Initial report on studied innovations of agroforestry for livestock farmers

Project name	AGFORWARD (613520)
Work-package	5: Agroforestry for Livestock Farmers
Milestone	Milestone 23 (M5.4) Initial report on studied innovations of agroforestry for livestock farmers
Date of report	20 January 2017
Authors	John E. Hermansen, Jo Smith, Monique Bestman, Boki Luske, Sandra Novak, Anne Grete Kongsted, Maria Rosa Mosquera Losada, Valerio Bondesan
Contact	John.hermansen@agro.au.dk
Approved	Paul Burgess (4 April 2017)

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

Integration of trees with livestock production can be a sustainable way to increase the productivity of land and to provide greater ecosystem services and environmental benefits than disaggregated agricultural and woodland systems. However, very little data are available regarding silvopastoral agroforestry systems and there is lack of knowledge on how such systems are constructed and managed, and how they perform in relation to farm profitability and delivering public goods.

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 third objective in relation to a Participative Research and Development Network (PRDN) that focuses on agroforestry for livestock farmers (Work-package 5). The reports cover three sectors (poultry, pig- and ruminant systems) as each has its own specific user-groups and constraints. The preliminary results of innovations are presented in this milestone in order to prepare the best way of synthesising and disseminate results.

2 Overview of systems

Eight systems were described in Deliverable 5.13 (Hermansen 2017). Innovations have been implemented in this systems and different evaluations and tests have been performed. The systems include two poultry agroforestry systems which focus on egg production, three systems including pigs, and three systems including cattle. An overview is presented in Table 1.

Table 1. Overview of silvopastoral systems in which innovations have been implemented and the key ecosystems provided

Livestock species and country	Tree species	Ecosystem services			
		Provisioning		Regulating	Cultural
		Livestock products	Tree products		
Poultry					
The Nether-lands	Fruit trees, willow	Eggs	Fruit (table and juice)	Shelter for hens, biodiversity, reduce nutrient leaching,	Diversified jobs
UK	Native broad-leaves and conifers	Eggs	Wood chips for bioenergy	Shade and shelter for hens, functional biodiversity, N-fixation	Jobs, diversified land-scape
Pigs					
Italy	Poplar, willow, chestnut	Pork meat	Timber, wood-chips for energy or for bedding-rooting materi-al	Reduce risk of nutrient leaching, shade and shelter for pigs	Jobs (alleviate aban-donment of land), diversified landscape
Spain	Mulberry	Pork meat	Feed (proteins)	Reduce tempera-ture fluctuations, carbon sequestra-tion, biodiversity	Jobs
Denmark	Poplar and willow	Pork meat	Woodchips for energy or for bedding-rooting material	Reduce risk of nutrient leaching, shade and shelter for pigs	Diversified landscape
Ruminants					
France	White mulber-ry, Italian alder, pear, honey locust, service tree, goat willow, field elm, black locust, grey alder	Milk, meat	Feed (leaves) , wood chips (bioenergy) timber	Shade and shelter for livestock, nutri-ent cycling, nitro-gen- fixation	Diversified landscape
The Nether-lands	Willow, alder	Milk	Feed (leaves) , wood chips (bioenergy)	Drainage, shade, N-fixation, biodiversi-ty	Jobs, diversified land-scape
UK	Willow, pop-lar, hazel, alder	Meat, milk	Feed (leaves), wood chips (bioenergy)	Shade and shelter for livestock, nutri-ent cycling, nitro-gen- fixation , functional biodi-versity	Jobs, diversified land-scape

3 Preliminary results and lessons for poultry agroforestry

In three plantations in the Netherlands planted in spring 2013 and integrating poultry, the best practices were evaluated for fruit trees, biomass willows and miscanthus, respectively (Bestman 2017). In the UK different type of understorey sward mixtures were evaluated regarding establishment and development in plantations of native broadleaves and conifers (Smith and Westaway 2016).

3.1 Main results and lessons

The main results from the measurements in two commercial apple orchards in commercial free-range poultry systems were:

- Fruit trees and poultry combine well during the first years after establishment of the orchard: good harvests can be achieved.
- If fruit is grown in a free-range poultry area, measures are needed to compensate for the effect of the chickens e.g. a need for cheaper/robust trees more close to the poultry house in relation to soil management and drainage.
- In organic apple orchards, apple scab can increase over time. Perhaps chickens can be of use by eating the leaves or speeding up decomposing the leaves in autumn and winter.

