System Report: Silvoarable Agroforestry in the UK

Project name	AGFORWARD (613520)
Work-package	4: Agroforestry for arable farmers
Specific group	Silvoarable agroforestry in the UK
Deliverable	Contribution to Deliverable 4.10 (4.1): Detailed system description of a case study system
Date of report	27 October 2015
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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 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, livestock, 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

The initial stakeholder report (Smith et al. 2014) and the research and development protocol (Fradgeley and Smith 2015 and Smith 2015) provide background data on silvoarable systems in the UK. These systems are currently rare in the UK. The few systems that exist are usually based on an alley cropping design with arable crops in the alleys. The tree component consists either of top fruit trees (apples, pears and plums), timber trees, or short rotation coppice for biomass feedstock production. The management of the tree understorey was identified by the UK silvoarable stakeholder group as an innovation for further development at the workshop held on 18 November 2014 (Smith et al. 2014). There are two main issues with the understorey – first, with regards to weed control, and second, the area between the trees is unproductive. The aim of this trial is to compare the impact of different approaches to understorey management in terms of economics, (including labour costs), productivity and biodiversity (plants (including weeds) and invertebrates) and potentially tree pests and diseases.

3 Update on field measurements

Field measurements described in the research and development protocol (Smith, 2015) were started in June and July 2015 when all the trees were measured and plant and invertebrate biodiversity assessed. This report presents these data and provides a detailed description of the case study system, Tolhurst Organics.

4 Description of system

Table 1 provides a general description of silvoarable agroforestry systems. A description of a specific case study system is provided in Table 2. Missing data will continue to be sourced during 2015.

Table 1. General description of the silvoarable system

General description of system	
Name of group	Silvoarable agroforestry in the UK
Contact	Jo Smith
Work-package	4: Agroforestry for arable farmers
Associated WP	3: High value trees
Geographical extent	Silvoarable systems are found throughout Europe, but rare in the UK,
Estimated area	Very small nationally – probably less than 1000 ha
Typical soil types	Varied
Description	In recent years, a small but growing number of adventurous farmers and growers have been planting new alley cropping systems. The tree component consists either of top fruit trees (apples, pears and plums), short rotation coppice, and/or timber trees, with arable or vegetable crops in the alleys. The drivers behind planting trees into arable systems vary from farmer to farmer, but are often related to improving the environmental conditions for the crops (reduced wind speeds providing shelter; improved functional biodiversity) as well as diversifying the business by introducing a new product. The systems are usually organised as alley cropping systems with alleys varying in width from 10 m to 24 m (workable alley).
Tree species	Varied: Fruit trees: *Malus domestica* (apple) SRC species such as willow (*Salix viminalis*) and hazel (*Corylus avellana*) Timber (e.g.): small-leaved lime (*Tilia cordata*), hornbeam (*Carpinus betulus*), wild cherry (*Prunus avium*), Italian alder (*Alnus cordata*), ash (*Fraxinus excelsior*), oak (*Quercus petraea*), and sycamore (*Acer pseudoplatanus*)
Tree products	Top fruit (apples) Woodchip for bioenergy and/or mulch/compost Timber Craft materials (willow for sculptures and hazel for thatching)
Crop species	Wheat (spring and winter varieties plus composite cross population) (*Triticum spp*) Barley (*Hordeum vulgare*) Oats (*Avena sativa*) Oil seed rape (*Brassica napus*) Field vegetables
Crop products	Grain, rape oil, vegetables and fruit
Animal species	Usually none; occasionally pigs, poultry and ruminants can be part of the system on a rotational basis.
Animal products	Not applicable
Other provisioning services	
Regulating services	The trees can provide shelter for the crops (reduced wind speeds, reduced soil erosion, reduce evapotranspiration in summer).

