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Agroforestry and Water Resources: How past practices can help improve the future

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TECHNICAL SYNTHESIS

AGROFORESTRY AND WATER RESOURCES: How past practices can help improve the future

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ABSTRACT

In France, withdrawal of water collection zones occurs in one case out of five because of no point source water pollution from agricultural activities. This is a consequence of decades of intensive cultures which have deeply affected agricultural practices and landscapes. To reverse the trend, research programs are interested in ancient cultural practices, which supposedly lower the need for inputs. Among these practices, agroforestry is expected to bring significant improvements of water quality. Agroforestry refers to the combination of both an agricultural (either crops or pastoralism) and a wood production on the same field. Combining trees and crops induces a competition for water and nutrients which trees overcome by growing deep roots allowing them to extract resources form the deeper soil. This root system therefore serves as a safety net which intercepts nitrates leaching resulting of the application of fertilizers on crop fields. Assuming that the plot has been carefully designed, a tree-crop combination reveals to be more productive than a separate crop and tree production. Crop yield decreases while trees are growing, but this financial loss is eventually balanced out by the income resulting from the disposal of wood production. Financial support would be helpful to compensate the temporary loss of income and motivate farmers and land owners to adopt this long-cycle scheme. This paper will conclude by having a look at agroforestry systems in France and worldwide, trying to understand what kind of measures are taken to promote agroforestry.

Key words: agroforestry – water resources – alley cropping – nutrient pump – nitrates – pesticides – tree and crop competition – safety net – deep roots system – nitrates leaching

RESUME

En France, la principale cause d'abandon de captages est la dégradation de la qualité de l'eau, consécutive aux pollutions diffuses d'origine agricole. En cause, les pratiques agricoles intensives qui, pour satisfaire des besoins de production croissants, ont transformé les usages et les paysages. L'agroforesterie fait partie des pratiques modernes mises en avant pour reconquérir une ressource qui ponctuellement peut se faire rare. Il s'agit de l'association, sur une même parcelle, d'une production agricole (qu'elle soit culture ou élevage) et d'une production forestière. Dans cet environnement, les arbres et les cultures entrent en compétition pour l'eau et les nutriments. Les arbres agroforestiers ont alors tendance à développer un système racinaire plus profond que ceux des arbres forestiers, leur permettant de capter l'eau et les nutriments inaccessibles aux racines des cultures. Ces racines jouent également un rôle de « filet de sécurité » en captant les fuites des intrants agricoles. Pour peu que les parcelles agroforestières aient été conçues avec attention, l'agroforesterie s'avère plus productive qu'une séparation des productions agricoles et forestières ; financièrement, les pertes de rendement des cultures pendant la croissance des arbres sont compensées par la vente des arbres à maturité. S'agissant d'un cycle sur plusieurs décennies, afin d'inciter la réintroduction de l'arbre dans les cultures, il apparaît nécessaire d'accompagner financièrement les agriculteurs désireux d'adopter cette pratique. Un état des lieux de l'agroforesterie en France et dans le monde nous permettra de nous intéresser aux politiques de soutien à l'agroforesterie.

Mots clés : agroforesterie – ressources en eau – cultures intercalaires – pompe à nutriments – compétition entre les arbres et les cultures – filet de sécurité – racines profondes – lessivage des nitrates

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INTRODUCTION

The quality of ground and surface water is nowadays a worldwide concern. In the temperate zone, water is easily available and thus has long been considered an endless, unalterable resource. After a few decades of industrialization, intensive agriculture and the hazard of climate change, the frailty of water balance is under stress. It took a few environmental and sanitary disasters to finally raise consciousness about the need to preserve water resources.

A study was led at the initiative of the French Ministry of Health in 2012, regarding water collection zones. The study showed that about 400 water wells are abandoned each year. In 41% of the cases, the abandon is related to a poor water quality. In 19% of the cases, nitrates and pesticides are found below the maximum rates for which water is considered suitable for drinkable water production (Secrétariat d'Etat chargé de la santé, 2012). The only possible source for nitrate and pesticide contamination is agriculture. Water being available in quantity on the French territory, the wells are easily replaced, so water supply is not an issue. The fact remains that the cost for abandoning the wells and treating the contaminations are tremendous. According to the Sustainable-development division of the French Ecology ministry, 1.1 to 2.4 billion Euros could be saved each year by changing agricultural practices responsible for non-point pollutions (Commissariat Général au Développement Durable, 2012). In 2014 the French annual report on environment still underlines the rate of nitrate in surface and ground water as a result of agricultural practices (Ministère de l'Ecologie, du Développement durable et de l'Energie, 2014).

