Innovative and sustainable intensification
of integrated food and non-food systems in Europe

April 2019

Technical guidelines for farmers and other stakeholders, factsheets on case studies and preparation of policy briefs

WP5. Dissemination of outputs and communication to stakeholders
Report

Innovative and sustainable intensification of integrated food and non-food systems to develop climate-resilient agro-ecosystems in Europe and beyond

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Innovative and sustainable intensification
of integrated food and non-food systems in Europe

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Introduction

The main objective of the SustainFARM project is to enhance agronomic, environmental and economic performance of integrated food and non-food production systems (IFNS) by optimizing productivity and valorising woody components, residual wastes and co-products. IFNS are systems in which trees, crops and livestock components are integrated in different ways at different scales (plot-field-farm). The specific objectives are to a) assess resource use efficiency and design innovative and cost-effective IFNS for optimum productivity, b) develop sustainability metrics to assess agronomic productivity and environmental performance and c) valorise the woody components, residual waste and co-products into high value bio-energy carriers and bio-products.

To achieve the objectives, SustainFARM has adopted an innovative case-study approach, whereby locally relevant IFNS are already identified, to work in close collaboration with the local end-users of the technology, such as farmers, advisory services and policy makers. By involving the end-users and other stakeholders from the start of the project activity, we have co-generated technology, relevant at the local scale to address productivity issues and enhance valorisation of the unused, residual and co-products. SustainFARM investigated the economic and environmental performance of the range of locally relevant IFNS across several agri-climatic zones of Europe and designed innovative IFNS systems, which are resilient and climate-smart. To improve the cost-effectiveness, different means of valorising the co-products (woody components and residual wet olive cake) for multiple uses (bedding material, compost etc.), have been demonstrated at two SME facilities in UK and Italy and the knowledge generated will be shared through the stakeholder platforms. Value chains and life cycle analysis (LCA) of the new bio-products (pellets, bio-energy and food supplements etc.) have been carried out to assess the environmental footprint of the valorisation processes. The best practices and innovative methods are synthesized into a decision support tool (DST) to enable informed decision making by farmers, advisory services and policy makers. To promote the adoption of IFNS in Europe, SustainFARM produced tailor-made products to facilitate knowledge exchange, based on the scientific and practical agronomic knowledge generated in the project and the needs of the various stakeholder groups.

The report presents the final conclusions of regional investigation in identified IFNS case studies of 6 countries in different climatic zones of Europe and consider evidence-based solutions for development IFNS innovative systems.

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Innovative and sustainable intensification of integrated food and non-food systems to develop climate-resilient agro-ecosystems in Europe and beyond (SustainFARM)

SustainFARM Policy brief

February 2019

Introduction

Global policies are currently aware of environment problems caused by agricultural intensive systems. The Millennium Ecosystem Assessment highlights that human society benefits not only from products delivered by ecosystems, but also from regulating and cultural services.

Agroforestry is defined as the deliberate integration of woody vegetation with agricultural activities in the lower story. Agroforestry systems provide a higher biomass production per unit of land and more ecosystem services than woody-less agricultural lands, such as the reduction of soil erosion and nitrogen leaching, and the increase in carbon sequestration and the improvement of landscape diversity.

Agroforestry practices fully respond to the need to implement multi-functional agriculture as requested by the most relevant International and European development strategies and agreements requiring sustainable development goals in Europe. Therefore, adequate policies promoting agroforestry practices and systems should be developed in order to increase agriculture and forestry sustainability as FAO recommends.

Agroforestry is one of the most common land use practice worldwide and have formed key elements in European rural landscapes until modern agricultural practices were introduced and adopted at wide scale in the last decades. Woody vegetation was deliberately retained or included in the cultivated or grazed lands by European farmers as it has traditionally served various purposes in the agrarian economy through multiple production as well as delivered environmental benefits. During the second half of the 20th Century, trees and shrubs were progressively removed from the cultivated land of Europe as a result of mechanization and intensification of agriculture, but also as a consequence of land consolidation schemes to increase the size of agricultural parcels carried out all over Europe. Since the end of the 20th Century, the important role of trees in producing valuable products and environmental benefits has been progressively recognized worldwide.

Agroforestry and Common Agricultural Policies (CAP)

Common Agricultural Policies (CAP) schemes favoring the preservation of large trees on farms have been implemented as part of the conditionality or cross compliance in Europe. However, most of Pillar I rules negatively affected the preservation or promotion of woody vegetation, and caused indirectly the destruction of millions of trees by farmers, in order to get the direct payment funds. Conditionality rules for retaining landscape features, including woody component (isolated trees, hedgerows, copses) in European Union agricultural systems have become inefficient due to the associate control complexity. Therefore, there is currently the need to re-introduce woody vegetation in agriculture to transform European Union agriculture in sustainable systems and promoting smart climate agriculture. Agroforestry practices should be promoted because they are able to increase productivity and profitability per unit of land in a sustainable way, providing various environmental benefits (reducing soil erosion and nitrogen leaching, and increasing carbon sequestration and landscape biodiversity). The introduction of trees in agricultural lands as a way to promote the woody component of agroforestry was recently promoted by the European Union Rural Development programs (Measures 221, 222 and 223 and Sub-measures 8.1 and 8.2 in the CAP 2007–2013 and 2014–2020, respectively).

The Measure 222 was poorly applied across EU27 during the analyzed programming period: only few EU Regions have allocated resources to implement the Measure 222 and only 3.4% of these resources has been effectively invested to create new agroforestry systems on arable lands. Moreover, only 2.3% of the expected beneficiaries has been targeted and 2.1% of the expected hectares has been realized. The main constraints that have hampered the success of the Measure 222 in EU27 were: i) the lack of knowledge and awareness of farmers, consultants and RDPs Managing Authorities concerning agroforestry; ii) the limited range of agroforestry systems that could be supported (only silvoarable systems such as the combination between timber trees and arable crops); iii) the lack of specific funding measures to cover maintenance costs of the new agroforestry systems; iv) the conflict between Measure 222 and other CAP instruments such as the Single Farm Payment, according to which the presence of trees across farmland reduces the amount of direct farm payments.

In the current CAP, 2014-2020, within the Pillar II, measure 8.2 supports the establishment of agroforestry systems covering the establishment costs (up to 80% of the expenses) and the maintenance costs with an annual premium for 5 years. Eight (only one Eastern country, Hungary) out of 27 European countries allocated budget to implement the agroforestry measure. Pillar II also indirectly supports agroforestry landscape through promoting small areas for biodiversity conservation (M10.1, M4.4), hedgerows maintenance (M10.1, M4.4), preserving isolated trees (M10.1), practicing forest grazing (M8.3; M10.1) and grazing orchards (M10.1).

Direct payments given through the Pillar I of the CAP are key to promote sustainable practices across Europe, as farmers receive a fixed amount of money per unit of land to develop if some conditions are fulfilled. One of these conditions affects directly agroforestry preservation and promotion as it put a tree limit to get the full payment per unit of land. In arable lands and permanent grasslands, the limit was 50 trees per hectare in the previous CAP, 2007-2013, being 100 trees/ha with tree cover < 10% and hedgerows < 2m in the current CAP. However, in permanent crops there is no limit to tree presence and density.

SustainFARM project activities and results

There is a diversity of agroforestry systems being practiced across Europe but the information on these agroforestry systems are scarce and often unavailable. Hence, the SustainFARM project focused on diverse agroforestry systems from different pedo-climatic zone of Europe to demonstrate the environmental and socio-economic benefits that could be obtained integrating crops, trees and animals. In SustainFARM project, a network of 6 agroforestry systems was described and analysed with the aim to: i) assess resource use efficiency and design innovative and cost-effective IFNS for optimum productivity; ii) develop sustainability metrics to assess agronomic productivity and environmental performance; iii) valorize the woody components, residual waste and co-products into high value bio-energy carriers and bio-products. The project demonstrated the role of agroforestry in different production systems across Europe and the rationale of agroforestry systems to fit into overall agroecosystems in the relevant environmental and socio-economic settings. The diversity of systems presented, will open up potential opportunities for implementation of adapted agroforestry systems in relevant contexts. Hence, the project provided a robust field based evidence on diversity of agroforestry systems and their multifunctional role in diverse contexts, for informed decision making for adoption by land managers, advisory services, farmers and policy makers.

SustainFARM project is focused on A network of sites representative of integrated food and non-food systems (IFNS) located in different socio-economic and environmental settings in Northern, Eastern and Southern Europe. The network comprises both traditional and innovative systems in which trees, crops and livestock are integrated in different ways and at different scales. The IFNS sites constituted the core of the project since they have provided necessary inputs and data to calibrate and validate models to assess agronomic

productivity, environmental performance and to design innovative land use systems.

IFNS category	Country	Description
Combined food and energy production systems	Denmark	Cereals (spring barley, winter wheat and oat) and fodder crops (Lucerne and ryegrass) with mixed stands of short rotation coppice: willow, alder and hazelnut.
Multipurpose olive tree production systems	Italy	Olive orchards with different management regimes: organic, conventional, abandoned, with pasture, and with natural grass.
Silvopastoral systems	United Kingdom	Silvopastoral system with tress (willow and alder) and a hedgerow network (maple, blackthorn, oak, willow, hazel)
	Romania	Silvopastoral system which combine natural grasslands, meadows and trees (beech, oak, alder, hornbeam, etc.)
	Poland	Silvopastoral system with wooded grasslands and hedgerows
Silvoarable systems	United Kingdom	Short rotation coppice with willow and hazel intercropped with different crops (Winter and spring wheat, Oats, Barley, Triticale, Potatoes, etc.)
	Poland	Orchard (apples, plum, pear, apricot) intercropped with vegetables
Agrosilvopastoral system	Spain	Fruit trees (olive, orange, almond, carob) with bees and combined with grazing

Each agroforestry system was described in terms of crop and tree components, inputs and outputs of the production system. Agronomic and economic data was collected and elaborated with the aim to assess the productivity and economic viability of these systems. Land Equivalent Ratio (LER) was used as an index to measure the agronomic productivity and gross margin was used as an indicator for economic viability assessment. All the studied systems perform a LER value higher than 1, demonstrating that specific agroforestry systems can be more productive than monoculture because they utilize better the available natural resources. Otherwise it is recognized that monoculture need more external inputs (water, energy, fertilizers, etc.) contrasting with the main international directives promoting sustainable and resilient agriculture. Hence, at field level, these agroforestry systems demonstrated that diversity of agroforestry practices, under different pedo-climatic zones, can enhance productivity and economic returns.

Considering the sites within the farms, a Public Goods Tool (DST) for agronomic, environmental and social performance of IFNS for informed decision making was developed. The PGT assessesed the agriculture-related “public goods” that are provided by a farm. A number of ‘spurs’ or dimensions of sustainability are covered. These dimensions include soil management, agri-environmental management, landscape and heritage, water management, fertiliser management and nutrients, energy and carbon, food security, agricultural systems diversity, social capital, farm business resilience, animal health and welfare management and governance. Each spur is assessed on a 1-5 scale by asking questions to farmers based on a number of key “activities”. The PGT assesses the agriculture-related “public goods” that are provided by a farm. The PGT assessment revealed diversified range of scores across most of the 11 spurs. Farms Business Resilience, Social

Capital, Systems diversity, Food Security, and Soil Management were particularly strong areas as a result of the diversity in marketing outlets, the high species / varietal diversity, importance of the farm for social involvement, local sales and a range of measures for enhanced soil protection. Weaker areas of performance were fertiliser management and agri-environmental management due to an absence of written plans for nutrient/water management and conservation. These results revealed the benefits that diverse agroforestry systems can provide across a range of sustainability criteria.

A value chain analysis of IFNS has been carried out with the aim to highlight how the valorisation of diverse products can add value at farm level. All case-studies have been performed by using qualitative expert-interviews. Interviewees are involved in each single value chain of integrated food and non-food products meaning farmers, processors, customers, politicians, researchers, resellers, contractors and members of NGOs. Considering the opinion of all these different stakeholders within a value chain provide a holistic view on the value chain to be able to give advice for future policy making to foster integrated farming projects. The studied agroforestry systems provided diversify farm products contributing to enhance farm resilience. Farms in Denmark, United Kingdom combining production of willow short rotation coppice (SRC) and arable cropping, in addition to food, they produce woody material that can be chipped for use in a biomass boiler on farm or for sale to smaller heating stations. Growing organic vegetables between the tree rows can also allow to produce high quality products (based on results from farms in UK and Poland).

Grazing olive orchard in Italy reduce treatment costs and chemical inputs. Sheep benefit from a good source of grass and so reduce cutting costs of weeds and olive shoots. In periods with food shortages, the olive leaves can supplement their diet reducing concentrate needs. In lactating sheep, feeding with olive leaves leads to an improvement in the quality of milk fat compared to diets based on conventional forages. From processing the olives, in addition to extra virgin olive oil, residues such as stone can be used to produce energy, vegetation water can be used as fertilizer and wet pomace to produce a kind of olive pâté destined to animal or human consumption.

Increasing the complexity of the systems, such as in Spain, introducing and managing a combination of different species, including goats and bees, on the same plot, contributes also to increase the biodiversity and reduce the environmental impact.

In Romania and Poland, traditional silvopastoral systems with pastures, hay-meadows, well-individualized trees, forest strips and grazing animals, woody vegetation, often spontaneous, is managed by pruning and pollarding and used as firewood to fill the farm energy requirement. Moreover, it might help to increase quality of animal products (milk, cheese, meat) due to improved welfare of grazing livestock.

Implications and Recommendations

There is a growing interest across Europe concerning agroforestry systems and practices. Several international agreements highlight the importance to promote and support agroforestry as sustainable land use practice able to promote multifunctional agriculture. European Union has funded several research projects starting from the Silvoarable Agroforestry for Europe (SAFE project, 2001-2005), continuing with AgroForestry that Will Advance Rural Development (AGFORWARD project, 2014-2017) and the current Agroforestry Innovation Network (AFINET project, 2017-2019). At the same time, European Agroforestry Federation (EURAF) has been constituted in 2012 and it actually involves about 280 members from 20 different European countries where national agroforestry associations have been also created.

This effort has convinced European Union to support agroforestry in the CAP in 2007-2013 and 2014-2020 programming periods. Many tools are available in the Pillar II of the CAP to support a more sustainable agriculture, including the introduction of agroforestry systems. Nevertheless, some constraints and contradictions still hamper the wide adoption of agroforestry systems in Europe: i) lack of knowledge and awareness among stakeholders about agroforestry; ii) CAP complexity and bureaucracy that limit small-scale farms to get subsides; iii) llimited allocation of resources to the agroforestry measures.

SustainFARM project demonstrated that specific agroforestry systems are able to combine the production of food and non-food goods, as requested by European policies and international agreements concerning sustainability. Although the project was focused on diverse agroforestry systems, the main policy recommendation should consider that:

- Agroforestry systems can produce more than monoculture reducing the use of external inputs such as fertilizers, water, etc.;
- Agroforestry systems can integrate and diversify farm's income delivering multiple products, both food and non-food;
- Agroforestry systems can enhance the delivery of ecosystem services such as biodiversity conservation, landscape improvement, soil erosion control;
- Agroforestry systems can valorize secondary bio-products in innovative value chains to promote rural development.

Acknowledgments

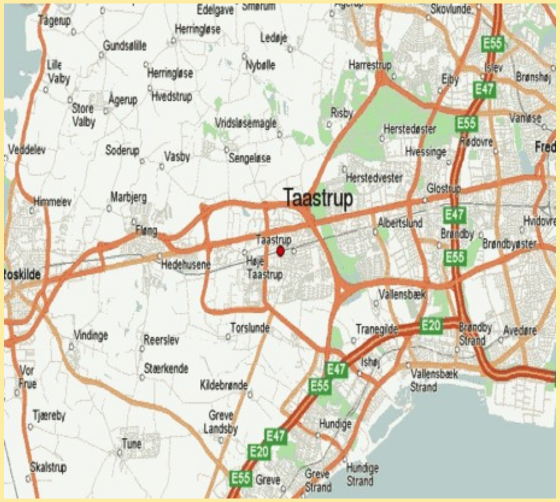
SustainFARM project has received funding from the European Union's Horizon 2020 research and innovation programme, grant agreement No 652615, under the frame of FACCE SURPLUS (Sustainable and Resilient agriculture for food and non-food systems).

About the Project

A network of farms and stakeholders were formed, to collect agronomic and socio-economic data to assess environmental, social and economic sustainability of the integrated food and non-food systems. CFE system was identified in Denmark.

Objectives

- To assess the agronomic productivity and environmental performance of the Danish CFE system
- To design innovative CFE with state-of-the-art tools and models



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Factsheet

Combined food and energy system (CFE), Taastrup, Denmark.

SUSTAINFARM

Combined food and energy system

The Danish CFE system is a Combined Food and Energy system, integrating food (spring barley, winter wheat and oat) and fodder crops (lucerne and ryegrass) with mixed stands of short rotation coppice (SRC): willow, alder and hazelnut.

Woodchips for energy production

The biomass belts are harvested and chipped every 4 years and the wood chips taken to a nearby heat and power station for the production of heat and electricity.