	Above-ground, the trees will increase carbon storage. Tree roots can reduce soil erosion and access nutrients below the crop roots, bringing nutrients to the upper soil horizons through leaf fall. The tree rows support functional biodiversity that regulate pollination, pest control and decomposition services.
Habitat services and biodiversity	The tree row represents a stable habitat in an otherwise highly disturbed agricultural landscape so can provide shelter and resources for plants and animals, and acts as corridors linking up other (semi)natural habitat patches. These species may be beneficial, neutral or detrimental to provisioning services.
Cultural services	Introducing trees into an arable system may increase job opportunities and skills with regards tree management. The landscape also changes from an open arable landscape to a partly wooded environment depending on design of the system. This landscape change can be both an improvement and degradation depending on the context and individual preferences.
Key references	

Table 2. Description of the specific case study system

Specific description of site	
Area	9
Co-ordinates	51.50°N 1.06°W
Site contact	Iain Tolhurst
Site contact email	tolhurstorganic@yahoo.co.uk
Example photograph	 Figure 1. Silvoarable system at Tolhurst Organics June 2015

Map of system

Figure 2. Aerial view of trial site before tree planting

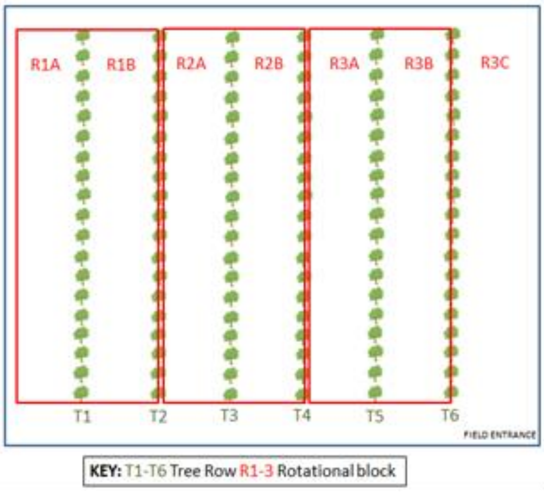

Figure 3. Field map

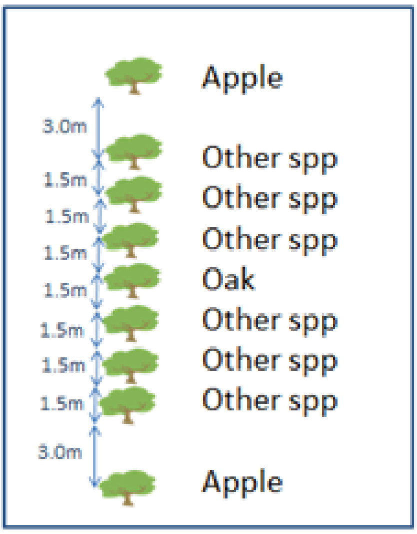

Figure 4. Tree row design

Possible modelling scenarios	
Comparison	Various approaches to tree understorey management (rhubarb, cut flowers, beetle bank, natural regeneration) to increase productivity, weed control and biodiversity
Climate characteristics	
Mean monthly temperature	5.9°C mean min temp and 14.4°C mean max temp (mean for 1981-2010)
Mean annual precipitation	612 mm
Details of weather station (and data)	Benson 51.620, -1.097, 57 m amsl http://www.metoffice.gov.uk/public/weather/climate/gcpjxj1hq
Soil type	
Soil type	To be determined
Aspect	South-East
Tree characteristics	
Species and variety	447 trees planted of 8 species Apples (18 varieties); field maple (*Acer campestre*); whitebeam (*Sorbus aria*); Italian alder (*Alnus cordata*); oak (*Quercus robur*); black birch (*Betula lenta*); hornbeam (*Carpinus betulus*); Myrobalan/cherry plum (*Prunus cerasifera*)
Date of planting	March 2015
Intra-row spacing	1.5 m between trees, except apples with 3 m to adjacent tree
Inter-row spacing	Vegetable alley 20 m wide
Tree protection	Tree guards and woodchip mulch
Typical apple yield	Apples won't crop until year 3 or 4 (blossoms removed)
Typical increase in tree biomass	To be determined – baseline measurements taken in June 2015 and will be repeated annually
Crop/understorey characteristics	
Species	Organic vegetables
Management	Organic rotation in three blocks – brassicas, potatoes and fertility building ley
Typical vegetable yield	To be determined
Fertiliser, pesticide, machinery and labour management	
Fertiliser	Woodchip compost applied and fertility-building diverse legume ley used (details needed)
Pesticides	None
Machinery	Tractor access in the alleys for vegetable cultivations (details needed)
Manure handling	None
Labour	Vegetable enterprise is labour intensive (need estimate of input)
Fencing	Field has boundary hedge
Livestock management	
Species and breed	Not applicable
Description of livestock system	Not applicable
Financial and economic characteristics	
Costs	To be determined Costs of tree establishment Vegetable enterprise, Understorey management Ongoing tree maintenance (pruning etc)

