AGFORWARD
Agroforestry for Europe

Lessons learnt - Agroforestry for free-range pig production in Denmark

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Date of report	10 July 2017
Authors	Anne Grete Kongsted, Heidi Mai-Lis Andersen and John E. Hermansen
Contact	Anneg.kongsted@agro.au.dk
Approved	Paul Burgess (21 July 2017)

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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 in that it focuses on the field-testing of an innovation within the "agroforestry for livestock systems" participative research and development network. This report contributes to Deliverable 5.14: Lessons learned from innovations in agroforestry systems.

2 Background

The initial stakeholder report (Kongsted 2014), the research and development protocol (Kongsted and Hermansen 2015), and the system description report (Kongsted and Hermansen 2016) provide background data on agroforestry for free-range pig production in Denmark.

In Europe, there is an increased interest in organic pig production where pigs are allowed outside for part of their life. Free-range pig production often takes place on grass and grass-clover paddocks, however it is often practiced with relatively high stocking densities and large inputs of nitrogen (N) from concentrate, and this is associated with high risks of nitrogen leaching, especially in farrowing paddocks (Eriksen et al. 2006). The risk of nitrogen leaching in these systems is amplified because it is difficult to maintain grass cover due to the pigs' inclination for rooting. At the same time, pigs are exposed to sun and are at risk for sun burn.

Trees like willow and poplar have a relatively deep root system and can take up large quantities of nutrient across a long growing season (Jørgensen, 2005). Additionally, the system seems to have clear animal welfare benefits because the crops provide the pigs a more natural and stimuli-rich environment with opportunities for seeking shade during hot weather and shelter during cold spells (Horsted et al. 2012). Thus, the overall hypothesis for this work was that integrating trees in the grass or grass-clover paddocks would reduce risk for nitrogen leaching and offer animal welfare benefits.

A few Danish organic pig producers have already established energy crops (willow and poplar) in paddocks for lactating sows. Two of these pig producers were involved in this work to gather insight in the possible benefits or drawbacks of including trees in the pig paddocks.

3 Activities

The activities included four experiments:

1. Investigating risk for nitrogen – leaching in paddocks with growing pigs and trees – revisiting an earlier experiment including complementary measurements,

2. Assessing soil nitrogen in high stocking density paddocks with grass-clover and willow depending on distance to trees,
3. Investigating sow behaviour and nitrogen leaching in paddock for lactating sows with or without poplar, and
4. Investigating effect of paddock design in farrowing paddocks with trees on sow excretory behaviour.

4 Results from four experiments

4.1 Effect of stocking density on nitrogen distribution in a combined energy crops and free-range growing pig system

The aim of this work was to evaluate the effect of stocking density on the distribution of soil mineral nitrogen (N) for a system that included zones of perennial energy crops and grass. The research was carried out in already established plantations of energy crops at Aarhus University Foulum (Foulum, Denmark; 56°29´N; 9°35´E). The soil type is loamy sand according to USDA soil taxonomy. The experimental area was established in early May 1996.

For two seasons each year, spring and autumn 2009, a total of 72 growing pigs were separated into six paddocks of two stocking densities (117 and 367 m^2 pig^{-1}). Each paddock was arranged across belts of willow mixed with polar, grass, miscanthus, grass, and willow. The detailed layout is described by Horsted et al. (2012) who reported the animal behaviour and crop damage caused by the pigs in such a system. Soil mineral N (ammonium and nitrate) was measured in soil depths of 0-25 and 25-75 cm on three occasions in each of three replications.

Calculations of N balances showed that N inputs in terms of feed exceeded N outputs by 626 and 185 kg N ha^{-1} for high and low stocking density, respectively. The pigs caused an uneven distribution of mineral N across the paddocks with highest contents in zones with willow and poplar. This was a consequence of the pigs showing preferred defecation behaviour in these areas. Stocking density had a significant effect on soil mineral N. Thus, soil nitrate was three to six times higher in paddocks with high stocking density than with low stocking density. Immediately after the second season ending in November 2009, the mean mineral N in the 0-75 cm soil layer was 361 and 100 kg N ha^{-1} in willow & poplar zones at high and low stocking density, respectively.

In the following winter period from November 2009 to April 2010 there was a marked reduction in soil mineral content of 79 kg N ha^{-1} across zones in the high density paddocks. It is assumed that this was lost to the environment. In the low-density paddocks no change in total soil mineral N was observed from November to April, and the total content was similar to a reference area with grass that had received no fertilizer or manure.

