Lessons learnt for livestock agroforestry in the AGFORWARD project

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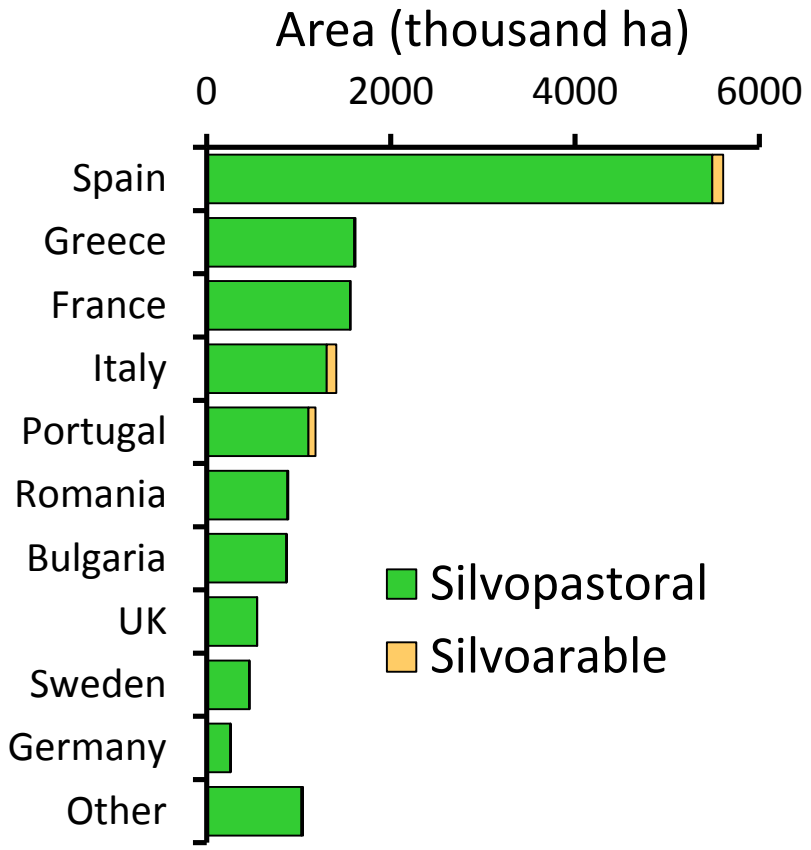
Content

1. To provide an overview of agroforestry with livestock across Europe
2. Review some innovation of trees with livestock
3. Review perceptions of agroforestry across Europe

Silvopastoral systems

Silvopastoral	Silvoarable	Hedgerows, windbreaks and riparian buffer strips	Forest farming	Home-gardens
				
Combining trees and shrubs with forage and animal production	Widely spaced trees and shrubs inter-cropped with annual or perennial crops	Lines of trees/ shrubs bordering farmland to protect livestock, crops, and/or soil and water quality	Forested areas used for harvest of speciality crops	Trees/ shrubs with vegetables in urban areas

Silvopastoral systems are important covering 3.6% of Europe



Area of agroforestry: Using LUCAS data:15.4 Mha (3.6% of total area and 8.8% of agricultural area) (den Herder et al. 2017) (excludes 1.8 Mha of homegardens).