5 Description of the tree component

Trees were planted into existing ground vegetation in March 2015, and woodchip mulch applied around each tree to reduce weed competition (Figure 5). There are six tree rows that separate seven 20 m wide and 150 m long alleys (see Figure 3).

Figure 5. Newly planted trees, April 2015

5.1 Tree height

Tree height has been measured with a height pole in June 2015. As trees have not yet grown above the height of the protective guards, tree canopy diameter has not been measured. Tree row composition in term of numbers of each species is recorded in Table 3. Overall, apple trees are the tallest trees (Figure 6) with a height around 1 m (1.20 m for the highest), followed by the plums. Oak and alder are the smallest tree species and all the other species have a similar size.

Table 3. Number of individuals per tree species in the tree rows

Tree row	Apple tree	Oak	Hornbeam	Alder	Birch	Whitebeam	Plum	Maple
1	10	8	9	15	8	13	6	1
2	10	9	5	6	11	12	13	6
3	10	10	15	5	4	9	6	17
4	10	10	11	13	11	4	8	8
5	10	9	12	8	10	6	8	13
6	10	10	11	3	10	9	15	10
Total	60	56	63	50	54	53	56	55

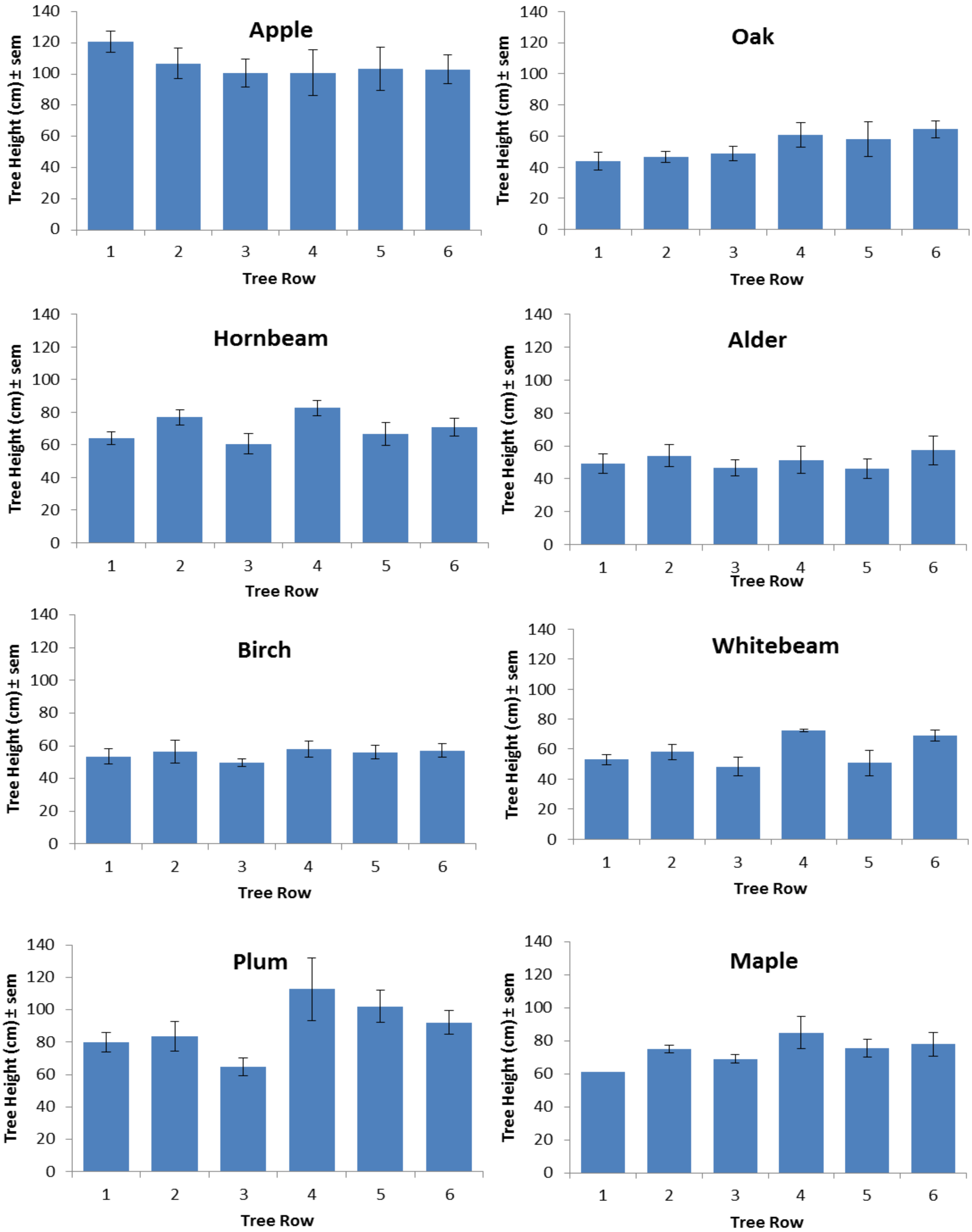

Figure 6. Average tree height (cm) in respective rows as measured in June 2015.

5.2 Tree understorey

The vegetation of the understorey is summarised in Table 4.

Table 4. Description of understorey composition (see Figure 3 for codes)

Row code	T1	T2	T3	T4	T5	T6
