularized.

On the site of the Cahors-Le Montat Truffle Research Centre (Lot, France), some plantations which are 20–30 years old or more are useful for truffle agroforestry experiments. Experiments evaluating truffle complementation with lavender, grape, or other plants are underway. Experimentation on root and aerial system manipulation of old truffle trees can be attempted without risk to production which has already either declined or disappeared. In some plantations causes of replacement of the initial *Tuber melanosporum* mycorrhization by that of *Tuber brumale* or *Tuber aestivum* deserve to be deepened both with work on soils and trees. In general, these experiments should be preceded by molecular biological analyzes of the presence of various truffle species in the soil.

12.2.4 Agroecology and Trufficulture

The concept of agroecology is perfectly adapted to truffle cultivation because it integrates the sensitivity of the truffle ecosystem to interventions or disturbing treatments (like mechanical or chemical). The exact reasons for the exceptional production of truffles in the late nineteenth and early twentieth centuries are not known in terms of soil or environmental biology. However, it is known that the truffle was extremely dominant, to the extent that people were concerned by its virulence and/or aggressiveness toward its host trees. In fact, they were apprehensive about the shortage of firewood in northern Lot (South West) because the oaks did not grow. People thought that truffles inhibited tree growth. This dominance of *Tuber melanosporum* at the beginning of the twentieth century can be partially explained by a great sufficiency of inoculum (even in the absence of certified mycorrhizal nursery plants), resulting in the perennial production of planted and natural "truffières," but this hypothesis does not seem sufficient.

Biodiversity in the soil and on the surface of the soil appears to be a poorly known track despite the relevant arguments put forward by Callot (1999) on the importance of soil fauna in the aeration process of the soil and of fruiting bodies. Wild boars, preferentially attacking the edges of natural "brûlés" for feeding (looking for the earthworms), show that it is in the area where the truffles grow best that the earthworms are located (Sourzat 2008). There is a relationship between the presence of earthworms and those of truffles. Large animals also have a role to play (including horses, sheep and cows). We have seen how the presence of horses in calcareous moorland situations (with scattered oak trees) has favored the appearance of long-lasting and productive "brûlés" (Sourzat 2004a). It has also been seen

that the disappearance of pastoralism with sheep herds has coincided with the disappearance of the truffle in many scrub woodlands in Provence and various other regions of France. The virulence of the truffle, which is illustrated by very marked and perennially productive "brûlés," is an indication of what must be sought to make the truffle dominant taking into account the biology of the environment.

The disappearance of mixed farming and the specialization of agriculture were indirect causes of the regression of the truffle. With pastoralism, in the moors and scrub woodlands where natural "truffières" had formed, the closure of the environment was delayed. Interactions between living organisms, the truffle, and its environment have not yet been explored. Some plants (e.g., grape, lavender, juniper, Jerusalem artichoke, rose hips, black spines) are considered to be beneficial (Sourzat 2004a). Before the invasion of the phylloxera root aphid (1870–1880), winemakers used to dig trenches between their vineyards and the surrounding oak woodlands in certain regions (e.g., the departments of Lot and Dordogne) so that the truffle did not damage the root systems of their grape plants. Grapes and the truffle have a long and shared history. The black truffle was introduced to new countries at the end of the twentieth century in the southern hemisphere (New Zealand, Australia, Chile) and in the northern hemisphere (USA: Oregon, California), where the vines were implanted a century earlier (in the nineteenth century).

Lavender, like grape, is widely cultivated on the Valensole plateau (Provence). Truffles are usually harvested among the roots of lavender when truffle oaks are present nearby. The development and vigor of the lavender are affected by the presence of the truffle *Tuber melanosporum*. In some cases, where juniper (*Juniperus communis*) offers the truffle shade to fruit beneath its canopy and among its roots, the shrub sometimes dies because of the intensity of the "brûlé" after several years of fruiting in its root zone. In the Pyrénées Orientales department (Pézilla de Conflent), truffle growers have noticed "brûlé" formation around *Cistus albidus* for 2 years, followed by a year or two of truffle production and then the death of the shrub.

