Wakelyns Agroforestry: Resilience through diversity

Photo: Maja Lindstrom, paradigmshiftfilm.com

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Revised 2024:
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Wakelyns Agroforestry: the evolution of an idea

Wakelyns, surrounded by a sea of large-scale conventional arable production, is an oasis of trees, alive with bird song and insects. Integrating trees for timber, energy and fruit production into an organic crop rotation, Wakelyns was established by the late plant pathologist, Prof. Martin Wolfe, to put into action his theories of agrobiodiversity being the answer to achieving sustainable and resilient agriculture. Marking 30 years of agroforestry at Wakelyns, this revised edition of *Resilience Through Diversity* celebrates the work of Martin and Ann, fellow researchers from the Organic Research Centre and the wider research and Wakelyns community; as evolved and expanded by their son David Wolfe and his wife Amanda from 2020.

Martin and Ann Wolfe

Amanda and David Wolfe

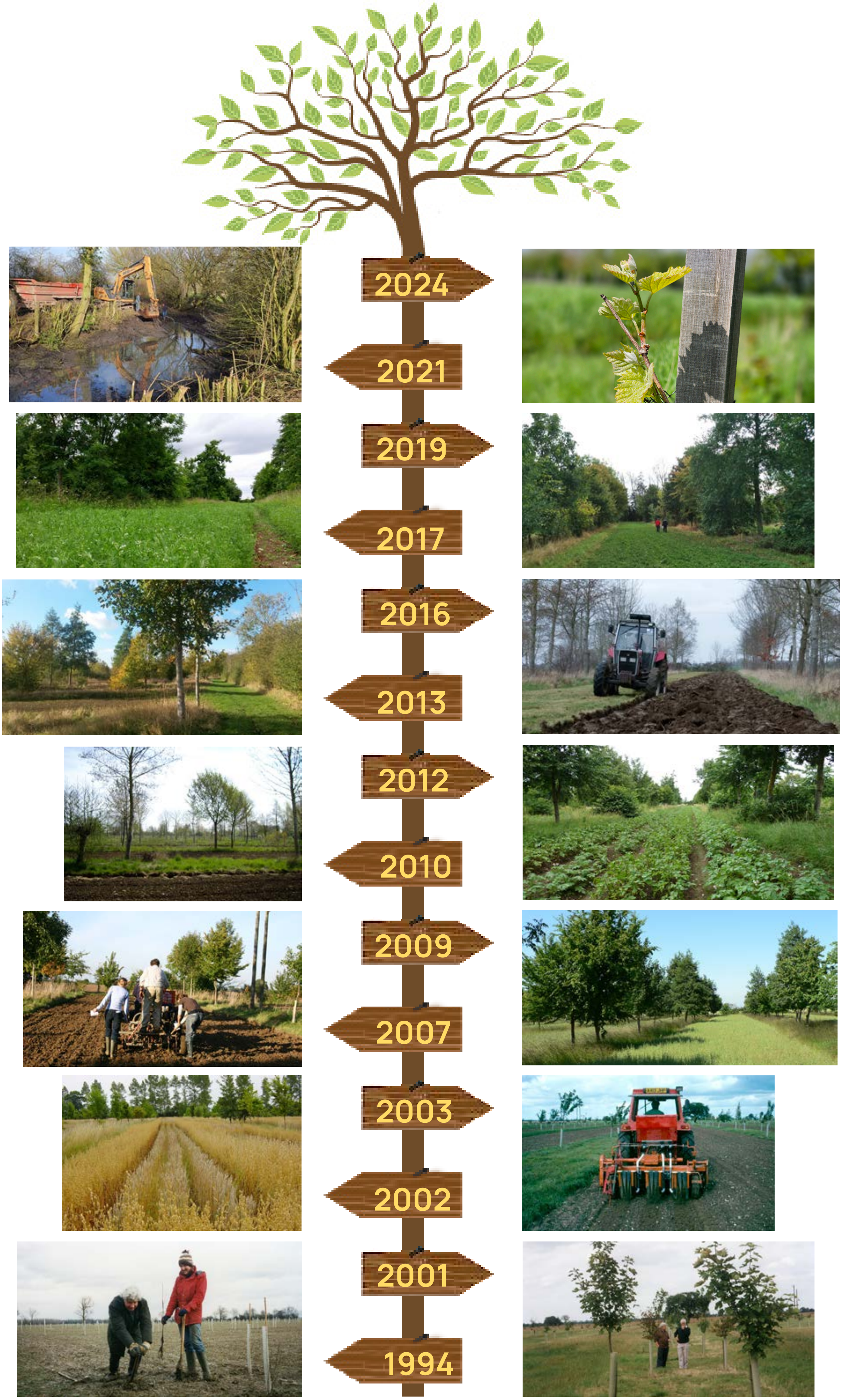
Martin and Ann Wolfe bought the fields that became Wakelyns in 1992, with the intention of trialling new farming systems and methods that were highly productive and sustainable without the necessity of inputs from outside the farm. Their aim was to provide both scientific evidence and a practical demonstration that alternative ways of food production are not only possible but advantageous.

When bought by Martin and Ann, the farm had been under intensive chemically-aided crop production for many years. Over the next few years they began the process of transforming the fields into the verdant haven that you encounter today when arriving at Wakelyns.

Diversity at all levels underpins the philosophy and approach to the development of Wakelyns. Martin firmly believed that the future of sustainable agriculture was rooted in Darwinian evolutionary processes, where adaptation to the agricultural abiotic and biotic environment leads to increases in overall productivity and resilience. This would be achieved by moving away from the industrialised monoculture approach towards polycultures with major increases in diversity both within and among crops, trees and livestock. Martin's early research showed how, for example, mixing just three varieties of cereal crop together in one field could restrict disease and stabilise crop yields. This simple principle has been extended to mixtures of species and ultimately to agroforestry systems involving multiple combinations of crops, from annual cereals and vegetables to perennial herbs and trees, together with livestock.

At Wakelyns four different agroforestry systems, based on a maximum use of biodiversity, were developed and contrasted. The agroforestry fields have been the site of many years of research trials and demonstrations, working closely with the Organic Research Centre (ORC) and other partners, to build up evidence on the production of a wide range of products from the agroforestry systems, and the delivery of a number of important ecosystem services such as maintaining soil fertility and health and biodiversity enhancement.

Wakelyns timeline



Diversity at all levels: from genes to landscape

Embedded in ecological theories linking biological diversity to stability in plant productivity and increased resilience, Wakelyns is a model of heterogeneity both at the genetic level as well as in terms of habitat structure. There are various approaches to increasing genetic diversity, including mixing different varieties of the same crop as well as mixing different species.