Understorey composition	Legume and herb mix planted in July 2013	Long term beetle bank	Grass, vetch, red clover	Natural regeneration	Legume and herb mix planted in July 2012	Legume and herb mix planted in July 2012
Width of the understorey	1.5 m	1.75 m	1 m	1 m	2 m	1.25 m

To measure the understorey vegetation diversity, 1 m^2 quadrats were used to determine the proportional plant cover. Six quadrats per row have been assessed. Each species was identified, the percentage cover assessed together with the proportion of bare ground and leaf litter. Measurements have been taken over two consecutive days by the same two people in order to reduce observer bias.

A total of 53 plant species were identified. The plant composition varies according to the tree row (Figure 7) and tree row 2 (long term beetle bank) had the highest diversity with 28 different species. Each row is characterized by two (tree row 5) to four (tree rows 1 and 2) dominant species and a varying number (but less than 25% of the row total plant abundance) of other rarer species. Among the dominant species there are: *Medicago sativa, Trifolium repens* and *Trifolium pratense* for tree row 1; *Centaurea nigra, Leucanthemum vulgare, Achillea millefolium, Lotus corniculatus, Poa trivialis* in tree row 2; *Vicia sativa, Lolium perenne, Trifolium incarnatum* in tree row 3; *Sonchus asper, Fumaria spp* in tree row 4, *Trifolium repens* and *Trifolium pratense* for tree rows 5 and 6.