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SustainFARM is funded through ERA-NET FACCE SURPLUS under the EU Horizon 2020 research and innovation programme (grant agreement No 652615).
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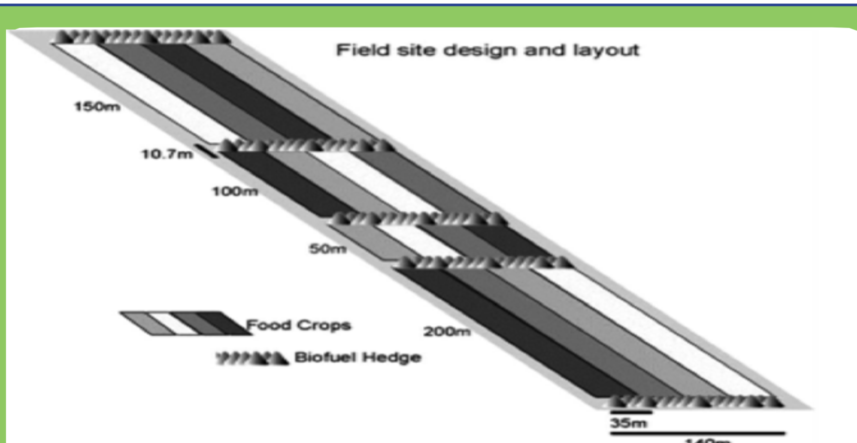
Short rotation coppice

The CFE system consists of 10.1 ha of food components like spring barley, winter wheat, oat and lucerne/ryegrass as fodder components and 0.75 ha of biofuels (biomass belts) consisting of five belts of SRC. Each biomass belt is 10.7 m wide and consists of 5 double rows of SRC; within the five double rows, three in the middle consist of three willow clones (one double row each) of *Salix viminalis* (L.) “Jor”, *Salix dasycladus Wimmer* and *Salix triandra cinerea* (L.) bordered by one double row of common hazel *Corylus avellana* (L.) on one side and one double row of alder (*Alnus glutinosa (L.) Gaertner*) on the other side

The trees are planted at within-row spacing of 0.5 m and between-row distance of 0.7 m. Each double row is 1.3 m apart, with a planting density of 18,600 trees/ha. Along the long edges of the SRC belts, 4 meter-wide “turning headlands” were created by fallowing a grass-ley, this area was only for machinery turning without any crop production. The biomass belts are established at varying distances of 50, 100, 150 and 200 m to assess the spatial effects of distance.

Tree Density	Stand biomass Yield	Dry biomass Yield
18,692trees/ha	50.8t/ha	25.6yield



Cost & benefits for CFE system

Table 1. Total Cost, revenues and cumulative net margin of different CFE scenarios after a four-year rotation

CFE Scenarios	Total revenue (€/ha)	Total cost (€/ha)	Cumulative net margin (€/ha)
50m(SRC -winter wheat)	3637.1	1952.3	1684.8
100m(SRC-winter wheat)	4249	2163.9	2085.1
150m(SRC-winter wheat)	4502.1	2238.6	2263.5
200m(SRC-winter wheat)	4673.6	2286.8	2386.8
Winter wheat	4473.9	2415.6	2058.3
SRC	1324.9	1534.7	-209.8

Results: 200m SRC-winter wheat CFE scenario gave the highest return of 2386.8 €/ha followed by 150 m (SRC-winter wheat)

About the Project

SustainFARM is a 3 year project uniting researchers and stakeholders across 7 countries to improve the agronomic, environmental and economic performance of farming systems that integration both food and non-food production.

OBJECTIVES

- To add value to on-farm woody resources including hedgerows and agroforestry
- To identify the optimal harvest and chipping practices and final uses for wood chip from coppice
- To encourage better management of hedgerow networks and more resilient farming systems.

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Factsheet

ALLEY CROPPING AND HEDGE COPPICE SYSTEMS IN EAST ANGLIA, UK

ALLEY CROPPING AND HEDGE COPPICE SYSTEMS

Alley cropping systems, consisting of hazel or willow short rotation coppice (SRC) combined with arable cropping (cereals, winter squash, lentils, camelina, quinoa, vegetables, fertility building legume ley).

Mixed species hedgerows managed by coppicing on a 15-20 year rotation.

COPPICING FOR WOOD FUEL

Coppice material can be chipped for use in a biomass boiler on farm or for on-wards sale.

SustainFARM is funded through ERA-NET FACCE SURPLUS under the EU Horizon 2020 research and innovation programme (grant agreement No 652615).
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THE ALLEY CROPPING SYSTEM

The alley cropping system is planted as 10m crop alleys separated by 3m wide twin-rows of trees. 0.4m saplings were planted through a mypex weed control barrier with no tree protection. Within rows, hazel is planted at a spacing of 1.2m and willow 1.5m. Trees were cut back to 5cm above ground one year after planting to encourage multiple stems. Coppicing takes place Jan-Feb., when there are no leaves on the trees. Hazel is cut 5-yearly and willow biennially, but the total amount of biomass harvested from the two species over a given time period is very similar (willow 6.31t/ha/yr; hazel 6.29 t/ha/yr @ 30% moisture content).

Cutting can be done with a chainsaw or by using a machine such as a circular saw, Bracke felling head or tree shears. Preliminary trials show that tree shears offer the best value for money for a system the size of Wakelyns (6 ha managed as agroforestry). Once cut, material must be dried and chipped. This can happen in either order.

COPPICING MIXED HEDGEROWS

Hedgerows are cut simultaneous with the harvest of the SRC alleys. Like the alleys, hedgerows can be cut with a chainsaw or with a specialist machine. They are cut on a 15-20 yr cycle with standing trees left every approx. 10m. Woodchip yield from a hedgerow allowed to grow for 20 years was 11.85 t/100m (30% moisture).

Cost for cutting ranged from approx. £1/m with tree shears, £4–8/m with a small chainsaw (three men) and £2–3/m with a Bracke felling head. Including haulage and chipping, costs increased to approx. £9–11/m.

In 2016, Woodchip sold for £84/tonne (@30% moisture) through a woodfuel cooperative. Less haulage, storage and handling, this was £7.56/m.

If used directly for energy on farm, however, woodchip costs 1.6–3.5p/kWh, versus 3.8p/kWh for gas, 3.3-4.5p/kWh for heating oil and 7.4–14.5p/kWh for electricity.

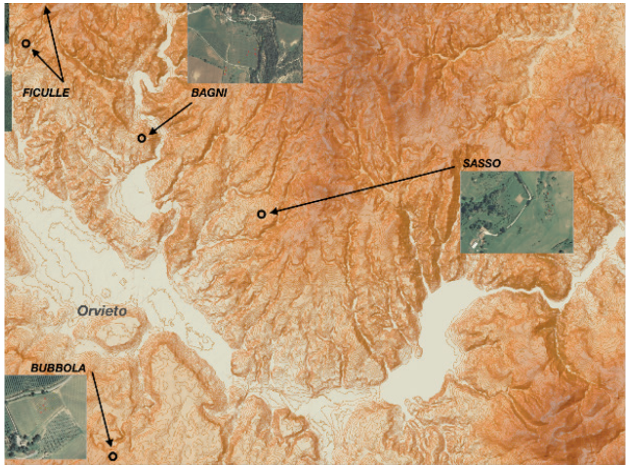
A typical farmhouse boiler (30-40kW) uses 30-40t of seasoned chip/year (at 30% moisture content). This equates to 4.76– 6.35 ha of agroforestry or 250–340 m/year.

About the Project

A network of farms and stakeholders has been created to collect biological and socio-economic data and parameters with the aim to assess the functionality of the systems, in terms of environmental, social and economic sustainability.

Objectives

- Improve farmer awareness about agroforestry management;
- Increase the resilience of olive orchards;
- Implement innovative value chains from olive processing residues (olive pomace, vegetation water, husk).



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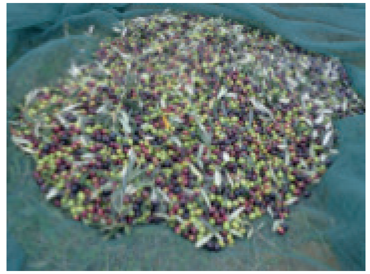
Factsheet

Multifunctional olive tree system in Italy, Umbria Region

SUSTAINFARM

Multifunctional olive tree systems

Multifunctional olive trees systems comprise olive orchards with different management schemes: organic, conventional, abandoned, with pasture, with natural weed.



Olive oil in Umbria

The olive oil chain in Umbria region, Italy, involves about 30,000 farms growing olive trees in about 27,000 ha and 270 oil mills to produce 9,000 tons (1.5% of the national value) of which 800 tons are DOP, Protected Designation of Origin, (7% of the national DOP value).

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Strengths and weaknesses

The main strength points of olive oil value chain in Umbria are: elevate landscape value of olive orchards as well as cultural and traditionally value; high quality of the extra-virgin olive oil; great awareness and expertise of farmers and oil mill managers.

The main weak points of the olive oil chain in Umbria are: high productive costs; low intensive management practices; small-scale farm dimension.

Tree Density	Olive Yield	Oil Yield
300/ha	3.5t/ha	12-15% of the olive yield

Phases of the supply chain

The olive oil supply chain involves the **agricultural phase** and the **olive oil production phase**.

The agricultural phase includes the cultivation of olive trees. Olive orchard management requires appropriate treatments such as soil management, fertilizations, pest treatments, pruning and harvesting. Cultivation can be conventional, integrated or organic. Pruning and harvesting are usually manual. After the harvest, olives must be brought to the oil mill within 24 hours in order to avoid fermentation process.

Olive orchards can be managed in agroforestry systems in several ways: intercropped with cereals, fodder legumes, horticultural crops or combined with pasture (sheep, cows, poultry).



The **olive oil production phase** comprises the extraction of the oil from the olives and the process produces additional by-products (water, pomace and husk) that require to be properly managed.

Olive husk can be used to produce bioenergy

Wet pomace can be used to produce olive paste

Olive pomace can be used to produce biogas

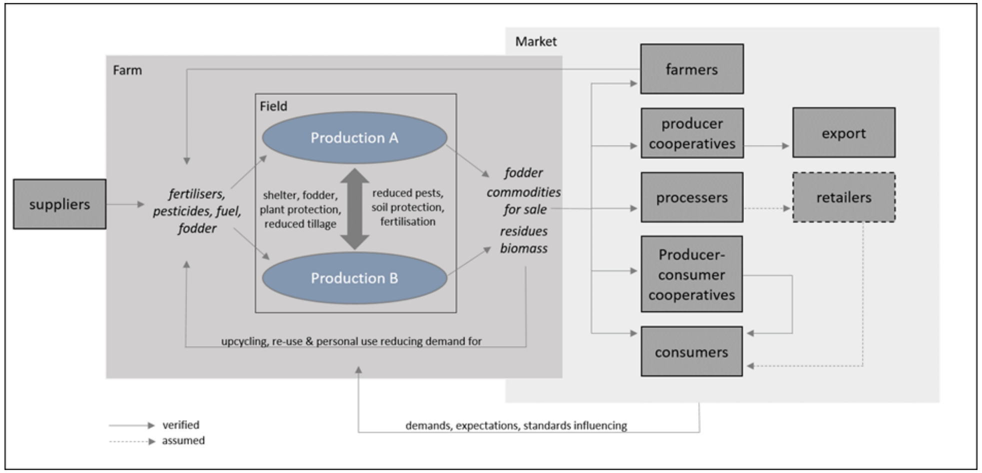
Wastewater can be used to fertilize fields or in phytotherapy recovering polyphenols

About the Project activities in Poland

A network of farms and stakeholders has been created in order to estimate the functionality of selected agroforestry systems (SRC biomass crops integrated with arable crops production, fruit trees intercropped with vegetables, production of wood in silvopastoral system) in terms of environmental, social and economic sustainability.

Objectives

- To add value to on-farm woody resource
- To assess sustainability of agroforestry farms
- To improve farmers' awareness about efficiency and resilience of agroforestry systems



Factsheet

SRC BIOMASS CROPS INTEGRATED WITH ARABLE CROPS PRODUCTION, POLAND

SUSTAINFARM

SRC willow and arable crops

Farms combining production of willow short rotation coppice (SRC) and arable cropping. Integration is at the farm level.

Coppice material can be chipped for use in a biomass boiler on farm or for sale to smaller heating stations.
At the same time, efficiency and profitability of alley cropping systems used potentially by farms combing both crops at field level is assessed.

Strengths and weaknesses

The main strengths: ability to reduce costs in heating farm buildings; reducing environmental impact of energy production by substitution of coal with Renewable Energy Sources (biomass); product diversification; reduced pollution and growing biodiversity.

The main weaknesses: lack of support for SRC crops production and agroforestry; unfavourable and unstable conditions for RES support; low farmers' awareness of ecological issues.

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SustainFARM is funded through ERA-NET FACCE SURPLUS under the EU Horizon 2020 research and innovation programme (grant agreement No. 652615). **http://www.sustainfarm.eu/en/**

Narodowe Centrum Badań i Rozwoju

Factsheet

SILVOPASTORAL SYSTEM WITH CATTLE AND SHEEP GRAZING AND WOOD PRODUCTION

Limousine cattle and sheep grazing on permanent pastures with difficult access and patchy landscape

Silvopastoral system integrating managed wooded grasslands and beef cattle/sheep grazing.

Wood is harvested for farm buildings heating or for sale to local buyers.

Beef/lamb meat is sold to counterparties as a high-quality organic product.

Strengths and weaknesses

The main strengths: diversification of production on permanent grasslands with difficult access; high-quality meat products; soils and water protection; lower costs of heat production on farm; greater biodiversity of grasslands; local social added value; increased local employment.

The main weaknesses: low/lack of support for woodland management; labour-intensity; high start-up costs; high labour costs; regionally differentiated wood prices and demand; different productivity and species composition of woodland/private forest habitats.

Factsheet

FRUIT TREES INTERCROPPED WITH VEGETABLES

Apples and cherries with cucumber, cabbage, peppers, tomatoes, zucchini, leeks and onions

Agroforestry organic farm integrating production of fruit trees and vegetables at field level. Farm is manufacturing processed goods, offering high quality products/high standards.

Dried cherry stones and wood pieces/ chips from thinning orchard and farm forest are burned in a boiler.

Strengths and weaknesses

The main strengths: wide range of high-quality products, produced on a small area of land in response to market demand, price development and weather conditions (agroecological production); reducing soils and water pollution, increased biodiversity and soil water absorption; lower costs of heat production on farm; positive impact of renewable energy production.

The main weaknesses: lack of support for agroforestry; broad agroecological knowledge and experience on species interaction in local environment; high labour costs; high investment in marketing strategy.

Contact: Robert Borek, Institute of Soil Science and Plant Cultivation – State Research Institute (IUNG-PIB, Poland) e-mail: rborek@iung.pulawy.pl

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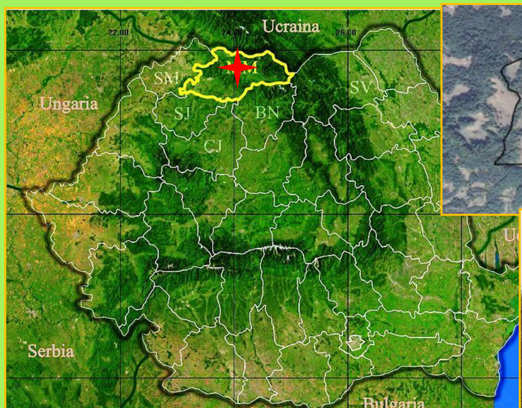
Factsheet
Silvopastoral system in Romania
Maramures county

About the project

We created a group of stakeholders with interest or involved in integrated farming, and collected quantitative and socio-economic data in order to assess these systems functionality in terms of environmental, social and economic sustainability.

<u>Objectives</u>

- To improve farmers awareness on agroforestry management,
- To add value to on-farm woody resource,
- To encourage better management of woody vegetation at farm and regional level,
- To identify the optimal harvest and valorising practices and final uses for wood from coppice.



In Maramures county approximately 40,000 farmers exploit an agricultural area of over 165,000 hectares. More than 30,000 of them exploit land with an area of one to five hectares. Only 110 farmers below 0.5% exploit agricultural areas larger than 90 ha.

Traditional silvopastoral systems with pastures , hay-meadows, well-individualized trees, forest strips and grazing animals are the most encountered form of land management in the mountain and hilly area of Romania.

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Contact person: Mignon Sandor, USAMV Cluj-Napoca
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Tree biomass production

Wood vegetation was not planted, but spontaneously emerged as a result of ecological succession of ecosystems.

The age of old trees on the meadows may be over 100 years, but the dominant trees are 5-10 years old trees.

The density of trees is very high in forest strips, characteristic for forest ecosystems.

In grasslands trees density varies from 20 ind / ha to 200 ind / ha.

The agro-silo-pastoral systems imply a management of the grasslands in their composition and also of the woody vegetation.

The management of grassland has as its actions the division of the entire grazing area in parcels, the organization of a grazing rotation, as well as the maintenance and improvement works. They are used in an extensive approach.

The woody vegetation, often spontaneous, is managed by pruning and polarding and used as firewood to fill the farm energy requirement.

Tree density	Wood demand	Wood cost
20-200 ind/ha (within pasture) 2000-2500 ind/ha (within forest strips)	100 m^3 needed to cover energy requirements	200€

Cheese production process

Coagulation

Boiling

Forming

Maturation

Packing

The milk produced is processed by traditional methods inside the farm, resulting in cheese and whey.

Whey is the watery fraction that separates from the coagulum during conventional cheese making process. It represents approximately 85-90% of the volume of milk used for processing into fermented cheese and contains about 55% of the milk's dry matter. In most farms in Romania it is thrown away, but with the right infrastructure it can be used to produce cheese and beverages.

Strengths and weaknesses

High production of secondary outputs from the system like wood biomass and whey resulted from cheese making process is considered as being a strong point for the system. Hard terrain and poor accessibility, as well as high production costs for the secondary outputs of the system are the main week points of the Petrova silvo-pastoral system.