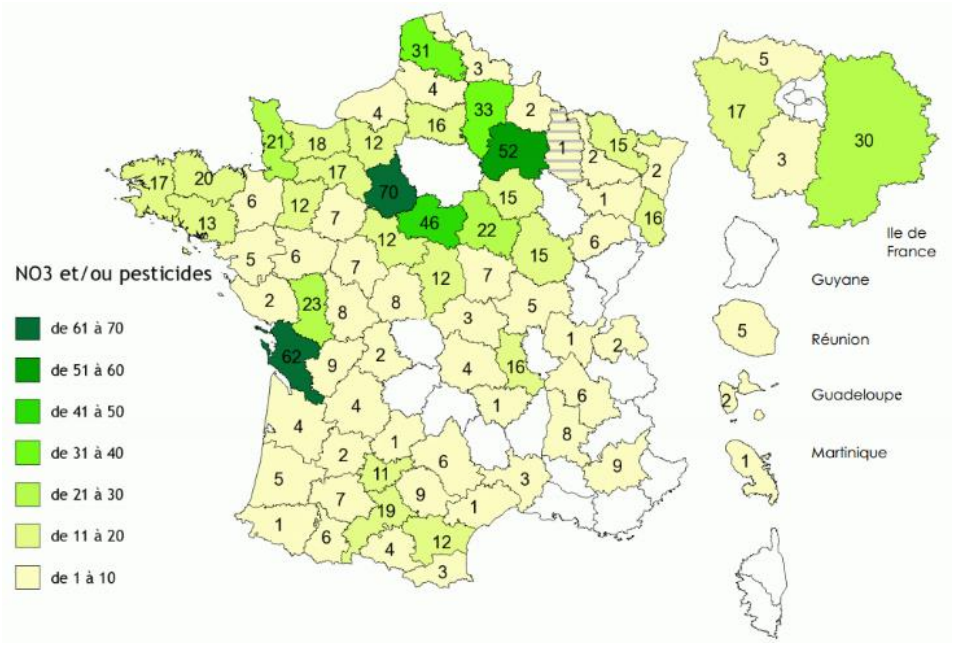

Figure 1: Water wells abandoned due to the presence of nitrates and/or pesticides (Secrétariat d'Etat chargé de la santé, 2012)

How can non-point pollutions be treated efficiently? Afforestation of agricultural land has proved to be an efficient alternative, mainly because forests usually do not require any fertilizer. In a few years after switching from agriculture to forest, the rate of nitrates is considerably lowered (Dupraz et al., 2011). But quitting any agricultural activity around water catching zones does not seem realistic. Organic agriculture has also showed interesting results. This solution was chosen by the city of Munich decades ago. As a result, the water delivered in the city is perfectly pure and requires little treatment (Lavabre and Andréassian, 2000; Dupraz et al.,

2011). What if mixing trees and crops could achieve both an acceptable yield and a reduction of water impacts? This is the point of view of agroforestry.

Agroforestry is a way of combining an agricultural and a forestry production on the same plot. There are many forms of agroforestry, by example hedges, alley fields, or agro-silvo-pastoralism in which crops, trees and cattle are grown. The concept in itself is old, as there are many examples of traditional practices which match this description. The word is more recent and appeared a few decades ago.

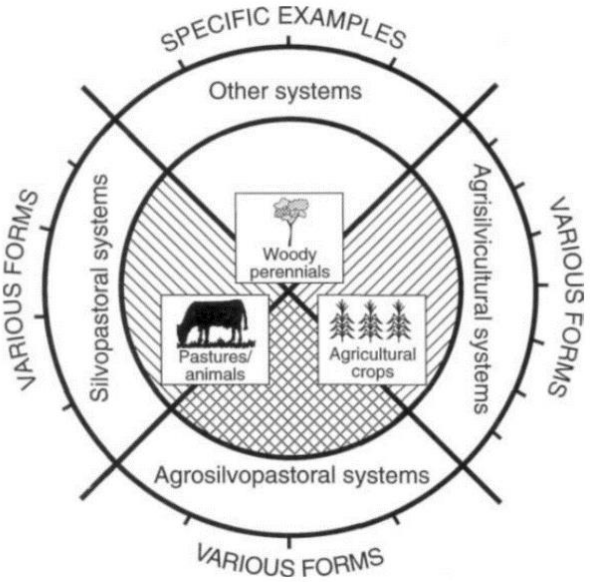

Figure 2: Classification of agroforestry systems based on the type of components. Agrisilviculture: crops (including shrubs/vines) and trees. Silvopastoral: pasture/animals and trees. Agrosilvopastoral: crops, pasture/animals and trees. (Nair, 1993)

Alley cropping is typical of modern agroforestry. It consists of growing crops in large alleys between lines of trees. This layout is particularly adapted to modern, mechanized agriculture, and thus is more accepted by farmers. This bibliotheque synthesis focuses on alley cropping systems.

The first part describes what benefits can be attained by agroforestry systems regarding water resources. In the second part, we will focus on the consequences of agroforestry for the farmers who are willing to convert a field into agroforestry. Finally, this bibliotheque synthesis will have a look on agroforestry in France and worldwide.

WHAT ARE THE IMPACTS OF AGROFORESTRY ON WATER RESOURCES?

For years, trees have been slowly but surely been removed from fields, as a result of land consolidation and mechanization. Planting trees in fields seems nowadays to be a strange idea. The first idea that comes to mind is that trees and crops are likely to compete with each other, and that it will necessarily occur to the detriment of one species. On the other hand, trees are clearly efficient to limit non-point source pollutions. But how efficient are agroforestry systems in order to preserve water resources?

IMPACTS ON WATER BALANCE

Impact of the presence of trees on the water table level

When the topic comes up of the possibility to plant trees near crops, farmers fear that trees could monopolize light, water and nutrients at the expense of the crops (Pointereau and Bazile, 1995).

Indeed, competition can occur, wherever either water or nutrients are rare. In this case, associating trees and crops will not be profitable. If water or nutrients are not limitative, mixing trees and crops is entirely possible (Dupraz and Liagre, 2008).