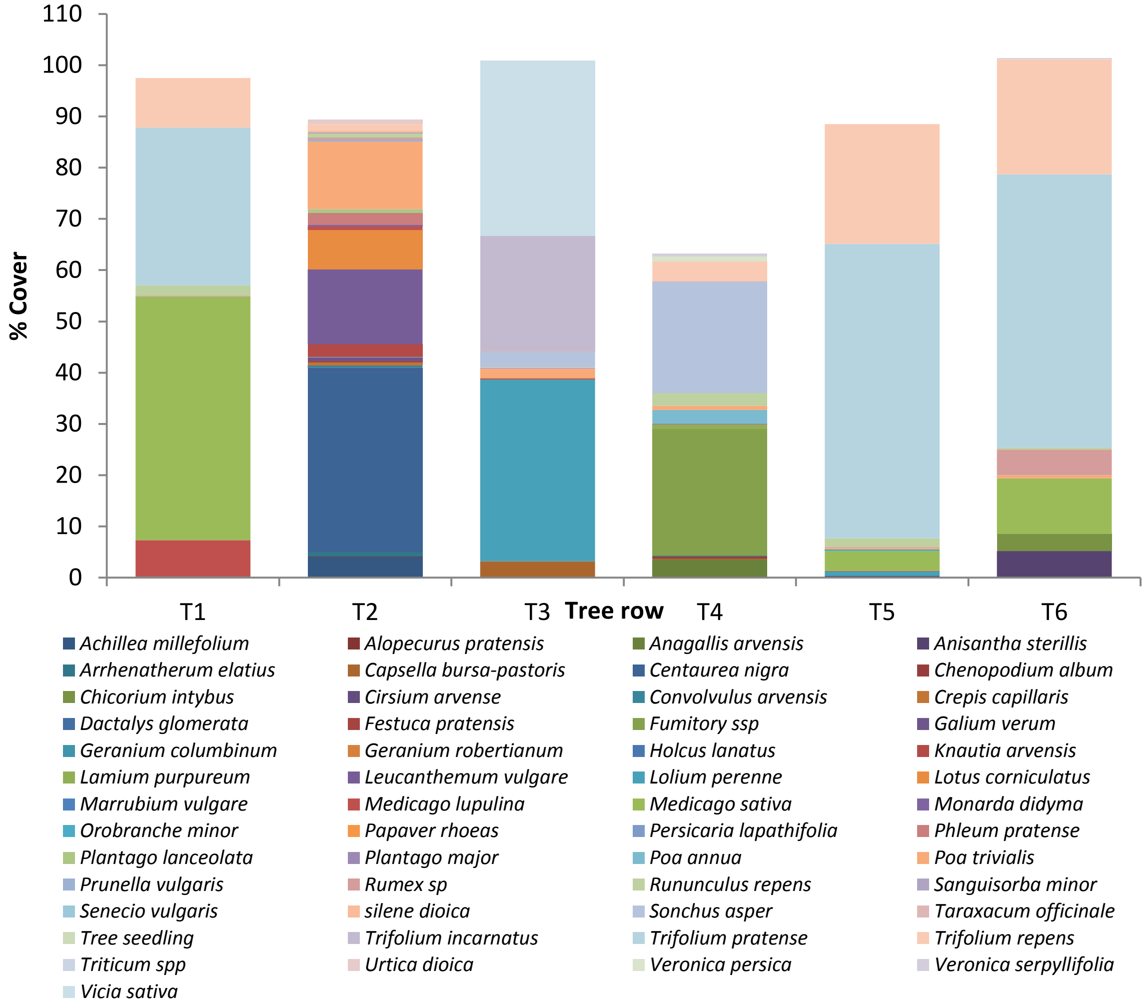

Figure 7. Percentage cover of plant species of the tree row understoreys in June 2015

5.3 Invertebrate biodiversity

In June pitfall trapping was carried out to assess the invertebrate diversity (Venot, 2015). This consisted of trapping ground fauna in plastic cups filled with 1/3 of water (and some drops of detergent to break the surface tension of the device and make the invertebrates fall in the water) and buried in the soil. The top border of plastic cups was level with the soil surface to enable ground fauna such as beetles, spiders and woodlice to fall inside the cup. A lid covered the trap 1 to 2 cm above the ground level to avoid mammals and reptiles from falling into the trap and to protect from rain or other disturbances. Six traps were set up in the tree rows, between apple trees and the following tree starting at the third apple tree in order to avoid edge/hedge influences. Traps were left for two weeks from 22nd June 2015 with an intermediary sampling after one week.