Preliminary results from biomass willows indicate the following:

- During the first 3 months after tree planting, chickens need to be kept out of the young trees; the free range area should be sufficiently large to ensure that this is possible.
- During the first 6 months after tree planting, weeds need to be controlled (mechanically) as the small willow cuttings have limited capacity to compete for water and nutrients.
- Once big enough, the willow plantations are very attractive to the chickens. The establishment of a willow area can encourage the chickens to move up to 200-300 m from the poultry house.
- The branches could be harvested every 2 to 4 years. However, since special machinery is needed for this and which was not available yet, it took some time before the first harvest was done. The harvest was done by a small company that used the branches for braiding decorative garden fences.

Preliminary results from the miscanthus indicate the following:

- During the first month after tree planting, chickens need to be kept out of the young plantation.
- During the first year, nearly 60 hours/year labour was needed for both mechanically and manually weed control. In the second year this was 30 hours.
- Miscanthus can be harvested yearly in March, before the new stems become too large to fit in the harvesting machine. The first harvest (one year after establishment) the material was left on the land. The 2nd harvest (two years after establishment) of nearly 6 t ha^{-1} was used as litter for poultry and pigs.
- The miscanthus plantation was very attractive to the chickens. They went much further from the poultry house than when the miscanthus was not there.

Preliminary results regarding improved understorey swards in silvopoultry system with native broadleaves and conifers show the following:

- All of the tested shade tolerant and diverse (including herbs) sward mixtures established well under trees with no significant differences in productivity. Hence the commercially available "standard" sward mixture performs as well as those containing more specialized plant species and varieties which are likely to be more expensive.
- Although the difference was not significant, the "standard" sward mixture produced the highest biomass. Hence the lowest cost sward resulted in the highest sward productivity.
- It typically took about four weeks after sowing to establish a competitive sward (in terms of weed control).
- Initially these was no significant effect of sward mixture on weed abundance in the first six weeks, however this may change with time and further assessments are being undertaken.
- The performance of the mixtures in the presence of chickens is currently being investigated. In two of the blocks the chickens have been given access to half of each treatment plot and survival rates of the different plant species will be assessed in spring 2017. In a third block, half of each treatment plot was cut with a strimmer in August 2016 to investigate management options.

3.2 Framework for dissemination

Key messages to be included in a briefing sheet regarding poultry agroforestry systems are presented in Table 2.

Table 2. Themes and potential messages to be included in a briefing sheet regarding poultry agroforestry systems

Managing woodland chicken systems	Content
Introduction	Benefits to chickens – animal welfare, productivity. Benefits to environment. Potential for tree products.
Planning and establishing a new system 1. Focus fruit trees 2. Focus willow 3. Focus Miscanthus	Tree species, system design, planting, tree protection and harvesting.
Managing trees and the understorey	Tree management, understory management

4 Preliminary results and lessons for agroforestry with pigs

The agroforestry pig system in Denmark and Italy concerns inclusion of poplar and willow for biomass production with the aim to reduce nitrogen leaching from the paddocks and improve animal welfare. A major issue here is how trees are protected against damage from the foraging pigs (Kongsted, 2016; Bondesan, 2017). In Spain the work is focusing on a novel way to find supplemental feeds for high quality pig production in forest areas where chestnut and oak trees are dominant (Mosquera-Losada et al. 2016).

4.1 Main results and lessons

Experiences and preliminary results from measurements and observations in a pasture based system with lactating sows and growing pigs in paddocks with poplar indicate the following:

- Lactating sows use the trees for grooming (e.g. rubbing) and bite off some of the smaller branches. Individual trees can suffer from severe bark damage, but the trees recover surprisingly well during a year without pigs.
- Poplar trees should be established at least four years before providing access to sows to prevent destruction. Piglets can have access after two years (if they are weaned at 7-8 weeks) without destroying the trees. The piglets' characteristic rooting behaviour reduces the need for supplementing weed control.
- During hot weather, the lactating sows use the shade from the trees when they are outside the farrowing hut, however lactating sows with access to trees do not seem to spend more time outside the hut than sows without access to trees.
- Two rows of 4-year old poplar trees in each paddock established with 3 m intra- and inter-row spacing are not enough to prevent sunburn of lactating sows under Danish conditions.
- Nutrient surpluses in paddocks with lactating sows are often very high mainly due to high nutrient inputs from concentrated feed. Calculations of N balances at paddock level reveal that removal of N from tree biomass (20% tree cover in each paddock) are not enough to counteract the high surpluses even if the trees (including leaves) are harvested once every year.
- When the trees are placed at the end of the lactating paddock, a large proportion of the urine and faeces is deposited outside the tree area. We expect that the majority of the urine and faeces would be deposited in the tree area if the trees were placed in the middle of the paddock with the main resources (hut and feed) placed on each side of the tree area as described in Horsted et al. (2012).
- Growing pigs cause considerable damage to two year-old poplar trees unless these are protected e.g. 7% of planted trees died after two years use.
- Among four different types of trees protection a cage shelter made of a thin metal wire (as compared to different layouts of plastic based product) was most resistant to damage from the pigs and resulted in no damage to the trees. The product was also the cheapest and had the best adaptability to the growth of the trees, but was more labour demanding to install.

