Research and Development Protocol for Agroforestry for Ruminants in France

Project name	AGFORWARD (613520)
Work-package	5: Agroforestry for Livestock Farmers
Specific group	Agroforestry for Ruminants in France
Milestone	Milestone MS22 (5.3) Part of experimental protocol for WP5
Date of report	31 March 2015
Authors	Sandra Novak, JC Emile and E Pottier
Contact	sandra.novak@lusignan.inra.fr
Approved	13 April 2015 (John E Hermansen)

Contents

AGFORWARD (Grant Agreement N° 613520) is co-funded by the European Commission, Directorate General for Research & Innovation, within the 7th Framework Programme of RTD. The views and opinions expressed in this report are purely those of the writers and may not in any circumstances be regarded as stating an official position of the European Commission.

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 the second objective. It contributes to the initial research and development protocol (Milestone 22 (5.3)) for the participative research and development network focused on the use of agroforestry in ruminant systems.

2 Background

Integration of trees with crops and/or livestock production (agroforestry) has been identified as a sustainable way to increase the productivity of land and to provide a number of ecosystem services and environmental benefits compared to disaggregated agricultural and woodland systems (Jose 2009). In cattle production systems agroforestry may also improve animal welfare and provide additional fodder from trees and shrubs leaves (Broom et al. 2013). Trees could also impact the seasonality and spatial distribution of the understorey production, by buffering microclimate (Ryan et al. 2010) and by generating an uneven spatial distribution of nutrient deposition.

At present, agroforestry systems constitute only a minor part of the French ruminant husbandry. For their development, farmers need more information, especially on the way to establish a profitable agroforestry system, as they expressed during two stakeholders meetings held in Hucqueliers and Lusignan respectively on 1 July and 28 August 2014 (Pottier and Novak, 2014). They pointed out a lack of knowledge in regards to the following issues: i) nutritive value of trees and shrubs, ii) protection of new established trees, iii) spatial organization of trees and iv) understorey forage production. They also need information on the way to simplify and limit the additional work created by trees. This report gives an overview of the studies that will be undertaken to answer these demands.

3 Synthesise existing knowledge of 'best practice'

3.1 Objective

The first objective is to identify and communicate 'best practice' in relation to design and manage an agroforestry system for ruminant production. Guidelines on integrating trees and/or shrubs in grazing systems will be produced e.g. with regards to tree species, tree density, animal density and design of the system.

3.2 Materials and methods

Data, information and experiences gathered at commercial farms and research plots will be combined with theoretical knowledge. Five steps will be carried out as shown in Table 1.

Table 1. Collection of data, information and experience

Step	Activity	Time
Literature review	Literature from France and abroad will be reviewed. Existing knowledge will be analysed and discussed.	Until May 2016
Interviews	Interviews of producers, consultants and forestry/horticulture experts will be carried out	Jan-April 2016
WP5 skype meeting	Meeting with partners from AFBI, ORC and LBI	May 2016
WP 5 workshop	Workshop with partners from AFBI, ORC and LBI to compile collected knowledge from United Kingdom, Netherlands and France	May 2016 (General Assembly)
Publication	Producing report	August 2016

4 Nutritive value of fodder trees and shrubs

4.1 Objective

At the stakeholders meetings, many participants highlighted that one key issue for livestock farmers is to know the capacity of ligneous resources to contribute to ruminant diets, especially for feeding high level production dairy cows. Thus the objective of this study is to evaluate the feeding value of various fodder trees resources for ruminants, according to the tree species, management and stage.

4.2 Materials and methods

A wide range of resources, such as trees, shrubs or lianas, may be present in hedges or planted in rows. As is the case for herbaceous fodders, the stage of harvest needs to be investigated as well as the tree management (e.g. pollarding). In order to better allow comparisons, (meta-analysis) studies will be first restricted to the tree leaves. Feeding value is expressed through the chemical composition, the *in vitro* digestibility (enzymatic method). and the ruminal degradation kinetics. Particular attention is paid to the protein content, the fiber content (ADF-NDF-ADL) and the content of tannins.