Existing studies have compared the level of water tables below agroforestry fields with those in monocropping systems. The studies show that water tables are usually lower; below the trees in alley-cropping at the end of the dry period (Liagre, 2008). Trees tend to dry the soil deeper because of drawing water from deeper sources than the crops. Studies have also shown that agroforestry trees grow deeper roots than trees in a forestry situation (Dupraz and Liagre, 2008).

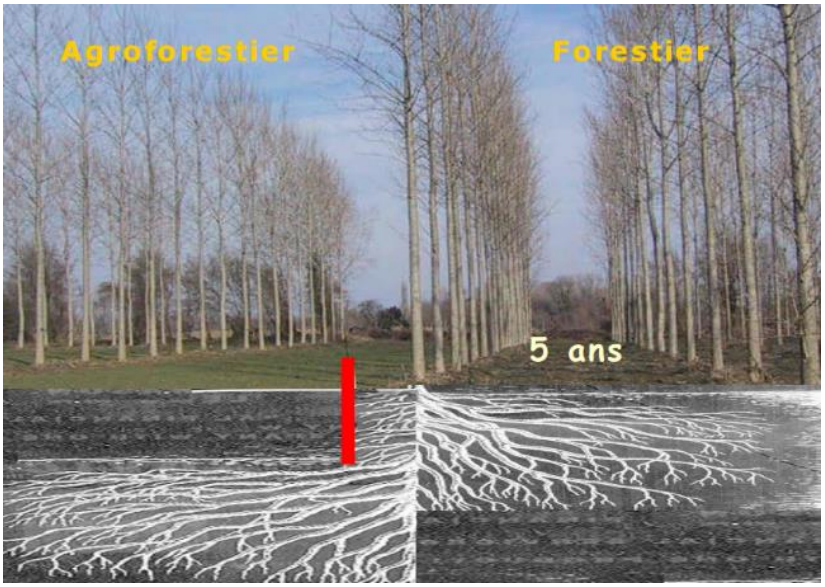

Figure 3 : Scheme of roots development of poplars in agroforestry and in forest at the INRA experimental parcel at Vézénobres (Gard, France). Competition with cereals lead the poplars to develop deep roots (Liagre, 2008)

Thanks to competition with crops, trees are forced to develop deep roots. An association of winter crops – such as wheat – with late budding trees enhances deep rooting. Winter crops develop roots earlier, before trees start their growth period. Once the soil at the surface has been dried by the crops, trees are forced to develop roots in deeper ground. Thus trees can reach deeper water tables not drawn by the crops.

This phenomenon is called « hydraulic lift ». It has been frequently described in literature. With their deep roots, trees capture water in deep water tables during the night. The water caught this way is then available for the roots at the surface during the day (Caldwell and Richards, 1989; Dawson, 1993; Ong and Swallow, 2003; Bleby et al., 2010).

Drying the water table in summer becomes an advantage when the rainy season comes. The soil water retention capacity is increased; runoff will also decrease as long as herbal buffers are kept between the trees.

Growing trees on irrigated lands is not advised. In this case, since water is not a limiting factor, trees do not need to grow deep roots. They rather tend to grow superficial roots which compete

with crops. Thus, roots being only superficial, trees are weakened and more vulnerable to weather hazards and wind.

Evapotranspiration

Among other positive effects is the decreased loss of water by evapotranspiration. The canopy reduces the impact of radiation. As a result, ground temperature decreases and thus crop water needs are lowered (Dupraz and Liagre, 2008; Dupraz et al., 2011).

These results are measured in modern temperate agroforestry, where trees are planted at a low density and are pruned regularly to reduce the canopy. In spite of these adverse conditions, the impact on evapotranspiration is decreased by 30% (Dupraz and Liagre, 2008).

To sum up, agroforestry systems induce a better use of the water table, create a microclimate which reduces evapotranspiration and increase the soil water retention capacity. However, no study has been carried out in order to link agroforestry to the hydrological regime of nearby streams. There is a possibility that the increased wood cover could exacerbate low-flow. But to assess this hypothesis, a long-term study is required.

IMPACTS ON WATER QUALITY

The natural ability of trees to cleanse soil and water is a strong argument in favour of agroforestry. Agroforestry maintains an agricultural activity while significantly reducing the impacts induced by these activities. Nitrate and pesticide pollutions are particularly targeted, since they represent the major water contaminations by non-point source pollutions.

Relations between the presence of trees and the soil pollution by nitrates are abundantly documented (Palma et al., 2007). The incidence on water pollution, however, is less studied. Only a recent study carried out by the INRA[1] led to a probable positive effect of agroforestry on the water nitrate content (Dupraz et al., 2011).

Several mechanisms can help support these results.

The nutrients pump

As explained previously, trees in an agricultural context will tend to grow deeper roots. Thus, they can capture water without competing with crops. Not only do roots capture water, but also catch all the nutrients required for the proper growth of the trees. These nutrients cannot be reached by the crops. They are stocked in soil, with the risk of being drained to streams or groundwater at each rainy period. Hence, the capture of the nutrients by the trees reduces the risk of nitrate leaching. Nitrogen is then assimilated by the trees. The leaves that fall on the surface of the fields enrich the soil with the nutrients they contain; so do the thin roots which decay belowground.