About the project

We propose a sustainable farming system that includes several Mediterranean tree crops and livestock that will be integrated to achieve a more economical-, ecological- and socially sustainable healthy-food production system

Objectives

- Improve sustainability and profitability of traditional tree crops in Andalusia (i.e, olive, citrus, and almond) by raising them in an organic fashion, and integrating them with animal husbandry raised in nature.
- Promote the production and consumption of a "neglected" Mediterranean tree crop, the carob, which has new marketing opportunities
- Increase biodiversity with four major tree crops to the point where honey bees can survive, feed, and be productive throughout the season
- Reduce the ecological impact of cellulose-rich residues, using them to feed livestock

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Factsheet

Proposal of an agrosilvopastoral system for Mediterranean environments

SYSTEM COMPONENTS

- **Olive**

The most extended tree crop in Andalusia and Spain
Olive oil is known to be a very healthy fat

- **Citrus**

Highly productive and well adapted to the Mediterranean, high export demand,

- **Almond**

Highly nutritious, healthy food with very good market perspectives

- **Carob**

Considered a superfood for its nutritional properties
Used as a substitute for coffee and cocoa

- **Honey bees**

Contribute to almond and carob pollination
Produce honey, wax, polen, propolis, bees…

- **Goats**

The best adapted ruminant to Mediterranean climate
Produce milk and meat, and manure

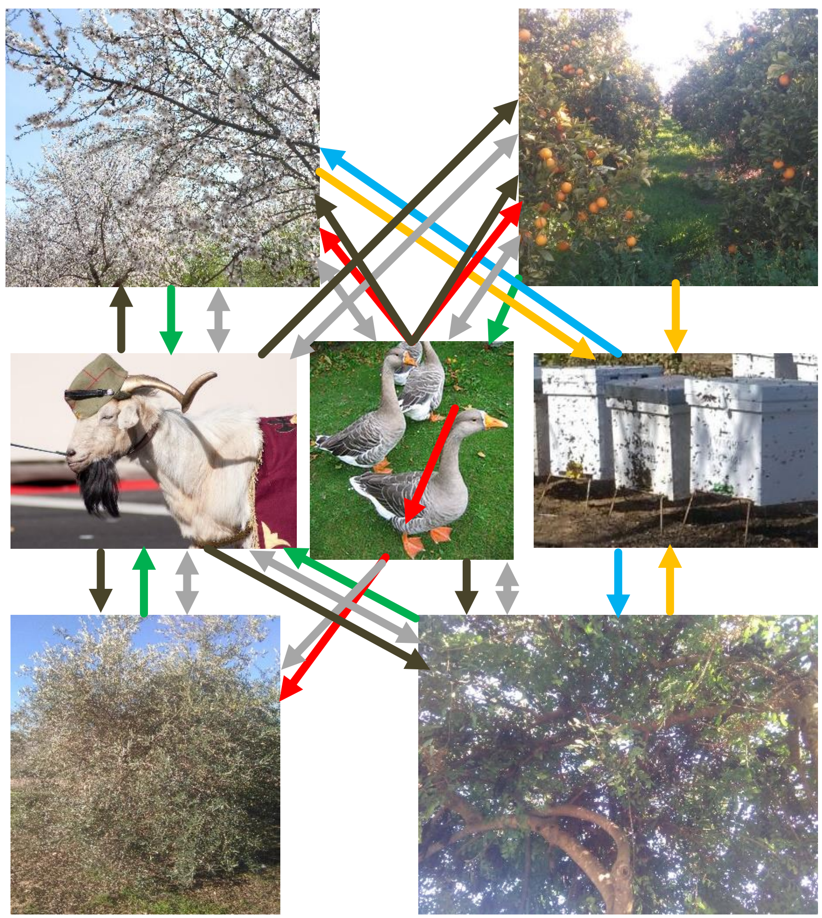
- **Geese**

Eat pasture and insects
Produce meat, feathers, eggs, and manure

SustainFARM is funded through ERA-NET FACCE SURPLUS under the EU Hprizon 2020 research and innovation program (grant agreement N° 652615)
http://www.sustainfarm.eu/en/

INTERACTIONS

- Feed
- Nectar and pollen
- Weed/covercrop control
- Pest control
- Manure
- Pollination



Martetable Outputs

- Olives/olive oil
- Oranges
- Almonds
- Carobs
- Honey, pollen, wax, propolis
- Goat milk and meat
- Geese eggs, meat and feathers

Net profits for a 10 ha* field

– 2.5 ha olive	5,000€
– 2.5 ha citrus	7,500€
– 2.5 ha almond	15,000€
– 1.5 ha carob	1,600€
– 120 bee hives	6,000€
– 60 goats and 100 geese	1,000€
Total	36,100€

*There is 1ha left for stores, machinery and animal shelters

Benefits of agroforestry: Insights from willow cultivation in Denmark

Agroforestry covers a broad range of practices incorporating a woody component into agricultural systems. One example is Integrated Food and Non-food Systems (IFNS). In Denmark, a group of farmers growing willow in Southern Jutland have formed an association to organize the sales of willow wood chips and share knowledge among them. Qualitative interviews with five farmers of the willow association provided an overview of the benefits and challenges of IFNS.

Table 1. Share of cultivated area used for willow production and variety of products from five farms in Southern Jutland, Denmark.

	Cultivated land (ha)	Cultivated willow (ha)	Share of willow (%)	Products
Farm A	150	25	17	Eggs, cereal, corn, wood chips
Farm B	84	10	12	Potatoes, corn, oat, wood chips, hay
Farm C	170	9	5	Eggs, cereal, beef, wood chips
Farm D	60	60	100	Wood chips
Farm E	20	20	100	Wood chips

Benefits of the agroforestry systems

Integration of willow with layer hens for egg production at field scale has proved to provide multiple synergistic benefits. Willow planted near the chicken shed provides shelter and shade for the chickens, while the chickens provide weeding and manure for the willow. Pollution from nutrient leaching can be prevented due to the willow's capacity to absorb large amounts of nutrients and heavy metals, which helps to meet the EU Water Framework Directive. As tillage is reduced, willow plantations also reduce CO_2 emissions compared to conventional agriculture.

IFNS provides good options for mitigating environmental impacts of agriculture. The tree-animal synergies result in reduced need for labour, pesticides and fertilisers, thus saving economic expenses and reducing the environmental impacts of farming. In addition, the integration of willow increases biodiversity by providing shelter and habitat for a range of other animals such as birds and insects, and even deer, which is ideal for hunters, enhancing the biodiversity at the field and farm scale.

Willow can be planted on degraded and marshy soil, less suited for crop cultivation, and is more resilient to droughts, thus helps to make best use of the available land. Although high production output requires the preparation of wet grounds prior to planting, once established, willow does not need much labour as it is only harvested every two years. Costs for production are thus comparably low even if harvesting makes up a significant part of production costs in the first years.

In times of low prices for wood chips, there are many other uses of willow. Willow oil is a natural painkiller and can be used in lotions, while other extracts can be used in cosmetics. Furthermore, willow can be used as compost for organic farmers and as potting mixture in garden shops.

IFNS have further proved to be beneficial for the marketing of the agricultural products obtained from the agroforestry system. This is due to both the psychological impact on buyers of eggs due to visual effect of raising chickens among trees, and the image of local energy production.

Sole willow plantations will lack the benefits provided e.g. chickens weeding and fertilising the plants. As the growth and production of the willow improves with weed control, this will lead to higher labour requirements for farmers. However, the willow areas can be leased for hunting purposes as it attracts deer by providing shade and shelter. In addition, incorporation of trees of any kind to a production system provides better aesthetic view, which have positive psychological impacts on other inhabitants in the area.

Figure 1. Heating plant in Denmark, where the willow wood chips are burned for heat production.

Role of the Willow Association

After the willow association was formed by farmers in order to organise the sales of wood chips, the involvement of a local heating plant has resulted in a good collaboration between seller and buyer from the beginning. This has led to good and stable prices, and the reassurance that the heating plant will buy all wood chips from the association. Farmers feel the prices could be slightly higher, but the guaranteed purchase as well as the production of cheap, local heat production, which also benefits the farmers, have made them accept the offered prices. Furthermore, the heating plant has agreed to buy the wood chips straight after chopping, so the farmers do not have to worry about storage. The association allows for a more open dialogue and facilitates knowledge exchange. Aside from meetings and online information letters, the association facilitates visits to members' farms for sharing experiences, which are greatly valued by members. Many farmers initially lacked knowledge of establishment and maintenance of willow, and the visits and advice from fellow willow farmers have been invaluable to farmers during the first years of willow cultivation.

Because the willow farmers were unsatisfied with existing machine performance, plant growth or weed development, the association events have helped to develop and build private machinery for harvesting and attempted different management practices in order to improve willow chip quality and yield. Thus, the association has become very innovative, and been a key vehicle for collaboration among the farmers.

Challenges

Besides the many benefits of IFNS as outlined above, members of the willow association have also met a few challenges with willow cultivation for wood chip production.

While wood chips constitute a reliable product and stable income compared to agricultural crops, prices can fluctuate due to competition with supply from abroad or forests, which increases wood chip supply when forests are suffering the impacts of storms and diseases.

Prices for wood chips are generally low compared to food crops, and farmers do not expect to make a living based on the willow cultivation alone. However, it can be profitable as a side business. Willow is only harvested every two to three years, so it does not generate revenues until approximately six years after planting. On the other hand, willow does not need to be re-planted every year and yields increase from year to year providing a good long-term investment. While wood chip prices are more stable than that of food crops, cultivation is not flexible. It can therefore still make farmers uncertain as to whether they are taking a risk with cultivating willow compared to agricultural crops. If the price of a crop is low one year, the farmer can reduce the area cultivated with that respective crop by extending the area for cultivation of a higher value crop the following year. Meanwhile, the area set aside for willow planting cannot quickly be withdrawn to expand the production of a high-paying crop, leaving the farmer in risk of missing out on the advantages of high crop prices.

The Danish farmers established their willow stands during a period when subsidies were provided for establishment of renewable energy sources. The national subsidy was about € 600 per hectare of planted willow but was withdrawn after three years due to the questions as to whether the willow stands qualified as forests or as crops. While farmers appreciated the economic incentives, they stated that the subsidy did not drive their decision to plant willow, which they credit to the knowledge sharing of the willow association. However, subsidising IFNS could be essential for the propagation of agroforestry systems in the future.

This technical sheet was compiled by Lisa Mølgaard Lehmann, Bhim Bahadur Ghaley (University of Copenhagen) and Nina Röhrig (Philips-University Marburg), within the context of the European project SustainFARM.

Taastrup, January 2019

Productive hedges:

Guidance on bringing Britain's hedges back into the farm business

Sally Westaway and Jo Smith, 2019

with contributions from Meg Chambers and Mary Crossland

THE ORGANIC RESEARCH CENTRE ELM FARM

Why hedges are important

Hedgerows are a prevalent feature across Western Europe, with an estimated 700,000 km in Great Britain alone.[1] They have significant cultural and historical value and provide many functions and benefits within the landscape, including sheltering crops and livestock, supporting wildlife and linking habitats, controlling erosion and visually enhancing the landscape. Hedgerows provide a habitat similar to that of woodland edge across agricultural landscapes, providing wildlife refuges from more intensive land use and connecting areas of semi-natural habitat. Many species live in or use hedges, with more than 600 plant species, 2000 insect species, 64 bird species and 20 mammal species associated with British hedgerows.[2] In the UK Hedgerow Habitat Action Plan, 84 of the species associated with hedgerows are of conservation concern.[3]

Hedges in the West Berkshire landscape

Productive hedges

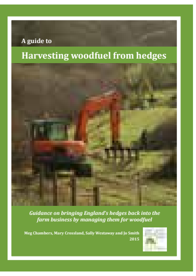
Hedgerows are an important part of the cultural landscape of lowland Britain. Traditional management provided a variety of hedgerow products, which included firewood, but as labour become more expensive and fossil fuels more available, this practice was lost. On today's farm, hedges mark field boundaries whilst also providing shelter for crops and livestock, important habitats for farmland biodiversity and contributing to soil and water management. However, as a resource most hedges are underutilised and are either cut back annually or are neglected altogether; both practices are eventually detrimental, and hedges need periodic rejuvenation by either laying or coppicing to sustain them into the future. Rejuvenation management methods are time consuming and costly and identifying practical economic uses for hedges and hedge material could help offset these costs and encourage sustainable hedge management. For example, management for woodfuel via coppicing or hedgelaying, provides an opportunity to rejuvenate old hedges and has the potential to:

- improve hedgerow vigour, longevity and value to wildlife
- provide logs, woodchip and other hedge products which can be used on farm or sold
- reduce the cost of annual flailing

As well as a woodfuel, hedges can provide other potential economic benefits, for example as a source of tree fodder for livestock, woodchip for animal bedding or soil fertility.

This guide builds on and compliments the 2015 guide ***Harvesting woodfuel from hedges***, downloadable from:

http://tinyurl.com/TWECOM-BPG



Bringing hedges back into the farm business

Markets for hedgerow products are in the early stages of development. However, those able to make use of hedge products, including woodfuel, on farm have the opportunity to bring hedges back into the farm business. Most hedges in the UK are managed by annual flailing; this takes time and costs money but earns nothing in return. Coppicing reduces the need for regular hedge flailing to just side trimming every two or three years to control outgrowth. The potential savings over fifteen or twenty years can be significant. A sample of flailing costs from a number of farms in South West England gave an average of £0.35 per metre for a medium to large hedge[4]; scaled up this equates to a **£5.25 per metre** over fifteen years of annual flailing. Alternatively, hedges could be left to grow up over 10-20 years and their outgrowth kept in check through side flailing every three years, before being coppiced giving an average cost of **£1.50 per metre** to side flail once every three years over a 15-year period.

In addition, there is the opportunity to benefit from the sale or use of hedge products. Four practical case studies in this guide outline some costed examples.

Managing different types of hedges

Every hedge is different and also constantly changing but most can be grouped according to their physical characteristics and previous management. For different hedge types a description and some management recommendations are given below. These categories are quite broad and the excellent Hedgerow Management Cycle available from Hedgelink (www. hedgelink.com) has a more detailed description of the different stages in the life of a hedge and management options for each stage.

Short gappy hedge

Generally, less than 2 m high, with few healthy stems and large gaps forming at the base, this hedge type is typical of arable enclosure hedges which have been flailed at the same point for too many years. Shrubs are often thorny species such as hawthorn and blackthorn. This hedge type needs a change in management to secure its future. If there are more gaps than stems the best management option is to coppice, retaining a few trees if possible, plant up the gaps and remove any invasive species such as elder. If there is still a reasonable stem density, plant up gaps and relax the flailing regime to every two or three years and raise the cutting height.

Photo: Rob Wolton

Thick shrubby hedge

A thick hedge with a high density of healthy stems 2-5 m high, at this stage in a hedge's management cycle it provides a great habitat for wildlife, as well as shelter for livestock and crops. Manage by flailing every two or three years to control field encroachment and maintain structure. Often mixed species, these hedges can be ideal for managing for woodfuel especially if there are high proportions of fast-growing species suitable for coppicing such as hazel, sycamore, willow or ash. For woodfuel, side flail only and coppice when stems are around 10-20 cm in diameter and 5-7 m tall. Any gaps can be planted up soon after coppicing.

Tall gappy hedge

A tall and generally gappy hedge which has not been managed for many years. Typically over 5 m high, comprises a line of small trees, often of several species. The shrub layer may vary from dense to thin, ideal for managing for woodfuel. Coppice when stems are around 10-20 cm in diameter. Any gaps can be planted up soon after coppicing. Can also be layed. Ideally leave one hedgerow tree every 50 m.

Photo: Emily Ledder, Natural England

Line of mature trees

A line of mature or nearly mature trees, often with little or no understorey due to shading. Where possible, retain these hedges as a line of trees and a landscape feature for as long as possible, managing on a long rotation appropriate for the species as you would in a woodland. When trees die or are felled gaps can be replanted.

Recently coppiced or layed hedge

A hedge that has recently been managed by coppicing or laying should be trimmed frequently in the first five years to ensure a dense structure, avoid top cutting if the hedge is to be managed for coppice products of woodfuel in future. Newly planted or coppiced hedges are vulnerable to browsing by rabbits, hares, deer and livestock. Erection of temporary deer or rabbit fencing may be necessary until the regrowth is well established. Another option for protecting the new coppice is stacking some of the brash back over the cut stools.

Planning for hedge management

Hedges are dynamic, the tree species that form them are constantly growing and changing and to retain their function they need to be managed. The management of hedges should be planned on a farm or landscape scale and for each hedge consider both the hedge's current role and its importance (e.g. as a wildlife resource, a landscape feature or as shelter for livestock) as well as the potential value to the farm business.

Hedge products

Whether you want woodchip, logs or another product from a hedge will affect how it is managed, harvested and how material is processed. Equally, hedge type and species composition will determine the products it can produce. Possible hedge products you might want to consider include:

- **Woodchip for fuel, compost or livestock bedding.** Each woodchip use has slightly different requirements – for fuel a higher proportion of larger diameter material will give the best quality chip while the opposite is true for composting as the nutrients are concentrated in the bark and buds. For livestock bedding it is advisable to avoid thorny species.
- **Logs for fuel or fencing materials, hazel hurdles.** Generally straighter coppice material will be best suited. Larger stems will be best suited to logs, hazel hurdles are best made from 6-8 year regrowth.
- **Livestock fodder.** Hedges can be managed in several ways for fodder. The simplest is direct browsing, giving livestock access to the hedge. This may involve managing the hedge to keep browse within reach (e.g. through pollarding or coppicing) and fencing to control access and protect the long term viability of the trees. Other options include cutting fodder to give to the livestock either fresh, dry or ensiled.