Resources will be collected at our experimental site (tree collections, agroforestry systems, hedges) and also in the neighborhood since the agroforestry trees were only planted in February 2014. The main data collected, from sampling to chemical and biological evaluations, are given in Table 2.

A first set of 12 fodder trees or shrubs were taken in summer 2014 on leafy resources (Table 3). We also collected and analyzed two herbaceous forage controls (perennial ray grass and alfalfa - 6 weeks old regrowth) collected on the same period. Further analytical evaluations on this preliminary set are in progress. New samplings are planned for 2015 and 2016 involving around 20 species and taking into account the effect of season (spring, summer, autumn) and the effect of management (pollarding or not).

Table 2. List of data collected on the nutritive value of fodder trees

Process step	Data collected
Sampling	Location (geo-referencing), photo Date of sampling Weather conditions Stage of growth Type of management
	Description of the organ visual sanitary aspects photo Dry matter content
Pre-treatment	Drying parameters Lyophilization conditions Grinding parameters
Chemical composition	Crude protein content (Dumas method) Fiber content (ADF, NDF and ADL content) van Soest method Tannins content (Folin method – in progress)
In vitro digestibility	Enzymatic digestibility (Aufrère method)
Ruminal degradation kinetics	2 to 72 hours incubation in ruminal fistulated dairy cows Organic matter and protein kinetics parameters

Table 3 – Main characteristics of the 2014 summer samples

Common name	Latin name	Location (department)	Date	DM (%)
Ash	*Fraxinus excelsior*	Jazeneuil (86)	4 August	37.6
Italian alder	*Alnus cordata*	Melle (79)	5 August	36.9
Black alder	*Alnus glutinosa*	Jazeneuil (86)	4 August	37.3
Chestnut	*Castanea sativa*	Lusignan (86)	4 August	42.6
Field maple	*Acer campestre*	Lusignan (86)	4 August	51.5
Hazel	*Corylus sp*	Lusignan (86)	4 August	42.0
Large leave lime	*Tilia platyphyllos*	Azay le B (79)	5 August	36.5
Black locust	*Robinia pseudoacacia*	Lusignan (86)	4 August	39.8
Field elm	*Ulmus minor x resista*	Azay le B (79)	5 August	42.1
White mulberry	*Morus alba*	Vialas (48)	22 July	36.9
Red oak	*Quercus rubra*	Lusignan (86)	4 August	47.3
Vine	*Vitis vinifera*	Jazeneuil (86)	4 August	34.6
Perennial ray grass	*Lolium multiflorum*	Lusignan (86)	7 August	36.8
Alfalfa	*Medicago sativa*	Lusignan (86)	30 July	28.4

Figure 1. White mulberry and lime managed as pollards

Figure 2. Black locust and chestnut leaves (4 August 2014)

Data from these investigations will be published and fed into a common feeding value table developed by AGFORWARD partners and organized by Louis Bolk Institute.

5 Agroforestry dairy cattle demonstration plot in a research facility

5.1 Background

To devise and design a demonstration plot which addresses some major concerns that arose during the first Lusignan stakeholders meeting on 28 August 2014 and a second workshop was organized on 5 December 2014 with 10 stakeholders (Novak, 2014). The reflection was centred on dairy cattle farming with the possibility to establish an agroforestry plot on the dairy experimental facility of INRA in Lusignan. As a result, participants proposed to implement an experimental set-up that will test options relative to i) diversification of tree uses, ii) spatial organization of trees, and iii) protection of trees against livestock.

5.2 Objective

The objective of the demonstration plot is to produce information regarding different methods in terms of i) diversifying the use of trees, ii) optimizing the spatial organization of trees in the plot, and iii) protecting newly established tree rows against livestock. The overall objective is to optimise both woody and herbaceous forage production, while contributing to animal welfare and limiting the load and complexity of work induced by tree establishment.