Prunus spinosa L and *Rosa canina* L. are shrubs among the roots of which it is common to harvest truffles when they occur within "brûlés" of *Tuber melanosporum*. It even happens that the "brûlé" of natural truffières are favored by a hedge or a group of *Prunus spinosa* shrubs. Truffle production develops and the shrub is gradually annihilated. The list of plants known to be beneficial for the truffle is far from complete, although the statistical analyses of plant surveys carried out within the framework of the SYSTRUF program did not validate a positive relationship between the so-called beneficial plants and the production of the black truffle (Taschen 2015). However, molecular (Polymerase Chain Reaction) analyses of the roots of all (non-ectomycorrhizal) plants present in the truffle "brûlé" showed the presence of truffle DNA. It is not known whether the DNA corresponded to mycelium present on the root surface or inside the root tissue of these plants.

All these elements show that the concept of agroecology applied to trufficulture must necessarily integrate the concept of biodiversity into a particularly sensitive and fragile ecosystem. *Mesobromion* (calcareous lawn dominated by the grass *Bromus erectus* Huds.), which has been discussed in connection with agroforestry

and truffle forestry, constitutes a very favorable environment for the formation of natural truffle trees on limestone with soft humus. Is it necessary to install it or let it grow in the plantation where it will compete for water with the tree or even the truffle?

12.3 The Socioeconomic Context of Truffle Cultivation in theTerritories

The history of the truffle is associated with that of the grape in many territories of the Occitanie region (south-central France). This history is manifested not only in cultural and agricultural habits but also in the economy of small territories. This historical and patrimonial capital is valuable to countries which do not have this prior relationship with the truffle and its culture. A better knowledge of the actors and the means used to maintain and develop this wealth should make it possible to adjust a number of choices and prepare the future in a vision that goes beyond the strict framework of truffle cultivation.

12.3.1 The Roles of Truffle and Truffle Cultivation in the Territory

The roles of the truffle and its cultivation are multiple on the territory. "The socio-economic impact of truffle cultivation on local development" was the subject of a study carried out by the Fédération Française des Trufficulteurs (FFT) with the assistance of FNADT (a French National Planning and Development Fund) and published in December 2005 (Savignac and Sourzat 2005). This study details the elements summarized below.

The black truffle is a source of economic income whose real or fancied opacity can penalize its development. It induces other activities such as gastronomic restauration, agritourism with discovery trails, rural lodgings, guest rooms in the territories where its footprint in the territorial identity is strong. It is the origin of events (truffle festivals or fairs) which attract a large public that consumes and spends money in the territory (Fig. 12.5). In France, there are a number of several truffle museums, often referred to as "Maison de la Truffe" (Home of the Truffle).

Truffle farming is an economic activity. It induces other economic activities such as those of the truffle nursery, tree planting services, the sales and installation of irrigation equipment, fencing, and "truffières" maintenance. It contributes to the preservation of traditional landscapes, prevents or limits the scrub development, and makes it possible to regain the bushy space. It may sometimes be in competition with sheep farming by creating truffle plots in vast areas of lawns or calcareous moors. Limiting shrubs is also a means of preventing forest fires.

Fig. 12.5 Festive gathering in Lalbenque (Lot, France) for a giant truffle omelette

If the black truffle *Tuber melanosporum* is at the origin of multiple activities in the territory, other species are likely to emerge in a context of free market and development of the territory. This is already the case with the white summer truffle *Tuber aestivum*, for which local markets exist during the summer (e.g. Limogne in Quercy, Lot). In Périgord, summer truffles are sold in the Sarlat market throughout the tourist season. This species also makes it possible to organize demonstrations of the search for truffles with a trained animal ("cavage" or truffle hunting with a dog or pig) outside the traditional winter season (Fig. 12.6). It appears in summer on the menu of some restaurants at the time of tourist influx. *Tuber brumale* is also a truffle with a modest market. Some truffle growers have already planted the first trees mycorrhized with the precious white Alba truffle of Italy, *Tuber magnatum*. Plantations of trees mycorrhized by the bianchetto truffle *Tuber borchii* have already been established in Lot et Garonne.