Cereal populations

Martin went a step further to increase genetic diversity with the development of a 'composite cross population' or CCP in the UK (Döring et al 2015). To produce a CCP parent plants from a range of wheat varieties chosen for particular qualities were crossed, the seeds from each cross multiplied and then combined, rather than separated into pure lines, to produce the first CCP generation. The theory behind this evolutionary plant breeding approach is that natural selection can act on the genetically diverse crop population and lead to local adaptation. Furthermore, genetic diversity can increase resilience to environmental stress over time and across different locations. This ability of the Wakelyns wheat CCP to respond to local conditions was demonstrated in 2012 when a wet autumn interrupted drilling of the winter wheat trials at Wakelyns. The cereals drilled at the optimum time all established well (Figure 1a) but when drilling was delayed a couple of weeks by heavy rain, the plots of the Alchemy variety failed while the CCP successfully established (Figure 1b). What has become known as the 'YQ' ORC Wakelyns Population Wheat was developed by the John Innes Centre and the team at Wakelyns from the Elm Farm Research Centre (as the ORC was then known) in 2001.

Growing CCPs under agroforestry could lead to the development of 'varieties' that are particularly well adapted to growing in close proximity to trees or even at different positions in relation to the trees. Pilot work carried out under the AGFORWARD project investigated this concept by comparing yields of a spring wheat CCP that had been developed into three populations based on where they had been harvested (East of the Tree line (EOT), West of the Tree line (WOT), and Centre of the alley (Smith et al, 2017)). Replicated cross-over trials found no difference between the populations in the first year, but in the second year a significant difference was found between the two 'edge' populations, with the EOT selection yielding 35% more than the WOT selection. This experiment indicates that the yield potential of a wheat population can be influenced by the position in an alley where it has been multiplied but the selection pressure may not be consistent enough for local adaptation. Furthermore, it may be unrealistic to expect farmers to drill different populations within an alley!

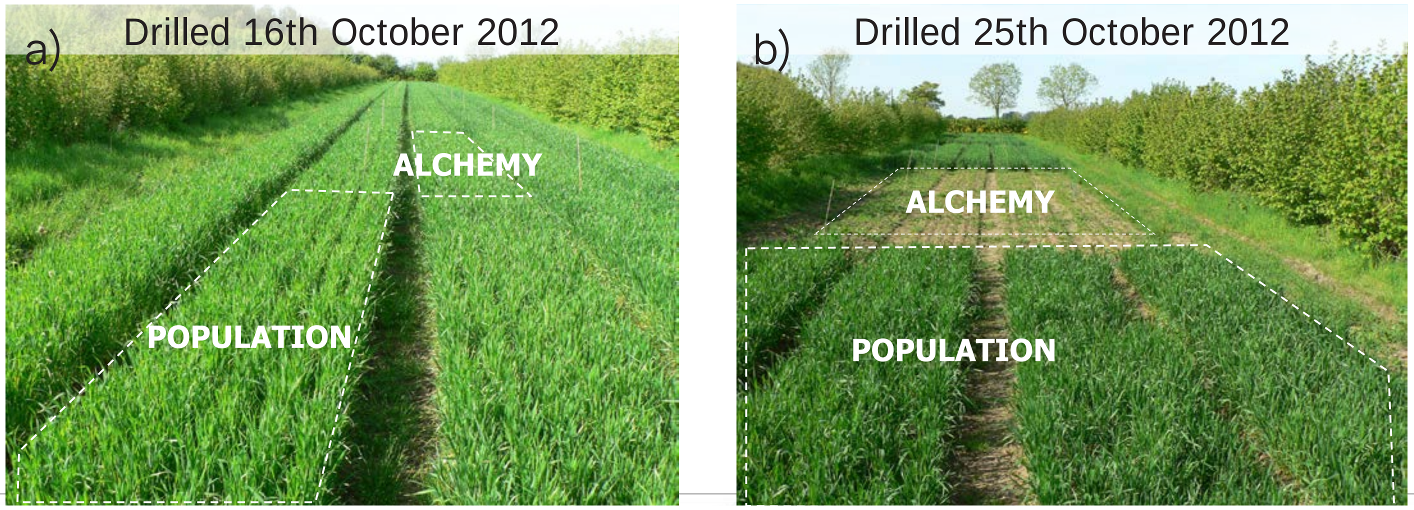


Figure 1: The trials above demonstrate that, unlike the population, the pure-line variety Alchemy failed when drilled only nine days later than the plots in which both crops established well, demonstrating the advantages of the greater genetic diversity in populations.

Diversity to reduce disease

This species mixture approach was extended to the trees, with eight different species mixed together in the timber system. The benefit of including apple trees in this mix was investigated in 2012 as part of a project investigating alternative approaches to reducing apple diseases (Smith et al 2016). Comparing apples in the agroforestry and a nearby organic orchard, the levels of the fungal disease apple scab (*Venturia inaequalis*) in the developing fruit were twice as high in the orchard as in the agroforestry system (Figure 2).

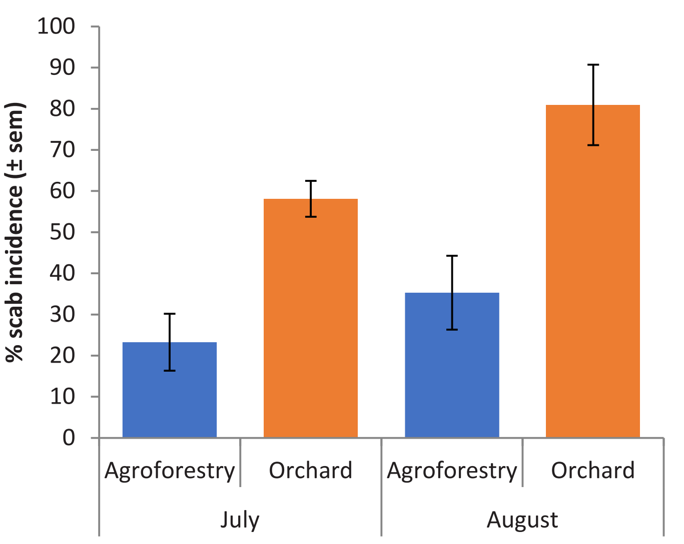


Figure 2: Incidence of scab disease in maturing apples at Wakelyns and a local organic orchard in 2012.

There are a few possible explanations for this disease reduction in the agroforestry apples:

- A greater distance between tree rows in agroforestry systems, with crops in the adjoining alleys, reduces the spread of pathogens.
- Lower densities of trees compared with orchards, favouring increased air circulation; this reduces the severity of scab by reducing leaf wetness duration.
- Regular cultivations within the crop alleys incorporates leaf litter into the soil, thus enhancing decomposition and reducing the risk of re-inoculation from overwintered scabbed leaves the following spring.

Species mixtures

As well as aiming to increase within-species diversity, various crop trials at Wakelyns have also explored the best ways to optimise species diversity, including diverse fertility-building leys containing up to 15 species (Döring et al, 2013). This trial, which was part of a series of on-farm trials of the same mixture against single species leys, found that by using mixtures of functionally diverse plant species, synergies between agricultural productivity and other ecosystem services can be optimised and fine-tuned to farm-specific needs. Intercropping combinations have also been investigated, combining wheat and beans, and in recent years, lentils and camelina.

