AGFORWARD
Agroforestry for Europe

System Report:
Traditional Pollard Agroforestry in South-West France

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Specific group	Traditional Pollard Agroforestry in South-West France
Deliverable	Contribution to Deliverable D3.7 (3.1): Detailed system description of a case study system
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1 Context

The AGFORWARD research project (January 2014-December 2017), funded by the European Commission, is promoting agroforestry practices in Europe that will advance sustainable rural development. The project has four objectives:

1. to understand the context and extent of agroforestry in Europe,
2. to identify, develop and field-test innovations (through participatory research) to improve the benefits and viability of agroforestry systems in Europe,
3. to evaluate innovative agroforestry designs and practices at a field-, farm- and landscape scale, and
4. to promote the wider adoption of appropriate agroforestry systems in Europe through policy development and dissemination.

This report contributes to Objective 2, Deliverable 4.10: “Detailed system description of case study agroforestry systems”. The detailed system description includes the key inputs, flows, and outputs of the key ecosystem services of the studied system. It covers the agroecology of the site (climate, soil), the components (tree species, crop system, management system) and key ecosystem services (provisioning, regulating and cultural) and the associated economic values. The data included in this report will also inform the modelling activities which help to address Objective 3.

2 Background

In North-western France, pollarding is still a living practice linked to the management of the “bocage” landscape of “traditional” hedgerows on field boundaries (Bernard et al. 2006). In southern France, pollards are generally found as remnants of a formerly much more widespread practice. The natural landscape has been substantially altered by humans. Extensive clearance was carried out to use the land for pasture or arable crops, but there are still areas of wood-pasture where land with trees is systematically grazed by domestic animals. Its structure consists of large open-grown or pollarded trees at various densities, in a matrix of grazed grassland and forest vegetation. Although pollarding was clearly an important part of the agrarian culture the trees are now largely overlooked. Due to mechanisation and intensification of agriculture, trees have been progressively removed from grasslands and traditional agroforestry systems have slowly disappeared. Encouragement needs to be given and awareness on pollards should be raised so that they can be maintained in landscapes. Pollarding is a way of getting a regular production from the trees (for example: wood-fuel or animal bedding) while also obtaining a revenue from the land underneath (Read 2006).

3 Objective of trial

The research aims to address the following questions:

- What is the average biomass of a mature pollarded tree? What is the variation of the average volume and the shape of the main stem?
- How is the aboveground biomass distributed between the trunk and the branches?
- How is the biomass of the branches distributed according to diameter sizes: cutting Ø ≥ 20 cm; 20 cm > Ø ≥ 7 cm, and 7 cm > Ø ≥ 4 cm in pollarded trees?
- How do branches biomass and volume production of pollarded trees change in accordance with the branch thinning intensity?
- Are there any allometric equations that can be used to predict the average aboveground biomass of agroforestry trees?

This research is being conducted by the Institute for Forest Development (IDF) in collaboration with the French Association of Agroforestry (AFAF) and the Pastoral Land Association of the town of Mont in the Hautes-Pyrénées.

4 System description

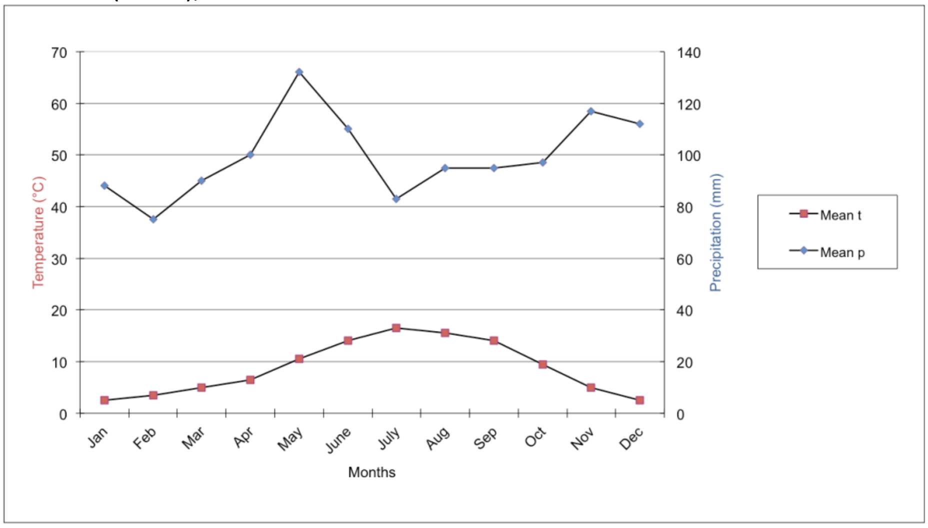
The trial is taking place in a 3.6 ha area with "bocage" located at Mont in the department of Hautes-Pyrénées. The agroforestry system is composed of traditional hedgerows of pollarded ashes (*Fraxinus excelsior* L.) orientated predominantly NNW to SSE on a rich grassland.