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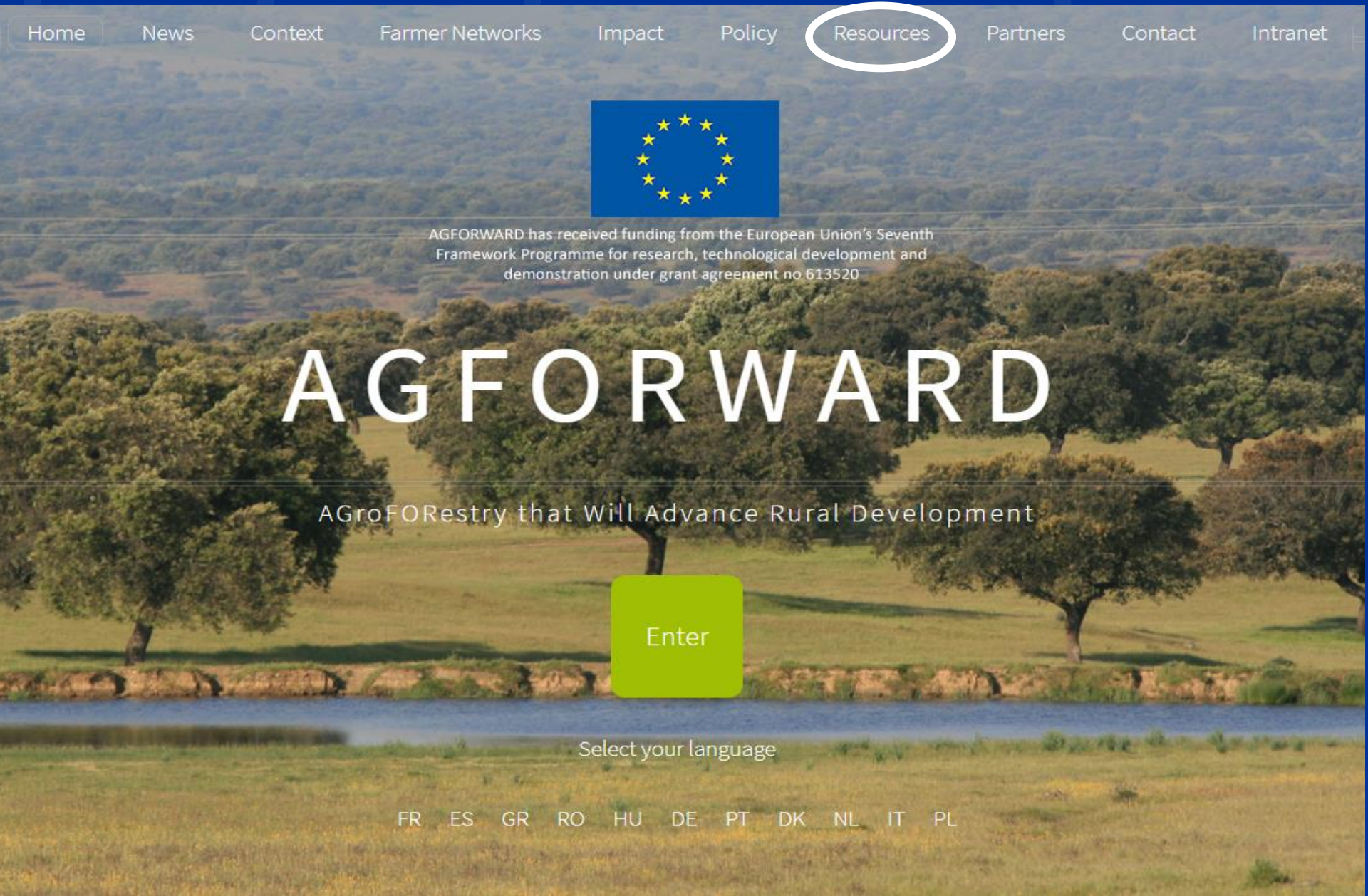

46 Innovation leaflets

Innovation leaflets

01 Agroforestry INNOVATION

Establishing pastures rich in legumes

How to develop a more sustainable dehesa farm
www.agforward.eu

View of pasture rich in legumes sown in November 2013 (picture taken in May 2014) in plots grazed by sheep in the dehesa farm in "Atoquedo", located in the National Park of Monfragüe (Torrejón el Rubio, Extremadura, Spain). *Ref : G.Moreno*

Why establish biodiverse pastures rich in legumes?

Dehesa is a man-made silvopastoral ecosystem. It is characterised by a high biodiversity, but pasture production can be low, especially in winter and summer. Consequently,

What kind of seed mixture is the most appropriate?

The dehesa is a distinctive ecosystem characterized by a mosaic of shade imposed by scattered *Quercus* spp. trees and shaped by the moderate grazing pressure (<0.5 Livestock Unit ha^{-1}). The biggest challenge to estabishing leguminous pastures is the spatial heterogeneity in terms of light, temperature and humidity,

02 Agroforestry INNOVATION

Triticale in Iberian dehesas

Searching for shade-adapted forage crops
www.agforward.eu

Dehesa Los Llanos in Siruela (Extremadura, Spain) cultivated with triticale to feed livestock. *Ref : G.Moreno*

Why triticale?

Productivity of natural pastures in Iberian dehesas is usually low and very variable (on average 1440 kg dry matter (DM) ha/yr). They also provide low nutritive value forage, containing 4-20% legume fraction, 9-12% crude protein, 44-59% neutral

Sowing and management

It is recommended that triticale sowing is carried out in late autumn, after the first autumn rainfall, following light tillage and using a seeding rate of around 200 kg/ha. Depending on the initial mineral soil levels, a N-P-K fertilization might be applied either before or during sowing (70 N kg/ha, 40 P_2O_5 kg/ha and 70 K_2O kg/ha).