5.3 System description

The trial will take place in a 3.0 ha paddock located at the experimental facility of INRA in Lusignan (Vienne, France). The plot is part of the grazed acreage of the OasYs system experiment (Novak and Emile 2014), and is engaged in a rotation consisting of five years of temporary pasture and two years of annual forage crops. Further details on the system are given in Table 4.

Table 4. Description of the site, with soil, tree, understorey, livestock, and climate characteristics.

Site characteristics	
Area:	3.0 ha
Coordinates:	46°25'12,91"N; 0°07'29,35"E
Site contact:	Sandra Novak
Email address	sandra.novak@lusignan.inra.fr

Soil characteristics	
Soil type (WRB)	Dystric cambisol
Soil depth	90 cm
Soil texture	loamy (25.3 % sand, 57.8 % silt, 16.9 % clay)
Additional soil characteristics	developed from loamy parent material of unknown origin over red clay; characterized by vertical tongues (Chabbi et al. 2009)
Aspect	Flat

Tree characteristics		
System	Agroforestry system	Reference system*
Date of plantation	17 February 2015	No tree
Tree species	High stem trees: pear, honey locust, service tree Pollards: white mulberry, Italian alder Coppiced trees: goat willow, field elm, black locust, grey alder The following will also be planted in 2016: liana beside pollards, and various shrubs and perennial species to create a "fodder hedge"	
Tree row spacing	20 m	
Tree row set (width)	single (2 m) , double (6 m) or triple (10 m)	
Tree protection	Single or double line of electric fence, electric fencing tape, metal or plastic fences, repellents	
Additional details	Details on the spatial organization are given in Figure 4	

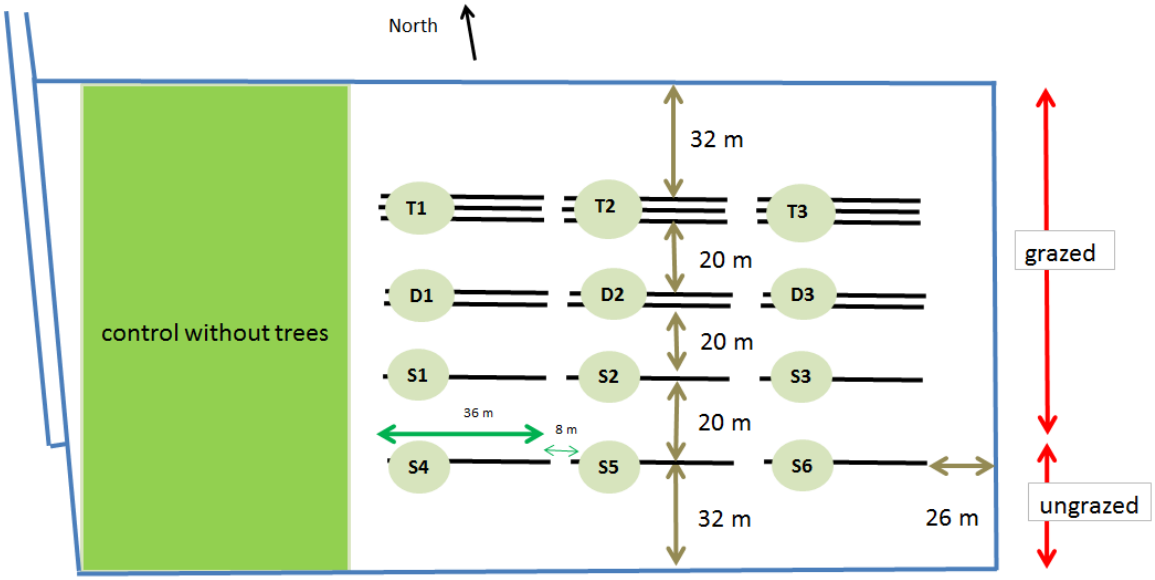
Understorey characteristics	
System	Agroforestry and reference system
Species	Crop-grassland rotation
Coverage	Complete
Additional details	Herbaceous layer is managed by grazing with dairy cows or heifers, or by mechanical harvesting (for one option)