Impacts of diversity on yield

The ORC have been involved in developing a new network model called GBRNM, designed to model biotic (living) interactions between trees and crops in English organic arable agroforestry systems, exemplified by Wakelyns (Figure 3). It was hypothesised that biotic interactions would stabilise arable yield to pest and disease attack. What has been found is that they boost the arable yield overall, but they do not increase crop yield stability in the face of such stresses.

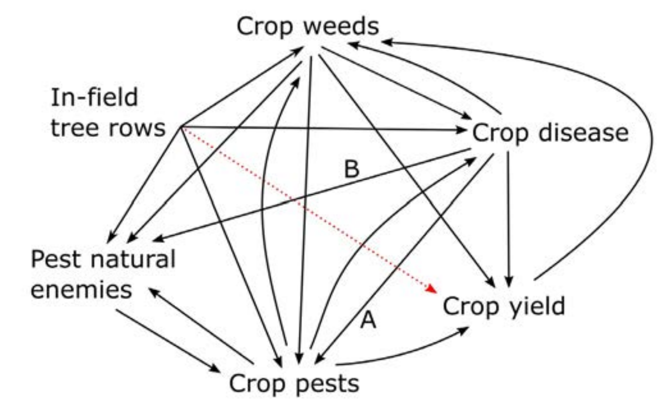
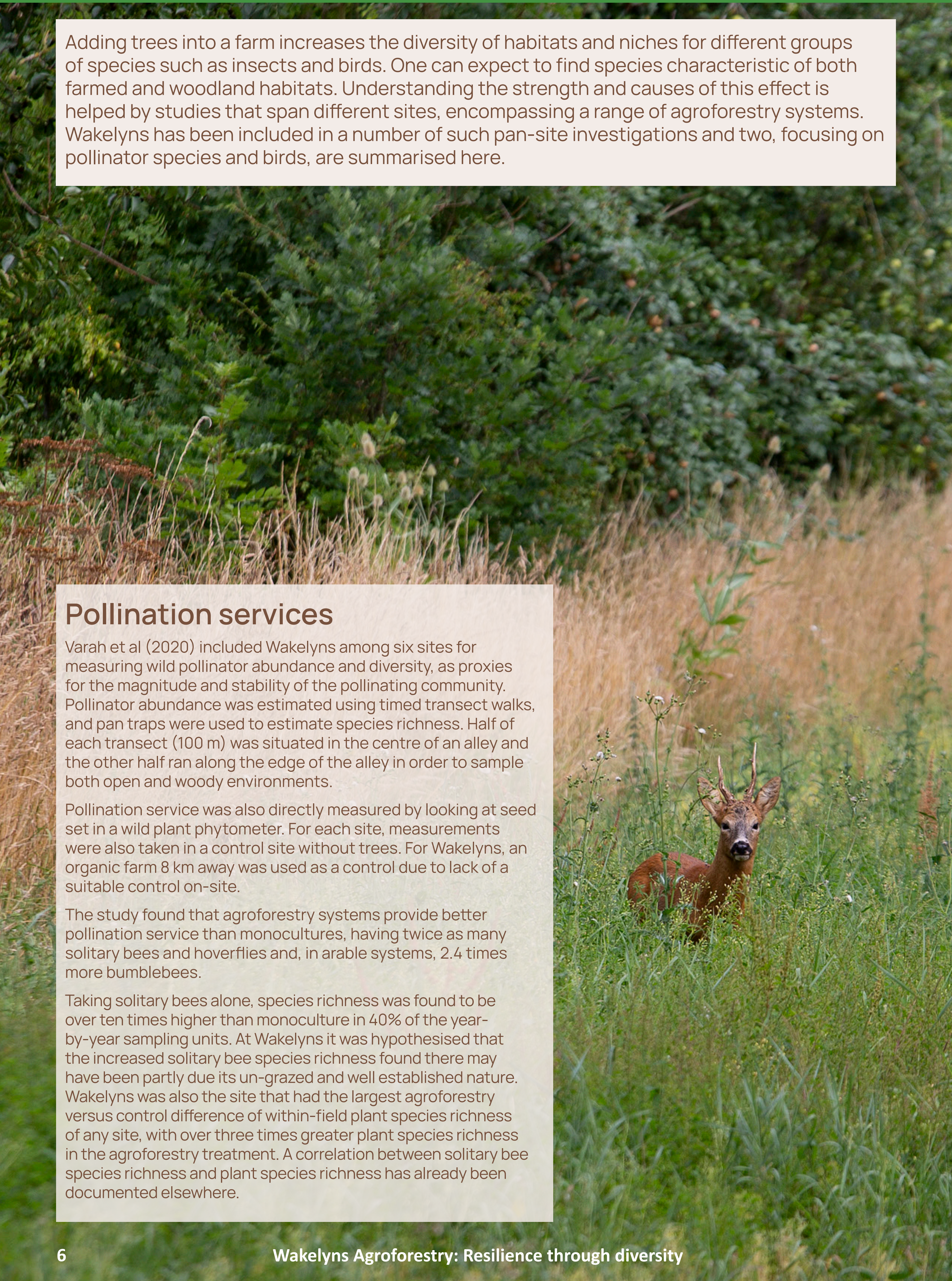


Figure 3: Network diagram showing the biotic interactions. The red arrow is the direct influence of trees on crop.

Biodiversity for agriculture and conservation

Adding trees into a farm increases the diversity of habitats and niches for different groups of species such as insects and birds. One can expect to find species characteristic of both farmed and woodland habitats. Understanding the strength and causes of this effect is helped by studies that span different sites, encompassing a range of agroforestry systems. Wakelyns has been included in a number of such pan-site investigations and two, focusing on pollinator species and birds, are summarised here.



Pollination services

Varah et al (2020) included Wakelyns among six sites for measuring wild pollinator abundance and diversity, as proxies for the magnitude and stability of the pollinating community. Pollinator abundance was estimated using timed transect walks, and pan traps were used to estimate species richness. Half of each transect (100 m) was situated in the centre of an alley and the other half ran along the edge of the alley in order to sample both open and woody environments.

Pollination service was also directly measured by looking at seed set in a wild plant phytometer. For each site, measurements were also taken in a control site without trees. For Wakelyns, an organic farm 8 km away was used as a control due to lack of a suitable control on-site.

The study found that agroforestry systems provide better pollination service than monocultures, having twice as many solitary bees and hoverflies and, in arable systems, 2.4 times more bumblebees.

Taking solitary bees alone, species richness was found to be over ten times higher than monoculture in 40% of the year-by-year sampling units. At Wakelyns it was hypothesised that the increased solitary bee species richness found there may have been partly due its un-grazed and well established nature. Wakelyns was also the site that had the largest agroforestry versus control difference of within-field plant species richness of any site, with over three times greater plant species richness in the agroforestry treatment. A correlation between solitary bee species richness and plant species richness has already been documented elsewhere.

Birds

Birds are an important indicator group for the health of an agroecosystem. An RSPB farm bird survey carried out in Wakelyns in 2010 recorded 43 species, which included eight species on the farmland bird indicator species list as well as several species commonly found in woodlands, orchards, parks and gardens (blackcap, bullfinch, chiffchaff, great spotted woodpecker).