A lower need for inputs

Deep roots catch nutrient sources that would otherwise remain unexploited, and enhance the soil structure. Aboveground and belowground litter improves the fertility of the soil and produce a humus of rather good quality. Besides, herbal buffers between the trees usually remain unploughed, with low fertilizer or pesticide use. As a result, biological activities are restored, to the benefit of both trees and nearby crops.

[1] French agronomy research institute (Institut National de la Recherche Agronomique).

Scientists have observed that the crop yield drops close to the trees, but then reaches the standard level, and even above, up to 6 meters from the line of trees (Lefroy and Stirzaker, 1999). Somehow, the presence of trees contributes to restoring the soil fertility, eroded after years of continuous agricultural activities.

Eventually, the use of pesticides can be reduced. Herbal buffers offer a living zone for auxiliaries that will help control the pest development. Planting trees is a way to restore biodiversity that once deserted the cultivated lands.

The deep root safety net

Not only are trees able to catch nutrients deep in the soil, but they are also helpful to lower the input losses. The roots which grow under the crops act like a safety net. Fertilizers efficiency lies around 70%. The rest is leached through rain. Tree roots that grow under the crops catch these leaches, thus improving the fertilizer efficiency. This is also a way of limiting non-point pollutions due to the loss of fertilizers. Numerous studies highlight the safety-net role of trees. Indeed, wide distant lines of trees are efficient enough to reduce significantly nitrates leaching (Allen et al., 2004; Dupraz et al., 2011). The more important the risk of leaching, the more effective the safety net (Dougherty et al., 2009).

Compared to conventional agriculture, agroforestry proves to be an interesting option to improve water quality. Is it more efficient than an organic agriculture option? Agroof Development compared four alternatives – “business as usual” with water treatment plants, agroforestry, forestry and organic agriculture – regarding their efficiency and their global cost. Of all, agroforestry is the best economical and technical choice. Each euro spent reduces the depollution costs by 29 euros (Dupraz et al., 2011). Only the costs for fertilizer treatment have been taken into account, the effect on the use of pesticides having not been assessed yet.

Agroforestry is indeed an interesting option to reduce non-point source pollutions. It is a certainty for scientists. But farmers need to be convinced. The second part will consider the impacts of agroforestry from the farmer’s point of view.

WHAT DOES AGROFORESTRY CHANGE MEAN FOR FARMERS?

TECHNICAL ASPECTS

In the past, it was very usual to find trees among crops. But decades of modernization of agricultural practices have completely transformed landscapes. Bringing trees back in the crops must be a considered choice, in order to minimize additional work. Farmers also need to learn new practices.

Choice of species

There are three key factors to the success of an agroforestry plantation: the choice of the species; the layout of the plantation; the way trees are taken care of. The type of crop is not critical, as long as crops are not intensively irrigated.

The choice of the tree species requires good knowledge of local climate, nature of the soil and the availability of water resources. It is primordial that the trees are adapted to the growing conditions they will encounter. Farmers willing to launch an agroforestry project should get advice from a forester technician, who is able to advise them in the choice of a tree species adapted to local conditions, as well as the most valuable ones. Fruit trees are often an interesting option, with the double advantage to produce valuable fruit while trees are growing, and to offer ornamental wood at maturity.

It is also possible to mix species on the same plot. It is a way of controlling pests, diseases and parasites. It can also be a way to space out tree harvestings.

As for the crops, as seen previously, it is recommended to choose winter crops, since these crops will develop roots before trees enter their growth phase. As a rule, irrigated crops are to be avoided. Irrigated trees can be frail and if they were to be lost prematurely, it could be disastrous for the farm.

In tropical zones, choice is often made to plant nitrogen fixing trees, meaning trees that are able to fix air nitrogen. The aim is to improve nitrogen inputs. In temperate zones, however, nitrogen fixing trees with a market value are quite rare. However, it is possible to plant leguminous crops, which are also able to capture and fix air nitrogen.

Plot layout

For years, trees have been removed from the plots in order to facilitate mechanical work. How can trees be planted again in such a context?

On new agroforestry plots, it is easy for the farmer to think about a layout which will be adapted to the material. This is why most modern intercropping plots are designed with straight rows of trees and large crop alleys in between. Sometimes, farmers decide to plant curved rows of trees, in order to break the monotony of such landscapes.

The most important criterions to design the layout are the direction of the rows of trees and the distance between the rows. The direction is important to ensure crops have enough light for optimum plant growth. Whenever possible, a North-South direction would be better. This direction allows more light for the crops. On hilly areas, though, trees rows better follow contour lines, in order to mitigate land erosion.

The distance between rows is usually left to the farmer's choice, depending on the width of the machines, with more or less margins at each side of the tree row. With narrow stripes, the surface left available for crops is larger. On the other hand, operating machines will require more attention, because damaged trees would lose their market value. It must also be kept in mind that, as trees get wider, the width of the cultivated alley will have to be reduced in order to keep the yield. For this reason, INRA studies have pointed out that a low density of trees (50 to 100 trees per hectare) allows better results (Dupraz and Liagre, 2008).

Taking care of trees

Once trees are planted, they have to be maintained. Two main reasons explain the need for this work: maximizing the value of the trees (or the value of the land, if the farmer is the land-owner) and maximizing the agricultural production by facilitating mechanized work and reducing the shading of the crops.