Livestock characteristics	
System	Agroforestry and reference system
Species	Holstein cows
Stocking density	24 cows ha^{-1}
Grazing management	rotational grazing

Climate data	
Mean monthly temperature	10.5 °C
Mean annual precipitation	900 mm

* To which the agroforestry system is compared

The experimental design is illustrated in Figure 3 and Figure 4. It combines different options of diversification of tree uses, spatial organization and protection that are detailed on the next page.



S=single row set ; D = double row set ; T = triple row set

Schematic representation of one 36 m unit

Pol HS Pol Pol Pol HS Pol Pol Pol Pol

Pollard
High stem tree

Figure 3. Schematic representation of the experimental site

Figure 4. Photo of the experimental design

Diversification of tree uses will be tested with various ligneous resources of different species, managed with different pruning techniques, mixed on the same row.

- High stem trees (pear, honey locust or service tree) will allow providing timber, fuelwood, wood chips for litter or as soil amendment, shade and fodder.
- Pollards will allow providing fodder but also wood chips for litter or as soil amendment, timber or fuelwood.
- Coppiced trees, liana and fodder hedge will be used as fodder or wood chips.

Three spatial organizations of trees are tested with single, double or triple-row sets.

Six types of protection are considered to protect the newly established tree rows against livestock:

- one option consists to exclude the paddock from livestock grazing by harvesting mechanically the alley forage cover the first years of plantation,
- the other protection types used in the grazed part of the plot are: single or double line of electric fence, electric fencing tape, metal or plastic fences or repellents.

Further details are given in Table 5 and Figure 5.

Table 5. Description of the combination of row set, spatial organization and protection types.

Row set	Spatial organization	Protection
Single row		
S4-S5-S6	Pollards x high stem trees x coppiced trees	No protection (ungrazed)
S1		Electric fencing tape
S2		Repellents
S3		Single electric fence
Double row		
D1	Pollards x high stem trees	Single electric fence
D2	Coppiced x high stem trees	
D3	Pollards x high stem trees x coppiced trees	
Triple row		
T1	Pollards x high stem trees x Coppiced trees x fodder hedges	Plastic fence
T2		Double line of electric fence
T3		Metal fence