Once collected, the pitfall traps were drained and transferred to flasks filled with alcohol (80%). Invertebrates were sorted and counted according to different orders except for the ground beetles which were identified to species level. 7169 invertebrates were collected, sorted into 13 invertebrate orders (Figure 8). The predominant family caught was the Coleoptera with 24 species of Carabidae identified (n=3171).

In terms of invertebrate abundance, tree row 1 showed the highest number of individuals caught (n=763), followed by tree rows 5 and 6, characterized by a “Legume and herb mix” understorey, with around 750 invertebrates caught. Tree row 4, characterized by a “natural regeneration” understorey, had the lowest abundance (n = 360), followed by tree row 3 (n = 603) and tree row 2, the “beetle bank” (n = 605) (Figure 8).

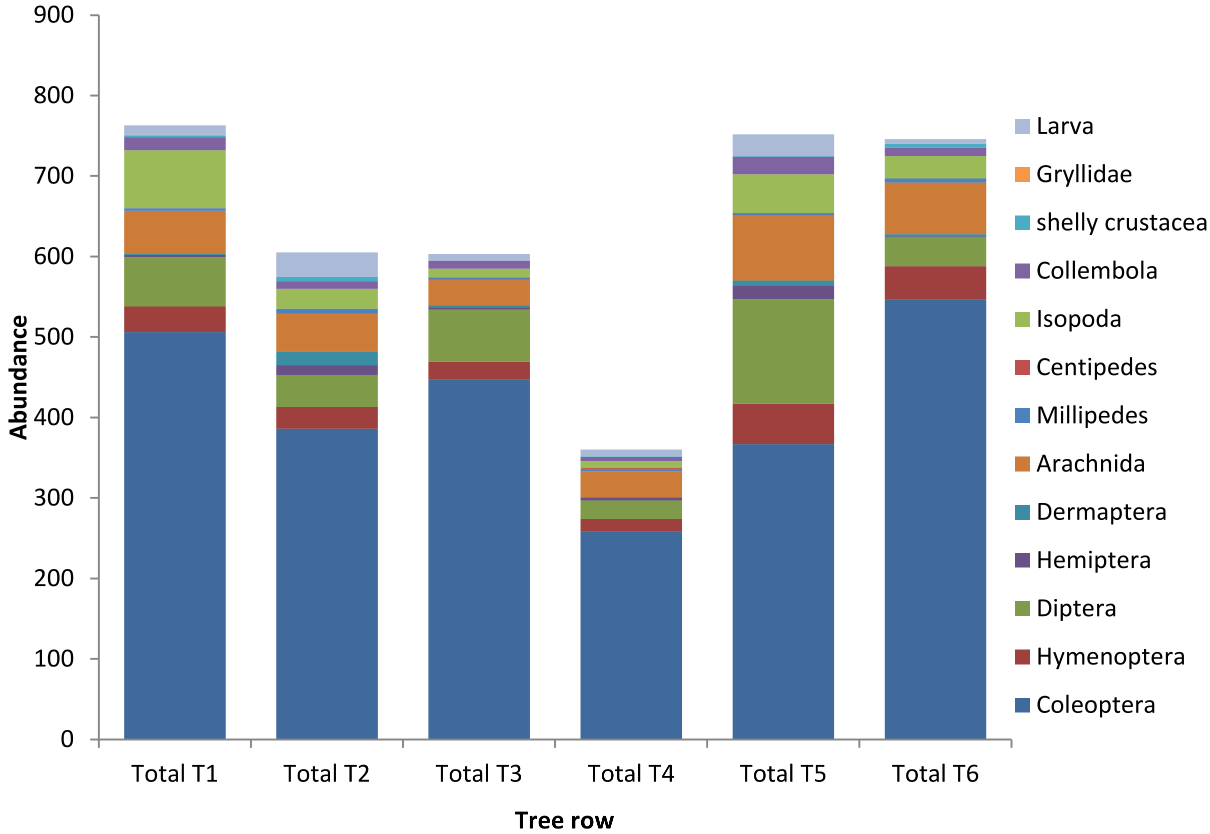

Figure 8. Total invertebrate abundance in each tree row

In all tree rows, Coleoptera was the most abundant invertebrate order caught in the pitfall traps. Proportions of other orders differed according to tree rows. Regarding Coleoptera, and focusing on Carabidae, the highest abundance was located in tree row 6 (n=442), decreasingly followed by tree row 1 (n = 300), 3 (n = 260), 5 (n = 247), 2 (n = 218) and 4 (n = 203). A minimum of seven different species were recorded in tree row 1 and a maximum of 10 species in tree row 3. The most abundant species in tree rows are increasingly: *Harpalus rufipes* (*n* = 87), *Pterostichus madidus* (*n* = 186), *Pterostichus melanarius* (*n* = 449) and *Poecillus cupreus* (*n* = 700).

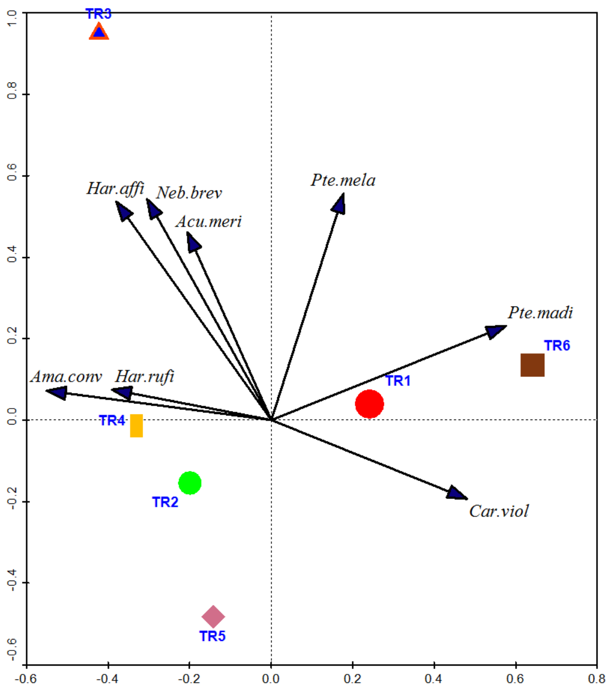