The recommended crop management is direct grazing by mid winter, to

03 Agroforestry INNOVATION

Fast rotational intensive grazing

A holistic management approach
www.agforward.eu

Sheep grazing under an intensive fast-rotation scheme in Mundos Nuevos Farm (Campillo de Llerena, Extremadura, Spain). *Ref : Maria Canalon*

Why holistic management?

The increased demand for meat is driven by a rising human population, and a dramatic growth in meat consumption per person. Farmers and scientists have sought to curb the adverse environmental impacts of livestock by in-

How it works

The concept of Holistic Management emphasises that the sward not only provides nutrients to the ruminants, but also contributes to "feeding the soil" (Savory 2013). The basis for this approach is the grazing patterns of

04 Agroforestry INNOVATION

Tree regeneration in grazed wood pastures

How to assist natural regeneration?
www.agforward.eu

View of the young surviving trees a few years after an artificial plantation in an open dehesa stand. *Ref. M. Bertomeu*

Why do we need to support tree regeneration?

Dehesas and Montados are very suitable for pasture production. However, livestock grazing hampers the natural regene-

The constraints of current approaches to tree regeneration

The three most common techniques to enhance the tree regeneration of Iberian dehesas and montados are (i) planting young plants (1-2 years old) at high density (400-600 plants/ha) with complete exclusion of grazing for 20 years; (ii) planting and protecting a small number of young trees scattered in very open stands and maintaining grazing; and (iii) sim-

Improved seasonality of grass production

06 Agroforestry INNOVATION

Modelling livestock carrying capacity in montados

Do trees really promote pasture production?
www.agforward.eu

Why use trees on grazed areas?

First impressions are often that the presence of trees in pasture systems will lead to a reduction in pasture production due to the light and water competition. However, other effects on the system dynamics and water availability may be beneficial to nutrient cycling, yield, and pasture productivity.

Trees affect wind speed and temperature, creating a milder climate by providing shade under the canopies. This microclimate can improve pasture production and availability (more production in winter and delayed drying in early summer), and reduce livestock energy requirements (Moreno et al. 2013, Pelaez et al. 2015)

Cutting cold winter grass grows more beneath the trees, ref. C.Moreno

Using models to predict productivity

"Yield-SAFE" is a model that is used for predicting the productivity of agro-forestry systems (Palma et al. 2014). One advantage is that it uses easily obtainable variables. The parameters for the main tree and crop species are already available, along with the main soil types, so there is only need to:

- choose the tree and/or crop species and soil type/depth
- select an area for the simulation (current and future climate data are automatically accessed)
- define initial values for biomass, leaf area, soil and water (otherwise default values will be used)
- define the management e.g. tree and/or crop density, days of planting, pruning, thinning and harvesting

The model simulates tree and understory growth, and all the interactions that exist between these two components regarding water use, light competition and the canopy effect on the microclimate. Growth is translated into energy and used to compute the carrying capacity of the system.

For Iberian dehesas and montados, the model can estimate:

- production of pasture and acorns
- the canopy effect on microclimate (temperature and wind)
- the carrying capacity (livestock units per ha)
- the effect of heat stress reduction on livestock weight gain.

The average carrying capacity values in montados/dehesas systems are between 0.3 and 0.5 (ranging from 0.15 to 0.7) livestock units per ha (López-Díez et al. 2014). The Yield-SAFE model can be used to experiment with different climate, soil quality and tree density values to determine the system's response and the number of days the system produces enough energy to support the determined carrying capacity.

There is a delay in pasture dryness in the summer underneath the trees. Ref. F. Canseco

Longer grazing season under the tree canopies in Spain and Portugal

Improved seasonality of grass production

In Northern Ireland, trees allow earlier access to grass in Spring and extended grazing in autumn

Conservation value of livestock grazing

Red Poll cattle in Epping Forest wearing collars for a virtual fencing scheme to allow unconstrained public access

10 Agroforestry INNOVATION

Invisible fencing in wood pasture

A comparison of costs

www.agforward.eu

Red Poll cattle wearing collars with sensors and GPS units (Epping Forest, UK)

Why invisible fencing?

Invisible fencing is an innovation that allows the control of cattle movement without needing physical barriers. In open areas, cattle can be fitted with a Geographical Positioning System (GPS) which will signal when a cow approaches a boundary.