Management for woodfuel: hedgelaying or coppicing?

Coppicing is more cost effective and has a higher biomass output (woodchip or logs) compared to hedgelaying; it also takes less time. As such, it is the recommended management option for woodfuel production. However, coppicing will leave a gap in the hedge for a short time until regrowth appears, and repeated coppicing will change the structure of the hedge. Hedgelaying is a good technique for stimulating dense bushy growth at the base of a hedge, creating a livestock-proof barrier, a great habitat for wildlife and producing some fuel. More information can be obtained from the National Hedgelaying Society (www.hedgelaying.org.uk/).

Hedge coppicing: which hedges?

If you would like to manage your farm hedges for woodfuel, start with a map and identify any hedges that are unsuitable. This may be due to their historical or wildlife value, or other functions such as visual screening of farm buildings. Assess the remaining hedges for their suitability for woodfuel, both now and in the future, in terms of size and species composition. As a general rule, no more than 5% of your hedges should be coppiced in any one year.[5] It is also important to consider landscape connectivity; try to maintain or improve linkages between habitats such as woodlands and ponds.

Hedges should be around 5-7 metres tall with stems 10-20 cm in diameter before being coppiced for woodfuel. If a hedge is not yet ready to coppice, avoid top-cutting allowing stems to grow up tall, but you can continue trimming the sides of the hedge. Both mixed and single species hedges can be valuable for woodfuel. Most broadleaf species respond well to being coppiced; those that are especially suitable include hazel, sweet chestnut, willow, ash, sycamore and alder. Some species (e.g. blackthorn) tend to regrow from the roots with suckers rather than coppice. Growth rate and length of coppice cycle will vary between species and site conditions. Fast growing species such as willow, sweet chestnut, ash and hazel are well suited to a shorter coppice rotation of 10-15 years. Slow-growing species like field maple and oak are better suited to longer rotations of 20 years and can also be managed as standards.

Preparing hedges for coppicing

Prior to coppicing it is important to remove all wire, such as old fencing, from inside the hedge to ensure machinery is not damaged. It may also be easier to coppice a hedge once any outgrowth has been cut back. Hedge coppicing on longer (15-20 year) rotations can coincide with fence replacement cycles to minimise the amount of work needed and the costs.

Coppiced hazel hedge, approximately eight months after cutting

Making sure a coppiced hedge regrows

It is essential that if you plan to coppice a hedge, you are confident it will regrow, and are able to protect it from browsing to ensure it does. If a hedge does not regrow or regrowth is poor it will need to be replanted or gapped up. The quality of the cut may also impact regrowth; ideally cuts should be clean with a minimum of 5 cm left when coppicing a stem. Cuts should be angled so water drains away from the centre of the stool or stump. The ability of stems to coppice well often declines with age and varies with species and site conditions, some stumps over 50 years may fail to regrow and require replanting.

Hedge coppicing: which machinery?

The most suitable machinery and management option for your situation will depend on the type of hedge you are coppicing, the length of hedge you plan to coppice and the product you are after (chip or logs). If you have a short section of hedgerow to harvest (less than 100 m) it will be more economical to use a chainsaw. If using larger scale machinery, make sure you have enough hedge length and material (over 250 m) to keep the machines busy for a full day; alternatively, you could team up with neighbouring farms and share the cost. More information can be found in the TWECOM guide to Harvesting Woodfuel from Hedges[6].

Chainsaw

The most basic yet versatile felling machine, comes in a variety of sizes depending on the size of timber and situation. Able to access most sites and hedges. No compaction or rutting in poor ground conditions. Slower working speeds.

Circular saw

Generally tractor-mounted on a hedge cutting arm, and can include 1- 4 circular saw blades. Also known as shaping saws and best used in combination with a second tractor with front-mounted fork to move material after felling. Not suitable for larger material due to lack of directional control of falling material and cutting diameter.

Tree shears

Cut or fell trees using hydraulically-powered shears or steel blades to slice through the timber and usually have an integrated timber grab or accumulator arm to hold and manipulate the felled material. Typically excavator mounted. Different sizes available to suit size of material. Not so well suited to multi-stemmed smaller diameter material.

Felling heads

With either an integral chainsaw cutting bar or circular saw. These are most often found in bioenergy felling heads or forestry harvesters such as the Bracke felling head, generally include a timber grab or accumulator arm and are excavator mounted.

Other considerations

Ownership: Ascertain the ownership of a hedge before you coppice it, particularly if it is a boundary or roadside hedge. Even if you do own it, you may want to consult your neighbours and inform local residents as coppicing a hedge can have a significant impact on the landscape.

When to coppice: There are legal restrictions on the timing of hedge management (see p14). Within these allowed times, timing will depend on ground conditions, access to the hedge and other agricultural operations. Coppicing in late winter allows birds to make good use of the hedgerow berries over the winter.

Access: Consider the accessibility of the hedge when choosing which machinery to use. Ensure all harvesting and processing machinery can get to the hedge without issues such as narrow gateways or overhead cables and powerlines.

Planning and planting new hedges and agroforestry

A useful short definition of agroforestry is 'farming with trees'. Agroforestry includes both the establishment of new trees in productive fields and the integration of existing boundary hedges and trees into the farming system. The aim is to benefit from interactions between the trees and the farming operation (crop and/or livestock) and when planning a new hedge or agroforestry planting it is important to consider how the trees can be planted to maximise the ecological and economic benefits.

Coppice agroforestry

An alternative approach to planting a new boundary hedge is to integrate trees within the farming system, for example with alley cropping, where rows of trees are separated by alleys of crops or pasture. By managing these tree rows as short rotation coppice or biomass hedges, competition for light is reduced compared to full height trees, the coppice regrowth can provide shelter for livestock and crops as well as a product. Species especially well-suited for coppice agroforestry planting are fast growing non-thorny species such as hazel, willow and alder. An example of alley cropping agroforestry for woodfuel production is outlined on page 9.

Design and species selection

Any new hedge or agroforestry planting should start with a review of the existing woody resources and features on the farm, where necessary bringing these features into active management e.g. gapping up, rejuvenation through coppicing or hedgelaying. The position, design and species choice will depend on the objectives of establishing a new hedge or agroforestry planting (e.g. marking a new boundary, providing shelter or a fuel source). Where possible plant new boundary hedges on existing field boundaries or join up gaps in the hedge network or wildlife habitats and if practical look at old maps and reinstate former hedgerows. For in-field planting consider the farming activities and machinery that will need to operate in between the trees.

If the aim is for a wildlife hedge and eventually a stockproof field boundary, plant 4-6 plants per metre in staggered double rows. Mixed species hedges are more valuable to wildlife, while for stock proofing aim for at least 70% thorn species such as blackthorn and hawthorn. Look at local hedgerows for guidance on which species that are thriving.

If the aim is to provide a coppice product such as woodfuel, faster growing species which respond well to coppicing will be more appropriate e.g. hazel, willow, alder and ash.

It is important to recognise that if allowed to grow tall for biomass production these hedges will have a bigger impact on the adjacent fields. Aim to plant species with similar growth rates to aid future management. If planting for production (e.g. woodfuel or timber) think about access for management and extraction of wood products.

Practical planting tips

- Bare root 40-60 cm whips are most commonly used for native species hedge and woodland planting.
- Plant in winter when ground conditions allow.
- Control weeds for the first few years to reduce competition using mulch or herbicide and gap up each year to replace any dead plants.
- Protect newly planted trees using tree guards and stock fencing if livestock are present. Stakes should also be used to support the young whips.
- Remove the stakes and guards once the hedge is well established.
- Hedgerow trees should where possible be planned into new hedge planting approximately one every 50 m. Consider planting taller whips than the hedge plants and tag the hedgerow trees to help identify them during regular management activities.

More practical information on agroforestry design and implementation can be found in the Agroforestry Handbook (2019).

Converting a flailed field boundary hedge into an economic crop of firewood

A fully costed hedge coppicing operation on a livestock farm in Dorset demonstrates that even on a small scale it is economically viable to move a hedge from annual flailing to a fifteen-year coppice rotation producing firewood for sale. Hedge coppicing for firewood production is widely applicable, the process requires no particular skill set, minimum demand for new capital and can be adapted to different farm circumstances.

The farm and firewood business

Racedown Farm in South West England is a 160 ha low intensity livestock farm. The farm has 12 miles of hedges all managed on a 15-20 year coppice cycle, except the roadside hedges which are flailed annually. Half a mile of hedge is coppiced annually. The farm has a small firewood business which sells approximately 175 tonnes of logs per year, hedges make up part of this. Hedge coppicing produces round and split logs for the firewood business as well as small diameter material which is used on-farm or sold as 'ugly sticks' at a lower price and brash material which is fed through a branch logger, netted and sold as kindling. Around 70% of the total hedge biomass produced from coppicing is used or sold. All firewood products are stored undercover for 10 months to reduce moisture content prior to use or sale.

Costing it out

The farmer, Ross Dickinson, was interested in the economics of the process and in 2017 coppiced a 220 m trial hedge and recorded in detail the time, costs, outputs and income[4]. The hedge was mixed species, 6.5 m high, with 15 years growth, on an old hedge bank: an old fenceline was removed prior to coppicing. The hedge was coppiced by hand using a chainsaw. Larger diameter material was processed with a tractor mounted saw bench and log splitter, a branch logger was used for the smaller material. The farm is relatively exposed with poor soils, hence the hedge growth is slower than average, and coppice rotation lengths may be shorter in more favourable conditions.

Headline figures

- 220 m of hedge produced 21.4 tonnes of saleable or useable material
- The overall cost was £3,378 (including labour for hedge preparation, coppicing, processing, burning brash and delivery)
- The income was £4,908 (including sales and savings from not flailing annually)
- The profit from 220 m of hedge was **£1530** (with no subsidy payments)

Welmac branch logger at Elm Farm.

Photo: Organic Research Centre 2013

Photos: Ross Dickinson, 2017

Most hedge material is processed with a saw bench

Operation (for 220m hedge)	Cost
Initial flail 2 hours @ £30/hr	£60.00
Manual coppicing 88.5 hours @ £15/hr	£1,327.50
Processing with branch logger 20 hours @ £30/hr	£600.00
Abstraction of nets 8 hours @ £12/hr	£96.00
Abstraction of cord wood 6 hours @ £30/hr	£180.00
Brash burning 5 hours @ £25/hr	£125.00
Processing saleable material and ugly sticks	£750.00
Delivery cost 15 tonnes @ £16/t	£240.00
TOTAL COST	**£3,378.50**

Product/saving (for 220m hedge)	Income
Savings in annual flailing @ £0.35/m (220 m in 15 years)	£1,155.00
263 x 15kg nets kindling twigs = 3.95 tonnes @ £190/t	£749.50
99 x 15kg nets of cobs = 2.48 tonnes @ £190/t	£470.50
6 tonnes of ugly sticks @ £150/t	£900.00
9 tonnes of saleable logs @ £181/t	£1,633.50
TOTAL INCOME	**£4,908.50**
PROFIT	**£1,530.00**

Case study: Elm Farm hedge management for woodchip

A trial coppicing a length of a traditional boundary hedge and chipping all the resulting material to produce woodchip for fuel was carried out on a farm in the South of England. This trial demonstrates that keeping the production chain as short as possible and using woodchip on-farm for heating greenhouses, barns or the farmhouse is the most cost effective and sustainable use of hedgerow woodchip, offsetting a large part of the cost of regular hedgerow management activities.

The farm

Elm Farm is an 85 ha organic livestock farm near Newbury, Berkshire. It is the site of the Organic Research Centre and this work was carried out as part of a series of research trials investigating the use of farm hedges for woodfuel production. The farm has a total of length of 9.5 km of predominantly unmanaged hedgerow, with approximately 5 km suitable for coppice management, on a 15-year coppice cycle.

A coppiced hazel hedge

The trial hedge is predominantly mature hazel coppice with some blackthorn and was last cut approximately 20 years ago. It is a roadside hedge and has been regularly flailed along the road to prevent encroachment. The hedge was coppiced by hand using a chainsaw in December 2016 and all material chipped immediately after cutting using a self-propelled hand-fed chipper. The total yield of chip from the hedge was 21 m^3 per 100 m. Half of the chip was sold green to a local woodfuel cooperative and half kept for use on the farm and moved to an open sided barn for storage and drying. After six months the moisture content of the on-farm stored chip had reduced to 27%.

The newly coppiced hazel stools. Organic Research Centre, 2016

Chipping material from coppiced hedge. Organic Research Centre, 2016

Headline figures

- 100 m of hedge produced 21 m^3 of saleable or useable woodchip
- The overall cost was £990 per 100 m including preparing the hedge, coppicing, chipping and moving the material
- When used on-farm the income was £1223 including a countryside stewardship grant for hedge coppicing
- The profit from 100 m of hedge when the woodchip is used on farm is **£233**

Harvesting methods using larger machinery, may be more cost effective where there is enough work, and machinery is available locally. This hedgerow was eligible for a coppicing grant under Countryside Stewardship, which in 2018/19 is worth £4 per metre, this contributes towards the cost of woodchip production. See page 15 for details of regional grant and funding bodies.

Operation (for 100 m hedge)	Cost
Fence removal (1 day by hand @ £10/hr for a 7 hour day)	£70.00
Chainsaw and chipping (£9.20/m contractor cost for 3-man team to cut, chip and move material to barn)	£920.00
TOTAL COST	**£990.00**
Product/saving (for 100 m hedge) Income	**Income**
Savings in annual flailing (field side only @ £0.17/m/yr for 20 years)	£340.00
Coppicing grant (£4/m in 2018/19)	£400.00
Sold off site (supplied green to a local woodfuel cooperative for resale @ £15.40/m^3)	£323.00
Own use (replacing the cost of bought in woodchip @ £23/m^3)	£483.00
TOTAL INCOME (when sold off site)	**£1,063.00**
TOTAL INCOME (when used on farm)	**£1,223.00**
PROFIT (sold off site)	**£73.00**
PROFIT (own use)	**£233.00**

Case study: Wakelyns Agroforestry

A pioneer of agroforestry in the UK over the last 25 years Martin Wolfe planted over 5,000 trees on his farm in Suffolk, whilst still producing a range of arable and vegetable crops. Woodchip from short rotation coppice agroforestry on the farm now provides all the farmhouse heat requirements with excess available for other uses.

The farm

Wakelyns agroforestry is a 22.5 ha agroforestry research farm near Diss, Suffolk. In addition to timber and fruit trees, the farm has hazel (*Corylus avellana*) and willow (*Salix viminalis*) short rotation coppice (SRC) agroforestry systems, which were planted in 1994. The trees are planted as production hedges with twin rows of trees running north/south and organic crops grown in rotation with a fertility-building ley within the 10-12 m wide alleys.

Woodchip production from SRC

Biomass production of the SRC willow has been measured since 2011 and the hazel since 2014. Willow is harvested on a two year rotation. Hazel is harvested on a five year rotation, with only one of the twin rows being cut in any year. The stools are coppiced using a circular saw and cut stems are collected and heaped up to be air-dried in the field during the summer and then chipped on demand. All material is chipped using a 15 cm (6 inch) timberwolf hand fed chipper and used in a Gilles 20 kw boiler to heat the farmhouse. The two species of SRC produce very similar yields under current rotations when converted to annual biomass production.

Woodchip production (results from Smith et al 2017[8])

	m^3/100m	Years of regrowth at coppicing	m^3/100m/yr
Willow SRC	5.74	2 years	2.87
Hazel SRC	14.32	5 years	2.87

Harvesting the SRC

In January 2017 coppicing trials were carried out to look at alternative harvesting machinery and the economics of woodchip production for bioenergy. The coppicing trials included:

- A tractor mounted circular saw. The usual harvesting method, this cuts well but results in non-directional felling which requires collection and stacking of material post-cutting.
- Bracke C16 felling head mounted on a low ground pressure purpose built valmet. This is a specialised machine, fast and efficient with minimal ground damage, which collects and places material in stacks, but there are only a few in the country and haulage costs are high.
- 360 degree tree shears. Effective at coppicing boundary hedges, the blades have a crushing action that can cause the SRC root ball to move and also result in significant splitting of the stems. As a result, the trial of the shears on the SRC was abandoned due to concerns of lasting damage.

Headline figures

- Annual production from a 100 m double row of either hazel or willow was 2.87 m^3 per year
- The cost of harvesting and chipping was between £222 and £443.90 depending on the species and the method used
- The willow woodchip production costs were lower, but the yield and income was also lower

Operation (for 100 m SRC)	Hazel	Willow
Circular saw (@ £48/hour)	£134.40	£112.00
Straightening willow sticks for collection (@ £10.50/hour)	£11.90	£52.50
Bracke felling head (exclusive of haulage) £1.02/m	£102.00	£102.00
Chipping (2.3m^3 per hour @ £48/hour)	£297.60	£120.00
Total cutting and chipping (circular saw)	**£443.90**	**£284.50**
Total cutting and chipping (Bracke)	**£399.60**	**£222.00**
Product/ saving (for 100 m SRC)		
Own use (replacing bought in woodchip @ £23/m^3)	£329.36	£132.02
Own use (replacing heating oil @ £30.45/m^3)	£436.04	£174.78
Profit (best case: Bracke and replacing oil):	**£36.44**	**-£47.22**
Profit (worst case: Circular saw and replacing bought woodchip)	**-£114.54**	**-£152.48**

The figures are more favourable when compared against the cost of replacing heating oil and when harvesting using the Bracke felling head. However, at £680, haulage adds a significant amount to the cost of using the Bracke and the decision as to when the larger machinery becomes effective comes down to scale and the location of the machinery.