In the AGROMIX Horizon 2020 project (see box), birds and bats were studied at Wakelyns and seven other mature silvoarable and silvopasture sites distributed across seven countries in temperate (England, Switzerland, Central France, Germany) and Mediterranean (Southern France, Italy, Portugal, and Spain) Europe (Edo et al 2024). For comparison, bird diversity was also assessed in nearby open agricultural land, forests, and orchards. Birds and bats were detected using AudioMoth acoustic recording devices (opposite), with a recording session encompassing dusk and the dawn chorus of the following day. Recording sessions were undertaken in the months of April, May and June.

Bird species richness in agroforestry was more than twice that of open agricultural land and similar to the diversity found in forests and orchards. Differences in bird communities were found between habitat types and between temperate and Mediterranean regions. In general, while temperate agroforestry systems hosted generalist and woody habitat species, in Mediterranean agroforestry they were composed of species from open and woody habitats.

The study supported the hypothesis that a high structural heterogeneity provided by the presence of trees increases bird species richness. Agroforestry can act as an important refuge for generalist and forest species in intensively managed, tree-poor agricultural areas. However, some specialist species associated with semi-natural grassland or arable land are not favoured or can even be deterred by the establishment of woody structures. Agroforestry doesn't necessarily bring back farmland birds in decline, and new agroforestry systems need to be adapted to regional conditions and the geographical as well as historical context.

European turtle dove (Streptopelia turtur)

AGROMIX

The AGROMIX project brings together farmers, researchers and policymakers to explore agroecological solutions for more resilient land use in Europe. It networks 83 sites with mixed farming, agroforestry and value chain networks (Wakelyns being one of them), and seeks to quantify biophysical indicators of agroecosystem resilience at the plot scale at a subset of these with long-term systems. Those indicators include the biodiversity value and function of key groups of organisms. In the context of climate change, biodiversity contributes to the resilience of agroecosystems; once conditions become unsuitable for certain species, a high species richness increases the chance of other species taking their role. Such roles include insects pollinating important crops, wild plants supporting animals and stabilising soils, and soil microorganisms recycling nutrients for the growth of crops. As well as birds and bats, at Wakelyns the species groups that have been sampled are plants (using quadrats), natural predators (using dummy caterpillars), ground dwelling spiders (using pitfall traps) and soil microbes (using shotgun metagenomic characterisation of soil samples).

Photo: David Bebber

Decentralised energy production

A key element of the research at Wakelyns has been to investigate different approaches to decentralise and localise agriculture, food and energy production and to provide a model to both prove the concept and act as a demonstration for others.

Martin and Ann very successfully achieved decentralised local energy by using the short rotation coppice (SRC) agroforestry tree rows and traditional field boundary hedgerows to produce woodchip for fuel. Woodchip from the SRC and the hedges is used to power a small 20 kW boiler which provides the year-round heat requirements for the farmhouse with additional woodchip left over for other purposes. The coppice species used for woodchip production are hazel (*Corylus avellana*), cut on a five-year rotation and willow (*Salix viminalis*), cut on a two-year rotation. Harvesting is carried out in winter using a tractor mounted circular saw and chipped the following summer using a small hand fed chipper.

From field to boiler. Willow harvested, dried and chipped to feed into a woodchip boiler that heats the farmhouse.

Biomass production of the SRC willow has been measured since 2011 and the hazel since 2014 (Smith et al, 2017). The two species of SRC produce very similar yields under current rotations when converted to annual biomass production (2.87m^3/100m/year). This gives two options; a willow system where the canopy is removed every other year so reducing the amount of shade on the alley crops, but requiring more frequent harvest (and potentially more competitive with crops for water and nutrients) versus a hazel system with slower growing trees, potentially casting more shade, but with fewer harvests to achieve the same yield.

One of the mature mixed species Wakelyns boundary hedges showing regrowth two years after coppicing; tree ring counts indicated that it had been 21 years since the hedge was last cut.

How many trees are needed to heat a farmhouse?

A typical 20 kW farmhouse boiler such as the one at Wakelyns uses approximately 80 m³ of woodchip/year. Therefore, based on the calculations in Table 1:

- 2800 m of Short Rotation Coppice (SRC) – double rows of willow or hazel – is needed to heat the farmhouse. Converting into field area with 3 m wide tree rows and 10 m wide alleys this equates to approximately 3.62 ha of agroforestry.
- 320 m of hedgerow is needed every year to heat the farmhouse; on a 15-year harvesting rotation, a total of 4.8 km of hedgerow would need to be in a coppice rotation to meet this demand.
- Wakelyns has 3.7 km of boundary hedgerow, 2.18 km (3.2 ha) of willow SRC, and 1.5 km (2.4 ha) of hazel SRC as alley cropping agroforestry, so is easily able to meet this need (Table 1), particularly with the recent upgrading of insulation in the farmhouse, leading to a significant woodchip surplus.

Table 1: Woodchip production at Wakelyns (Smith et al. 2017; Westaway and Smith, 2018)

	Length (m) at Wakelyns	Number of trees per m	Volume of woodchip per m (m³)	Coppice rotation length (years)	Length coppice in one year (m)	Annual woodchip production (m³)
Willow SRC	2175	1.65	0.0574	2	1087.5	62.42
Hazel SRC	1500	1.33	0.1432	5	300	42.96
Boundary hedge	3700	variable	0.25	15	247	61.75

Wakelyns

Wakelyns is a 22.5 hectare (ha) innovative farm situated right in the arable heartland of eastern England. The farm incorporates four silvoarable agroforestry systems into an organic arable rotation.

Location: Suffolk, East Anglia, 52.36°N, 1.35°E what3words slugs.meatball.megawatt

Climate annual averages: Rainfall 606 mm, sunshine 1535 hours, minimum/maximum temperature 6.0 °C / 13.8 °C.

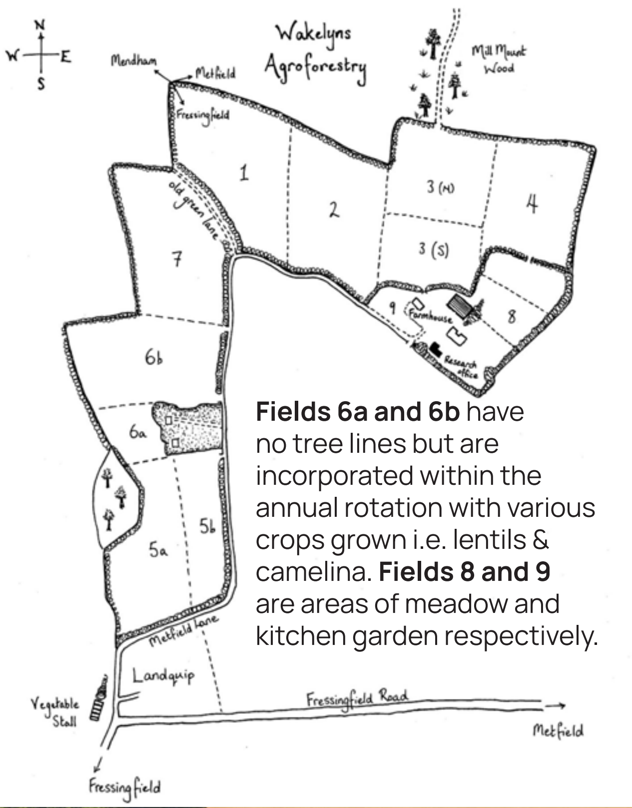
Soils: Clay loam over chalk with clay content of 25-30%, pH 8.0, organic matter approximately 3.5%, and low indices for P and K.