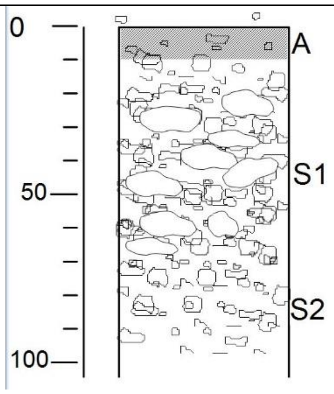
Table 1. General description of traditional pollard system on rich grassland in France

General description of system	
Name of group	Traditional pollard system on rich grassland in France
Contact	Philippe Van Lerberghe
Work-package	3: High value trees
Associated WP	Use of livestock
Geographical extent	Presence of “bocage” of pollarded ashes for increased production of wood are found in many French regions such as Poitou-Charentes, Loire, Brittany, and the Pyrenees.
Typical soil types	Brunisols
Description	Ashes are planted on hedges around the fields. It’s a traditional way to delimit the plots, to bring shadow and fodder to livestock and to restrict erosion. Trees are pollarded to increase the quantity of wood production during a short-term rotation. The cutting tree height depends on the region. Grazing provides a means of maintaining a short sward and providing fodder for sheep. The sheep may be lambs which are being fattened or ewes that need to maintain body weight until the next lambing season.
Tree species	European ash (*Fraxinus excelsior L.*)
Tree products	Until the 1970s, ash trees were pollarded every 4 to 5 years in August or September. The leafy branches were gathered into bundles and stored in barns or simply left in the plots. Livestock was fed with dried leaves in January or February. Large branches were used as firewood (Métailié 2006b). With the disappearance of farms in mountain areas, tree management and branches pollarding were abandoned. Currently, the large amount of branches biomass could make harvest economically worthwhile. Fuel and fire wood demand is high and growing in the touristic valleys of the Pyrenees.
Crop species	Grass species such as *Lolium perenne.*
Crop products	Grass is grazed directly by livestock. The grass is used to fatten lambs and to maintain the weight of ewes.
Animal species	Sheep
Animal products	Sheep produce milk for cheese manufacture.
Other provisioning services	Possibility of using tree foliage as livestock fodder. Food diversity helps sheep health and contributes to a better cheese quality.
Regulating services	The trees provide shade for the sheep in summer and shelter in the autumn. In mountain context; trees help to stabilize the snow and contribute to soil erosion prevention. The trees will increase carbon storage.
Key references	See end of report

Table 2. Description of the specific case study system

Specific description of site	
Area	3.6 ha
Co-ordinates	The site is located in the glacial valley of Louron in the municipality of Mont (42°49'03"N - 0°25'45" E; 8.41 km^2 - 41 inhabitants in 2012), near the Lake Génos-Loudenvielle in the Hautes-Pyrénées (65).
Altitude	1204-1255 m
Example photographs	

Map of system	
 The numbered blocks correspond to tree rows where all the trees have been inventoried and measured.	
Possible scenarios	
Comparison	Technical and economic analysis of variation in branches biomass of the pollarded trees according to the intensity of opening thinning.
Climate characteristics	
Mean annual temperature	Low monthly temperatures with an annual average of 6.6°C.
Mean annual precipitation	816 mm, distributed irregularly over the year, the maximum being observed in spring and secondarily in the fall, the minimum in summer with 184 mm in June and July.
Details of weather station (and data)	Data (1961-90) from "SILVAE – Système d'Informations Localisées sur la Végétation, les Arbres et leur Environnement, 2015.
Water balance	Despite the location of this dry valley, there is no sub-dry month as defined by Gaussen (P <3T), due to altitude.  Data (01/01/1960-31/12/1989) from the French Meteorological Office (Météo France) station of Loudenvieille (altitude : 985 m).

