Agroforestry for livestock farmers: Results of innovations

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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 Deliverable 5.14 (5.2) contributes to the second objective in that it provides a summary of eight reports which individually describe the results of the innovations studied across eight stakeholder groups in a participatory research and development network focused on agroforestry for livestock farmers. Similar reports have been produced for the networks focused on agroforestry of high nature and cultural value, agroforestry with high value trees, and agroforestry for arable farming.

2 Overview

Table 1 provides an overview of the lessons learnt report for innovation activities related to poultry, pig and ruminant systems.

Table 1. Titles and references for the lessons learnt reports related to agroforestry for livestock farmers

Group	Title of report	Reference
Poultry	Agroforestry for organic and free-range egg production in the Netherlands	Bestman (2017)
	Poultry agroforestry in the UK	Smith et al. (2017a)
Pigs	Agroforestry for free-range pig production in Denmark	Kongsted et al. (2017)
	Agroforestry for free-range pig production in Veneto Region, Italy	Bondesan and Ricardi (2017)
	Fodder tree evaluation in Galicia, Spain	Mosquera Losada et al. (2017)
Ruminants	Agroforestry for ruminants in the Netherlands	Luske et al. (2017a)
	Agroforestry with ruminants in France	Novak et al. (2017)
	Agroforestry for ruminants in England	Smith et al. (2017b)

3 Results of agroforestry innovations for poultry systems

Studies in the Netherlands focused on best practices in combining poultry with fruit and nut trees, biomass willows and miscanthus. In the UK different types of understorey sward mixtures were evaluated regarding establishment and development in plantations of native broadleaves and conifers. Table 2 shows the focus of the innovations, the partners involved and the type of work.

Table 2. Focus of agroforestry innovation activities related to poultry systems

Activity	Partner(s)	Type of work
Poultry combined with fruit trees	Louis Bolk Institute; Netherlands	Analyses from existing farm network
Poultry combined with biomass trees	Louis Bolk Institute Netherlands	Analyses from existing farm network
Shade tolerant sward mix.	Organic Reseach Centre, UK	Comparative study with different understory in native broad leaves and conifers

Based on studies and analyses of 10 commercial farms in the Netherlands combining poultry and trees the following overall lessons were drawn (Bestman 2017):

- In the Netherlands, several examples of combining both commercial poultry production and trees exist: egg production with apples, biomass willows, *Miscanthus*, tree nursery, walnut trees and broilers with cherries.
- These combinations have advantages for animal welfare and animal health and using the same land for two types of food production may reduce the total land required for food production. The risks of this combination are the high investment costs needed to plant large areas with trees, lack of skills to manage the trees, conflicting interests between the poultry and tree enterprises on the farm, and fear of financial consequences of land use change from pasture to woodland.
- A typical organic egg production farm in the Netherlands has 11,000 hens and needs about 4.4 hectares for the free-range area. Planting such an area with trees requires high investments. It is argued that revenues from the trees could help offset these costs. However to derive an income from the trees, the tree will need to be managed professionally.
- Fruit production skills or willow production skills are different from poultry farming skills. They cannot always be combined in one person. So if a poultry farmer wants to start profitable tree production, he or she is advised to establish a partnership with a 'tree professional'.
- Keeping chickens in a professional way and managing trees in a professional way may lead to conflicting interests. For example, because of health risks such as avian influenza, a poultry farmer does not want to have other people interacting with his or her chickens. Fruit production sometimes requires immediate action in case of frost in spring or an apple disease. Sometimes chemical interventions are needed in fruit production and these will not be allowed in areas with poultry.

The impact of trees in the hen yard on the risk for avian influenza is further described in Bestman et al (2017)

Based on a comparative replicated study at an UK organic chicken farm, different seed mixtures including herbs were compared to a traditional seed mix in order to search for a more shade-tolerant understorey sward that could contribute towards the nutrition/health of the birds (Smith et al. 2017). The following overall lessons learnt were drawn:

- Establishing a sward under the trees is possible but the challenge is to maintain the sward in the presence of chickens. Optimising chicken pressure appears to be important for maintaining a healthy sward.
- Once the trees are thinned, commercially available seed mixtures can be sown to provide understorey ground cover. This has economic implications for poultry keepers as the more specialised mixtures are likely to have higher seed prices.
- Sward establishment rates increased one month after sowing for all mixtures, indicating higher weed suppression potential after four weeks and the minimum growth time required for establishment.
- In order to develop systems that are beneficial for both farmers and chickens further research is needed into how to distribute the flock more evenly, spreading the pressure across the range.

The results are elaborated more in Westaway et al. (2017)

4 Results of agroforestry innovations for pig systems

The work included agroforestry pig systems in Denmark and Italy with inclusion of poplar and willow for biomass production with the aim to reduce nitrogen leaching from the paddocks and improve animal welfare. In Spain the work was focusing on a novel way to find supplemental feeds for high quality pig production in forest areas where chestnut and oak trees are dominant. Table 3 shows the focus of the innovations, the partners, and the type of work.