All trees are planted in north-south rows, with an organic arable and vegetable crop rotation grown in the 10-12 m wide alleys between the tree rows. Timber trees were planted in pairs of the same species. Lower limbs have been pruned to maintain form and facilitate crop management. Coppicing of the hazel and willow short rotation coppice is carried out in winter using a circular saw; cut material is then air dried in the field during summer and chipped the following winter to feed a Gilles 20 kW woodchip boiler which heats the farmhouse.

Over the years, a wealth of data has been collected on all elements of the different systems including tree growth and productivity, annual and perennial crop yields, pest and disease incidence, functional biodiversity and whole system sustainability.

Willow short rotation coppice (Field 5): Planted in March 1998 with a mixture of five fast-growing willow (*Salix viminalis*) varieties; each row coppiced every two years for woodchip production.

A mixed hardwood and fruit tree system with eight different species (Fields 1&2): Planted Feb 1994. **Far Field (1)** seven timber species (Ash (*Fraxinus excelsior*), Wild Cherry (*Prunus avium*), Italian Alder (*Alnus cordata*), Small-leaved Lime (*Tilia cordata*), Sycamore (*Acer pseudoplatanus*), Oak (*Quercus petraea*), Hornbeam (*Carpinus betulus*)); **Water Field (2)** timber tree mix, plus 42 apple trees of 21 heritage varieties



Vegetable-growing enterprise

3

Ley alley pods

4

Fields 6a and 6b have no tree lines but are incorporated within the annual rotation with various crops grown i.e. lentils & camelina. **Fields 8 and 9** are areas of meadow and kitchen garden respectively.

A fruit and nut tree system **(Fields 3&7)**: Planted February 2001. **Home Field (3)** tree rows partially planted to fruit and nut trees (plum, cherry, apple, pear, quince, apricot, peach, hazel), each of multiple varieties. **North Field (7)** 20 walnut trees and in January 2002 interspersed with varieties of plum and walnuts. Grapevines were planted in the tree lines in 2023.

Hazel short rotation coppice **(Field 4)**: Planted in February 1995 with 1200 hazel (*Corylus avellana*) bushes, each individual genetically distinct; alternate rows coppiced every five years for woodchip production.

Aerial photos: David Bebber (main) and Jeremy Gugenheim

The diverse range of produce that has originated from Wakelyns over the years demonstrates how truly productive a small plot of land can be. Products have included bioenergy from willow and hazel coppice, timber, fruit, vegetables, cereals and pulses, nuts, cider, and craft materials from the willow and hazel.

Martin and Ann's core ethos of decentralising food production led them to work with the local community and local businesses to enable food produced locally to be consumed locally and challenge multinational models of food production and distribution. They helped the local shop remain open as a community shop and initiated working closely with the champion of UK-grown pulses Hodmedod's, playing host to some of Hodmedod's early naked barley trials and pioneering at Wakelyns, amongst other things, British grown lentils, Several varieties have since been grown at Wakelyns, including olive, coral and 'Beluga' (black) lentils, which were celebrated and enjoyed in the first 'Wakelyns Dal Festival' held in 2023.

The core ethos continues today, with lunch often being an important part of any event at the farm, and visitors encouraged to enjoy eating the farm produce. Wakelyns produce is often cooked and baked by the Wakelyns Bakery for sale as food to families within the local area and beyond, and visitors can now buy on-site from 'The Wakelyns Carport.'

Enterprise stacking

Since Martin and Ann's deaths, David and Toby Wolfe and their families have continued with the organic rotation agroforestry whilst evolving Wakelyns into a hub for farming, food, research and the environment. To help make Wakelyns more sustainable they focus on short food chains, enterprise stacking, and people. The Wolfes manage the farmhouse and ley alley pods as visitor accommodation for holidays, NGO retreats and the many people attending courses and events. Others use Wakelyns as a base to build up their own independently run – but interconnected – businesses, drawing on what the land produces and offers, whether ingredients for cooking/baking, materials for crafts, or space for inspiration and education. Here are some of the diverse enterprises that are or have been part of Wakelyns in recent years...

Wakelyns Bakery

Led by Wakelyns Bakery founder, Henrietta Inman, it is the only 100% wholemeal bakery using local grains in Suffolk. Whilst not generally open to the public, its sourdough bread is sold through a bread club, local shops, and online through Hodmedod's. All the wheat (including the YQ population wheat) grown at Wakelyns is used on site by Henrietta along with lentils, squash, and all the fruit from the agroforestry tree lines. The bakery sells delicious food during farm open days, caters for courses and events at Wakelyns, and cooks for visitors staying on the farm. Henrietta's vision is to 'become a model of an agroecological bakery and food business which demonstrates resilience, holistic productivity, and longevity for all Beings.' They would like to share their learning so that others can build bakeries and agroecological food businesses in their communities, enabling greater accessibility to healthy and localised food.

Community Supported Agriculture

Since 2021 Wakelyns has hosted a CSA no-dig organic horticulture initiative inspired by Charles Dowding, providing opportunities for volunteers to get involved in producing healthy and nourishing vegetables. New growers are taking over the market gardening in 2024.

Contemporary Hempery

Hemp enthusiast Claire O'Sullivan and textile artist Kitty Wilson Brown have brought hemp (*Cannabis sativa*) to Wakelyns as a valuable organic weed-suppressing crop within the organic rotation which, along with natural dyes grown at Wakelyns (2024 will see Kitty establish a dye garden), will also produce fine fibres for high-quality clothing.

Willow Phoenix

Adam and Emma from Willow Phoenix used Wakelyns willow (*Salix viminalis*) for several years for various projects, including a commission for a living willow sculpture of The Mayflower and a family of life-sized elephants! Now, based at and running courses and events at Wakelyns, they have planted special basket willow within the agroforestry so that all their course material can come from Wakelyns fields. They have also started to grow chairs too!

Be More Bee

Several healthy wild honey-bee colonies thrive at Wakelyns (having remarkably out-evolved the deadly parasite varoa), but Gill Horrocks is developing other housing to replace tree cavities at Wakelyns when they are no longer able to support the bees. A Wakelyns hive has been developed which offers the same sort of protection as the inside of a tree trunk and is easy to construct using available bits of wood. The hope is to supply the bakery with a little honey, but it can also simply be left as a bee hollow for species conservation. There are plans to also introduce traditional bee homes ('skeps') made from the farm's long-stemmed straw and willow crop.