In order to improve the interest in wood production, the value of the wood must be maximized. Beside the embedded value of the specie, wood quality can be classified by its potential use: slicing (for wood ornaments, veneer wood), lumber wood, wood for industrial or heating purposes. A long and regular trunk has a higher market value. For this reason, regular pruning should be done, in order to favour a straight trunk.

Pruning also facilitates the work on crops: since low branches are removed, work with machines is easier. Moreover, crops will benefit from the thinning of the canopy since the enlightenment will be improved. It is recommended that the low branches should be eliminated up to 6 meters height.

Farmers are not used to such practices, but this work should not be neglected, if they want to produce a valuable wood. It is noticeable, however, that agroforestry trees require less dedicated work than forest trees. Trees being relatively isolated from each other, they will grow

more straight and more regularly. Less thinning is required, if any. Having more space around each tree also allow easy access, and this makes the work easier.

Cut branches can be used as litter which will decompose and enrich the surface soil with nutrients.

Since farmers must work in their fields every day, they can easily detect if trees are infected by diseases or if pruning is required. A forester, on the contrary, does not visit parcels as often. The increased workload for farmers has been estimated to 20 hours of work per hectare per year at the most (PIRAT, 2007).

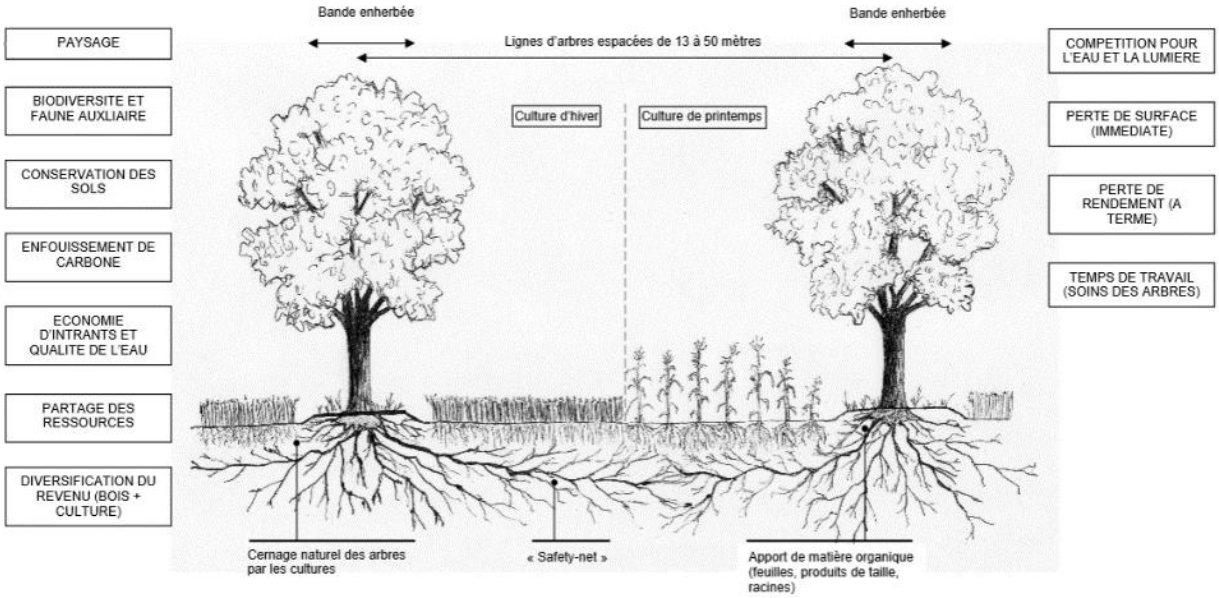

Figure 4: Advantages (on the left) and restraints (on the right) of modern intercropping agroforestry systems. Adapted from C. Dupraz (INRA) (Hamon, 2007)

FINANCIAL IMPACTS

One of agroforestry's main concerns is to ensure financial profitability of the farm. This profitability depends on two sources of income: on the one hand the agricultural production; on the other, the wood production. To assess the profitability of the farm, these two productions must be calculated. Since the tree growth cycle can be decades long, the income from an agroforestry plot can be lower than a conventional plot until the trees are harvested.

Crop yields

To assess the crop yields, the loss of cropped surface due to the presence of trees must be taken into account. On the remaining surface, the crop yield will be dependent on the layout of the plot, as seen previously. A well dimensioned layout in addition to well-maintained trees will ensure a limited shadowing of the crops and thus a reasonable yield is reachable. Due to competition with trees, the yield will be diminished but only on the ranges of crops which are the closest to the trees. It is possible to restrain competition using root pruning techniques. Root pruning consists of cutting the tree roots following a 1 meter straight line depth. But the effect will be limited in time, since roots will grow below the cutting line. An annual root pruning can also put at risk the development of trees.

In order to maintain a correct yield, it is recommended to reduce the width of cropped alleys as trees are growing. On the remaining surface, crop yield will be maintained at the level of the agricultural standard. The crops cultivation should even be abandoned for the few years before tree harvest, if the density of trees does not maintain a reasonable yield (Dupraz and Liagre, 2008).

Forestry yields

The forest part of an agroforestry plot starts to be productive when trees are old enough to be harvested, which takes a few decades. It is a long-term investment, except in the case of double-purpose trees (see “Choice of the species”). Agroforestry tree yields have to be compared to the yields of a conventional forestry plot.

Trees benefit from the open agricultural space in many ways.