Soil type - This information is gathered during this research	
Soil type	The soil is slightly acid BRUNISOL (Baize 2009), characterized by the presence of coarse load horizon appearing in greater or lesser depth depending on the position of the soil profile on the slope. In a very localized manner, rocky outcrops appear on hilltops (west side of the site).
Soil depth	>70 cm
	 The soil profile is characterized by a high volume of the coarse particles. This volume is low to medium in the surface horizon (0-20 cm) and high in the middle horizon (20-60 cm) with at least 50% of gravel (35% weight) and pebbles. In the deeper soil horizon (60-100 cm), the coarse elements are still present without preventing the auger survey. This volume reduces the soil moisture reserves. This is compensated by the soil depth (more than 80 cm).
Soil texture	The soil profile has a silt sandy clay texture. It is dark brown (with a crumbly structure) in the surface horizon (in A), grayish brown (blocky sub-angular structure) in the intermediate horizon (S1) and yellowish brown in depth (S2). *This information is gathered during this research*
Additional soil characteristics	The soil is slightly acidic (pH = 5.0) without the presence of calcium in fine soil or in coarse elements. The soil profile is normally drained with no trace of hydromorphy.
Tree characteristics	
Date of planting	The lower part of the pastoral territory of Mont is located in an "intermediate zone" as defined by Bozzolo (2009). This natural mountainous landscape is ideal for forest expansion and growth. The ownership of these intermediate areas is mainly private. The ecological environment is particularly favorable to the spread of woody species and reestablishment and proliferation of pioneer species (hazel, birch, mountain ash, alder, boxwood), then followed by ash and oak trees. The natural rapid scrub encroachment, that may cause the loss of grassland area and landscape closure, is controlled by livestock. The terraces borders and the slope features of grazed meadow were not planted by humans but were naturally colonized by valuable hardwood species, creating a typical linear wooded landscape, called "bocage".
Species	The peak of the Pyrenean Bocage took place during the seventeenth and eighteenth century. The common ash (*Fraxinus excelsior* L.) is still the key. Its presence in the Pyrenees is attested by the pollen diagrams from the Neolithic era (Galop et al. 2002). This area has a high agroforestry potential, based on the use of hardwood species with high commercial or forage value. If the common ash is the ideal forage species, the list of all taxa is long (Métailié 2006a): *Populus nigra italica Populus, Quercus petraea, Q. pyrenaica, Q. pedunculata, Prunus avium, Tilia cordata, Alnus glutinosa, Salix, Acer* and *Fagus sylvatica. Castanea sativa.*
Inter- and intra-row spacing	Variable
Tree protection	None

Crop/understorey characteristics	
Species	Grassland, including *Lolium perenne*, *Poa pratensis and Festuca rubra.*
Management	Grassland management is complex because of labour deficits, narrow access networks and difficult mechanization on these small sloping terraces. Maintenance of pastures is done only by sheep.
Livestock management	
Species and breed	Sheep; Lacaunes.
Description of livestock system	Traditionally, the ewes will conceive in the autumn with lambing occurring in the spring. During the weeks immediately before lambing the sheep are often kept indoors. After lambing, the ewes and the lambs will be let free in the large wood pasture. The herds will go back indoors to be milked every evening. There is also a milking procedure in the morning. The farmers make the cheese every morning.
Date of entry to site	The entry of the sheep to the site is constrained by the snow which is present until April.
Animal health and welfare issues	Sheep need to be check daily to ensure health and welfare.
Annual mortality rate	-
Typical level of sheep production	-

5 Description of the tree component

5.1 Circumference at breast height

The frequency of different circumference at breast height classes is shown in Figure 1 and Table 3. In total 325 trees were measured on the experimental site. Trees in the hedgerows (Restricted growth) and isolated trees (Free growth) have respectively a circumference at breast height of 127 (± 32 SD) cm (n = 249) and 158 (± 32 SD) cm (n = 76).