"...stacked enterprises link back to the farm and create economic, health, environmental and social synergies that are more than the sum of their parts."
(Thompson 2023)

Ramial woodchip trials

Trees have the ability to access and cycle soil nutrients in the deeper soil horizons that are not available to annual crops. Harvesting and chipping tree branches and applying this fresh 'ramial' woodchip to the soil increases the availability of these nutrients to vegetable and cereal crops. Ramial woodchip has also been shown to increase soil organic matter and promote soil biological activity (Lemieux and Germain, 2000). Through the EU-funded *Woodchip for Fertile Soils* (WOOFS) project ORC investigated this potential, with Wakelyns taking part in a trial applying Ramial Chipped Wood (RCW) as a soil improver.

Sampling earthworms in the RCW trial plots at Wakelyns 2018

RCW is made by chipping small (<7cm) diameter branches and twigs with a high proportion of buds and bark and applying the chip fresh to the soil in the ley phase of an organic rotation. It can be produced from hedges or short rotation coppice (SRC) agroforestry and provides a further piece in the jigsaw of decentralising food production. RCW gives the potential ability to grow your own soil fertility and organic matter thereby using perennial crops to improve soils that are part of an annual crop rotation.

The RCW trial at Wakelyns was one of three on-farm trials in the UK investigating the use of woodchip as a soil improver and was unique in comparing single species SRC woodchip (willow, hazel and poplar) with mixed hedge woodchip and a control of no woodchip input.

Trial results indicated that RCW may have many of the beneficial effects of compost, offering an option where livestock are scarce or the raw materials for composting are unavailable. When applied to a legume ley or with fertiliser, RCW was found to have a minimal or a positive impact on crop yields. The addition of RCW increased phosphorous (P) availability across all the trial farms; in fields with low P both RCW and compost might be worth considering. RCW has the potential to increase crop resilience to pests and diseases and extreme weather events. It was concluded that, whilst not a panacea, it offers some significant benefits in terms of carbon capture and storage and overall soil and crop health, as well as helping farms move towards self-sufficiency in inputs and closed system farming.

Three technical guides (Westaway 2020) resulted from the WOOFS project, covering not only the trial results but work looking into the logistics and economics of RCW and its use in the whole farm context.

RCW woodchip piles from the three different SRC species at Wakelyns

Pond restoration and creation

Unexpected funds from Natural England's Great Crested Newt habitat restoration scheme allowed Suffolk Wildlife Trust (SWT) to restore 10 ponds in Suffolk in spring 2021, one of which was an old (somewhat neglected) pond at Wakelyns. SWT were optimistic about recreating a rich habitat for wildlife. Their farm adviser Sam Hanks visited several times to carry out bird, pond and pollinator surveys and contractors set to work restoring the pond which was mostly filled with silt and polluted with chemicals leached from neighbouring fields and reaching the pond via a ditch. When the fields dried out, the digger dredged the pond and diverted the ditch that ran through it. With the pond now empty, they removed the silt that had built up since it was last cleaned out and took it back to being exactly its old profile. It gradually filled from rising ground water and rain and is now thriving, as evidenced by the return of great crested newts and previously dormant pond plants.

On the back of that success, SWT applied for planning permission to create two new ponds at Wakelyns, which they dug out in March 2023. One had been filled in decades ago, the other involved creating a completely new pond to provide more habitat for the newts and, in conjunction with the RSPB turtle dove conservation project, more habitat for the growing population of these rare and generally declining birds (in 2023, there were four pairs at Wakelyns). The RSPB are planting the surrounding area with a mix which should give a good habitat for the turtle doves.


Spring 2021


August 2022


May 2024

A preliminary ecological appraisal carried out in September 2022 revealed that land within the grounds of Wakelyns was an appropriate area to create two ponds due to its existing breeding pond and good quality terrestrial habitat of rough grassland and hedgerows, along with records of great crested newts in the surrounding area. Hedgerows surrounding the site were classed as 'important' under the Hedgerows Regulations 2007, (having six or seven woody species and other defined features in a 30 m length), and as Priority Habitat. They were identified as being species-rich and supporting a diversity of plants and animals, offering nesting opportunities for farmland and hedgerow birds. Turtle dove and yellowhammer were breeding on the site and barn owl were known to forage there. It was identified that carrying out pond restoration and creation would have positive impacts on the habitats and species present, offering further water sources and habitats for species such as great crested newt, common toad and turtle dove, which are known to breed on site.

Although the site is farmed land, it has excellent diversity and offers habitats for a variety of species groups. The existing ponds on site were also classed as Priority Habitat. There were eight records of great crested newts within 2 km of the site, and one of the three ponds on site scored as having excellent suitability to support the newts. The site also offers excellent terrestrial habitat and hibernation opportunities. (Green 2022)

Tree/crop interactions

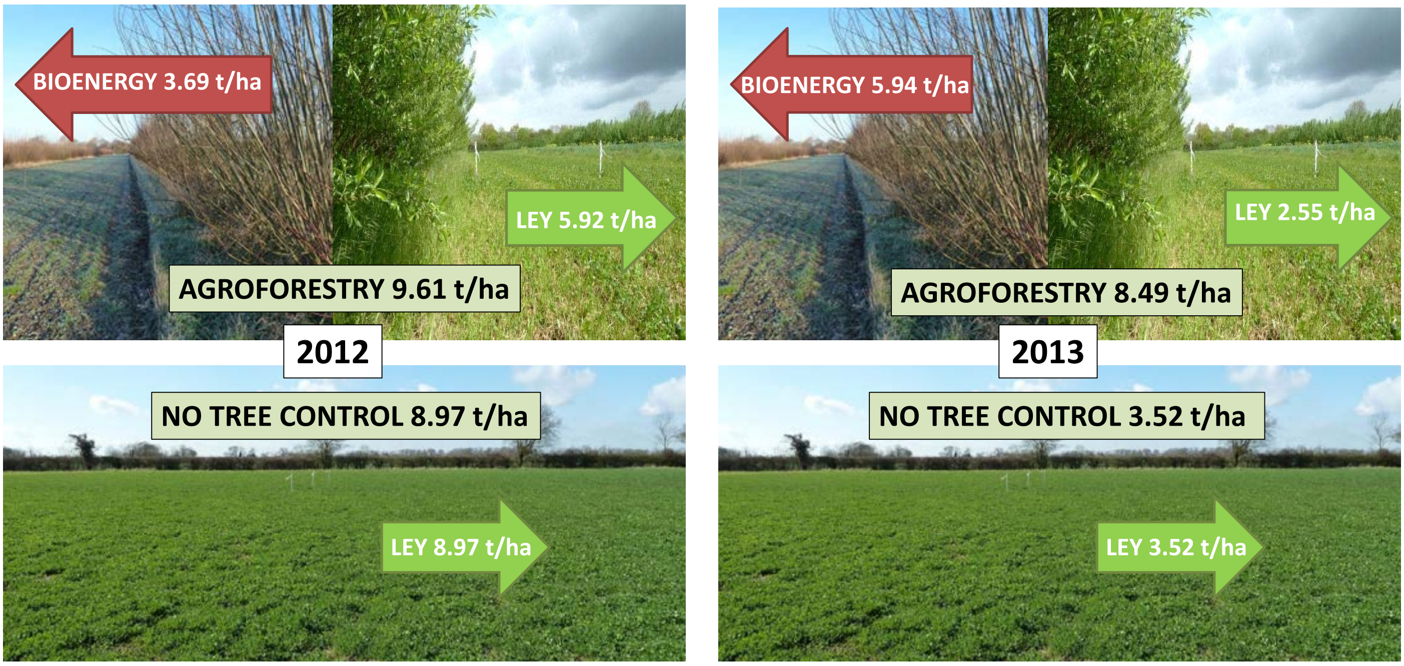
The productivity of an agroforestry system is determined by the balance between positive and negative interactions between the tree and agricultural components. The design and management of agroforestry systems should aim to maximise positive interactions that lead to complementary use of resources and minimise negative interactions that result in competition for resources.