The high mean mineral N contents of the topsoil of the energy crop zones is in line with the behavioral observations of the pigs. The pigs clearly performed the majority of excretory behavior in zones with willow and only very few pigs were observed to urinate or defecate in the feeding zones, as reported in Horsted et al. (2012). There were no large differences between urinating and defecating with regard to preferred sites. This suggest that the availability of energy crops affects the excretory behavior of the pigs and thereby also the nutrient distribution significantly compared to what is observed on bare grasslands, where feeding and hut areas are characterized by substantial nitrogen losses.

The results are described in more detail in Jørgensen et al. (2017)
Jørgensen U, Sørensen J, Eriksen J, Horsted K, Hermansen JE, Kristensen K, Kongsted AG (2017). Nitrogen distribution as affected by stocking density in a combined production system of energy crops and free- range pigs. Agroforestry Systems, submitted

4.2 Effect of stocking density and distance from trees on soil-nitrogen

The aim was to determine soil-N in paddocks for lactating sows as influenced by distance from tree rows of willows. The experiment took place in a free-range organic pig farm at Hovborgvej Brorup, Region of Southern Denmark (Ulvehøjvej 1, 6650 Brørup) located at 55° 34' 35'' N, 8° 59' 30'' E as part of an MSc study (Lao 2015).

The measurements were carried out in three experimental paddocks that were 12 m wide and 23 m long (Figure 1). At the both ends of the 23 m length, two rows of 6 year old willows were present separated by 18.5 m distance covered by grass. At distances of 0.5, 2.5, 4.5, 6.5 and 9.5 m from the willows at one end and at a depth of 1.45 m, ceramic suction cups were installed in October 2014 and soil water samples were taken every two weeks until March 2015 the following spring. In addition, close to the ceramic cups, soil samples were taken at three soil layers at depths of 0-25, 25-50 and 50-100 cm for determination of nitrate and ammonium. In the paddocks the hut was placed around 4.5 m from the willow.

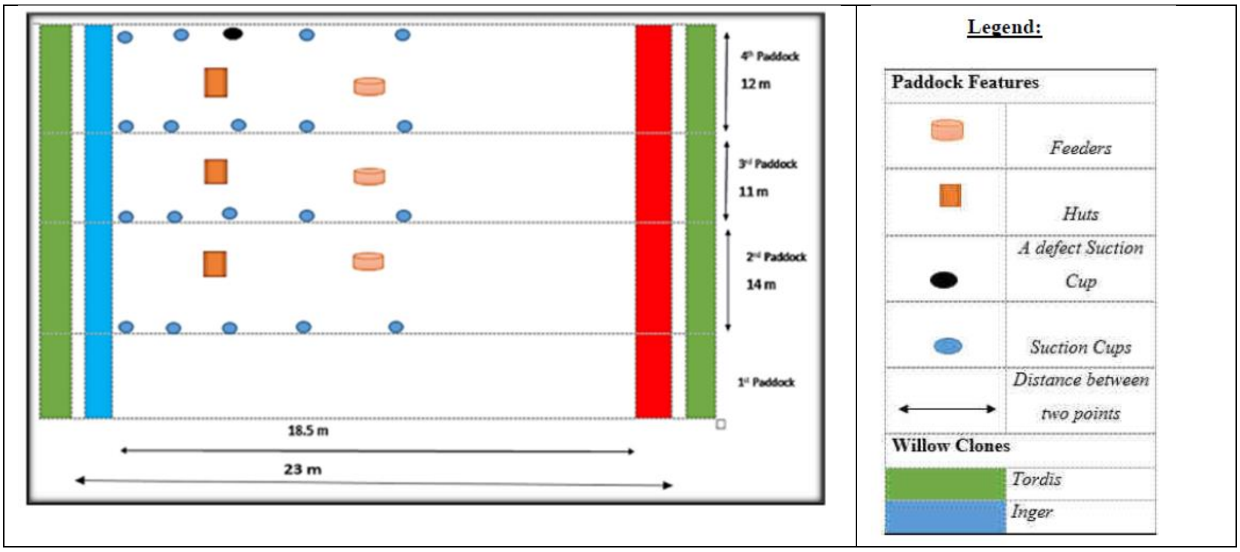

Figure 1. The experimental layout for lactating sow paddocks showing four measurement rows, each with five suction cups (except in row 1 which had a defect suction cup) established against the two rows of willow trees in each side. The grazing area in the paddock had minimal grass cover during autumn and winter. The hut is located at nearly 4.5 m while the feeders are between 6.5 and 9.5 m. The first paddock was not used in the experiment while paddocks 2 to 4 are where suctions cups were installed and soil samples were taken. Note that 18.5 m is the distance covered by grazing area while with willow the length becomes 23 m. Also a paddock ends in the middle of the two willow rows in each side of the paddock. The sketch is not in scale (From Lao 2015).