First, agroforestry’s initial investment is less expensive than in forestry. In forestry, numerous seedlings are planted and only the most valuable are kept, which means that on average, one tree out of three is kept. In agroforestry, the thinning rate is lower since one tree out of two has to be removed at the most. Thinning is achieved during the early years of the plantation.

In agroforestry, trees grow more regularly than in forestry. Agroforestry tree trunks are well developed with more heartwood, which adds value to the trunk. Since trees grow more rapidly, the wood structure is less compact, so the purchase price should be slightly lower but in compensation the volume of the trunk is increased.

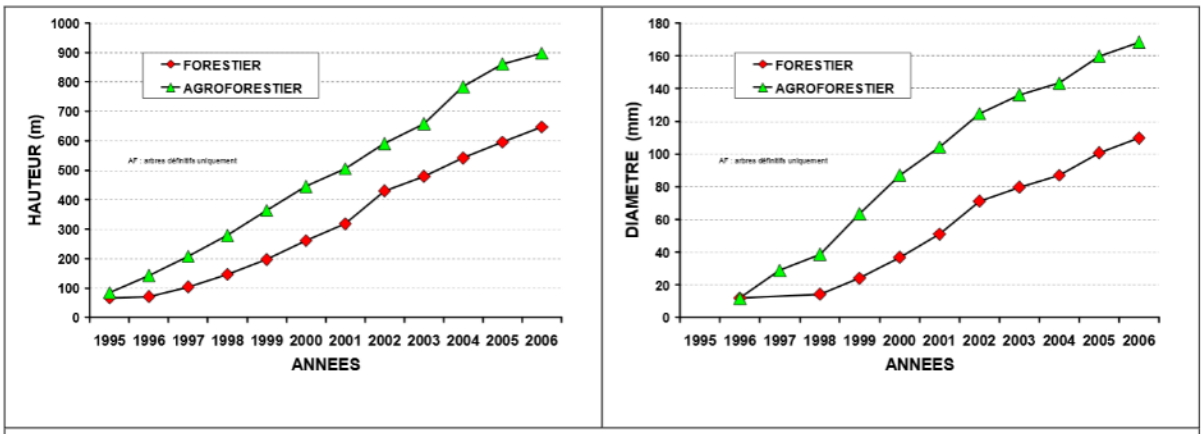

Figure 5: Compared growth of trees in agroforestry and forestry at the Restinclières Domain (Hérault, France) (PIRAT, 2007)

Cut branches can also be valued as biomass for heating purposes. They can also be used as mulch for the cultures. Mulching is an interesting way to recover nutrients that would otherwise be lost for the farm and thus to improve the soil fertility.

Associated yield

Associating trees and crops on the same plot has proved to be efficient in order to preserve water resources, with little constraint for the farmers. But is it productive enough to convince farmers to adopt this system? The total productivity of an agroforestry plot is the sum of the crop production on one side and the wood production on the other side. To compare the productivity of agroforestry and conventional separated agriculture and forestry, the Land Equivalent Ratio (LER) has been introduced.

The LER is the surface of separate crops and wood plots which will produce as much wood and crops as an agroforestry plot. During research programs led by the INRA on the Domaine de Restinclières, yields of agroforestry crops and projected yields of agroforestry wood were compared to those of nearby plots where forestry and agricultural productions were separated. The measured agroforestry crop yield was inferior to the monocrop yield. This result is partially explained since the surface available for crops are lowered in agroforestry systems. A simulation of the yields that could be reached until the harvest of the trees has evaluated the mean crop yield at 60% of the monocrop system. Similar results were obtained for the estimated wood yield. Wood yields are disadvantaged in agroforestry because of the low density of trees (130 trees per hectare at Restinclières). In contrast, agroforestry trees grow faster than forest trees, thus the harvest is likely to be anticipated. The yields obtained for agroforestry trees have been estimated at 85% of the forestry system.

This means that one hectare of agroforestry at Restinclières can produce as much as 0.6 hectare of the monocrop system plus 0.85 hectare of forest. In other words, one hectare of agroforestry produces as much as 1.45 hectares would, where crops and trees are grown separately (PIRAT, 2007). Several experimental plots around Europe were followed by the INRA; the LER usually are in a range from 1.3 to 1.6, meaning that the global productivity of agroforestry plots is increased by at least 30% compared to conventional systems (Dupraz et al., 2005).

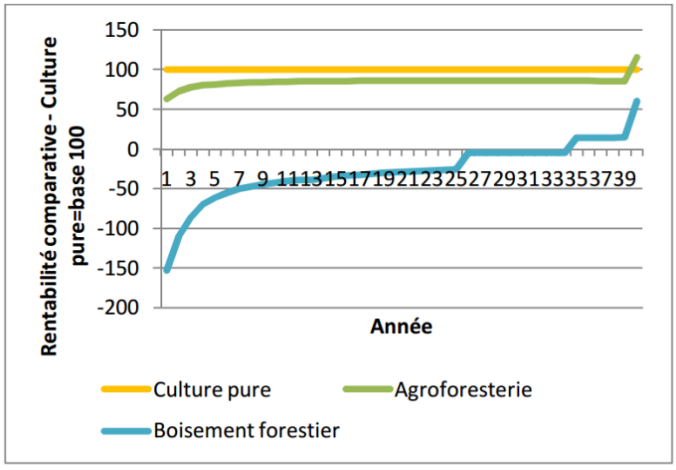

Figure 6: Compared incomes of three scenarii : agriculture, forestry and agroforestry (agriculture = base 100) (Dupraz et al., 2011)

In addition to protecting the environment, agroforestry is also a profitable practice for farmers in the long term. However, the short term loss of income induced by the decrease of crops yield makes them reluctant. It appears essential to support the development of agroforestry with incentive politics.