12.3.2 Sociology of Truffle Growers

Truffle growers have no specific status. The typology below is based on the status of farmers, with sub-categories that can be refined in their definition.

Farmers can be divided into several sub-categories with their own characteristics:

Fig. 12.6 Demonstration of truffle hunting with a piglet in Lalbenque (Lot, France) as an example of active agritourism

1. *Truffle growers who generate their main income from truffle production.* These few truffle growers own at least 20 ha and are rare. In order to live from truffle cultivation, they must overcome their production which is highly dependent on summer climatic conditions. In the department of the Lot, there are currently only three farmers who have fully equipped their truffle farms for irrigation. In the absence of rational irrigation, a truffle farm cannot be a viable economic entity.
2. *Truffle growers who get a secondary portion of their income from truffle production.* More numerous than the first category, they are generally nut-growers, winemakers, or sheep breeders who devote several hectares of their farm to truffles. On the economic level, they have a real desire to generate income from truffle production.
3. *Truffle growers who have one or a few plantations to perpetuate a family tradition.* They are the most numerous. They feel satisfied to get an income from their plantations when the summer climate is favorable with rainy thunderstorms. They generally believe that truffle money is good to take but do not depend on it.
4. *Truffle growers who have given up truffle farming.* Despite the presence of some old plantations on their farm that have become unproductive, they have little or no interest in truffle cultivation.

The proportion of farmers who grow truffles varies from region to region. In the traditional truffle-growing regions, analysis of areas planted and subsidized by local and regional funds shows that vocational farmers grow as much truffle acre-

age as do non-farmer landowners (i.e. traders, civil servants and retirees), who are much more numerous. Farmers hold most of the land that can be used for truffle cultivation.

Non-farmer truffle growers are distributed as follows.

1. *Investor truffle growers*. They plant at least 5–10 ha and have a real economic project that they do not display. They have invested substantially in equipment for their truffle project (e.g. for irrigation). They come from various primary professions: liberal professions, industrialists, and craftsmen.
2. *Passionate truffle growers*. They show their attachment to the land and to family memories with emotional motivation. However, they also have an economic incentive that encourages them to take up the challenge of truffle cultivation in earnest. They may have one or more hectares with or without irrigation.
3. *Retired truffle growers*. They value a land space received as an inheritance or bought to satisfy the pleasure of producing truffles. Economic considerations are not excluded from their project. They are often "gardeners" as truffle growers on plots limited to a few acres, sometimes more (1 acre = 4000 m^2).
4. *Small and discrete truffle growers* have only a few producing trees.
5. *Former truffle growers.* They gave up truffle farming because their plantation(s) grew old and stopped producing.

A more precise typology, locating the proportions of each type by region or department, would lead to a wider study. By way of summary, however, it can be said that the sociology of truffle growers is essentially depending in the south of France of the possibility to realize or not a cultivation integrating irrigation or not in the cultural process.

12.3.3 The Status of the Truffle Grower

There is no official professional status for truffle growers. Each truffle grower is either a farmer, a solidarity member of the "Mutualité Sociale Agricole" (Health insurance fund), a member of a socio-professional status group, or retired. This is not without problems in terms of taxation, social security coverage, the SAFER (Land Development and Rural Settlement Company), and also in cases of damage caused by large game (for example deer or wild boar), because only farmers can be compensated by the National Federation of Hunters. For the passionate truffle growers or investors, the solution remains to take the status of farmer.

12.3.4 The Development of Truffle Cultivation in the Southwest

In the Midi-Pyrénées or Occitanie region (southwestern France), this development depends on several actors. The truffle farmers' associations and unions, under the aegis of the Regional Federation of Truffle Farmers, help to develop truffle cultivation,

Fig. 12.7 Truffle plantation gardened by a retiree

maintain animation around the truffle and its culture, ensure the quality of the truffles marketed, and ensure the promotion of *Tuber melanosporum* specifically.