What has not been costed here are the potential economic and environmental benefits of introducing trees into agricultural systems (shelter, soil protection and nutrient recycling) or the loss of productive field area for the SRC rows.

Case study: Woodchip from hedges for soil health

An alternative use of material from hedges, especially suited to smaller diameter twiggy material, is to use woodchip produced from farm hedges as a soil improver or to make compost. This offers both a sustainable source of fertility and organic matter that you can grow yourself and a practical on-farm use for hedge material.

The farm

Tolhurst Organics, an eight hectare organic vegetable farm near Reading, Berkshire, is one of the longest-running organic vegetable farms in the country. The farm is stock-free organic and there have been no animal inputs on the farm for 25 years. Fertility comes from fertility building crops, green manures and woodchip compost. The farm has 1.5 km of field boundary hedges as well as a small area (0.2 ha) of willow coppice for fuelwood and a 3 ha newly established (2015) mixed agroforestry alley cropping system. The farm uses composted woodchip applied to a two-year legume ley as part of the fertility-building part of the rotation. The woodchip for the compost currently comes from a local tree surgeon; an alternative would be to use chip produced from on-farm hedges or agroforestry. This has been investigated at Tolhurst Organics.

Growing your own woodchip

Material from a mixed native broadleaf boundary hedge was coppiced and chipped in January 2017 to produce ramial chipped wood (RCW) for use as a soil improver. RCW is fresh woodchip from smaller diameter, younger branches which are nutritionally the richest parts of trees. The hedge material came from a hedge planted 29 years ago and last coppiced nine years ago. The hedge was coppiced by hand with a chainsaw and all material was chipped using a self-propelled hand-fed 7" Timberwolf chipper straight into the back of a muck spreader. The chip was applied at a rate of 7.5 litres/ m^2 to the legume ley in a replicated trial alongside the woodchip compost. Soil testing has been carried over the subsequent two years with no significant differences seen so far. This suggests that applying woodchip green, and so avoiding the need to compost, maybe a viable alternative – research is ongoing.

Costing it out

The total volume of chip produced from the 300 m hedge was 27 cubic metres (9 m^3/100 m); this is quite low but remember it is only the small diameter material being cut and chipped. RCW was applied at 70 m^3/ha.

The woodchip for compost is delivered free of charge by a local tree surgeon, so the costs here are minimal (labour to turn the compost and field space for compost pile).

Operation (per 100m)	Cost
Coppice and chip	£666.00
Cost to spread RCW (at £80/day)	£18.00
TOTAL COST	**£684.00**

Product/saving (per 100m)	Income
Savings in annual flailing of £0.35/m over a 10-year period	£350.00
Coppicing grant @ £4/m	£400.00
Total income	£750.00
TOTAL INCOME	**£750.00**
PROFIT	**£66.00**

The relative costs of the different methods will vary between systems and farms, but RCW is likely to make most economic sense when coppicing to rejuvenate an old hedgerow, where local supply of woodchip is limited, costly and/or the quality cannot be guaranteed, or where hedge or tree management for logs produces brash that will not otherwise be used. It also has the significant advantage in that by sourcing inputs from the farm and getting the infrastructure and systems in place you are essentially future proofing the farm.

Woodchip compost

Iain Tolhurst has been successfully composting woodchip for use as a propagation compost and as a source of soil fertility and organic matter for his polytunnels and fields for over ten years. To make a propagation compost, the woodchip is composted for 12 - 18 months, turned using a mini digger three times a year, then sieved to remove any remaining larger wood pieces and enriched with vermiculite.

The composting process for field application can be achieved in a shorter time period and does not require sieving or enriching.

Breakdown of costs to produce propagation compost from woodchip[10]

Raw woodchip	No charge delivered free to the site by local tree surgeon. A waste transfer licence might be necessary from the local authority.	£0.00
Turning	Using 1.5 t digger, assuming production of 100 m^3 p.a. Hire charge 3 days per annum.	£200.00
	Farm labour 3 days @ £80	£240.00
Grading	Material for compost production	£160.00
Additional material	(vermiculite) and mixing	£500.00
Total	approximately £1,100.00 or 11p per litre	

Storing and drying woodfuel

There are a number of options for drying and storing woodfuel and the best solution will depend on specific farm conditions. The availability of field, hard standing or barn space on your farm may determine when you chip your hedge material or dictate the volume of logs/woodchip the farm is able to produce each year.

Options for fuel drying and storage

The moisture content (MC) of wood significantly affects the amount of heat produced, water has to boil away before the wood will burn, reducing the useful heat (as opposed to steam up the chimney). Wet wood smoulders and creates lots of tars and smoke which can also damage stoves or boilers. To reduce the MC of woodfuel, fell trees during winter when they are dormant and contain least moisture then season the logs or woodchip to reduce MC to 25-30% before burning.

1. Air drying in field prior to chipping

If you have space or can be flexible with agricultural operations, coppiced material can be stacked in the field or at the field edge to air-dry for a few months before chipping. With a relatively dry winter, you can expect a final woodchip moisture content (MC) of around 25%. This method of drying can reduce handling or storage costs, but chipping dry material may result in more shards and fines and material can be difficult to handle later if the branches tangle and weeds grow up through them.

2. Self-drying under cover

The moisture content of newly cut wood is around 50%. Woodchip and logs can be stored to dry in a well-ventilated barn or outside under a geotextile cover on a concrete hardstanding. Even small piles of green woodchip heat up quickly, and the heating process drives moisture up through the heap where it evaporates, and steep-sided piles aid this process. A small amount of dry matter (3-5% per month) is lost due to decomposition when drying chip this way. Drying logs can be speeded up by logging, splitting, stacking off the ground and covering soon after felling. If possible, logs should be split to less than 10 cm diameter allowing moisture to move to the surface more easily. After six months for woodchip, and slightly longer for logs, you can expect a MC of around 25-30%, an acceptable level for combustion.

3. Active drying

Green chip or logs can also be force dried in a barn or hooklift bin with underfloor ventilation, where either heated or ambient air is forced under and through the logs or woodchip pile using fans or a grain dryer. This is likely to increase the cost of drying but will decrease drying time and dry matter losses.

Case study: Chip quality from hedges or SRC

Woodchip is a variable fuel. Most woodchip boiler systems are designed to work at high efficiencies requiring woodchip of the correct size, with a low proportion of both fine material and large shards. Using unsuitable woodchip may cause blockages in the fuel feeding system and inefficient operation. The European biomass industry has defined woodfuel standards to ensure consistency and quality.

This case study suggests that hedgerow and SRC woodchip can meet industry standards for quality and that the drying, processing or chipping method used does not significantly impact the chip quality.

Processing to increase chip quality

In 2016/17 trials were undertaken on two different farms to identify techniques for improving the quality of woodchip from hedgerows and agroforestry short rotation coppice (SRC) for use as a biofuel and to look at the associated costs. Some chippers are designed to produce fuel grade chip from large volumes of material, these chippers are usually fed by crane and include an integral sieve to produce a more even sized chip. More widely available and less costly are small-scale manually-fed chippers without a sieve. Both were used in the trials and chip samples were collected and analysed from the different chippers and the different drying and processing methods. Coppiced hedge material was treated in three different ways.

Drying and processing method used	Woodchip quality			Income (£/m^3)	Deductions (£/m^3)		Net return (£/m^3)*
	Moisture content (%)	Ash content (%)	G30 (% particles 3-16 mm)		Handling & admin	Drying & screening	
Dried in the field for six months and then chipped	23.2%	2.6	80.4	£23.00	£4.60		£18.40
Chipped straight after cutting and passively dried undercover for six months	28.6%	2.0	86.8	£23.00	£4.60		£18.40
Chipped straight after cutting then actively dried to 10% MC and passed through a 4 cm^2 screen	10.0%	2.4	81.3	£23.00	£4.60	£3.00	£15.40

**2018 prices, chip delivered in to Hampshire Woodfuel Cooperative's Odiham Hub, does not include haulage costs*

Woodchip quality results

None of the processing methods tested or chippers used had a substantial effect on chip quality. All samples collected met the criteria for G30 wood fuel accreditation that 60 - 100% of particles are between 3 - 16 mm. Screened and dried samples were generally more even sizes with less of the sample falling into the large and small categories. The presence of long shards and slithers in the chip is one of the biggest issues with hedgerow or SRC woodchip, and even when screened all the samples contained a proportion of chip which exceeded the maximum particle length.

Conclusion

If you have a local facility, active drying has potential, especially if space on the farm is limited. Existing farm equipment, for example a grain dryer, can also be used to actively dry chip on farm removing the requirement for haulage. Used directly, the energy cost of hedgerow woodchip ranges from 1.6 to 3.5 pence per kilowatt hour depending on hedge type and machinery used[8] which compares favourably with the cost of commercially produced woodchip from forestry roundwood which retailed at 3.10 pence per kWh in 2017[11]. The best way to make use of the woodchip produced on farm is to use it on farm. Fuel quality can be an issue, and these trials demonstrate that this is likely to be the result of the smaller hedge material rather than the chipper used, or the drying or processing methods. Boiler specifications need to be matched to the locally available woodchip; consider purchasing a robust woodfuel boiler and design a feed system which can tolerate variable woodchip.

Wildlife considerations

Hedgerows are one of the most important farmland habitats for wildlife. They provide food and shelter for numerous mammals, birds and invertebrates, including rare species such as the dormouse and beneficial insects such as bees. When managing hedges it is essential to consider any potentially harmful impacts on wildlife, for example, hedges which link woodlands and are potential dormouse corridors could be maintained as thick hedges with minimal management. It is also important to be aware of the legal restrictions with regards to nesting birds and protected species (see p14).

Managing hedges for woodfuel brings a number of benefits. Coppicing on a rotation creates a diversity of hedge structure within the landscape, providing more habitats for a wider range of flora and fauna. Although healthy hedges regrow rapidly, coppicing does create breaks in habitat continuity and may temporarily affect the movement of some species such as the hazel dormouse. A hedge allowed to grow tall to produce suitable sized stems for coppicing may also become less dense at the base reducing shelter for wildlife.

Hedgerow management has a strong influence on fruit (berries and nuts) production with experimental studies showing hawthorn berry yields from hedges cut every three years exceeds those annually and biennially flailed due to fruit only occurring on second year growth.[12] Although fruit production will be diminished for a few years after coppicing, a hedge under coppice management which is only side flailed every three years is likely to provide a better food resource to wildlife than a hedge which is flailed annually.

Recommendations

- No more than 50% of hedges on a farm should be managed for woodfuel[5]
- No more than 5% of hedges on average should be coppiced in one year, or 10% every two years [5]
- Aim to maintain and improve habitat connectivity across the farm, linking existing habitats
- Coppice hedges in late winter (Jan-Feb) to maintain food resources (hedgerow nuts and berries) and avoid nesting birds
- Retain dead wood within hedgerows wherever possible
- Maintain existing hedgerow trees and allow new ones to grow up; ideally aiming for one mature hedgerow tree every 50m or so. As these trees mature they can be thinned to avoid shading out coppice regrowth.
- Use native and locally appropriate species when planting new hedges or gapping up old hedges. Layer existing hedgerow shrubs where possible to fill any gaps.
- Side flail every two to three years, or if cutting every year, retain about 10 cm of the previous year's growth
- Do not cultivate, spray or fertilise within 2m of the centre of the hedge

A healthy hedge for wildlife has

- **Good density:** especially at the hedge bottom providing food and cover
- **Good size:** good width and height to provide livestock shelter and wildlife habitat
- **Good diversity:** of tree, shrub and ground flora species to provide food and shelter for a wide range of wildlife
- **Good connectivity:** with other hedges and semi-natural habitats within the landscape
- **Well placed:** hedges across slopes (contour planted) to provide extra buffering from erosion and runoff.

More information

For more information on how to manage hedges for wildlife, see the Hedgelink website (www.hedgelink. com) and the Hedgerow Guidance Leaflet produced by PTES (www.ptes.org). The Hedgerow Biodiversity Protocol developed by The Organic Research Centre is a rapid survey-based tool which can be used to evaluate and monitor the wildlife impacts of managing your hedges for woodfuel. The protocol is freely available from The Organic Research Centre website: http://tinyurl.com/TWECOM

Legal considerations

Rural Payments

Farmers and landowners claiming rural payments from government need to comply with the cross compliance (CC) rules. Under current (2018) CC regulations, hedges and trees can only be flailed or cut between 1st September and 1st March, although it is possible to carry out hedge and tree coppicing and hedge laying from 1st March until 30th April. Support for hedgerow and tree management is provided through agri-environment schemes such as the Countryside Stewardship in England, Glastir in Wales, Agri-Environment Climate Scheme in Scotland and the Environmental Farming Scheme in Northern Ireland. Most schemes provide support for creation, restoration and management of hedges, as well as capital support for coppicing and hedgelaying. Check government websites for up-to-date information.

Renewable Heat Incentive (RHI)

RHI is a UK Government financial incentive to promote the use of renewable heat. Annual payments are based on the amount of heat produced. Ofgem is responsible for administering the scheme, for more information visit their website (www.ofgem.gov.uk).

Biomass Suppliers List (BSL)

Self-suppliers, producers and traders of woodfuel who wish to access the RHI market need to register on the Biomass Suppliers List, regardless of whether they sell, give away or use their woodchip themselves. BSL accreditation requires that 100% of timber in the supply chain is legal and 70% is sustainable. Application for small businesses and self-suppliers is quick and simple. For more information see the BSL website (www.biomass-suppliers-list.service.gov.uk).

Felling licence

A felling licence will be necessary from the Forestry Commission before coppicing a hedge if stems are to be felled which are 15 cm or larger in diameter when measured at breast height (1.3 m from the ground) and more than 5 m^3 (timber volume) are to be felled in any defined calendar quarter, reducing to 2 m^3 if any of the wood is to be sold. This licensable diameter reduces to 8 cm or larger in diameter if felling single stems such as hedgerow trees. See the Forestry Commission website for more information(www.forestry.gov.uk).

Hedgerow Regulations 1997

It is not normally necessary to apply for consent under the Hedgerow Regulations 1997 before coppicing a hedge, provided cut stools are given adequate protection and allowed to regrow. If the intent is not to allow the hedge or any part of the hedge, however small, to regrow then a notice of intent to remove must be submitted to the local Planning Authority.

Tree Preservation Order

You will also need to contact your local Planning Authority if any of the trees to be felled or coppiced have a Tree Preservation Order (TPO) or are in a Conservation Area. Local Authorities usually have a map which shows the locations of all TPOs so you can check.

European Protected Species (EPS)

Several of the species covered by the Conservation of Habitats and Species Regulations 2010 may be associated with hedgerows. These regulations therefore have implications for how hedgerows can be managed and operations carried out. Such species include: all 17 species of bat, hazel dormouse, great crested newt, otter, sand lizard and smooth snake. For more information on EPS and the steps land managers should take to safeguard them see: www.forestry.gov.uk/england-protectedspecies.

Protection for designated sites

Work within Special Areas of Conservation (SACs) or Sites of Special Scientific Interest (SSSIs) may require Natural England's consent under Part II of the Wildlife and Countryside Act 1981 (as amended). Check with your Local Authority about more local wildlife site designations. For more details on protected sites see: www.gov.uk/topic/planning-development/protected-sites-species.

Wildlife and Countryside Act 1981

Wild birds and certain woodland animals and plants are protected under Part I of this Act. It requires you to carefully assess the impacts of tree work on wildlife, and ensure animals listed in the Act's schedules are not harmed or killed and that their nests or habitat are not damaged or destroyed.

Summary

Owing their existence to agriculture, hedgerows have been shaped by centuries of human activity. However, the last century has seen a large decline in their presence and quality due to the loss of a direct economic value, agricultural intensification, and the abandonment of traditional management practices such as coppicing and hedgelaying.

As a valuable resource within our rural landscapes, hedges need to be managed in a way which is sustainable, both economically and ecologically, and allows them to continue being healthy and vigorous so they persist for generations to come. The coppicing of hedges for woodfuel or other products has the potential to not only reduce the cost of managing hedges but to provide local communities with a renewable, low cost energy source whilst supporting wildlife and improving the health of hedges. Although markets are in the early stages of development, those able to supply themselves with woodfuel from hedges have an opportunity to make significant savings on the cost of energy. It's time to make the most of this under-utilised resource and bring our hedges back into the farm business.

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FACCE SURPLUS
SUSTAINABLE AND RESILIENT AGRICULTURE FOR FOOD AND NON-FOOD SYSTEMS

Resources

Hedge management

Hedgelink www.hedgelink.org.uk

National Hedgelaying Society www.hedgelaying.org.uk

Devon Hedge Group www.devonhedges.org

The Woodland Trust www.woodlandtrust.org.uk are offering support for new hedge planting and reinstatement of old hedges. Contact the woodland creation team on Tel: 0330 3335303 or at plant@woodlandtrust.org.uk

Wildlife

People's Trust for Endangered Species (PTES) www.ptes.org

Game and Wildlife Conservancy Trust www.gwct.org.uk

Policy and legislation

Defra www.gov.uk/government/organisations/department-for-environment-food-rural-affairs

Forestry Commission www.forestry.gov.uk

Natural England www.gov.uk/government/organisations/natural-england

Sustainable energy and woodchip quality

DECC www.gov.uk/government/organisations/department-of-energy-climate-change

Ofgem www.ofgem.gov.uk

Biomass Energy Centre www.ofgem.gov.uk

Woodsure www.woodsure.co.uk

Grants and funding

England: https://www.gov.uk/government/collections/countryside-stewardship-get-paid-for-environmental-land-management

Wales: https://gov.wales/topics/environmentcountryside/farmingandcountryside/farming/schemes/glastir/?lang=en

Scotland: https://www.ruralpayments.org/publicsite/futures/topics/all-schemes/agri-environment-climate-scheme/

Northern Ireland: https://www.daera-ni.gov.uk/topics/rural-development/environmental-farming-scheme-efs

Useful publications

The Agroforestry Handbook: Agroforestry for the UK. Edited by Ben Raskin & Simone Osborn (2019). Soil Association Limited.