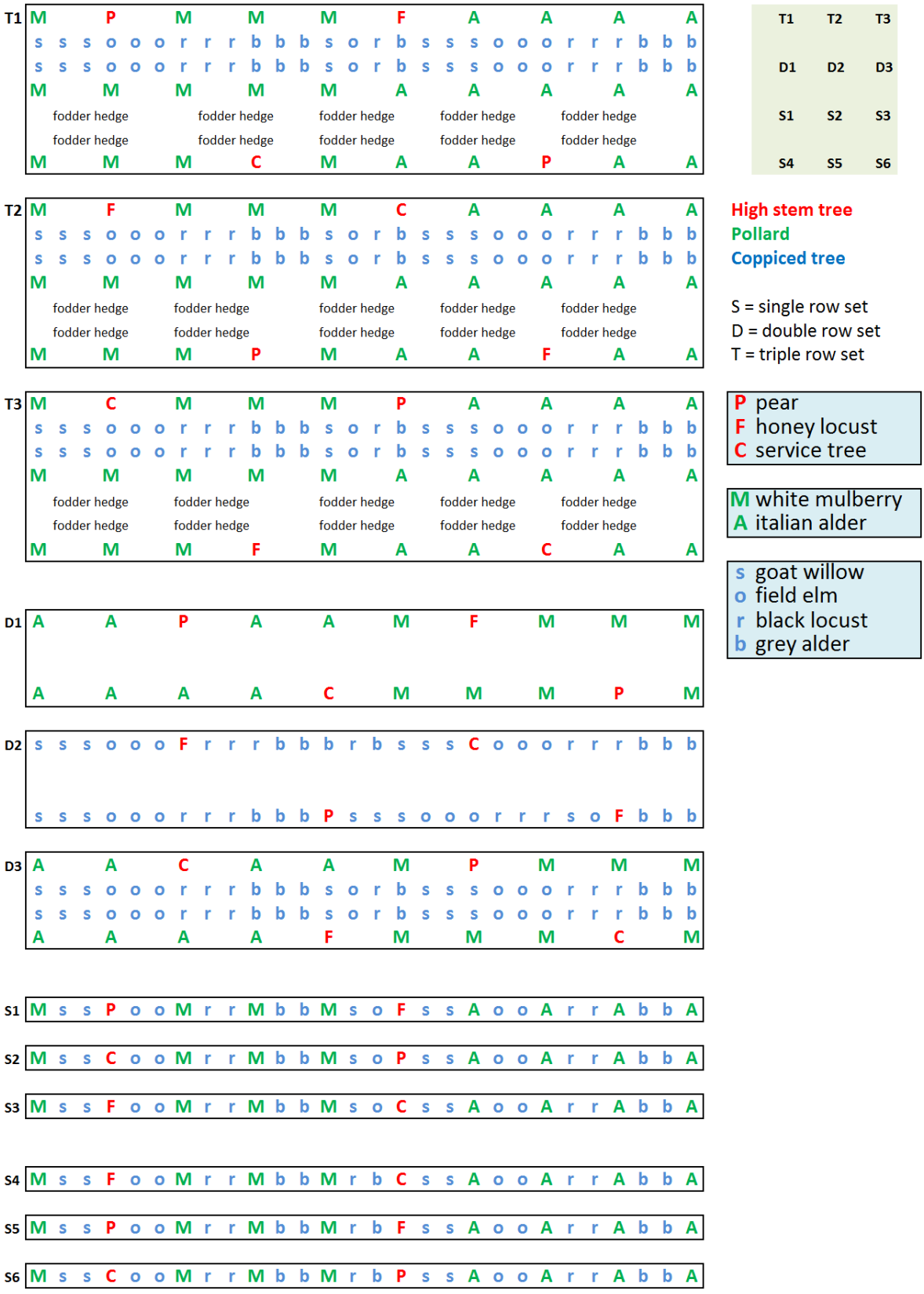


Figure 5. Species location on the experimental design

These different methods will be evaluated regarding their overall technical and economic results (Table 6), during the time of the AGFORWARD project but also beyond.

Table 6. List of observations

Variable	Observation and measurements
Farm work	Work load relative to tree planting, protection, maintenance and management Work load relative to the management of the understorey present in inter-row alleys (by grazing or mechanical harvesting) *vs* a plot without tree rows
Farm economy	Costs relative to tree implementation and maintenance
Animal behaviour	Behavioural observations (e.g. individual and collective movement in the plot)
Protection efficiency	Visual evaluation (photographs) of tree damages
Grazing management	Number of grazing days, cattle numbers
Tree growth	*To be determined*
Tree production	Beyond the time period of the project we will evaluate the quantity and quality of forage, timber and the biomass of fuelwood and wood chips
Understorey production	Grassland and crop production (agroforestry plot *vs* control without trees)
Nutrient deposition	Distribution of dung patches (agroforestry plot *vs* control without trees)
Climate	Air temperature, precipitation, wind speed etc. will be automatically recorded every hour at an adjacent meteorological station

6 On-farm experiment on grass growth

6.1 Objective and hypothesis

The objective here is to study the impact of trees on the herbaceous forage production. The impact of an agroforestry system on the production of grassland is currently poorly documented. It can be assumed that trees will induce negative impacts of competition as well as positive impacts by the role of thermal regulation that trees can play. This experiment aims to quantify the impact of trees on the understorey forage production depending on the season and climate.