The Truffe Research Centre of Cahors-Le Montat (Lot, France) has a decisive role in support of truffle growers, but also with experimentation on the Montat site and with the regional network of experimenters. The Centre takes part in technical field days and training workshops on the site of the Agricultural School of Cahors Le Montat.

The Midi-Pyrénées Regional Council, the Lot and Tarn Departments, provide direct subsidies or subvention plantation establishment in general. The Department of Lot also supports the creation of "truffle gardens" (Fig. 12.7), and the renovation and uprooting of truffle woods. For several decades, there was a territorial engineer at the Truffle Research Centre of Cahors-Le Montat for the development of truffle growing on its territory. Unfortunately, this position has not been re-filled.

12.3.5 Trufficulture in France

The French Truffle Growers Federation (FFT) encourages truffle research (SYSTRUF program from 2008), experimentation (Bussereau protocol, Le Foll protocol, FranceAgriMer contribution), popularization and training of truffle growers and truffle plantation establishment, and market development. The FFT disseminates scientific, technical, and professional information through the French quarterly magazine "Le Trufficulteur" [The Truffle Grower].

12.3.6 Lessons from Truffle Farming Abroad

The natural area of the black truffle is located in the northern Mediterranean arc comprising Spain, France, and Italy. However, other countries have begun to take an interest in truffle cultivation. In the southern hemisphere, New Zealand was the first country to invest in truffle cultivation, followed by Australia and South America (Chile and Argentina). South Africa is also developing truffle cultivation with the first harvests (Miros et al. 2016).

In the northern hemisphere, the United States of America (North Carolina, Tennessee, Virginia, California, Oregon, etc.) and Canada (British Columbia) produced black truffles. If China exports the truffle *Tuber indicum*, it is also interested in the production of *Tuber melanosporum*.

Tuber uncinatum, Tuber borchii, and *Tuber magnatum* are species that are established or are being experimented with in various countries. The ecological plasticity of *Tuber uncinatum/Tuber aestivum* allows its successful establishment in many pedo-climatic situations, especially in Central Europe. No establishment of *Tuber indicum* is known outside its natural area of production.

The success of truffle cultivation efforts abroad depends on its ability to generate gastronomic and economic interest, especially in the countries already cited for its cultivation. The production potential of newly engaged regions, especially in the southern hemisphere, should not be underestimated. There is no water constraint insofar as watering equipment is common in agriculture. Viticulture and arboriculture are established with irrigation in climates where it does not rain for 4–6 months (Chile, Argentina, California).

12.4 Socioeconomic Motivations for Truffle Cultivation in the South of France

12.4.1 Become a Grower: Farmer, Gardener, or Future Retired Truffle Grower

The study of the socioeconomic context showed that the window of opportunity is large enough to become a truffle grower if one has land with an appropriate soil. One can be a truffle grower without being a farmer. It is enough to have a minimum of knowledge, the necessary land, the required funds, and the determination to follow through with the project. It is possible to produce truffles from the fourth or fifth year following planting if maintenance is done properly and the trees are protected from damage by big game animals.

A determining element in the success of the project is the possibility of irrigation. Climatic change (recurrent summer droughts) requires the installation of a watering system. Then, the technical itinerary must be studied in order to properly manage the constraints of the local environment (type of soil, topography, pressure

of fungal contamination/competition) and the available means (labor, agricultural, or gardening equipment).

12.4.2 Planting to Harvest or Occupy Space

The motivations presented in the sociology of truffle growers point out that some people undertake truffle cultivation with serious economic objectives while others are more engaged for the pleasure of the process. In the first case, success is an important issue, while for the latter, the outcome is somewhat less urgent. However, all projects aiming at contributing to production are encouraged by growers' associations.