A main hypothesis in agroforestry research is that while productivity from individual agroforestry components may be lower than if grown in a monoculture, overall productivity is higher in agroforestry systems compared to monocropping systems due to complementarity in resource-capture. The Land Equivalent Ratio (LER) is a means of comparing productivity of intercropping (e.g. agroforestry) and monocropping systems. It is calculated as the ratio of the area needed under sole cropping to the area of intercropping at the same management level to obtain a particular yield.

$$\text{LER} = \frac{\text{Tree agroforestry yield}}{\text{Tree monoculture yield}} + \frac{\text{Ley agroforestry yield}}{\text{Ley monoculture yield}}$$

An LER of 1 indicates that there is no yield advantage of the agroforestry system compared to the monocrops, while an LER of 1.1 indicates a 10 % yield advantage, i.e. under monocultures, 10 % more land would be needed to match yields from intercropping. The LER reflects the ability of crops to partition resources in space and time. We have calculated the LER at Wakelyns in three different ways: for a specific system over a single growing season; for a full arable crop rotation in a specific system; and for all of the agroforestry systems on the farm for a single year (Westaway et al 2021).

Overall productivity (as oven dry weights) in the willow SRC agroforestry system and the no-tree control at Wakelyns was compared using the data collected in 2012 and 2013 on biomass production of the ley and woodchip production from the willow.



Biomass production in the agroforestry and no-tree control in 2012 and 2013 (a standard SRC willow plantation yield of 8.33 t/ha was used for the no tree control)

The LER for 2012 was 1.10 (LER = (3.69/8.33) + (5.92/8.97)) and in 2013 was 1.44 (LER = (5.94/8.33) + (2.55/3.52)). This equates to a 10 % yield advantage for agroforestry in 2012 and a 44 % yield advantage in 2013. These calculations demonstrate that while there was a reduction in ley productivity, probably due to competition at the alley edge, and a reduction in land area under ley (77 % of land area), overall productivity was higher in the agroforestry system in both years. In 2013 when ley productivity was low in both systems, overall productivity was much higher in the agroforestry (8.49 odt/ha compared with 3.52 odt/ha, and an LER of 1.44), with increased wood biomass production compensating for the lower ley yields in the agroforestry. This suggests that an agroforestry approach can help buffer against fluctuations in yields by spreading the risk across a number of components.

The LER for a full arable crop rotation (and three willow SRC harvests) of six years (spring wheat/ley/potato/ley/winter squash/ley) was calculated using a modelling approach (Smith et al 2017). Using a special agroforestry model called Yield-SAFE, it was possible to model and thus compare the yields that might be expected at Wakelyns as a pure arable system, a pure willow SRC system and a willow-arable agroforestry system. The LER was calculated as:

$$\text{LER} = \frac{42.81}{46.79} + \frac{14.34}{32.07} = 0.91 + 0.45 = \mathbf{1.36}$$

And finally the LER combining all of the agroforestry systems on the farm for one year was calculated using the SustainFARM Public Goods Tool (see Page 18). This returned an LER of 1.34, suggesting that there is a 34% yield advantage for agroforestry compared to when the components are grown separately as monocultures.

Looking forward

As the agroforestry systems at Wakelyns age, the interactions between the trees and crops are changing. In the SRC systems, the regular coppicing of the trees means that aboveground competition for light is controlled and it is likely that arable cropping can continue in the alleys for years to come, potentially until the trees need replacing. In contrast, the timber trees have grown to heights of up to 13 m (Figure 4) and viewed from above, the system is now starting to resemble a woodland (Below). The shading impacts on crop yields are likely to mean that commercial arable cropping will be eventually unviable; however, over recent years, Martin introduced pollarding to manage the tree canopies and provide more light into the alleys. An alternative approach would be to selectively thin or harvest the trees to reduce tree densities and open up the canopy or to convert the alleys to pasture and introduce grazing animals to the system. Natural tree regeneration has been occurring between the planted trees and when you look across the tree rows, you can now see a wonderfully diverse, mixed-age, low-density deciduous woodland.

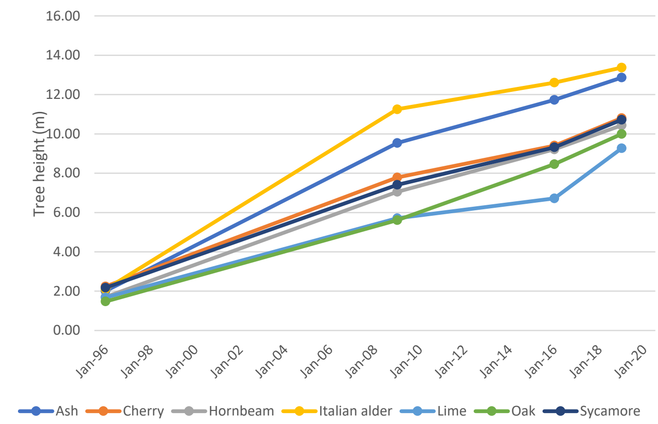


Figure 4: Tree height (m) of the timber trees at Wakelyns, planted in 1994

Aerial view of the mixed timber system. Photo: Jeremy Gugenheim.

Hi-sAFe modelling

Hi-sAFe (as described in Figure 5 by Dupraz et al. 2019) is a very detailed model of crop and tree growth in agroforestry and biophysical competition (i.e. for light, water and nutrients) between crop and trees. The walnut-arable system at Wakelyns, best exemplified by areas of North Field, is being modelled in this way between 2001 and 2100 to determine how climate change will impact the relationship between tree and crop. The model is in development, but early findings suggest that walnut trees can protect winter wheat against "complete failure" in very harsh years and that the benefits of trees will increase as climate change intensifies.