Nitrate-N leaching was estimated based on the nitrate concentrations in the soil water collected by the ceramic cups. This was highest near the huts (4.5 m distance from the willow rows) with an average of 37 mg NO_3-N/litre followed by 28 mg NO_3-N/litre at 6.5 m. The concentration of the leachate from the other points (0.5, 2.5, 9.0 m) did not differ significantly and amounted to 10-20 mg NO_3-N/litre.

Since excretory behavior of pigs was not part of the experiment, the lower concentrations of NO_3-N in the leachate (at a depth of 1.45 m) closest to the willow (compared to that close to the huts) could be due to both lower excretion, high nutrient uptake by trees, or a reduction in soil water content (because of the trees) that subsequently reduced leaching. The concentration of NO_3-N in the soil samples at 0-50 cm depth near the willows were more than double that for soil samples far away from the willow, indicating that significant defecation had taken place near the willow. This indicates the low levels of nitrogen in the leachate close to the willows were probably due to a high nitrogen or water uptake by the trees whose roots may extend as far as 3.5 m away from willow.

The results are described in more detail in Lao (2015)

Lao, EM. 2015. Combined free-range piglets and energy crop production: Impact on nitrate leaching. MSc thesis, Agro-environmental management, Aarhus University, Dept Agroecology, 80 pp. http://orgprints.org/31408/1/Emanuel%20Joel%20Lao%20-%20Thesis.pdf

4.3 Effect of poplar on lactating sow behavior and N-leaching in paddocks

The aim of the third experiment was to investigate the impact of lactating sows with access to a zone of trees in their paddocks on the risk for nitrogen loss and animal welfare. A comparative study described in the research and development protocol (Kongsted and Hermansen, 2015) began in May 2015, and continued to April 2016. In each of four farrowing batches, 21 ringed sows were randomly assigned to 21 individual paddocks with either a) grass-clover and a zone of poplar trees where the sows had access to the trees, b) grass-clover grass and a zone of poplar where the sows had no access to the trees or c) solely grass-clover. Sow behavior and location, mineral N in soil, N in soil water and crop damage were investigated. The experimental setup is illustrated in Table 1. At present only the sow behavior data have been processed.

Behavior of the lactating sows

Sow behaviour was monitored in the different zones. Generally, sow activity was not affected by the presence of a zone of trees, but sows with access to poplar trees, spend the main part (~48%) of the resting time in the paddock in the zone with the trees. The excretory behavior is presented in Figure 2. Defecation took place more or less equally distributed according to the area of each zone, whereas urination took place farthest away from the trees – and the sows resting zone. Thus, when a few rows of trees are placed in one end of a rectangular shaped lactation paddock, a large proportion of the excretory behaviour is performed outside the tree zone. This reduces the beneficial effect of the trees in relation to reducing nutrient leaching. It is expected that a larger part of the urine and faeces 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. This analysis provided the background for Experiment 4.4.

Table 1. Description of the experimental site and layout

Specific description of site	
Area	The case study system comprises 21 paddocks of 333 m^2 (0.7 ha). The total farm area is 130 ha, hereof approximately 30 ha used for pigs. Poplar is established on an area of 6.8 ha (including grass clover without trees).
Address and co-ordinates	Ulvehøjvej 1, 6650 Brørup, Denmark: 55°34'38.1N; 8°59'36.5E
Example photographs	 Photo: Individual farrowing/lactation paddocks (one hut in each paddock). Each sow has access to an area with grass clover (10 x 33 m^2) including two rows of poplar. Next year two rows of paddocks will be established in the area in the middle.  Photo: The paddocks are separated by an electric fence. The fence keeps the sows within the paddocks, but the piglets run between paddocks.

	Relative area (%)	Urine (%)	Faeces (%)
Zone 1	27	50	31
Zone 2 Feed	27	32	22
Zone 3	14	10	14
Zone 4 Hut	12	0	12
Zone 5 Trees	20	8	21

Figure 2 Distribution of excretory behaviour (% of behavioural observations) in five different zones in paddocks with two rows of poplar trees at one end of the paddock. Relative area is equal to the proportion of the area of each zone.

4.4 Effect of paddock design of farrowing paddocks with trees on sow excretory behaviour

The objective of the fourth experiment was to investigate the effect of the spatial arrangement of trees, hut and feeding location on lactating sows' excretory behaviour in a pasture-based system with four rows of poplar trees. The experiment was carried out during the spring and autumn of 2016 on the same farm as Experiment 3. It included 24 lactating sows housed in individual farrowing paddocks (36 m x 13 m). Each paddock was divided into five zones. Zones 1-3 consisted of grass clover and zones 4 and 5 each included two rows of four poplar trees. The sows were randomly allocated to the six treatments: three different hut locations x two different locations of feed trough.