TWECOM Best practice guide on Hedgerow harvesting machinery and methods (2015). Available from: www.twecom.eu

Agricology: https://www.agricology.co.uk/resources

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Wood processing from integrated farming. Pellet production

Over the last few years, alternative energy has gained more and more market segments dedicated to conventional energy, liquid and solid exhausts and pollutants. For years, emphasis has been placed on wind and solar energies, but another essential and accessible energy source, namely biomass, the most abundant on the planet, is neglected.

The diversity of product results from agroforestry systems facilitates the use of resources in an integrated way. In the case of wooded grasslands, residues from the yearly pollarding of trees have considerable potential for recycling in the agricultural system as energy usable in the farm.

Romania has a very high potential for biomass, about 50% of the potential of renewable resources, which is insufficiently exploited. This apparent disadvantage, supported by European grants, allows for greater accessibility to environmentally friendly solid fuel companies. The European Union is thus becoming a major supporter of the renewable energy scene, through its environmental policies and the funds allocated to it.

What are pellets?

Pellets are considered an efficient source for home and water heating, wood debris representing cheaper energy than traditional fossil fuels (coal or oil). They are eco-fuels because they contain no dangerous substances and emit less CO_2 than coal or oil. Pellets have a calorific power of 1.5 times higher than firewood and 1 kilogram of pellets has an energy output of 4.8 kWh.

Pellet making is the process by which solid fuel is produced from agricultural and forestry materials such as sawdust, branches, wood scraps or other woody scraps, leaves, straw, sunflower or corn stalks.

How to do it?

For this technological process to be complete we need besides fuel and the following equipments, a pellet manufacturing line.

Shredder - or **wood chipper** (see figure 1.) is a machine used for reducing wood (generally tree limbs or trunks) into smaller woodchips. They are often portable, being mounted on wheels on frames suitable for towing behind a truck or van. Power is generally provided by an internal combustion engine from 3 horsepower (2.2 kW) to 1,000 horsepower (750 kW). There are also high power chipper models mounted on trucks and powered by a separate engine. Tree chippers are typically made of a hopper with a collar, the chipper mechanism itself, and an optional collection bin for the chips. A tree limb is inserted into the hopper (the collar serving as a partial safety mechanism to keep human body parts away from the chipping blades) and started into the chipping mechanism. The chips exit through a chute and can be directed into a truck-mounted container or onto the ground. Typical output is chips on the order of 1 inch (2.5 cm) to 2 inches (5.1 cm) across in size. The resulting wood chips have various uses such as being spread as a ground cover or being fed into a press during pellet making.

Figure 1. Wood residue shredder (www.boels.cz)

Dryers - are used to dry the chopped material witch must have a moisture content of less than 30% for classical driers or less than 50% for rotary drum dryers. In the rotary drum dryer, the strong hot air feeds the chopped material into the suspension to dry it (see figure 2). Due to the high velocity of the air flow and the fact that the chopped material is suspended, the transfer surface between the air and the solid material is high, so a high rate of heat transfer results. The hot air generator is a wood-based or coal-fired furnace but can also be fitted with a gas or liquid fuel burner. The wet chopped material is dry in minutes and is further transported by means of a centrifugal fan.

Figure 2. Rotary drum wood chip dryer (http://www.uzelacind.com)

Presses - can also be used in households, farms, production units, for granulation of animal feeds or for the recycling of various materials and their transformation into pellets having a higher calorific value than the raw material used or can be combined with shredders and dryers to form complete pellet product lines (see figure 3). Pellet presses are machines that use power motors that roll metal rolls that press the chopped material onto a hole mold. After pressing through these holes the raw material is compressed and forms a compact mass that takes shape, the diameter and the length of the mold hole. Due to the temperature of about 70-80 ^{o}C due to friction, the fibers in the raw material are joined together and plasticized so that the pellets have a rather tough consistency. The molds can have two different planar and circular shapes, thus generating two different types of presses: flat-press presses and circular molds with each of these models having advantages and disadvantages.

Figure 3. Wood pellet press (http://www.homemadepelletmill.com)

Automatic packing machines - in plastic bags with adjustable capacity between 10 and 30 Kg or in raffia bags with adjustable capacity between 50 and 100 Kg

Figure 4. Automatic packing machine (eaglepackmachine.en.made-in-china.com)

The pellet process flow

Stage I:

Working principle:

Shredder crushing wood residues, both cylindrical and rectangular, fine grinder (hammer mill) - reduces raw material to 3-10 mm. The final fraction is fully trained for production line pellets.

Stage II:

Then the raw material falls into the aerodynamic dryer humidifier, in the drying process, the cold air, with the aid of the heat generator is heated and mixed with the wet raw material. The wet raw material is dryed for a few seconds. Then the dry raw material is evacuated by cyclone.

Stage III:

From the cyclone of the aerodynamic dryer, the raw material falls into the metering unit (silo) to maintain the flow rate. This hopper bunker (silo) allows us that the pelletized press work at one constant capacity in case we have the wetter raw material than in normal operating parameters an aerodynamic dryer.

Stage IV:

The raw material (wood chips) arriving in the pelleting press is pressed into the press channel by the eccentric mechanism actuated by an electric motor. As a result of the pressure exerted by the piston, the raw material is passed through the press channels and compressed as pellets.

Exercised pressure is sufficient to bake the raw material in a solid mass without the addition of binders and adhesives.

The baking process is continuous at a temperature of 110-200 ° C (depending on the moisture content of the raw material).

The pellets that come out of the press enter the cooling line (6-7m) .Depending on the setting can then be packaged.

(The process flow can be seen in figure 5)

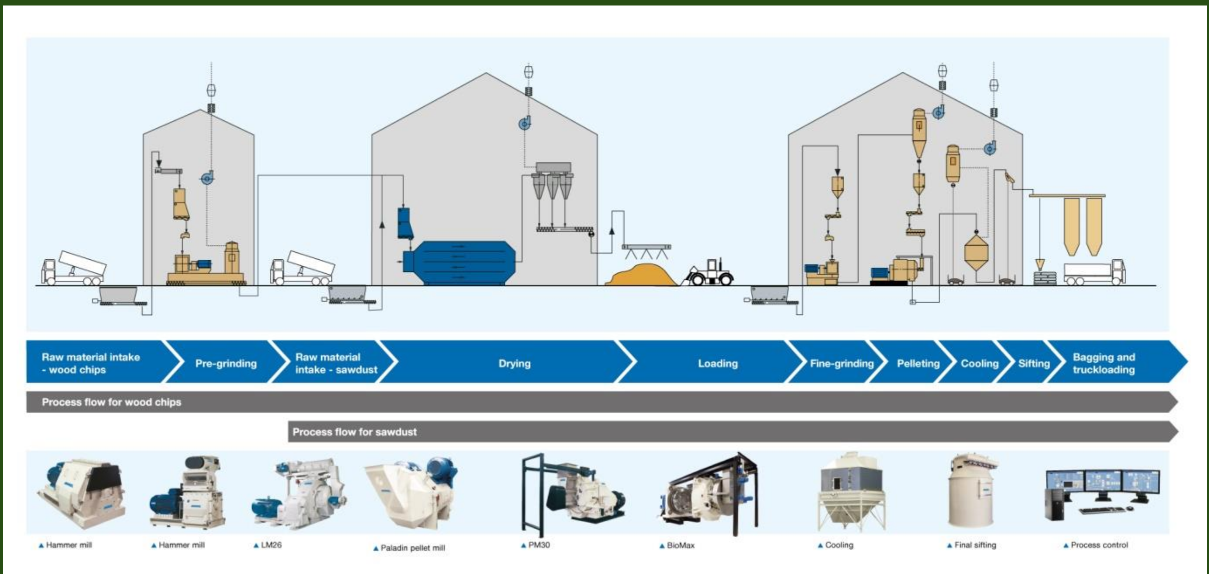

Figure 5. Biomass pellet process flow (www.andritz.com)

Production costs?

The price of a pellet production line is variable depending on the component equipment, the production capacity, the quality of the fuel resulting from the processing, etc. The cheapest line of production goes from 15,000 € + VAT. and can reach a value of 100,000 € + VAT or even more.

Some additional reading

Infiintarea unei activitati nonagricole in zone rurale – Submasura 6.2 Plan de afaceri: Infiintare fabrica de peleti.

Prezentare linii de brichetare si/sau peletizare din resturi vegetale si beneficiile acestei activitati.

This technical sheet was compiled by Adrian-Eugen Gliga and Mignon Sandor (University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca), within the context of the European project SustainFARM.

Cluj-Napoca, February 2019

Using Production Network Analysis for economic evaluation of farming activities

The complexity of Global Production Networks

The project SustainFARM aimed at fostering the environmental, agronomic and economic performance of integrated food and non-food systems (IFNS). Combining the management of trees, livestock and crops at plot, field and farm, these systems offer a range of environmental benefits such as erosion control, prevention of nutrient leaching, greenhouse gas emission reduction or increased infiltration capacity. Yet, implementing such systems needs to be interesting for farmers from an economic point as well. With ongoing globalisation, agricultural production systems have become less detached to the local and more involved with broader, even global, structures of supply, distribution and consumption. When evaluating agricultural production systems, it is therefore not enough to consider one farm by itself, as it will necessarily be part of a bigger network, its scope for decisions influenced by power of other actors, possibilities to generate and secure values and the political and social regulations it is embedded in (Coe & Yeung 2015; Henderson et al. 2002). This technical sheet introduces the concept of global production networks (GPN) analysis with emphasis on the different actors involved with integrated farming systems and illustrates how it was used to reveal structures and dynamics influencing individual farmers' economic performances and possibilities.

Different actors and their roles within IFNS networks

Different actors and the connections between each other shape (global) production networks as well as political and societal conditions determining an actor's individual scope of economic performance. Placing the farmer or the farm at the centre of a network's inspection, Table 1 summarises different actors that will in some way or another be able to influence decisions on the farm scale. Farmers use materials (e.g. feed) and inputs (e.g. labour) to convert them into products or services. This process is influenced by state or supranational institutions in forms of general legislation on ownership or market rules, influencing farm activity e.g. by taxation or subsidy allocation.

Table 1: Roles, activities and influence of different network actors

Actors	Role	Value Activity	Areas of Influence
State / Supranational Institutions	Promotion and (global) regulation, rules, agreements	Ownership, innovations, market rules, international sanctions	Capital, land and labour markets, taxation, social and environmental issues, subsidies
Consumers	Buyers of goods or services	Preferences and choices	Limited, only collective
Civil Society Organisations	Ensuring corporate social responsibility	Lobbying and social sanctions	Ethical sourcing, gender equality, environmental sustainability
Financial Intermediaries	Credits, information and knowledge services	Managing financial risks and promoting innovation and investment	Credit lines, financial advice, investment evaluation, value projections, tax strategies
Intermediaries in Standards	Establishment, enforcement and harmonization of protocols and codified knowledge; consultancy and information	Compliance, certification and private regulation	Production (e.g. labour and environment), consumption (e.g. quality and safety), innovation (e.g. standardization, protocols and interface)
Strategic partners (cooperatives)	Partial or complete solutions for group of actors	Collective development	Market access, compliance, advice, capital, bargaining

Source: Coe & Yeung 2015; adapted

Consumers have a big influence on decisions related to products on offer as well as production methods by their choices and preferences. Their power to take influence is however limited to a collective notion of individual choices. Civil society organizations and NGOs influence e.g. on-farm environmental or labor conditions by socially sanctioning actions of non-compliance and lobbying activities for greater incorporation of the relevant topics into law. Financial intermediaries can play a major role for farmers when it comes to investment planning, debt and credit management and general financial advice. Standard intermediaries affect production strategies by regulations and sanctions with implications to market access. In IFNS, farmers involved in seller's groups or cooperatives can be considered strategic partners for farmers able to offer easier market access, bargaining power or general advice and capital sharing.

Main Problems for IFNS and where to look for Solutions – The example Romanian smallholders

When trying to foster production networks and value chains connected to integrated farming systems, it is important to focus on several dimensions with different key roles. As many goods from integrated farming systems are produced in small quantities, distribution channels are often hard to access. Be it because of hygiene regulations, missing economies of scale, no proper regional or local branding or the price pressure put on the producers by supermarkets and wholesalers. Access to subsidies and financial resources for investments are prerequisites for keeping these highly productive systems working and are therefore crucial for their success. Figure 1 exemplarily shows how Romanian smallholders producing raw milk in silvopastoral systems are connected to local and global networks.

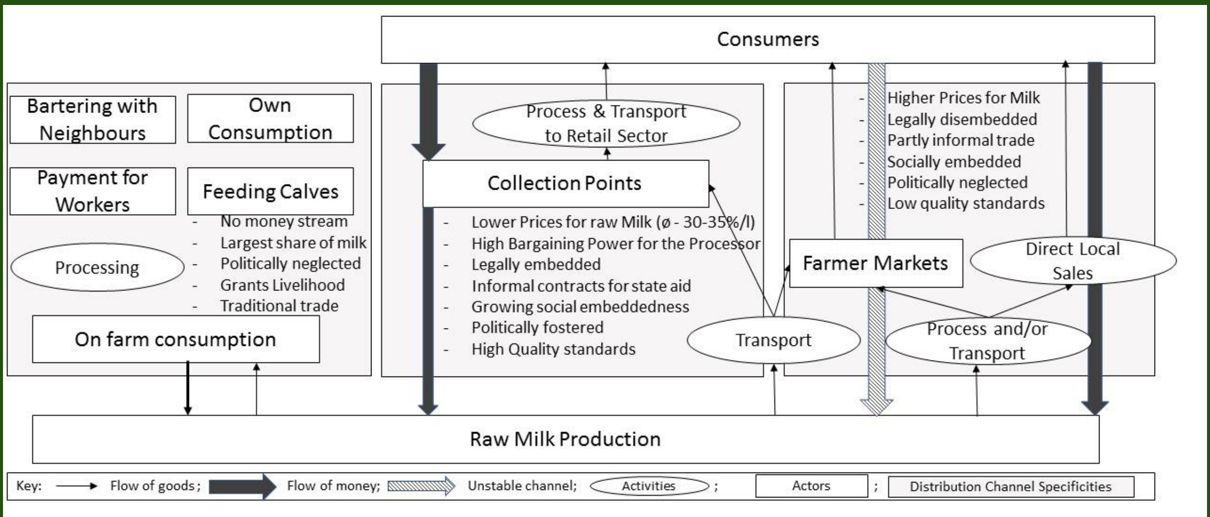

Figure 1: Value generation from raw milk for Romanian smallholders in the Carpathians
Source: von Oppenkowski et al., 2019, p. 8

Through consolidation in the retail and dairy sector, the price pressure has moved toward the producers of raw milk. This development is reinforced by new European, national and private standards as well as global actors tapping into the Romanian market. At the same time, the smallholders, who accepted to be acting on an informal level, can no longer access their main distribution channels. Because of several legal constraints, which developed since Romania's accession to the European Union, smallholders are not considered juridical persons and are therefore unable to issue invoices or access certain subsidy programmes. This leads to globally sourcing dairies having a bargaining power surplus toward the farmers, who see themselves forced to sell their raw milk to the collection points at 30-35% lower prices than sold via short local value chains. In the Romanian case, there are several fields, which need to be improved in order to foster smallholder farming and integrated production methods. These include legal embedding of smallholders and small quantities of produce from integrated farms, subsidy design for high value farming, certification of organic or closed circle agriculture for those, who cannot afford existing certificates, education on farming methods and subsidy access. Table 2 shows the huge variety of products and ecosystem services provided by these systems and clarifies, why they are important to be kept as a part of the Romanian farming landscape.

Table 2: Ecosystem Services and Products from IFNS in Cluj and Maramureș.

Primary Production	**Integrated Production**	**ESS with major monetary value creation**	**ESS with lower monetary value creation**
Meat products (sausage, smoked, fresh)	Burning (smoking, heating, cooking) & construction wood (farmhouse, stables, fences, haystacks)	Food, genetic resources (e.g. Bruna de Maramureș), raw materials (sales)	Nutrient, water & gas regulation Pollination
Milk and dairy products (soft cheese, hard cheese, fresh cheese, yoghurt)	Fruit products (liqueur, jam, compote, juice, syrup)	Recreation, Aesthetic information, cultural & historic information, spiritual information (tourism)	Soil formation, pest control, disease control, source for science and education
Grains & vegetables	Tree hay, manure		Disturbance prevention, climate regulation
Fodder	Medical plants		Refugium, Nursery, Medicinal Resources

Source: Own elaboration

Summary and policy implications

The investigated value chains of IFNS in different European countries show, that different stakeholders and links between them play major roles when analysing the value creation and enhancement process. Amending the legal framework with proper subsidy design can enhance IFNS farming methods in the first production step already. This can be of special importance when the establishment of systems requires initial investment, which will only pay itself back with a considerable time lag, e.g. willow short rotation coppice in the Danish case. Concerning CAP subsidies, farmers, e.g. in the Polish case opted for the highest subsidy grant, without caring about effective yields. Raising awareness for positive features of the products and production methods must be fostered, both, among farmers and consumers. This can be achieved through certification of products and production systems as well as education of producers and consumers. Furthermore, as the Polish example showed, certified high-value organic manufacturing and processing is far behind certified agricultural production in terms of available and usable quantities. A higher valuation for the existing systems could also help overcome parts of the problem of rural exodus (e.g. in the case of Romania). Further, the problem of small quantities of integrated produce is glaring. Retaining value creation and capture at the production level rather than relocating it toward intermediaries and retailers is possible. through the support of cooperative movements or regional branding for products such as local jams, honey, olive paté, wood chips from hedges and short rotation coppices, etc. and simplifying market access for small producers. Otherwise, transaction costs both for the smallholders to gain access to markets, for the European Union to spread subsidies and for intermediaries such as organizers of farmers markets are hindering efficient processes. Many NGOs, cooperatives, associations and research institutes are already working on these topics, which would make them proper partners to adapt policy measures to the highly varying local contexts.