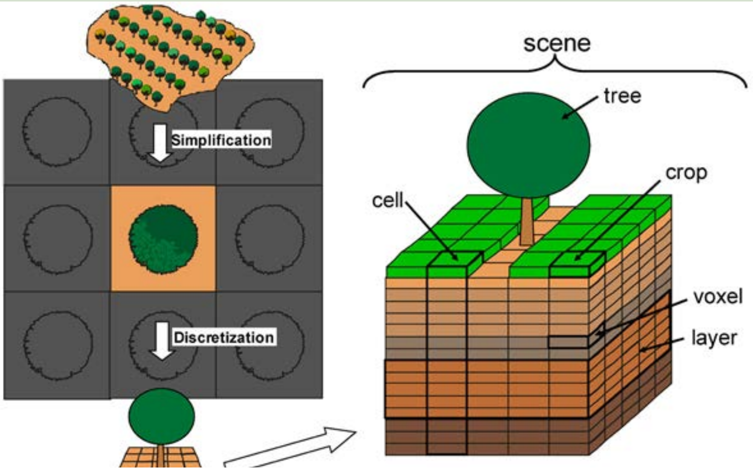


Figure 5: Hi-sAFe models agroforestry as a series of replicable units in a 3D grid of voxels. Dupraz C et al (2019)

Sustainability

Agroforestry systems such as Wakelyns are often promoted as sustainable alternatives to the highly industrialised agricultural model with its associated negative environmental externalities. However, our research often focuses on just a single factor (or limited range) of sustainability measures. A combined approach applying a range of tools and metrics can help to reveal costs and benefits from a range of perspectives (environmental, economic, social) and help determine the extent to which contrasting agroforestry systems can deliver on a range of sustainability objectives.

ORC used a comprehensive sustainability assessment tool, the SustainFARM Public Goods Tool, which is modified for agroforestry systems, to consider the many aspects of sustainability (ORC 2019; Smith 2019). The assessment takes a broad approach, using information that a farmer would have in their farm records already and covers a specific 12-month period. It takes between 30 minutes and an hour to complete, depending on the complexity of the farm. It assesses a farm on a number of areas (spurs) which may be impacted by agricultural management practices and are related to public goods such as water quality, air quality, etc.

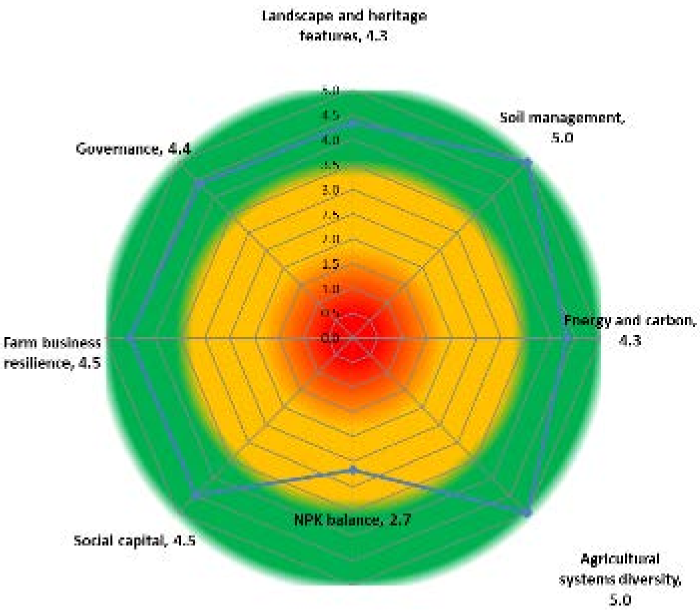


Figure 6: Radar diagram showing the results of the SustainFARM PG Tool assessment at Wakelyns.

As a diverse organic farm, Wakelyns scores highly across nearly all the spurs (Figure 6), achieving a top score in soil management and agricultural systems diversity. Its lowest score is for the NPK balance; currently the fertility building legume ley fixes more nitrogen than is exported in crops, thus risking leaching of nitrogen from the farm.

An energy and emissions audit was carried out at Wakelyns in 2009; this assessed energy production and consumption of the farm business including the domestic property (Smith, 2009). The whole estate energy production, including woodchip from the SRC, was 1086 GJ, while the whole estate energy consumption was 189 GJ. This gives a production:consumption ratio of 5.1:1. Energy benchmarking using the SustainFARM PG Tool found that while the arable enterprise uses only 61% of arable benchmark systems, the domestic energy use is considerably higher than an average farmhouse (367% of benchmark). The farmhouse at Wakelyns is a beautiful, but old and leaky building that is hard to insulate. 80% of the farm energy use is from renewable sources (photovoltaic panels and woodchip from the agroforestry system), and the CO_2 balance is -10.2 tonnes CO_2 equivalent per year.

As the farm changes and trees mature, further opportunities to apply the PG Tool at Wakelyns are being taken up, such as through the European Horizon ReForest project. The previous PG Tool results can act as a baseline, allowing for the tracking of farm sustainability over multiple years, as well providing opportunities for comparisons with agroforestry farms across Europe.

Aerial view of the short rotation coppice willow. Photo: Jeremy Gugenheim.

The story of Wakelyns, an inspiration to all

Martin always retained and conveyed his enthusiasm for sharing the Wakelyns message. Since he and Ann first started planting trees, Wakelyns has played host to thousands of visitors from across the world, inspiring and motivating farmers, foresters, growers, students, researchers, bakers, artists, politicians, industry, conservationists... David and Amanda are enthusiastically continuing and developing that tradition.

Agroforestry Open Weekend

Since 2021 Wakelyns has been leading the way on a yearly event designed to celebrate the growing global community of agroforestry farms and farming. This farmer-led initiative provides a great opportunity for farmers and others to see agroforestry in action. Sites across the UK, Ireland, and the rest of the world, can open their farm gates to visitors over the weekend. 2024 will see over 40 farms participating.

"*30 years ago planting trees in lines into a wheat field (as per Wakelyns) was regarded as eccentric, even foolish (certainly by the farming establishment). But it's now about to become mainstream to plant agroforestry... In its 2023 Carbon Budget Delivery Plan, the UK Government has committed to 10% of UK arable land being agroforestry by 2050.*" David Wolfe

https://agroforestryopenweekend.org/

Stephen Briggs

Stephen Briggs, pioneering organic farmer and advisor, took inspiration from Wakelyns when designing and planting 4500 apple trees as UK's largest commercial silvoarable system on his farm in the Cambridgeshire fens: *"Martin was a pivotal sounding board with whom to discuss my ideas of developing commercial agroforestry at Whitehall Farm. Sharing ideas and experiences helped shape our direction. Martin's quiet wisdom encouraged us all to look more deeply at Nature and try and take lessons to shape our farming systems – his inspiration will live on long through many."*

Maria Finckh

Maria Finckh, professor of organic farming at University of Kassel, based at Witzenhausen, has been part of the Wakelyns story from the start: *"Some very special times were the planting of trees at Wakelyns in 1994 and 1995 and the beginnings of the work with the CCPs. Martin's vision was to enhance diversity among crops and within crops. This has inspired scientists across Europe and the wheat composite cross populations (CCPs) are now in the F18, growing from Hungary to the UK."*

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Further information

Farm Woodland Forum: www.agroforestry.ac.uk/

European Agroforestry Federation (EURAF): www.eurafagroforestry.eu/welcome

Organic Research Centre: www.organicresearchcentre.com

Woodland Trust: woodlandtrust.org.uk/agroforestry

Agricology: www.agricology.co.uk

Wakelyns Agroforestry: www.wakelyns.co.uk

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