HOW IS AGROFORESTRY DEVELOPING IN FRANCE AND WORLDWIDE?

A LOOK AT FRENCH AGROFORESTRY

Agroforestry surfaces in France

A few illustrations of traditional agroforestry remain in France. By example, walnut plantations in Dauphiné and Périgord traditionally associates double purpose walnut trees to durum wheat alternated with colza. In Drôme, truffle fields usually combine truffle oaks with lavender or grapevines (Dupraz and Liagre, 2008). In 2008, about 170.000 hectares of traditional agroforestry were exploited by 45 000 farmers, while modern agroforestry is estimated at 2 500 hectares set up by 400 farmers. According to an estimate, 3 000 hectares are set up in agroforestry each year (Agroforesterie et Conseils, 2014). The French association of agroforestry (AFAF) assesses the surfaces in modern agroforestry between 6.000 and 10.000 hectares (Campagnes et environnement, 2013).

The INRA led the first experimental agroforestry plots during the 80's in the regions Languedoc-Roussillon, Auvergne and Pas-de-Calais. The most emblematic are those of the Domaine de Restinclières in the French department Hérault, where hybrid walnut trees are cultivated in association with durum wheat and colza. These plots, belonging to the Departmental Council of Hérault, have been exploited in collaboration with the INRA since 1995, which makes it the oldest agroforestry experimentation in Europe. France is indeed a pioneer in European modern agroforestry. Results of the experimentations are published thanks to the PIRAT[2] project, which aims at covering all aspects of agroforestry (root systems, biodiversity conservation, plant associations…) (AGROOF, 2013). It is significant that this experimentation was led without any backing from the French State.

France's difficult support for agroforestry

For years, financial grants for agriculture have had a negative impact on agroforestry. As a consequence of CAP rules, agroforestry plots have been consecutively dissuaded (tree strips were not taken into account as eligible areas), forbidden (agroforestry plots were ineligible to grants if the density of trees was higher than 50 trees/ha) or tolerated (agroforestry being considered a landscape feature) (Liagre et al., 2011)[3].

With measure 44 of the Rural Development Regulation 2007-2013, which was decided in 2004, Community aids were finally granted to agroforestry systems. This measure was only allowed in France in 2010 by measure 222 of the Hexagonal Rural Development Programme (PDRH). The funding, which can cover up to 80% of the plantation costs, are granted by the European Agricultural Fund for Rural Development and the regions. Regions are in charge of managing the grants but, since activating the measure is not mandatory, only a few regions adopted measure 222 in their Regional Rural Development Document (DRDR) in 2010, namely Aquitaine, Midi-Pyrénées, Nord-Pas-de-Calais, Pays de Loire, Picardie and Poitou-Charentes. In 2011, only 4 applications for funding gave grants of 4.545€ and around 30 other applications were made (Ministère de l'Agriculture, de l'Agroalimentaire et de la Forêt, 2012). The main reason for this low level of mobilization is that farmers are afraid to lose all their CAP grants. This is the consequence of the lack of transparency of the CAP regulations (Association

[2] Integrated Agroforestry Research Program at Restinclières (Programme Intégré de Recherche en Agroforesterie à ResTinclières)

[3] Liagre F., Dupraz C., Canet A., 2011. *Key policy changes that made agroforestry accelerate in France.* Athens, NAAC, 90 p. [Posted 06/06/2011].

Française d'Agroforesterie, 2012). To give an example, fruit trees are not covered by the scheme (Ministère de l'Alimentation, de l'Agriculture et de la Pêche, 2010).

Yet, farmers are positively engaged towards a change of practices. During the SAFE[4] program, European farmers were asked about their interest in agroforestry practices. It appeared that nearly 30% of the interviewed French farmers were not opposed to starting an agroforestry plot in their fields. Two years after the interview, some of the farmers had by themselves started the procedures to set up agroforestry projects (Dupraz et al., 2005).

Since 2009, France has started a shift towards a support to agroforestry, first by naming agroforestry as a part of a new sustainable agriculture model ("Objectif Terres 2020"), then by measure 222 in the PDRH (Ministère de l'Agriculture et de la Pêche, 2009b). More recently, a ministerial mission was created to identify the restraints to the development of agroforestry and, the 1st December 2014 was held a national meeting on the theme "Agroforestry as a way to build an agro-ecologic project for the territories". Thus, the French State clearly puts agroforestry forward as a way to modernize French agriculture (Ministère de l'Agriculture, de l'Agroalimentaire et de la Forêt, 2014a; Ministère de l'Agriculture, de l'Agroalimentaire et de la Forêt, 2014b). The programme Agr'eau, led by the Water Agency Adour-Garonne and the French Agroforestry Association, also started in 2014 with the aim of promoting vegetation cover and agroforestry (Association Française d'Agroforesterie, 2014). This is the first programme linking directly agroforestry to water resource protection.

AGROFORESTRY IN EUROPE AND WORLDWIDE

For the same reasons of CAP application and land consolidation politics, in France as in the rest of Europe, agroforestry has slowly disappeared form the landscape.