Figure 9. Beetle communities according to the tree rows (TR1-6) – Redundancy analysis (RDA) biplot with beetle species as response variables and tree rows as environmental variables. Only species with a fit greater than 15% are included. Species: *Ama.conv: Amara convexus; Har.rufi: Harpalus rufipes; Har.affi: Harpalus affinis; Neb.brev: Nebria brevicollis; Acu.meri: Acupalpus meridianis; Pte.mela: Pterostichus melanarius; Pte.madi: Pterostichus madidus; Car.viol: Carabus violaceous.*

As the tree rows have different plant species in the understorey, a difference between the studied soil macrofauna assemblages can be expected. RDA analysis showed that beetle community composition is significantly different in the tree rows (sum of all eigenvalues 0.313). Tree row 6 and 1 are characterized by a higher abundance of *Pterostichus madidus*, which separates it along the first axis from tree rows 2 and 4 (Figure 9). The second axis separates tree row 3 from tree row 5 which is characterized by an overall lower abundance of each beetle species. Tree row 3 is characterized by a larger amount of *Harpalus affinis, Nebria brevicollis* and *Acupalpus meridianis*. It will be interesting to repeat the research in summer 2016 to identify changes to the invertebrate communities following changes to the understorey vegetation in autumn 2015, when rhubarb and flowering bulbs will be planted.

6 Vegetable component

Table 5. Description of alleys (see Figure 3 for codes)

Alley code	R1A	R1B	R2A	R2B	R3A	R3B	R3C
Composition	Fertility-building ley	Fertility-building ley	Brassicas	Crop residues	Potatoes	Potatoes	Maize

7 Plans for 2016

Iain Tolhurst has planted daffodil bulbs in tree rows 1 and 2 in December 2015 and is planning to plant cut flowers and rhubarb in other tree rows in spring 2016. Assessments of tree height (and canopy diameter if appropriate), vegetation and invertebrate diversity will be repeated in 2016. Economic data on the establishment and performance of the system will be collected also.

8 References

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