Occupying space with truffle trees is not sufficient reason for "truffières" establishment, despite the objective of combating desertification due to the disappearance of farms. A lack of maintenance generally results in a lack of results. Extensive truffle cultivation has become increasingly uncertain due to summer droughts and heat waves associated with global warming. Under dry and hot summer conditions, truffle development suffers, and the mycorrhizae of *Tuber melanosporum* become replaced by those of other species more adapted to such dry summer soil conditions (i.e. *Tuber aestivum*).

12.4.3 Improving Results

Where plantations on suitable soils have potential, improved outcomes are possible and should be encouraged. The potential is recognized by the presence of strong "brûlés" (burnt area extending beyond the margin of the tree's canopy) with additional space for enlargement. Analyses of mycorrhizae from root samples taken from the inner border of "brûlés" confirms the presence of *Tuber melanosporum*.

Management of the truffle's water needs is essential in the current climatic context. If the water resource does not exist naturally, it may be possible to create it by various means: water well drilling, hilly reserve, tank, basin, etc. The various systems put in place by truffle growers of the Aveyron department in the valley of the Tarn or the Dourbie are very good examples (Sourzat et al. 2014). These are masters in the art of collecting rainwater in small artificial pools. Then, by gravity or by means of a motor pump, the water is distributed through polyethylene pipes and micro-sprinklers judiciously distributed under the producing trees.

Other cultivation practices consist of adapted tillage (manual or mechanical, without root trauma), tree pruning and thinning if necessary (removing unproductive trees), and the creation of the so-called truffle traps by means of supplementary inoculation. The Short Guide to Truffle Cultivation provides key information in this domain (Sourzat 2004b).

When the plantation is young (5–10 years), if the trees have no real potential (stunted trees left in the grass, absence of *Tuber melanosporum* mycorrhizae, inappropriate soil), the recovery may be long, delicate, and expensive, so it may be preferable to tear the plants out and start again with solid fundamentals (favorable soil, well-mycorrhized plants, possibility of watering). When the orchard is older (15–25 years), in the absence of any sign of production (neither "brûlé" nor mycorrhizae of *Tuber melanosporum*) and unsuitable soil, it is better to give up. If the soil is calcareous with the presence of natural "truffières" in the immediate vicinity, it is possible to ensure a resumption of this plantation by restoration of the old plantations.

12.4.4 Restoration of Old Plantations

Reclaiming the land with truffle cultivation is not a vain project if the soil conditions are favorable and if there are (or have existed) natural "truffières" not far from the site in question. The uprooting of old truffle plantations on a large scale is a project that can only be carried out collectively. Elected representatives are appreciative of the potential benefits, but the implementation of such projects requires great efforts that do not constitute a high priority for local and regional authorities.

The natural "truffières" observed in the moors and natural grasslands alongside oak woodlands are an indication of the presence of the black truffle *Tuber melanosporum* and a favorable environment. The work of SYSTRUF showed that, in the scrub woodland of Provence, *Tuber melanosporum* persisted for many years despite the closure of the environment (Richard et al. 2005). This change in vegetation formation takes the form of coppice or a tight wood, a frequent haunt of wild boars. The presence of the black truffle was detected as DNA by molecular analyses.

In the reconquest of the land area, priority must be given to restoring old truffle plantations. These are not in short supply in traditional departments such as Lot where agricultural abandonment is obvious (Fig. 12.8). The wooded sites formed by old truffle plantations, woods of *Quercus pubescens* and *Quercus ilex* on limestone soil, are suitable for the implementation of truffières renovation or truffle silviculture (Diette and Lauriac 2005).

Different strategies of renovation and truffle forestry based on the following practices can be applied:

- Clearing,
- Thinning.
- Pruning of oak.
- Tillage (root cutting) with different tools (chisel, cultivator or discs).
- Maintenance of the soil over time according to sequences over several years (tillage, grassing, gyro grinding and pastoralism)
- Water supply (through irrigation)
- Inoculation (supplementary application of spores).

These strategies continue to be the subject of experiments and demonstration projects in the Midi-Pyrénées (Occitanie) region and also in Provence.