Preliminary results from fodder trees evaluation

- The four tested mulberry clones showed a good survival rate after a year of being planted.
- The Galician clone of *Morus alba* (IL) was the clone that showed the greatest height, followed by *Morus alba* var. criolla (CR), *Morus alba* var. tigrenda (TI) and Galician clone of *Morus nigra* (MN). IL has also showed the highest basal and crown diameter and highest dry matter yield

when compared to the other mulberry clones. The differences found between the clones growth could be explained as the plant material for the *in vitro* propagation of the IL clone was collected in the same area as the experiment and therefore this clone could be better adapted to the specific local conditions of the experimental site.

- There were no significant differences in protein content between clones

4.2 Framework for dissemination

Key messages to be included in a briefing sheet regarding the agroforestry for pigs systems are presented in Table 3.

Table 3. Themes and potential messages to be included in a briefing sheet regarding agroforestry for intensive free-range pig production

Sows and growing pigs on pasture with willow or poplar	Content
Introduction	Farrowing/lactating sows and growing pigs, risk of nutrient leaching, animal welfare
Tree species and tree protection	• No large differences in tree damages between willow varieties ('Jorr', 'Bjorn') or between tree species (poplar, willow) in an experiment with growing-finishing pigs (Horsted et al. 2012). No different between two clones of polar (Bondesan 2017) • Cutting all branches in 1 m height seems to reduce tree bark damages of poplar trees. Further, it reduces the risk of sows using the branches as nest material in the farrowing huts. The latter may increase the risk of piglet mortality because the piglets' mobility inside the hut is inhibited the first hours after birth. • Equipment for tree protection.
Tree and animal density	• Tree density for optimum shade • Poplar established with approximately 3 m intra- and inter-row spacing work well with regard to weed control, but the shadow and shelter effects are limited the first 5-6 year compared to e.g. willow. • An experiment with growing-finishing pigs in willow and poplar indicate more root damage at high stocking densities compared to low densities (Horsted et al. 2012). • Stocking rate and risk for N leaching
Spatial arrangement of the different elements (trees, paddock, feed and water	When the trees are placed at one end of a rectangular shaped lactation paddock, a large proportion of the faeces and urine in deposited outside the tree zone . We expect that a larger part of the urine and feces will be deposited in the tree zone if the trees are places in the middle of the paddock with the main resources (hut and feed) placed on each side of the tree area as described in Lao (2015) and indicated in Horsted et al. (2012).
Morus alba production for supplementary feed	Content
	Choice of clones Feeding value

5 Preliminary results and lessons for agroforestry with ruminants

The work in France focussed on i) the diversification of tree use, their spatial organization, and the protection of newly established trees in systems with grazing cattle and ii) the evaluation of the feeding value of various fodder trees resources for ruminants (Novak et al. 2016). In the Netherlands the focus was on using willow (*Salix viminalis*) and alder (*Alnus glutinosa*) as 'Fodder trees' which the cows could use for three dimensional grazing according to their preference and nutritional needs (Luske et al. 2017).

5.1 Main results and lessons

Experiences and preliminary results from measurements and observations in the demonstration plot designed with stakeholders and established in February 2015 in France are summarized below. The results of the feeding value of fodder trees are summarized in Table 5.

Tree damage

- 11% of the high stem trees and future pollards were damaged and 4% died at the end of 2015, whereas 14% of the future coppiced trees were damaged and 21% died, black locust being the most damaged species (nearly 40% of loss).
- Voles were the major reason for tree damage at this stage. Dairy cows only contributed to the tree mortality on one trial.