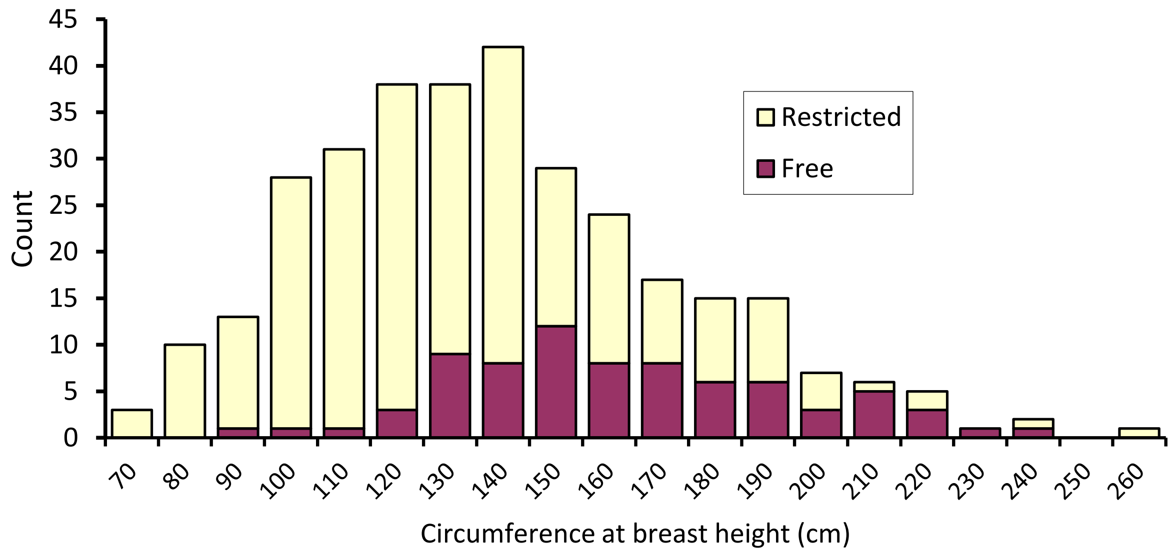


Figure 1. Effect of shading position on the frequency of different circumferences at breast height

Table 3. Frequency distribution of the circumference at breast height (130 cm)

	Free growth	Restricted growth	All
Number (n)	76	249	325
Mean circumference (cm)	158.5	127.39	134.67
Standard deviation (cm)	32.16	32.23	34.77
Minimum circumference (cm)	85	68	68
Maximum circumference (cm)	236	241	251

5.2 Tree height and branches

The mean tree heights of free- and restricted trees in shown in Table 4. Four types of trees are excluded (EXCLU) from this study:

- isolated trees;
- trees whose cutting is potentially harmful to the woodcutter (on steep slopes);
- non-pollarded trees;
- trees with dry branches [Total number of branches (NTBT) > Total number of live branches (NBVT)] (Table 5)

Table 4. Mean tree, trunk and crown height of trees with free- and restricted growth

	Free growth	Restricted growth	All
Mean tree height (m)	20.16	18.42	18.79
Standard deviation (m)	3.51	3.95	3.92
Mean trunk height (m)	5.12	4.88	4.93
Standard deviation (m)	1.61	1.64	1.63
Crown height (m)	15.04	13.54	13.86
Standard deviation (m)	3.24	3.51	3.50

Table 5. The number of live and total branches found on 73 restricted growth trees

Number of live branches	Total number of branches								
	2	3	4	5	6	7	8	9	10
2	18	3	2						
3		10	3	2	1				
4			12	3	1				
5				7	2	1			
6					3	1			
7						2			
8							1		1

5.3 Tree allometric equation measurements

Studies of tree biomass partitioning (including the weight of branches) in a temperate climate are rare (Lotfi 2008). The steps include i) felling a tree without leaves, ii) cutting the trunk and branches into small manageable pieces, ii) drying the wood in an oven, and iv) careful weighing (Walker et al. 2011). This destructive method is then used to develop allometric relationships.

An above-ground biomass allometric equation is a statistical model relating the components of a tree to parameters such as diameter at breast height (DBH), height of the tree (Feldpausch et al. 2011), or the height of the crown (Chave et al. 2005).

The collection of field and laboratory data necessary for quantifying the ground biomass of trees takes place in three phases (Bauwens and Fayolle, 2014):

- Phase 1 is an exploration phase, which is comprised of identifying the geographic location of trees corresponding to a previously defined circumference;
- Phase 2 corresponds to the collection of field data, a series of measures to be taken before and after tree harvest. Trees are harvested one at a time.
- Phase 3 corresponds to the collection of laboratory data, for this purpose various measurements will be carried out on subsamples (aliquots) from trees sampled in the field. These samples are weighed before and after drying in an oven at 105°C until a constant weight. The analysis of the data will also be conducted during Phase 3.