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Project partners

For further information, please visit
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Marburg, March 2019

Agroforestry and olive orchards: by-products and innovative value chains

Olive value chain in Umbria region

Italy is the second olive oil producer of the European Union and Umbria can be considered one of the most interesting region because of the high quality of the extra virgin olive oil (EVOO) and the close connection with traditional knowledge and local environment. The regional olive oil chain, involves about 30,000 farms growing olive trees covering about 27,000 ha and including 270 oil mills. The olive oil production phase comprises the extraction of the oil and additional by-products (water, pomace and husk). The by-products management is very important as the olive oil mill wastes have a great impact on soil and water because of the high phyto-toxicity (phenol, lipid and organic acids). In the other hand, such wastes may be valorized in alternative and innovative products (figure 1).

Figure 1: possible use of oil mill residues to produce energy, biogas and bio-materials.

The main strength points of olive oil value chain in Umbria are: elevate landscape value of olive orchards as well as cultural and traditionally value; high quality of the extra-virgin olive oil; great awareness and expertise of farmers and oil mill managers.

The main weak points of the olive oil chain in Umbria are: high productive costs; low intensive management practices; small-scale farm dimension.
The main opportunities should increase the cultural awareness of stakeholders; increase adoption of agroforestry management; facilitate synergies and cooperation among the stakeholders; implement innovative value chain from the olive processing residues.
On the contrary, the main threatens are related to the risk of abandonment of olive orchards and limited market opportunities.

Agroforestry management in olive groves

Olive orchards have been traditionally managed as agroforestry systems, intercropping the olive trees with arable crops (fodder legumes or cereals) or combined with livestock (mainly sheep). Today, agriculture practices need to combine food security with environmental protection, safeguarding biodiversity, soil fertility and combating Climate Change. The modern management of the agroforestry systems of the olive orchards can address issues such as multifunctional sustainable agriculture throughout green mulching, grazing and intercropping. Olive trees produce the maximum amount of fruit yield when tree canopy intercepts 55% of the available light. If the olive trees have a too high planting density, the consequent self-shading causes a decrease in the fruit yield. Thus, 45% of residual solar radiation that is not used efficiently by olive trees - if water and soil nutrients are not limiting factors - can be exploited by the associated crops or understory vegetation and/or rearing animals.
In Italy, many fruit trees plantations, included olive trees groves, are often located in hilly areas which are at risk of soil erosion if the soil is mechanically cultivated or chemically treated to contain weeds. An alternative solution is the maintenance of a permanent and controlled herbaceous cover (figure 2), with positive effects against soil erosion and on the physical, chemical and biological characteristics of the soil. In this way, green mulching influences soil fertility increasing the organic matter, with the accumulation of carbon (C) into the soil. Important additional benefits of green mulching are the elimination of the compacted ploughing layers, the increase in soil micro-porosity, together with the improvement of the soil structure promoting soil water storage and its availability to cultivated plants.

Figure 2: traditional management of olive orchards intercropped with cereals

Alternatively, rearing of domesticated husbandry in agroforestry systems can contribute to animal welfare, improving the quality of animal productions (meat, milk, eggs, etc.) and ensuring the supply of supplementary fodder resources to grazing animals from the arboreal

component (acorns, fodder fronds, fallen fruits) in addition to the grass/pastureland. The animal dejections are disposed directly on site, and tree root systems can intercept the leached nitrogen, reducing the nitrate pollutions of soil water, water tables and connected waterbodies. Furthermore, the C emitted from the animals can be stored in the woody biomass of the associated trees.
Animal grazing (especially sheep, cattle and goats grazing) under olive trees is still widespread in Italy. Unfortunately, there are no reliable statistics about the current use of grazing under olive trees with traditional low tree density and large tree size (figure 3).

Figure 3: olive orchard with sheep grazing

Olive leaves are fibrous with a low digestibility, especially in crude protein, and they promote very poor rumen fermentation. However, if adequately supplemented, they may be successfully used in animal diets mostly fresh when the nutritive value of olive tree leaves is greater. When olive leaves are rich in oil, ruminal protozoa decrease, and this could increase the efficiency of microbial protein synthesis in the rumen. Furthermore, for lactating animals, olive tree leaves result in an improvement in milk fat quality due to the high linolenic acid content, compared to diets based on conventional forages. Feeding olive tree leaves to ewes also has a positive effect on the fatty acid profile of cheese and therefore improves its human nutrition quality. Olive orchard grazing can offer a lot of benefits: sheep reduce costs by controlling grass and suckers growing and increasing nitrogen recycling, while the olive leaves provide high quality feed in winter when the availability of grass is reduced.
There are different ways to include olive leaves in animal diets, varying from feeding it fresh, ensiled, dried or as a component of concentrate pellets and multi-nutrient feed blocks. In a silvopastoral system with sheep and olive groves, it is sufficient to leave pruned residues on the ground and, after the branches have been cleaned by sheep, place them in windrows for chopping. All these operations must be done during the winter. In the spring, despite the abundance of pasture, the sheep will continue to feed on olive leaves, contributing to the control of the suckers. In autumn, when it is the time of oil extraction, it is possible to keep the olive leaves to provide cheap energy and fibre to the animal.

New bio-products and innovative value chain from olive processing

Olive mill wastes can be considered as resources to be recovered. The olive pâté production is an example of possible innovative value chain that could be implemented using bio-residues.

However, its promotion depends on the market demand and the implementation of specific legislative roles.

In our experiment the olive pâté yield can integrated the extra-virgin olive oil production, guarantying an alternative source of income at the oil mills. However, the commercialization of such product, since it is destined to human consumption, requires the respect of appropriate regulations and the implementation of specific technical skills at the oil mills. The relevant legislation about this matter is the Legislative Decree 3 April 2006, n. 152 "Environmental regulations", published in the Official Gazette no. 88 of April 14th 2006 - Ordinary Supplement n. 96, on waste management.

Additional uses of bio-residues from the olive process (figure 4), that can give a surplus of income, are:

- Olive husk used to produce bioenergy;
- Olive pomace used to produce biogas;
- Residues also used to produce bio-materials.

Figure 4: possible utilization of olive mill waste to create innovative value chain

Currently the prices of extra virgin olive oil often do not guarantee an adequate income for the operators. The situation is aggravated by the fact that the processing residues resulting from the oil production (pomace and vegetation water) represent a problem for the millers in terms of disposal. With that innovation it will be possible to obtain two products of the highest quality from olives.

The production of olive pâté has been empirically tested in October-November 2017 (figure 5).

Figure 5: production of olive paté re-ulitizing wet pomace

The experimental protocol has been set up adopting the following steps:

1 Check of the integrity and quality of the olives

2 Check of the integrity and quality of the row olive pomace extracted during the processing
3 Transport of the row material in suitable containers (stainless steel) to the processing laboratory
4 Processing with the addition of other ingredients and sterilization or pasteurization
5 Packaging of the final product (olive pâté)

The olive pâté production is estimated to be about 6% of the weight of the processed olives and about 50% constituted by water (figure 6).

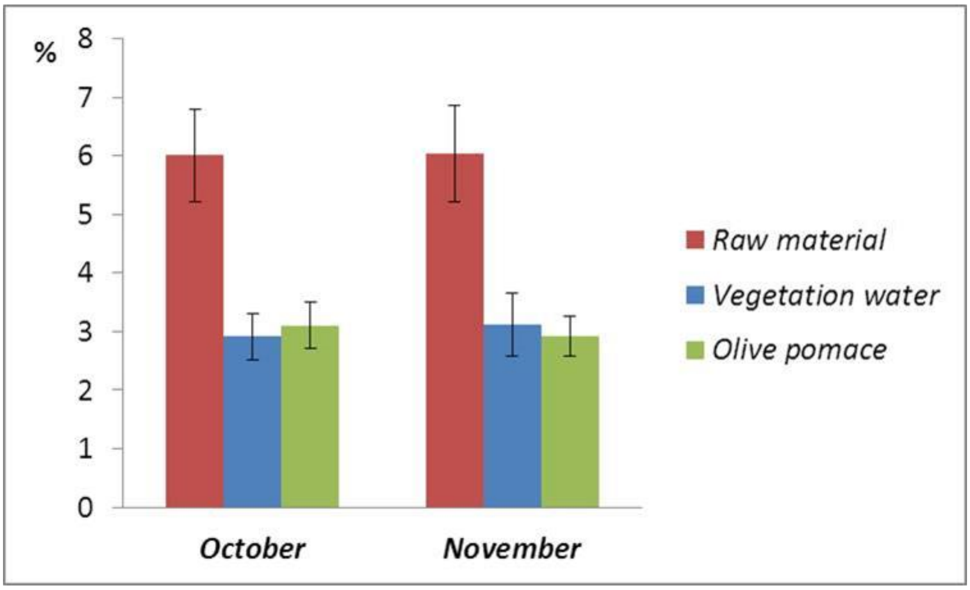

Figure 6: Percentage of raw material, vegetation water and olive pomace compared with the quantity of olive fruits harvested during the season. The yield of olive pâté is about 3% of the olives processed at the oil mill.

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Circular use of olive pomace for soil health

The high diversity of outputs from agroforestry systems facilitates the use of resources in a circular and integrated way. In the case of olive trees intercropped with herbaceous species (e.g. pastures, cover crops or inter-row sown annual crops), the residues obtained from olive oil production (e.g. olive mill pomace) reveal considerable potential to be recycled into the farming system as a soil health promoter. This leads to several agronomic advantages such as soil organic matter increase with the consequent improvements is soil physical and chemical properties (nutrient supply), allelochemical suppression of yield reducing factors (e.g. F*usarium, Verticillium, Sclerotinia*) and other soil conservation mechanisms equivalent to those induced by conventional mulches.

Only in Andalusia, Spain, about four million tons of olive mill pomace are annually produced. The modern two-phase or three-phase continuous decanter processes of olive oil generate a semisolid pomace in which soil and liquid residues are mixed. Contrary to traditional techniques, the modern extraction processes do not fully separate liquid from solid matter, turning the use of such by-products more complex and costly. Some alternative uses of this waste material have been tested: production of pellets due to its high calorific value (approx. 20 MJ/g), heat production for warming water at the mill through combustion, and nutrient recycling through the application of olive pomace compost into agricultural fields. The current technical sheet focuses on the recycling and application of olive pomace to agricultural fields.

Olive pomace properties for composting

Some of the potential harmful substances in olive pomace are biologically degraded through composting. There is instead an enhancement of beneficial bacteria and fungi activity that break down organic matter and create humus. This allows a safe and desirable re-introduction of waste material into agricultural fields. However, the low porosity of this waste material, the high moisture content and the low nutrient concentration (i.e. N and P since it is quite rich in K), might turn difficult its use for composting (see initial composition in table 1).

To optimize composting performance, initial properties should be adjusted. The material must be subjected to a brief storage-drying phase (see figure 1), during which the moisture content should decrease, from its initial values of about 60-70%, to approximately 40%. If necessary, plant ashes and/or dried grass might be added to help reducing the water content. Other bulking agents such as olive tree leaves and small branches, straw and other animal or plant based materials may be used as well.

Figure 1. Olive pomace storage; visual appearance.

Olive pomace composition	
Moisture content	56%
pH	6.15
EC (dS/m)	5.95
Cl- (mg/L)	402
Organic C (%)	59.5
Water soluble C (%	2.68
Volatile matter (%	96.2
Organic N (%)	1.15
N-NH4+ (mg/Kg)	101
N-NO3 (mg/Kg)	123
C:N ratio	51
P2O5 (%)	0.197

Table 1. Representative olive pomace composition. All data (except moisture content, pH, EC and Cl^{-}) are expressed in dry weight basis. Information obtained from Canet et al. (2008).

The initial pomace C:N ratio (see table 1) must be decreased to a range of 25-35 to avoid nitrogen losses through volatilization while slowing the metabolic reactions during composting.

It is important to put values into context to avoid false expectations. Note that while olive pomace could be a an alternative source of N to cattle and/or pig manure (up to 75 and 70% less N respectively), the same must not be mentioned when compared to poultry manure (up to 80% more N). Addition of poultry manure is therefore highly recommended when available in order to increase both N and P content of the amendment.

How to do it?

The compost of olive pomace can be produced by storing the waste material in concrete block enclosures, covered by a shading layer and installed over a double plastic waterproofed layer (see figures 2 and 3). The composting piles height must be kept at about 1.2 to 1.5 m (see figure 4).

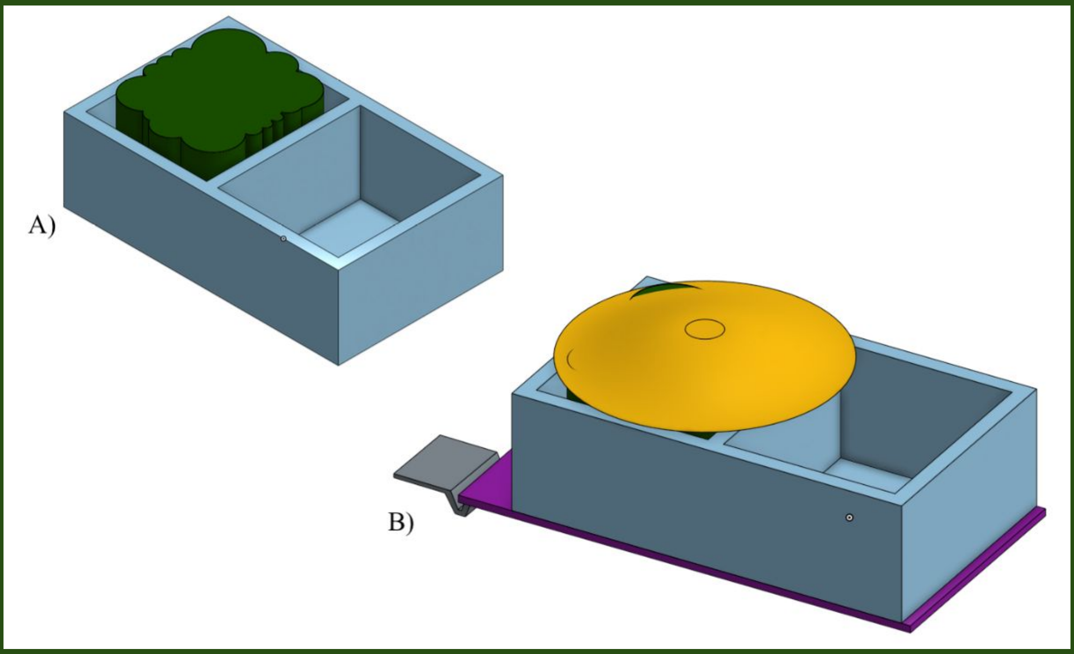

Figure 2. Tridimensional model of the proposed composting container. A) the blue structure represents the concrete block enclosures and the green element the composting pile; B) block enclosures are represented by the same color, the yellow element represents the shading layer, the purple one represents the double plastic waterproof layer and the small grey element represents a leachate-collecting vessel.

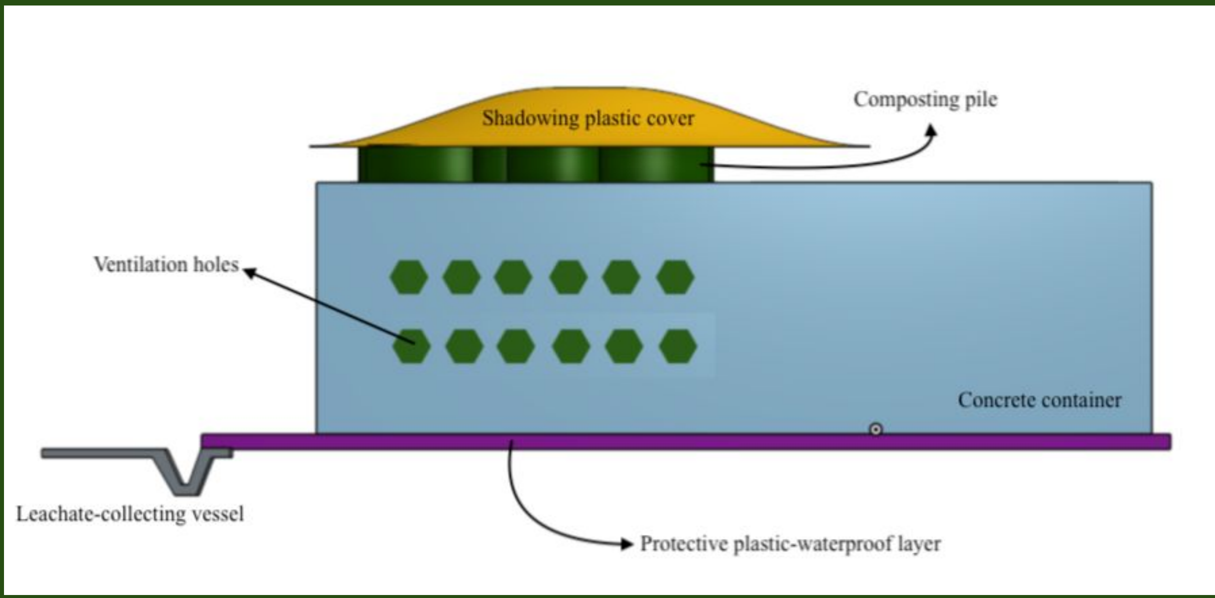

Figure 3. Lateral view of the operational design.