Efficacy of tree protection

- Electric fence, electric fencing tape and metal fence were very efficient in protecting trees from cow damage during the 2015 and 2016 grazing periods.
- Four olfactory repellents were tested in 2015: garlic essence, spirit vinegar, a repellent for deer used by hunters (which is a mixture of spices and NPK fertilizer) and fresh cow dung. They turned out to be ineffective from the first day of grazing, either when they were sprayed directly on the trees (at the first grazing) or on the wood chips around trees (at the second grazing period).
- In 2016, all trees were replanted and equipped with new stakes and mesh guards. A new repellent called "trico" based on sheep fat and used against wild deer was applied on the half of this tree row (the other part being untreated). A barrier tape was reinstalled along the tree row. During the 2016 grazing period, some cows played with mesh guards and browsed some branches of few trees (essentially on the part without repellent) but no tree was considered to be damaged at the end of 2016. The cows frequently used the two poles equipped with brushes as rubbing posts and apparently they did not use the stakes anymore for rubbing in 2016.

Effect of the spatial organization of trees

- As indicated above, the mortality of coppice (21%) was five times higher than for future pollards and high stem trees (4%). As the coppice seedlings were planted closer than pollards or high stem trees (1.3 m compared to 4 m), the hay litter surrounding the seedlings may have attracted increased damage by deer and voles.

- Brushing the vegetation was trickier for coppice planted between two tree rows of high stem trees and pollards, especially as the grass sward included chicory which grows higher and faster than trees.
- The triple row sets required a longer time to mechanically control the vegetation on tree rows and the planting costs were higher than for double and single row sets. However when considered relative to the number of tree seedlings, double and triple row sets become more beneficial than single row sets. Double and triple row sets open opportunities not offered by single row set, for instance the mix of different tree uses. It should be noted that the plan is now for new woody species to be planted in triple row sets.

Experiences regarding willow (*Salix viminalis*) and alder (*Alnus glutinosa*) to serve as 'fodder trees' in the Netherlands showed:

- In this trial, the dairy cows preferred to browse the willow (in general) than the alder trees. Just a couple of browsing marks were found on the alder trees, where in some rows all willow twigs within reach of the cows were browsed. However it should be noted that the alder trees were not in the best condition as the leaves were eaten by beetles of the species *Agelastica alni.* This may have reduced the palatability of the leaves and twigs.
- Tree morphology (affected by cultivar and management) defines whether or not a willow tree can be used for three dimensional grazing by dairy cows.
    - Not all willow cultivars are suitable as a fodder tree for dairy cows. Cultivars especially selected for biomass production grow too fast and new shoots quickly become too thick at browsing height.
    - Willow cultivars with wide tree morphology appear to be the most suitable 'fodder trees'. They need less intensive management for fodder management than tall erect willow cultivars. As dairy cows have many twigs within their reach, they can browse those and prune in a natural way.
    - Fast growing willow cultivars need to be managed as a 'fodder hedgerow' instead of a 'fodder tree'. They need more intense management, but they may have the advantage of both producing biomass and providing fodder. Harvesting the tree biomass every year promotes the development of new palatable shoots, twigs and leaves within browsing reach of dairy cows.
- The levels of important minerals for dairy cows are promising. As expected, the intake of browse material is small: 0.6 and 0.4% of the required dry matter intake for dry and lactating cows respectively. Nevertheless, the intake of for instance potassium (Na), zinc (Zn), manganese (Mn) and iron (Fe) is reaching up to 2-9% of the daily requirements.
- The soil samples show that tree species significantly affect soil parameters like earthworm biomass and soil water content.

5.2 Framework for dissemination

Key messages to be included in a briefing sheet regarding agroforestry for ruminants and dealing with the protection of new established trees and their spatial organization as well as preference and nutritive value of tree leaves are presented respectively in Tables 4 and 5.

Table 4. Themes and potential messages to be included in a briefing sheet regarding agroforestry for cattle production systems, and dealing with the protection of new established trees and their spatial organization