The iberic Dehesa is the most widespread of traditional agroforestry systems still in use. The Dehesa extends over nearly 4 million hectares in Spain and Portugal. It is an agrosilvopastoral system composed of low density oak plantations (30 to 100 trees per hectare) used as pasture; from time to time the Dehesa is cropped in order to control weeds (Dupraz and Liagre, 2008). The Dehesa system, although still abundant, is in decline due to competitiveness reasons (Aviles Benitez, 2009). The Dehesa system was also weakened due to the abandon of the ancestral practices that allowed its maintenance (no overgrazing, cropped period to control the weeds, regular oak regeneration).

Modern agroforestry develops mainly in the countries where experimentations took place, in particular during the SAFE projects. Among the countries involved in the project were Spain, Italy, Greece, Switzerland and the United Kingdom. One of the missions of the SAFE project was to assess the potential for agroforestry development in Europe, on the basis of several criteria (risk of land erosion, nitrates leaching, landscape diversification). As a result, it appears that more than 56% of European arable lands could benefit from agroforestry (Reisner et al., 2007).

The SAFE project ended in 2005. To continue the research in agroforestry, the European Commission started a new program, AGFORWARD (AGroFORestry that Will Advance Rural Development). This program is planned from 2014 to 2017, with participation of the INRA and the French Agroforestry Association (AGFORWARD, 2014).

Outside Europe, China is the leader of modern agroforestry in temperate zones. Due to its important demographic and economic growth, China soon had to cope with a high deforestation rate, coupled with farmland grabbing. The country relied on agroforestry to improve agricultural productivity. Since the 90s, significant financial means were allocated to the development of agroforestry systems (Simard, 2012). The most represented species in Chinese temperate agroforestry are pawlonias cultivated with soft wheat-cotton, soft wheat-

[4] Silvoarable Agroforestry For Europe (http://www1.montpellier.inra.fr/safe/french/index.htm)

sorgho or soft wheat-maize-peas associations (Dupraz, 1994). Chinese agronomists have led numerous experimentations on the most diverse parameters such as protein rate in agroforestry wheat, the impact of above-ground litter on productivity, or the influence of natural and artificial mulch on crop water needs (Dupraz, 1994; Mao et al., 2012). Scientific investigations related to the optimal tree density concluded that low-density systems are more efficient, which merges the results of the European teams.

The regions where agroforestry grew considerably are tropical and subtropical zones. In these countries, agroforestry is based on traditional systems such as taungya (where crops are grown between ranges of young trees, during the early years of a tree plantation), or cocoa and coffee plantations. These dense systems (it is not unusual to find up to 300 different species per cultivated hectare) are the most adapted to the climate, and handles well with low mechanization practices (Buttoud, 1994; Dupraz and Liagre, 2008). Many tropical countries chose to use Payments for Environmental Services (PES) to support agroforestry, with varying degrees of success (Zanella et al., 2014).

Payment for Environmental Services is a contractual agreement with which a supplier (the farmers) is committed to adopt environmental-friendly practices in exchange for a financial reward, given to them by either a private or a public entity (Ministère de l'Agriculture et de la Pêche, 2009a). PES are often used in the United States and in New Zealand for example. In Europe, the CAP scheme also includes agri-environment measures (AEM) which can be used in addition to PES. In France, PES are poorly exploited. However, it may be noted that Nestlé Waters initiated a programme to preserve water catchment areas from non-point source pollutions, with the participation of local actors (farmers and local communities) (Prokofieva et al., 2012; Valette et al., 2012; Pur Projet, 2013). According to the French Economic Council for Sustainable Development, the incentive effect of PES seems to be an effective model; this could help PES to be more widely applied, in addition to existing funding measures (Conseil Economique pour le Développement Durable, 2010). Given the numerous positive impacts of agroforestry (regarding water and soil conservation, biodiversity, reduction of polluting inputs, landscape preservation) and its wide potential for development, agroforestry projects would be good candidates to such encouragements.

CONCLUSION

It is becoming urgent to counter the slow degradation of water resources as a consequence of decades of intensive agriculture. To mitigate non-point source pollutions, the current agricultural model has to be questioned. But which model shall be adopted? On the one hand, intensive agriculture leads to terrible contamination of water and soil. On the other hand, the growing population requires more productive practices. Could agroforestry be part of the solution?

Studies carried out since the beginning of the 70s, and in particular the works led by the INRA, have shown scientific proof of the efficiency of traditionally inspired systems. The deep root development of agroforestry trees provides better water and nutrient efficiency. As a consequence, water and soil quality is improved, as well as the soil water retention capacity. Although competition between trees and crops is a reality, agroforestry is still more cost-effective for the farmers than conventional agriculture. Attention should only be paid to the choice of the species and the layout of the plot.

It is interesting to notice that very few studies draw a link between agroforestry and water quality. Contrarily, the impact of agroforestry on soil quality is well documented. This indicates that preservation of water resources is an emerging problem in temperate developed zones. Similarly, the topic of pesticides is rarely discussed.

The impact of agroforestry on water availability should be considered, as it could be an obstacle to promoting agroforestry in water-stressed areas. This study, however, was focused on a single scheme in temperate zones.

Finally, since agriculture has since long lost its attractiveness, it could be interesting to examine how agroforestry as well as other agroecological practices can improve the reputation of agricultural professions.

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