The protocol of data collection in the field and establishing tree biomass allometric equations are based on work done in tropical Africa (Bauwens and Fayolle 2014; Picard et al. 2012). Details of the measurements are described in Table 6.. They include total height, the circumference at a height of 1.3 m (CBH), and every 50 cm from ground to top of the trunk. The weight of the trunk and branches are also measured.

5.4 Variables

The protocol of data collection in the field and building tree volume and biomass allometric equations are based on work done in tropical Africa (Bauwens and Fayolle 2014; Picard et al. 2012).
16 trees will be harvested. The planned measurements to be taken are described in Table 6.. Letters [c], [l] and [f] respectively indicate that the variable is calculated, measured in the laboratory or measured in the field.

Table 6. List of measured and calculated tree variables

Variable	Abbreviation and formula	Unit
Tree		
[f] Reference circumference	C_{ref}	m
[f] Reference circumference height	H_{ref}	m
[f] Total height	H_{tot}	m
[c] Total woody aerial biomass	$B_{tot} = B_{Sa} + B_{La} + B_{Ba}$	kg
Stump		
[f] Stump height	H_S	m
[c] Wet stump volume	V_{Sw}	m^3
[l] Wet stump sample volume	v_{Sw}	m^3
[l] Wet stump sample biomass	m_{Sw}	kg
[l] Dry stump sample biomass	m_{Sd}	kg
[c] Infradensity of stump wood	$ID_S = m_{Sd}/v_{Sw}$	kg m^{-3}
[c] Water content of stump wood	$WC_S = (m_{Sw} - m_{Sd})/m_{Sw}$	%
[c] Dry stump biomass	$B_{Sa} = V_{Sw} \text{ x } ID_S$	kg
Log		
[f] Length of piece$_i$	l_{pi}	m
[f] Wet biomass of piece$_i$	m_{pi}	kg
[f] Top diameter of piece$_i$	d_{ti}	m
[f] Butt diameter of piece$_i$	d_{bi}	m
[c] Log length	$L_L = \Sigma_i \, l_{pi}$	m
[c] Volume of wet piece$_i$	$v_{pi} = (\pi \text{ x } l_{pi}/12) \text{ x } (d_{ti}^2 + d_{bi}^2 + d_{ti} \text{ x } d_{bi})$	m^3
[c] Wet log volume (if cubing)	$V_{Lw} = \Sigma_i \, v_{pi}$	m^3
[c] Wet log biomass (if weighing)	$B_{Lw} = \Sigma_i \, m_{pi}$	kg
[l] Wet log sample volume	V_{Lw}	m^3
[l] Dry log sample biomass	m_{Ld}	kg
[c] Infradensity of log wood	$ID_L = m_{Ld}/V_{Lw}$	kg m^{-3}
[c] Water content of log wood	$WC_L = (m_{Lw} - m_{Ld})/m_{Lw}$	%
[c] Dry log biomass (if weighing)	$B_{La} = V_{Lw} \text{ x } (1 - WC_L)$	kg
Branches		
[f] Length of piece$_j$	l_{pj}	m
[f] Top diameter of piece$_j$	d_{tj}	m
[f] Butt diameter of piece$_j$	d_{bj}	m
[c] Volume of wet piece$_j$	$v_{pj} = (\pi \text{ x } l_{pj}/12) \text{ x } (d_{tj}^2 + d_{bj}^2 + d_{tj} \text{ x } d_{bj})$	m^3
[c] Wet branches volume (if cubing)	$V_{cBw} = \Sigma_i \, v_{pj}$	m^3
[c] Wet branches biomass	B_{Bw}	kg
[l] Wet branches sample volume	v_{Bw}	m^3
[l] Wet branches sample biomass	m_{Bw}	kg
[l] Dry branches sample biomass	m_{Bd}	kg
[c] Infradensity of branches wood	$ID_B = m_{Bd}/v_{Bw}$	kg m^{-3}
[c] Water content of branches wood	$WC_B = (m_{Bw} - m_{Bd})/m_{Bw}$	%
[c] Dry branches biomass (if weighing)	$B_{wBa} = B_{wBw} \text{ x } (1 - WC_B)$	kg

6 Acknowledgements

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