Under trees in a wood pasture, due to the intermittent GPS signal, an alternative method is to bury an electric cable in the soil surface that emits a shortwave radio signal which is sensed by a transponder on a cattle collar. The transponder emits a noise as a cow approaches the boundary and, if she does not turn back, it provides an electric pulse similar to an electric fence. At Epping Forest, each collar also includes a GPS sensor which helps to locate the cattle.

Background

The Corporation of London at Epping Forest have demonstrated the technical feasibility of virtual fencing to control livestock in areas of high recreational use that require uninterrupted access. Dr Jeremy Dagley at Epping Forest, with colleagues has developed a best practice guide covering the equipment, fitting and training, design, installation and safety (Dagley and Phillips 2016). The focus of this leaflet is on the costs of invisible fencing, relative to wooden fencing.

Financial comparison

Using data from Epping Forest, we examined the cost of invisible fencing relative to wooden fencing with two horizontal beams and mesh netting. A spreadsheet model was developed to describe the main costs with key variables including: fence length, the area, the cattle number, and the capital and running costs of the components. Although the model included grant support options, the results presented in this leaflet assume no grant support (Burgess et al. 2017). The costs of each system were calculated over a period of 30 years, to account for the lifetime of the different components e.g. wooden fence and collars (15 years), generator for invisible fencing (10 years), and generator batteries (5 years). Although the model allows the discounting of future costs, this leaflet presents only the undiscounted costs.

Cow collar with the sensing unit

a) Wooden fencing

b) Invisible fencing

A study was undertaken to compare the costs of a) wooden fencing and b) invisible fencing where the cattle wear a collar which senses the output from a buried wire

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Grazing of high-stem cider orchards


24 Agroforestry INNOVATION

Economic benefits of grazed apple orchards in England

Grazing under half-standard or standard trees
www.agforward.eu

Why graze orchards with sheep?

Orchard grazing can offer financial and environmental benefits. The experience of stakeholders in the AGFORWARD project is that some lowland sheep breeds (e.g. Shropshire) can successfully graze on orchards which have been pruned to a height of 1-2 m without noticeable losses in apple yields. Sheep producers can profit from an additional source of grass in the orchards, and the release of grazed land for hay production. Orchard owners can profit from reduced mowing costs, increased nitrogen cycling and a rent from the sheep owner. There can also be societal benefits in terms of employment and plant biodiversity.