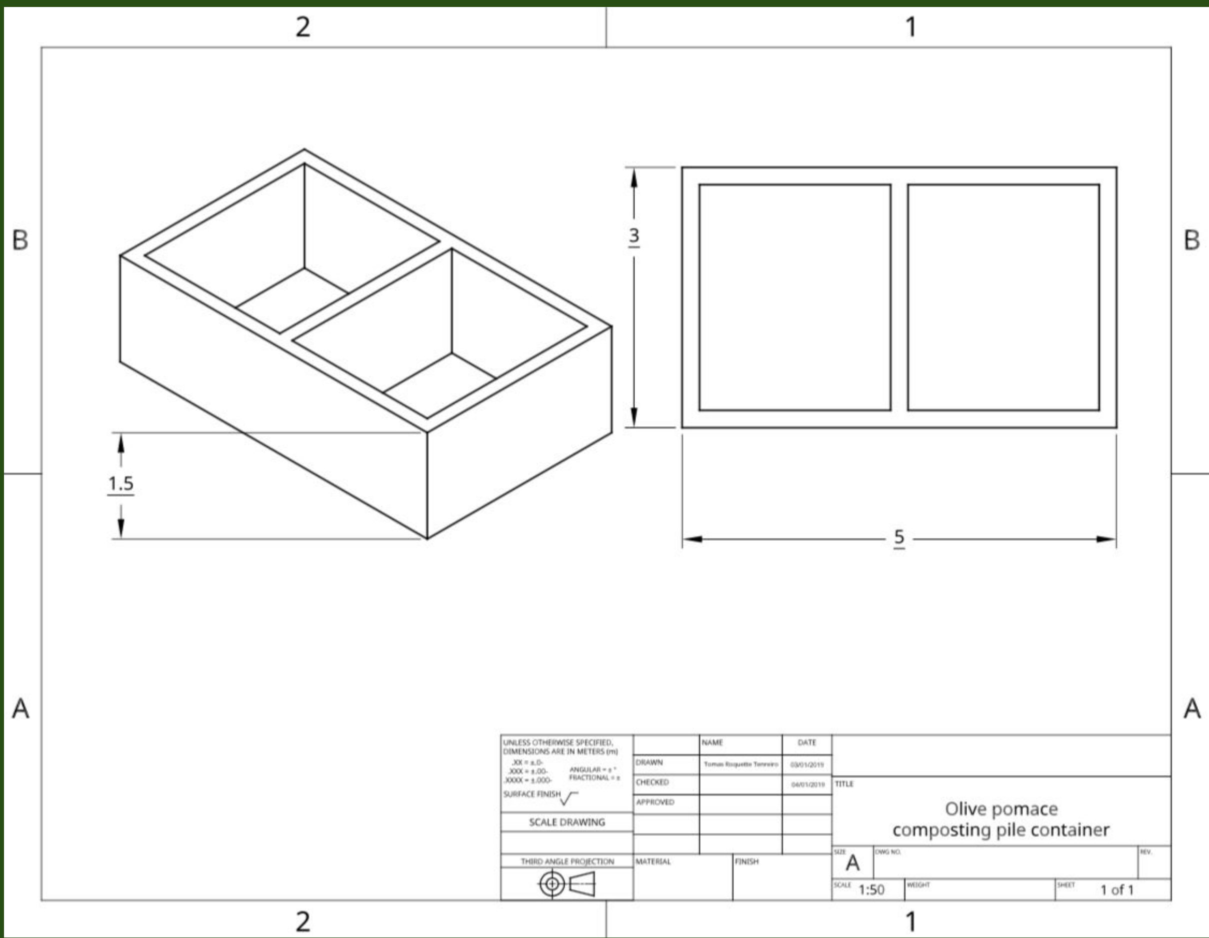

Figure 4. Scale scheme of the concrete block enclosures design (1:50) with units expressed in meters.

Temperatures must be measured daily at 5-10 different sites in each pile using an electronic thermometer, introduced at about 1 m depth with different angles. The measured temperatures of the pile must be above 50^{0}C to control pathogenic activity but not to exceed 60^{0}C. Cooling and aeration measures must be done weekly using a shovel.

The optimal oxygen levels are between 15 and 20%. The moisture level, measured weekly, must be kept at about 40% by manual irrigation if necessary.

Large increases of pH might be observed (up to 3 units). The compost alkalinity could be decreased by adding ammonium sulphate or elemental sulphur.

The levels of heavy metals tend to be within the required ranges proposed by the European eco-label (European Commission, 2001), but the literature mentions that Cu might exceed the required threshold.

When is the compost ready?

At the end of the process, the moisture content must be about 30%. The compost mass should occupy about 35-50% of the initial volume. The density of the pile should be considerably larger, visually detectable. The material should smell like "rich" soil and look darker (see figure 5). None of the particles that were initially composing the pile should be recognizable. Under desirable conditions, the composting process will take about 7-9 months to be fully completed.

Figure 5. Visual aspect of composted olive mill pomace (after 7 months of composting); the image was obtained from García-Ruiz et al. (2012).

How to apply?

The compost should be applied annually between October and November (for Southern-Spain conditions). For an average orchard with 30% of the soil covered by olive trees, single annual applications of about 4 to 6 Mg ha^{-1} (wet weight, moisture content around 20%) are recommended by García-Ruiz et al. (2012). The compost should be spread over the land surface.

Production costs?

The production costs vary largely according to the type of materials selected for compost storage, the frequency of aeration and other intervention costs. However, an average production cost of about 5.5-10 € ton^{-1} (DM of compost) can be expected.

Some additional reading

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García-Ruiz, R., Ochoa, M. V., Hinojosa, M. B., & Gómez-Muñoz, B. (2012). Improved soil quality after 16 years of olive mill pomace application in olive oil groves. Agronomy for sustainable development, 32(3), 803-810.

This technical sheet was compiled by Tomás Roquette Tenreiro and Elías Fereres (University of Córdoba), within the context of the European project SustainFARM.

Córdoba, January 2019

Multifunctional landscape design with agroforestry

Introduction of agroforestry systems on agricultural land should be carefully planned and an economic investigation of local demand for timber/biomass and an environmental analysis of afforestation demand should be carried out beforehand. Bearing in mind the need to maintain green infrastructure in agricultural landscape and carry out effective and consistent actions with the aim to protect soil and water, it is recommended to design agroforestry systems in line with the applicable law, local land development plans and strategies of adaptation to climate change. Such actions will contribute to improving the effectiveness of delivering ecosystem services. Otherwise, soil and waters may be exposed to degradation and result in decrease of profitability of agricultural production. Last but not least, it is important to select the right plants and suitable for the neighbour vegetation as well.

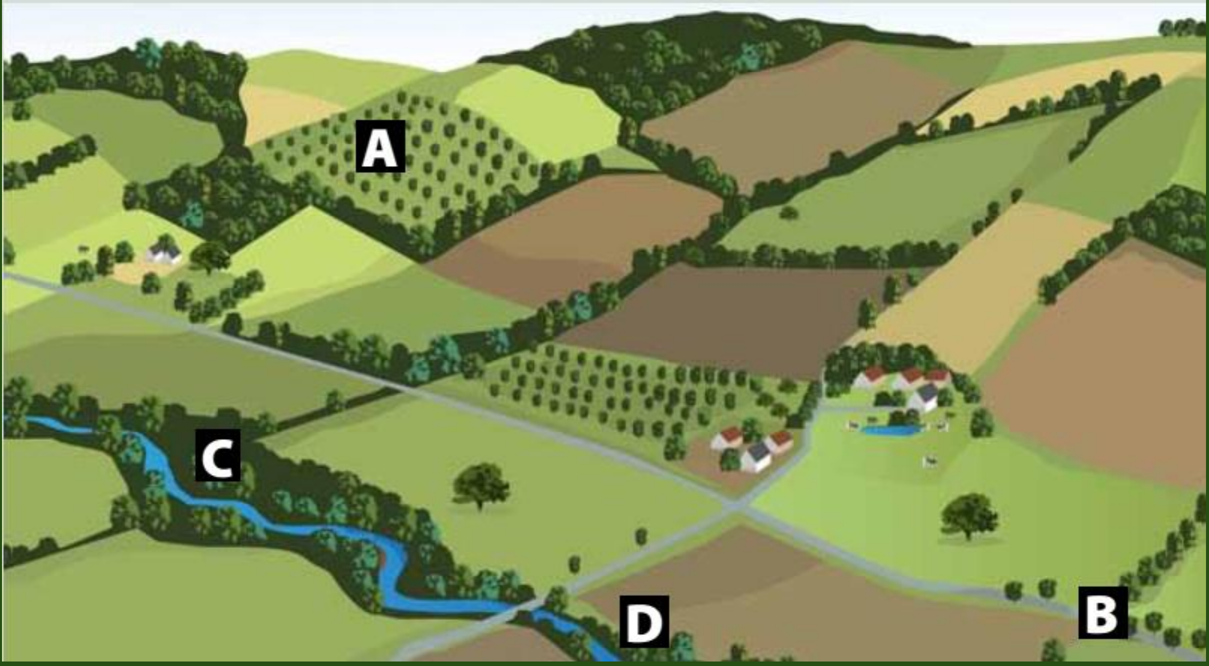

Figure 1. *Network of woodlands, shelterbelts, buffer strips and agroforestry systems should be created based on afforestation needs of the local area: protection against soil erosion (A), water evapotranspiration (B), flooding (C) and nutrients leaching (D). Connections between all the elements maintain green infrastructure in the agricultural landscape and in this way improve biodiversity (based on Arbre et Paysage 32 - http://www.ap32.fr/page01.html, modified by J. Józefczuk, In: Kujawa A., Kujawa K., Zajączkowski J., Borek R., Tyszko-Chmielowiec P., Józefczuk J., Krukowska-Szopa I., Śliwa P., Witkoś-Gnach K., 2019 – EcoDevelopment Foundation http://drzewa.org.pl/publikacja/1655-2/zadrzewienia-na-obszarach-wiejskichpodglad)*

What you should look for when establishing agroforestry system?

The best method of establishing agroforestry systems takes into account the following environmental conditions and risks at the landscape scale, resulting in the subsequent needs:

1) Water losses due to evapotranspiration from crops cultivated in low forestation areas with a significant share of light soils;
2) Soil losses (from fine sands, silt and dry peat layers) in areas exposed wind erosion;
3) Soil losses on slopes exposed to water erosion;
4) Watercourses and reservoirs existing near arable fields;
5) Biodiversity losses (enemies of pests or pollinators) in sparsely wooded areas (afforestation <15%) with a high share of arable land (>75%) and

lack of connections between at least 20% of the refuge areas, existing in the agricultural landscape;

6) Local conservation needs in the agricultural farm (securing slopes, reducing noise pollution, particulate matter emissions and noxious smells, protection of pastures against wind, etc.).

Each problem needs specific solution. Therefore, the environmental risks should be minimized as far as possible by careful implementation of set of measures to be operating in most effective way. Introduction of agroforestry systems shall not be considered in one-size-fits-all approach. As far as reasonable practical, woody species should be carefully selected, grouped and maintained in a proper design (vertical and horizontal) taking into account local conditions to improve production efficiency.

How to effectively introduce trees in an agricultural landscape?

The main need of the particular area defines the requirements concerning orientation of tree rows, planning the understorey layer, the width of greensward within shelterbelts, share of fruit and thorny species of trees and bushes as well as diversification of their flowering periods. For each need there are specific recommendations:

1) The protection range of shelterbelts (reduction of wind speed by at least 10%) is directly proportional to its height. Under optimal conditions the protection range may exceed the trees height even twenty times (20h). Windbreaks should be perpendicular to the prevailing wind direction, with additional cross strips, connected to them (figure 2). The most effective are wide, double-row barriers, with not too dense crown leaf horizontal density (with 20-30% in the canopy of full-grown trees). It is also important to include bushes in the understorey layer (figure 3).

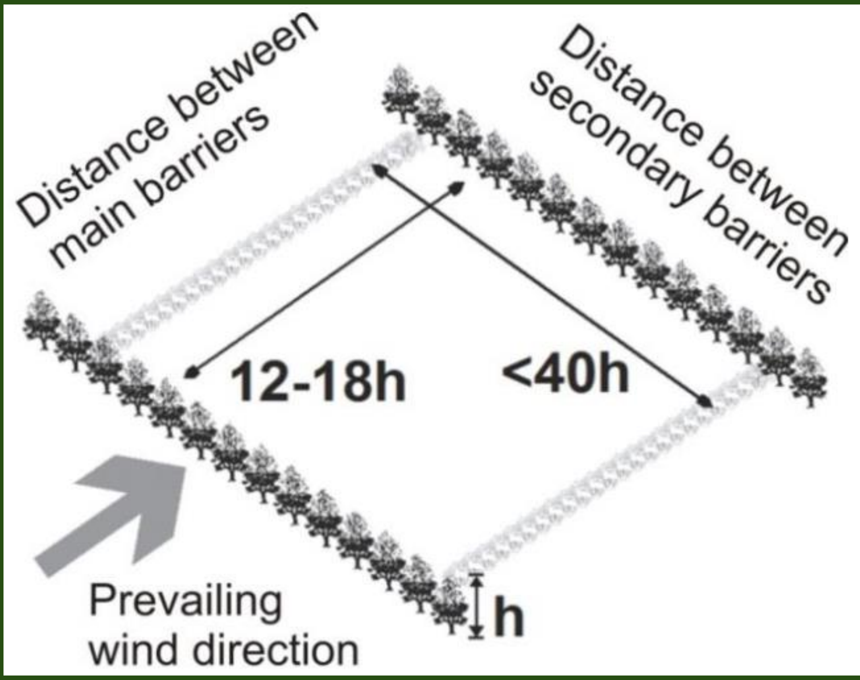

Figure 2. *Optimum spatial orientation and distances for the network of shelterbelts designed to mitigate evapotranspiration and wind erosion on adjacent crop fields (J. Zajączkowski).*

Figure 3. *Optimal structure of tree row is a crucial factor to reduce effectively wind-induced erosion and evapotranspiration at landscape scale (J. Zajączkowski).*

2) The distance between the main barriers (from 12- up to 18-fold of the target height) depends on the risk of wind erosion phenomena in the particular area. In winter, when the risk of wind erosion is the greatest, the effectiveness of

the wind barrier decreases, hence the need to keep two rows of trees and a complementary layer of bushes in the understorey.

3) Shelterbelts against water erosion should be several metres wide, rows arranged across the slope, spaced at intervals of 300 m in case of short slopes or up to 200 m on longer slopes, both with well-developed sward to prevent surface runoff.

4) Along watercourses and reservoirs the strip of greensward should be at least 10 m wide, with loosely distributed trees preventing the runoff of pollutants (e.g. fertilisers) from the field (figure 4). The trees shouldn't be planted closer than 20 m from active drainage ditches.

Figure 4. *Buffer strips along sides of water reservoirs should comprise wide grass strip with loosely distributed trees (K. Zajączkowski).*

5) Agroforestry systems should be arranged in a way that makes it possible to connect them (e.g. along roads, watercourses or field margins) with the already existing groves, shelterbelts, water bodies or old parks (figure 1). To improve biocenotic conditions it is necessary to create a network of thin corridors up to 500m long, connected to net nodes. Agroforestry systems should have a varied species composition of trees and bushes, melliferous and fruit species are highly recommended.

6) To secure slopes, species with extensive root system should be chosen. It is also important they have rich foliage to provide high amounts of organic matter to the soil. Relatively wide and high strips of trees with bushes in the

understorey with thick canopy may help protect against dust particles and noxious smells. To reduce noise pollution, usually spruce is used (figure 5).

Figure 5. *Spruce works perfectly for reduction of noise pollution (J. Zajączkowski).*

Above recommendations might be not in accordance to standard recommendations for agroforestry systems (optimal orientation of rows North-South maximally reducing light competition to crops or optimal design in terms of trees species productivity) or attitude of farmers towards mono-species trees production. These restrictions should take into account numerous trade-offs in the individual decision processes.

Figure 6. *Hawthorn is melliferous plant providing number of food products, including honey however is not recommended to be planted nearby orchards (Heildebergerin/pixabay.com).*

For design of agroforestry system, it is advised to use native species and already adapted to local conditions. Companion plants are welcomed. Due to the risk of transmitting crop diseases, rose bushes (especially hawthorn, figure 6) are not recommended for orchards, nor is barberry suitable in the proximity of cereal crops. Some bushes shouldn't be planted near field and horticultural crops, as they provoke occurrence of aphids. Invasive and toxic tree and shrub species should also be avoided.

When planting trees, bear in mind the canopy size of a full-grown tree and maximum extent of roots, especially when they are located near the field margin – in such cases planting should be consulted with the owner of the adjacent land. The same rule applies to planting alongside road, where it can be incompatible with the provisions of law.

Only spatially continuous and properly designed shelterbelts/hedgerows network is capable to effectively mitigate large-scale environmental threats. Agroforestry should contribute to coherent vision of sustainable rural development through rational management of natural resources building on local needs of ecosystems and expectations of farmers.

Further information

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This technical sheet was compiled by Robert Borek (IUNG-PIB - Institute of Soil Science and Plant Cultivation in Puławy, Poland) and Jacek Zajączkowski (SGGW – Warsaw University of Life Sciences) within the context of the European project SustainFARM.

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