Fig. 12.8 Aerial view of the region of Aujols (Lot, France) showing a landscape of agricultural abandonment. Truffle plantations are more or less young

12.5 Conclusion and Perspectives

The disappearance of mixed farming and the specialization of agriculture have been indirect causes of the decline of the truffle. The traditional know-how is no longer operational in regions where there are fewer and fewer farmers. The know-how codified at the end of the nineteenth and early twentieth centuries must be adapted to environmental conditions deeply modified by new agricultural practices. After World War II, agriculture became specialized and led to the abandonment of less productive agricultural areas, favoring in turn the scrub and natural afforestation. The management of limestone spaces of truffle cultivation interest must take into account the fungal contamination pressure exerted by the old truffle plantations and the oak woods. This is true both for plantations and for truffle forestry. The truffle growers strive to protect and promote the biodiversity observed under natural conditions of production. They strive to maintain and protect a truly sensitive and fragile truffle ecosystem.

In the context of truffle development and truffle cultivation, truffle production remains an economic asset for the territories of poor limestone regions, particularly in the south of France. The direct and indirect societal impact of the precious fungus on local life is undeniable. Its worldwide reputation and its history contribute to the character and the lifeblood of the territories, to the development of a truffle tourism associated with products of gastronomy (wines, cheeses, foie gras, saffron and nuts) and the preservation of the environment. Truffle cuisine contributed to the

classification of French gastronomy as a UNESCO World Heritage Site in November 2010.

The sociology of truffle growers shows that truffle production depends as much on non-farmers as on farmers. The French federation of truffle growers, however, believes by its president that it is the agricultural world that holds the key to the development of truffle cultivation because it is the farmers who own most of the land and the means of its management (Tournayre, pers. comm.). In the traditional areas where agriculture has declined and the forest has progressed, grubbing up old truffle plantations on a large scale is a project that can only be achieved in a collective framework that is difficult to implement at the moment.

Truffle cultivation remains an instrument of land reconquest for the maintenance of the quality of landscapes and the fight against fires. It is a brake on desertification when agricultural abandonment is significant. In spite of all these positive elements, there are still questions about the means to be used to multiply truffle production on its traditional area in the south of France. Control of water needs becomes necessary in a context of climate change. The first is to correct the negative effects of drought in the absence of summer storms that have become rare in the last four decades.

Acknowledgments Sincere thanks to Alexis Guerin-Laguette and Jesus Pérez-Moreno for their encouragement to propose and write this article. Heartfelt thanks to Johann Bruhn for his proofreading work, his corrections, and his very pertinent remarks.

References

Callot G (1999) La truffe, la terre, la vie [The truffle, the earth, the life]. INRA, Paris. 212 p. In French

Chatin A (1892) La Truffe [The Truffle]. Baillère, Paris. 372 p. In French

De la Bellone F (1888) La truffe: étude sur les truffes et les truffières, réédition 1999 “Rediviva” [The truffle: study on truffles and truffières, re-edition 1999]. Nîmes. 312 p. In French

De Bosredon A (1887) Manuel du Trufficulteur [Truffle Grower Manual]. Laport, Périgueux. 238 p. In French

Delmas J (1976) La truffe et sa culture [The truffle and its cultivation]. INRA, Versailles. 56 p. In French

De Montigny L (1862) Rapport de la commission chargée d’examiner les reboisements et les semis ou plantations de chênes opérés dans l’arrondissement d’Apt, en vue de la production des truffes, Société d’agriculture et d’horticulture de Vaucluse et comice agricole de l’arrondissement d’Apt, 14 et 15 septembre 1862. [Report from the commission in charge of assessing the reforestation and the sowing of oaks carried out in the district of Apt, with the view of producing truffles, Society for agriculture and horticulture of the Vaucluse and Comice Agricole (i.e. Agricultural Assembly) of the district of Apt, 14 and 15 September 1862]. Société d’agriculture et d’horticulture de Vaucluse. In French