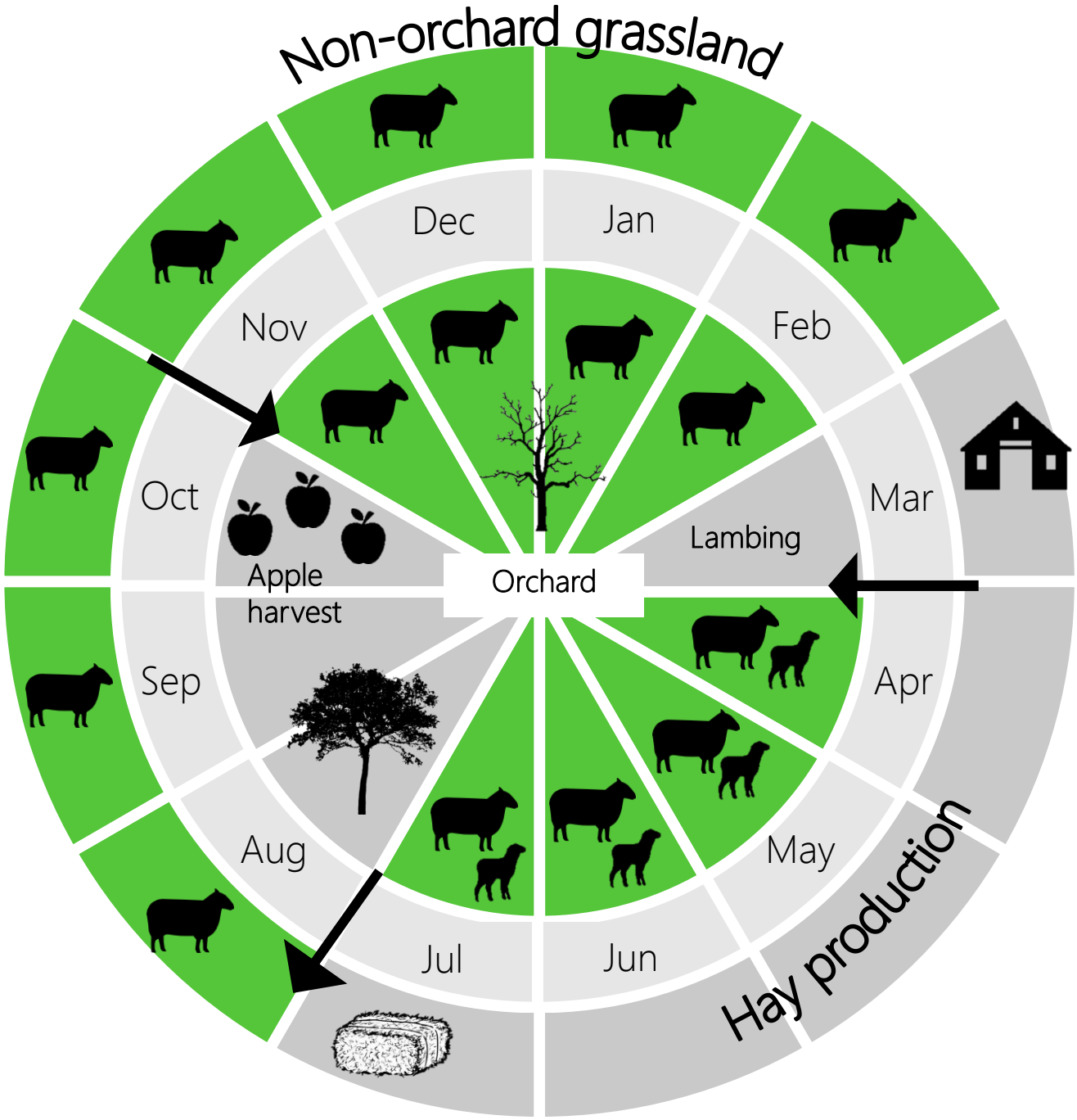
Cider apple orchards and sheep

Cider apple orchards have significant economic, biodiversity, and societal benefits (Robertson et al. 2012). Cider apples are sold for their juice rather than their appearance and therefore the pesticide regime can be less intensive than that required for dessert apples. This reduction in agrochemical use provides opportunities for integrating sheep. In the UK, about a third of the cider apple orchards are comprised of "standard" or "half-standard" trees, which have been pruned to a height of 2 m and 1-2 m respectively. This pruning allows the yields from apple trees to be maintained when the grass understorey is grazed by "tree-friendly" sheep. In England, orchard owners commonly use Shropshire sheep because, if managed correctly, they cause minimal levels of bark damage.

A key feature of grazed orchard systems is that it is necessary for the sheep to be absent from the orchard for 60 days before apple harvest (generally from August to October) to minimise faecal contamination of the fruit. Hence, a sheep producer must have access to separate non-orchard grassland where the sheep can be kept at this time. Thus, a grazed orchard system involves sheep, apple trees, the grass understorey, and an area of separate non-orchard grassland for supplementary grazing.

Reduced mowing costs

Opportunities for improved off-site grass use


Non-orchard grassland
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Lambing
Orchard
Apple harvest
Hay production

Hens in organic apple orchards

Woodland eggs

- Hens use more of their range
- Less feather pecking damage
- Fewer wild fowl visits

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Commercial apple orchards in poultry free-range areas

Increase revenues from your investment in animal welfare
www.agforward.eu

Why plant trees?

Where, how and which trees to plant?

Sward establishment under trees

- Commercial standard sward mixture established as well as customised seed mix
- Rotation of access to manage pressure across the range

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Silvopoultry: establishing a sward under the trees

www.agforward.eu

Chickens under the trees in the silvopoultry system? Ref : Organic Research Centre

Why do chickens need a sward under trees?

Trees in the outdoor run are beneficial to the welfare of chickens. The ancestors of domestic chickens roost in trees, and hens are happier and use more of the range when it is enriched with trees. However, one problem with including trees in the range is the lack of ground vegetation under the trees, due to reduced light levels and increased competition. Further, where the tree canopy opens) unpalatable weeds, rather than grasses, may grow.

European regulations for organic and free-range chickens state that the outdoor area should be mainly covered with vegetation. Establishing and maintaining a healthy sward under the trees has multiple benefits; it protects the soil, provides alternative food sources for the chickens and enhances biodiversity.