Paddock design for cattle	Content
Introduction	In cattle production systems, agroforestry may deliver a wide range of agroecosystem services, and provide advantages for cattle (welfare, supply of forage and wood products such as timber, woodchips and fuelwood). Farmers need information regarding the protection of new established trees and their spatial organization.
Tree protection	Several types of protection can be used, depending on the farmer preferences in terms of cost, installation time and facility of the mechanical control of the tree row. Electric fence and electric fencing tape are quick installed and facilitate the mechanical control of the vegetation, but they are relatively expensive. Metal fences are cheaper and offer the opportunity to be used as trellis for lianas but it needs more time to be installed and it complicates the control of the vegetation on the tree rows. Olfactory repellents such as garlic essence, spirit vinegar, a repellent for deer used by hunters, and fresh cow dung are not efficient in protecting trees from cow damage. Installing poles with brushes (to be used as rubbing posts) and a barrier tape along the tree row seem to be efficient to prevent cattle from damaging the trees of single row set (results to be confirmed in 2017). This solution presents the advantage of being cost and time-efficient and of requiring less control of the vegetation on the tree row. Another interesting option is if the farmer has the possibility of excluding the paddock from grazing during the first years of the establishment phase, because it has the advantage to involve no additional cost to protect trees from cow damage. In all cases it seems necessary to use strong (e.g. mesh guards) individual tree protections and chestnut stakes to limit the damage of deer. The additional use of wild deer repellents (e.g. trico) is also recommended.
Spatial organization	Grazing is not complicated by the tree rows, but the establishment of trees induces a loss of grazed surface area that increases with the number of rows in the set, and that will only be recovered when the trees will be exploitable. However when considered relative to the number of tree seedlings, double and triple row sets could become more beneficial in terms of time needed to control the vegetation on the tree rows and on costs. Double and triple row sets also open opportunities not offered by single row set, for instance the mix of different tree uses.

Table 5. Themes and potential messages to be included in a briefing sheet regarding the nutritive value of tree leaves for ruminants

Nutritive value of tree leaves	Content
Introduction	Leaves from hedgerows, coppices, shrubs, or pollarded trees may become a forage resource for livestock during periods of low grasslands production (summer and autumn), either directly by browsing or fed after cutting. The lack of data on the nutritive value of this unusual forage is an important limitation to their adoption in forage systems of oceanic regions.
Choice of tree species	Preferences Digestibility (The digestibility ranges from less than 50% in holm oak and black locust to more than 75% in ash and white mulberry) Secondary compounds Mineral and micro-nutrients Protein content (the crude protein concentration varies from less than 85 g kg^{-1} in holm oak to more than 220 g kg^{-1} in black locust, chestnut, ash and white mulberry) . Effects on soils and biodiversity
Some trees are of higher quality than classical forage	White mulberry (*Morus alba*) and common ash (*Fraxinus excelsior*) have sufficient digestibility and nitrogen degradability to be included in the diet of lactating cows in mixed crop-livestock systems. Their quality is higher than those of grasses or lucerne in summer. Other species such as lime, elm, Italian alder, chestnut and black locust seem also potentially interesting to feed ruminants.
The type of management of the tree affects its feeding value	Leaves collected on pollarded or coppiced trees seem to be of higher value than leaves coming from high stem trees. Direct browsing would then be a promising management mode to valorize these leaves while saving time and energy. However it implies to be vigilant on the way to protect the tree from an excessive defoliation. The effect of season has a lower impact on trees than on herbaceous forage.

6 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.

7 References

Bestman M (2017). Agroforestry for organic egg production in the Netherlands, preliminary results. Internal report for AGFORWARD project.

Bondesan V (2017). Agroforestry for free-range pig production in Veneto Region, Italy, preliminary results. Internal report for AGFORWARD project.

Hermansen J (2016). Agroforestry for livestock farmers: synthesis of system descriptions. Deliverable 5.13 (5.1) for AGFORWARD project. 21 May 2016. http://www.agforward.eu/index.php/en/describing-agroforestry-systems-for-livestock-farmers-a-summary.html

Horsted K, Kongsted AG, Jørgensen U, Sørensen J (2012). Combined production of free-range pigs and energy crops – animal behavior and crop damages. Livestock Science 150:200-208

Kongsted AG, Hermansen JE (2016). Agroforestry for free-range pig production in Denmark, preliminary results. Internal report for AGFORWARD project.

Lao EJ (2015). Combined free-range piglets and energy crop production: Impact on nitrate leaching. Master thesis, Dept. Agroecology, Aarhus University.

Luske, B, van Eekeren N, Vonk M, Kondylis AA (2017). Agroforestry for ruminants in the Netherlands, preliminary results. Internal report for AGFORWARD project.

Mosquera-Losada RM, Dominguez NF, Lorenzo JLF, Hernandez PG, Rodriguez AR (2016). Fodder tree evaluation in Galicia, Spain, preliminary results. Internal report for AGFORWARD project.

Novak S, Emile J-C, Ferlus UE, Pottier E (2016). Agroforestry for ruminant systems in France, preliminary results. Internal report for AGFORWARD project.

Smith J, Gerrard C (2016). Agroforestry for ruminants in England, preliminary results. Internal report for AGFORWARD project.

Smith J, Westaway S, Kling C (2016). Poultry agroforestry systems in the UK, preliminary results. Internal report for AGFORWARD project.