Diette S, Lauriac A (2005) La sylviculture truffière: aperçus historiques, apports techniques et enjeux pour la région méditerranéenne [The truffle sylviculture: historical insights, technical inputs and challenges for the Mediterranean region]. forêt méditerranéenne XXVI(2):157–168. In French

Grente J, Delmas J (1974) Perspectives pour une trufficulture moderne [Perspectives for a modern truffle cultivation]. INRA, Clermont-Ferrand. 66 p. In French

Miros V, Miros P, Hall I, Zambonelli A (2016) Black truffle production in South Africa—abstract book of the 8th international workshop on edible mycorrhizal mushrooms (IWEMM8), Cahors, France, 10–13 Oct 2016. p 121

Olivier JM, Savignac JC, Sourzat P (2018) Truffe et Trufficulture [Truffle and truffle cultivation], 4th edn. Fanlac, Périgueux. 352 p. In French

Pradel L (1914) Manuel de Trufficulture [Truffle cultivation manual]. Baillère, Paris. 156 p. In French

Rebière J (1981) La Truffe du Périgord [The Périgord Truffle]. Fanlac. 204 p. In French

Reyna Domenech S (2000) Trufa, Truficultura y Selvicultura trufera [Truffle, Truffle cultivation and Truffle sylviculture]. Mundi-Prensa, Madrid. 232 p. In Spanish

Richard F, Millot S, Gardes M, Selosse MA (2005) Diversity and specificity of ectomycorrhizal fungi retrieved from an old-growth Mediterranean forest dominated by *Quercus ilex*. New Phytol 166:1011–1023

Savignac JC, Sourzat P (2005) L'impact socio-économique de la trufficulture sur le développement local—Etude réalisée par la Fédération Française des Trufficulteurs (FFT) avec le concours de la FNADT (Fonds National d'Aménagement et de Développement du Territoire). [The socio-economic impact of truffle cultivation on local development—Study carried out by the French Federation of Truffle Growers (FFT, ed) with support from the FNADT (National Fund for the Planning and Development of the Territory)]. 68 p. In French

Sourzat P (2004a) Questions d'écologie appliquées à la trufficulture—Station d'expérimentation sur la truffe [Ecological questions applied to truffle cultivation—Truffle Research Centre], Lycée professionnel agricole of Cahors-Le Montat. 64 p. In French

Sourzat P (2004b) Short guide to truffle cultivation. Station d'expérimentation sur la truffe [Truffle Research Centre], Lycée professionnel agricole of Cahors-Le Montat. 20 p. In English

Sourzat P (2008) Le principe de précaution en trufficulture—Station d'expérimentation sur la truffe [The principle of precaution in truffle cultivation—Truffle Research Centre]. Lycée professionnel agricole de Cahors-Le Montat. 72 p. In French

Sourzat P (2010) L'environnement truffier: contraintes et gestion—Station d'expérimentation sur la truffe [The truffle environment: constraints and management—Truffle Research Centre], Lycée professionnel agricole of Cahors-Le Montat. 56 p. In French

Sourzat P, Bouyssières D, Sanchez A (1997) Etude sur les conditions techniques et environnementales de la trufficulture en Midi-Pyrénées—Rapport financé par la Région Midi-Pyrénées. Truffle Research Centre], Lycée professionnel agricole of Cahors-Le Montat. 38 p. In French

Sourzat P, Genola L, Saenz W (2014) Compte rendus des actions d'expérimentation sur la truffe (selon le programme validé par FranceAgriMer et la Région Midi-Pyrénées)—[Review of experimental activities on truffle (according to the programme validated by FranceAgriMer and the Région Midi-Pyrénées)]—Truffle Research Centre, Lycée Professionnel Agricole of Cahors-Le Montat. 61 p. In French

Taschen E (2015) Biotic interactions and reproductive biology of the Black Truffle (*Tuber melanosporum* Vittad.), from spontaneous to planted truffle grounds. PhD thesis, Université de Montpellier 2. 226 p. In French with English abstract