Table 3. Focus of agroforestry innovation activities related to pig systems

Activity	Partner(s)	Type of work
Poplar in the paddocks for lactating sows	Aarhus University, Denmark	Comparative study (+/- poplar in lactation paddocks) in relation to animal behaviour and risk for nitrogen leaching
Tree protection with growing pigs	Veneto Agricoltura, Italy	Comparative studies on tree protection measures and potential wood chip production
Morus alba and *Morus nigra* as protein sources	University of Santiago de Compostela, Spain	Comparative study of growth potential on different agroecological zones in Spain

Based on the study with willow or poplar in paddocks for lactating sows in Denmark, the following overall lessons were drawn (Kongsted et al. 2017):

- Poplar trees should be established at least four years before sows are given access to prevent destruction. Piglets can have access after two years without destroying the trees. The piglets' characteristic rooting behavior reduces the need for supplementing weed control.
- The lactating sows use the trees for shade when they are outside the farrowing hut in hot weather, 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.
- When the trees are placed at the end of a lactating paddock, a large proportion of the excretory behavior is performed outside the tree area. A strategic location of hut and feed trough can stimulate the deposition of a relatively higher share of faeces in the tree zone.
- The presence of willow trees seems potentially to reduce the risk for leaching of nitrate either though a higher uptake of N by the roots compared to a (destroyed) grass sward or through reduced percolation of water, but the magnitude is only very moderate in paddocks with high N-surpluses.
- From 2018, it is mandatory in Danish organic pig production for pigs to have access to shade, apart from the hut, during summer months for the benefit of animal welfare. Establishment of trees in the paddocks seems the most appropriate way to comply with this requirement.

Concerning growing pigs, the impact of trees on risk for nitrate leaching in systems with growing pigs are described in Jørgensen et al. (2018).

Based on the study with in free-range organic pig paddocks in an agroforestry system in Italy using different densities of poplars and focussing on tree protection and tree growth, the following overall lessons were drawn (Bondesan and Ricardi, 2017):

- Free range pigs (farrowing sows, piglets or growing-finishing heavy pigs) receive a substantial welfare benefit from the shade created by poplars foliage, after 3-4 years of growth when poplars are in rows (single or twin) bordering the paddock, or from the second year of growth with high density plantations.
- The shade from established poplars moderates the microclimate in the paddocks and protects pigs from sunburn. However, with temperatures often above 33°C in summer months in Veneto's climate, water puddles and mud are also necessary to reduce the heat stress and skin temperature of the pigs.
- The most efficient tree protection was a cage settled around the tree (about 70-80 cm high) made of thin metal wire net. This type of shelter should be removed from trees after the fourth or fifth year (depending on the diameter of the cage) to avoid the cage constraining tree growth.
- Poplars could be an important secondary product and source of revenue from pig paddocks; a correct balance needs to be found between stem pruning to provide good quality timber logs and a lack of pruning to encourage shade.
- The beneficial effects of agroforestry in organic pig production, farming and pork quality are not well known by "more informed consumers" who normally buy organic and local food. However, there is an opportunity for marketing "pork-products from agroforestry" and receiving a premium price from a niche group of consumers.

The overall lessons learnt from the experiment with different species of Mulberry in Spain were (Mosquera et al. 2017):

- The Cuban-source mulberries (*Morus alba tigrenda* and *criolla*) presented the highest growth (total height, shoot and base diameter) during the first year of establishment when compared to Galician-source mulberries (*Morus alba Illaverde* and *M. nigra*).
- *Morus alba* clones (both Cuban and Galician-source) presented significantly higher yields when compared to *Morus nigra*.
- The different *Morus* clones showed no significant difference in protein contents (ranging from 9.8 to 21.6 % in leaves) for this first year of establishment. Significant differences only occurred between sites.
- Thus, most the promising results were found for the use of Cuban-source mulberries as a source of animal fodder in temperate European regions. However, increasing the duration of the field trial will provide further evidence of the best cultivar(s) for temperate climatic conditions.

5 Results of agroforestry innovations for ruminant systems

The feeding value of leaves for ruminants was a focus of research in France, the UK, and the Netherlands. In addition, the work in France focussed on the diversification of tree use, their spatial organization, and the protection of newly established trees in systems with grazing cattle, and in the UK there was a focus on the biomass yield of trees and biodiversity related to agroforestry. Table 4 shows the focus of the innovations, the partners, and the type of work.