6.2 Materials and methods

The proposed site is in the west of France. Experiments on two mature fields with agroforestry trees and on controls without trees will be conducted for two whole years to assess the grassland productivity. An assessment of the effects on flora will also be performed. On each plot two zones of exclosure will be installed and, in each, 4 samples will be collected at specific distances rows of trees. A similar system will be set up on the control. In total, 16 samples that will be made at each time (Figure 6).

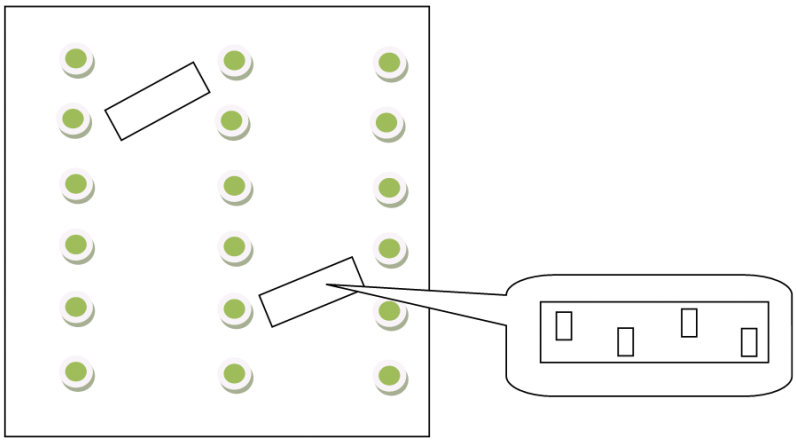


Figure 6. Diagram of sampling devices on agroforestry plots

The samples will be carried out five times each year at specific times:
In the spring: defined on the basis of the sum of temperature reached, in order to capture the growing momentum.
Summer and autumn: the regrowth time for a minimum grass height of 8 cm
Winter: at the end of January

At each sampling date simplified flora composition measurements will be made in quadrats at the four areas identified samples (grass proportions and various legumes, and grasses stages of development) (Table 7). Grass samples will then be collected in four frames on each zone. Grass heights are measured before and after each sampling. Each sample is then stored in order to analyse food values. For conservation each sample is dried (60°C for 72 hours).

Table 7. List of measurements

Variable	Measurements
Production	Grass height Biomass Dry matter
Flora	Cover of gramineae, legumes and other species. Development stage
Climate	Air temperature, precipitation, wind speed will be automatically recorded every hour at an adjacent meteorological station

7 Acknowledgements

The AGFORWARD project (Grant Agreement N° 613520) is co-funded by the European Commission, Directorate General for Research & Innovation, within the 7th Framework Programme of RTD, Theme 2 - Biotechnologies, Agriculture & Food. The views and opinions expressed in this report are purely those of the writers and may not in any circumstances be regarded as stating an official position of the European Commission.

8 References

Broom, D.M., Galindo, F.A., Murgueitio, E. (2013). Sustainable, efficient livestock production with high biodiversity and good welfare for animals. *Proceedings of the Royal Society B: Biological Sciences* 280.

Chabbi, A., Kögel-Knabner, I., Rumpel, C. (2009). Stabilised carbon in subsoil horizons is located in spatially distinct parts of the soil profile. *Soil Biology and Biochemistry* 41: 256-261.

Jose, S. (2009). Agroforestry for ecosystem services and environmental benefits: an overview. Agroforestry Systems 76 : 1-10.

Novak, S. (2014). Compte rendu du séminaire de co-conception du 5 décembre 2014. INRA Lusignan, 8 p. (in French).

Novak, S., Emile, J.C. (2014). Combining analytical and systemic approaches for developing an innovative dairy system: from the Fée to the OasYs. *Fourrages* 217: 47-56.

Pottier, E., Novak, S. (2014). Initial stakeholder meeting report – agroforestry with ruminants in France. http://www.agforward.eu/index.php/en/agroforestry-with-ruminants-in-france.html