The preliminary results, across paddock design, showed

- Defecation mainly occurred in the tree zone
- Urination was randomly distributed between the tree and grass zone
- Location of hut and feed affected the sows' choice of defecation area
- No effect of hut and feed location was found on the sows' choice of urination area

Figure 3 shows the combination of hut and feed placement resulting in the lowest and highest defecation in the tree areas, respectively.

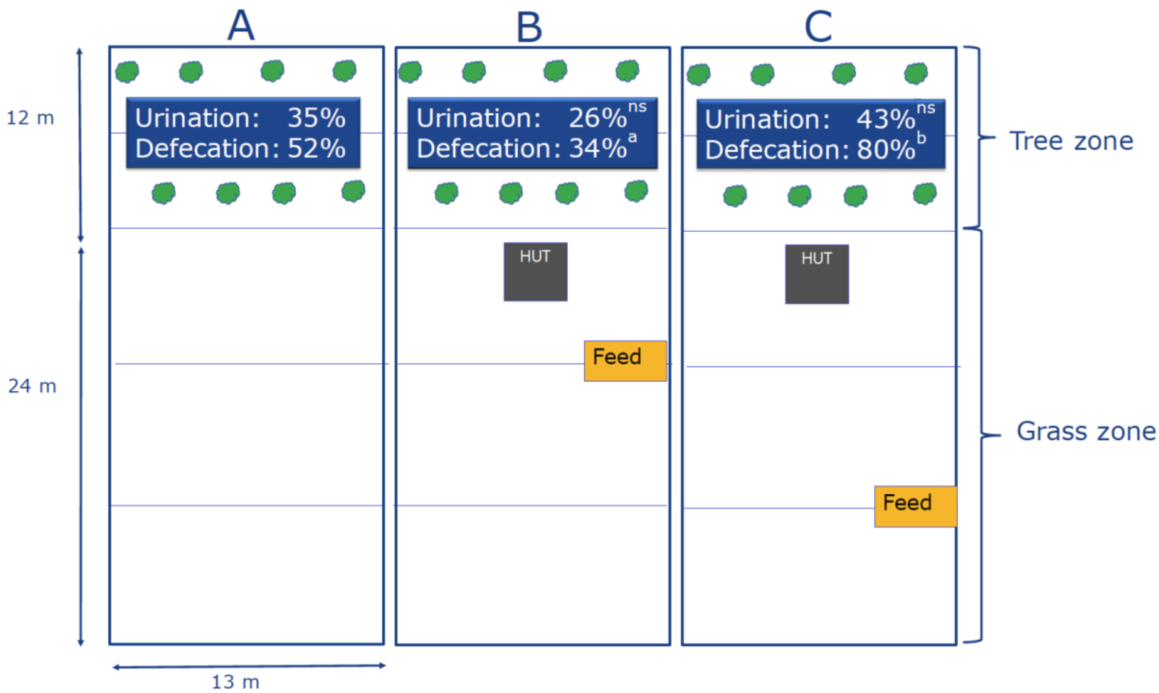

Figure 3. The mean proportion of urination and defecation in the tree zone (layout A), and the paddock design with the lowest (layout B) and highest (layout C) urination and defecation in trees zone. The zone with trees comprised 34% of the total paddock area.

In conclusion, the elimination behaviour seems to be affected by the location of the feed and hut, which has also been reported by Eriksen & Kristensen (2001) and our results indicate that that the location of the hut and feed trough can be used to motivated the sows to defecate in the tree area.

The results are described in more detail by Andersen et al. (2017)

Andersen, HML, Kongsted AG, Jakobsen, M (2017). Integrated production of tree biomass and piglets - Effect of paddock design on sow excretory behavior. NJF Seminar 495, 4th Organic Conference Mikkeli, Finland. http://orgprints.org/31414/

5 Main lessons

Experiences and preliminary results from measurements and observations in a pasture-based system with lactating sows in paddocks with two rows of poplar indicate the following:

- Lactating sows use the trees for grooming behavior (rubbing for skin care) and bite off some of the smaller branches. This causes severe bark damage to individual trees, however the trees recover surprisingly well during a year without pigs.
- Poplar trees should be allowed to establish for at least four years before sows are given access; this is 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.
- The lactating sows use the tree 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.
- The presence of trees seem to reduce the 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.
- 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 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.

Postscript. From 2018, it is mandatory in Danish organic pig production that pigs are allowed 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.

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.

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