Table 4. Innovation activities of the three stakeholder groups focused on agroforestry for ruminant systems

Activity	Partner(s)	Type of work
Nutritive value of trees and scrub	National Institute for Agronomic Research (INRA), France	Detailed analyses of 13 species
Spatial organization of trees in an AF dairy system	National Institute for Agronomic Research (INRA), France	Comparative study (three types of organization for high stern trees pollards, and coppiced trees)
Dairy cows and fodder trees	Louis Bolk Institute, the Netherlands	Farm observations on organic dairy farm in existing network
Cattle (non lactating) in short rotation coppice	Organic Research Centre, UK	Comparative experiment with different tree species in an alley cropping system

The overall lessons learnt from the French study regarding feeding value of leaves were (Novak et al. 2017):

- The composition, nutritive value and ruminal degradability of leaves from woody resources exhibit large variation between species with crude protein concentrations varying from less than 85 g kg^{-1} for the leaves of holm oak to more than 220 g kg^{-1} for the leaves of black locust,

chestnut, ash and white mulberry. The digestibility ranges from less than 50% in holm oak and black locust to more than 75% in ash and white mulberry.

- 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 the generally found in grass or lucerne in summer. Other species such as lime, elm, Italian alder, chestnut and black locust seem also potentially interesting to feed less productive ruminants.
- For some species, the nutritive value of the leaves of fodder trees depends on the pruning technique (pollarded or coppiced trees *vs* high stem trees). The effect of season has a lower impact on trees than on herbaceous forage.

The major lessons learnt from the French study regarding tree protection and spatial organization of trees were (Novak et al. 2017):

- Electric fence, electric fencing tape and metal fence were very efficient in protecting trees from cow damage in grazing periods.
- Garlic essence, spirit vinegar, and a repellent for deer used by hunters (which is a mixture of spices and NPK fertilizer) and fresh cow dung were ineffective as tree protection.
- The mortality of coppice seedlings (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.
- A triple row of trees 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.

The overall lessons learnt from the study in the Netherlands regarding feeding value of leaves from willow (*Salix viminalis*) and alder (*Alnus glutinosa*) were (Luske et al. 2017a):

- Despite a low intake rate of browse material, the contribution of the leaves for micronutrients were significant with, for example the contributions for Zinc (Zn), Manganese (Mn) and Iron (Fe) reaching up to 2-9% of the daily requirements.
- Dairy cows prefer willow (in general) over alder trees for browsing. Just a couple of browsing marks were found on the alder trees, whereas in some rows all willow twigs within reach of the cows were browsed.
- Tree morphology (affected by cultivar and management) defines whether or not the three-dimensional structure of the willow tree is suitable for grazing by dairy cows.
- Cultivars especially selected for biomass production grow too fast for the cattle, as the new shoots quickly become too thick at browsing height.
- Willow cultivars with a spreading morphology are best suited as fodder trees for three dimensional grazing. These willow cultivars require less intensive management than willow cultivars with a tall upright morphology.

More details on the nutritional potential of fodder trees is given in Luske and van Eekeren (2017c).

The major lessons learnt from the UK regarding biomass trees for ruminant systems and focusing on biomass yield, feeding value of leaves, ands tree-crop interactions were (Smith et al. 2017):

- A considerable higher yield of woodchips was achieved by alder compared to willow on an organic farm. This may be related to the particular cultivars but it may also be a result of alder being able to fix nitrogen.
- The high levels of minerals in tree fodder suggest that trees can offer an alternative source of mineral supplementation. However, differences in mineral content between species, between fresh and dried samples and between seasons indicate establishing the actual nutrient value of tree fodder may require further leaf analysis.
- There was little observed impact of the trees on the oats crop between the alleys, except for a potential effect of shading immediately adjacent to the tree row, resulting in taller oat plants. As oats is a competitive species, they may be well suited to being grown in an agroforestry system. The results suggest that there was no significant impact of trees on the alley crops in this system during the first six years.
- Earthworm abundances were higher in the tree rows, which represent an undisturbed stable habitat, buffered from extremes of temperature, while the more active ground beetles were in greater abundances in the crop alleys. The impact of the tree rows in providing a refuge for ground beetles throughout the winter or during periods of cultivation in the alleys should be investigated further.

6 Conclusions

Many innovations have been assessed in this work regarding the potential role of agroforestry to benefit poultry, pig and ruminant systems. The organization of the agroforestry systems needs to be arranged according to the specific type of livestock species. However some general features stand out.

1. Trees in these systems benefit animal welfare by providing shade and protection. The protection include protection from wind, but also in the case of poultry a perceived protection from predators supporting the poultry in using the entire range area which is beneficial in terms infection risk and risk for excessive nutrient load in certain areas of the range.

2. Across systems the inclusion of trees supports biodiversity, including soil organic matter, while the capacity of the trees to significantly reduce nitrogen leaching from areas with a high deposition of manure seems less than that anticipated in areas with a high rainfall.

3. The foliage from the trees may represent a significant feed resource depending on tree species, in particular in terms of energy, protein and micronutrients for cattle. In particular, white mulberry (*Morus alba*) and common ash (*Fraxinus excelsior*) seems interesting in this respect.

4. Data on composition and feeding value of tree leaves can be found in Luske et al. (2017b) in an on-line fodder tree database. www.voederbomen.nl/nutritionalvalues/

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