Establishing a sward in the understorey

The development of a sward mixture that can establish and survive under trees has been identified as a priority by a focus group of UK farmers producing woodland eggs. To address this issue, sward establishment trials were set up within an existing silvopoultry system at a commercial organic laying hen unit in southern England. Mixed broadleaved tree blocks of 144 trees were originally planted within the chicken enclosures in 2006 at 2 m x 2 m spacing. These blocks were selectively thinned to approximately 50% of planted density in February 2016 prior to sward establishment.

Three sward mixes were tested against a natural regeneration control to identify a mixture that performs well under trees. The trial mixes were: (1) a standard commercially available chicken sward mix; (2) a customised mix with shade tolerant grasses and (3) a diverse mix with grasses, legumes and forage herbs. The mixes were sown in four tree blocks in spring 2016 after a shallow cultivation using a pedestrian power harrow. Mixtures were sown by hand at a rate of 52 kg/ha, rolled and watered in. Chickens were excluded for the first three months to allow sward establishment and then introduced to two of the blocks for a ten week period from August to October 2016.

Growth and establishment of the mixtures was monitored weekly for the first six weeks, and environmental factors including soil moisture, canopy cover and temperature were also measured. Biomass cuts were taken after six weeks to measure sward productivity. After the chickens were introduced, biomass cuts and surveys of plant diversity were repeated every six weeks to identify the impact of the chickens on the different mixtures.

Preparing the ground for sward sowing using a pedestrian power harrow. Ref : Organic Research Centre

The sward six weeks after sowing (a) Mix 3 (b) The control. Ref : Organic Research Centre

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Pigs and trees

- Reduced heat stress
- Trees need to be established for 2-4 years before access
- Metal cage tree protection was most effective


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Lactating sows integrated with energy crops

Produce pork and tree biomass on the same area

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Why introduce trees?

Trees, like poplar and willow, can provide pigs, managed in pasture-based systems, with a natural and stimulus rich environment. Sows and piglets can find shade in hot seasons and shelter in wet and windy weather. Further, the pigs can rub against the trees for skin care.

The introduction of trees can reduce the nutrient leaching from soils in outdoor production because, compared to grass, fully established trees are more robust to the pigs' rooting behaviour. Further, trees have a deep root system with nutrient and water uptake occurring over a long growing season. The trees can be harvested to provide biomass to be used for production of energy, or as rooting material for pigs in housing systems.

Trees in pasture based systems also have a positive effect on biodiversity and landscape aesthetics.

Where and how to plant

Two private organic pig farms in Denmark have been studied for two years. The farms are involved in large-scale organic pig production, with 200 and 300 sows, respectively. The sows are kept outdoors all year round on grassland (grass clover). On both farms, poplar and/or willow have been established in the areas used for lactating sows. On one farm, the paddocks are approximately 30 m long and include two rows of trees at one end. On the other farm, the paddocks are 40 m long and include five rows of trees at one end. Behavioural studies were carried out. In addition, data on nitrogen in soil and soil water was collected on one of the farms to evaluate the effect of trees on animal welfare and nutrient leaching.

Poplar or willow?

Willow has a more shrub-like growth compared to poplar and may grow to 7-8 m. The dense multiple stem growth may hinder supervision of the animals and restrict human movement between the trees, for example, when catching piglets. On the other hand, the shrub structure provides the pigs with a solid shelter all year round.

Poplar has a more vertical growth and may become 20-30 m tall. It gives a more "open" expression and the shelter effect may be lower compared to willow. No matter whether willow or poplar is chosen, it is recommended that the area to be established is planted with, at least, three different clones in order to reduce the risk of diseases.

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Pigs and poplars

A smart combination for environmental protection, animal welfare and meat quality

www.agforward.eu

Why keep pigs together with poplars ?

Free-range systems aim to support animal welfare and are common in organic pork production. However, they do represent an environmental risk due to the deposiiting of manure. Maximum stocking rates are prescribed assuming that nutrients released with manure will be spread uniformly in the field and may be absorbed by cover crops roots. In practice, there are several problems with these assumptions: pigs often decide to use one specific part of the paddock to defecate; sandy-soil fi... es a small amount of nutrients; and herbaceous cover crops are more active during spring summer and less so in other seasons (Tagliapietra et al. 2007).

Trees, especially fast growing ones, such as poplar (but also willow, black locust) absorb high amount of nutrients and can reduce the risk of leaching, as well as spot water contamination through better drainage (AA.VV. 2011). Moreover, developed trees can provide a good welfare environment for pigs: cool shade in hot weather conditions and shelter from cold winter wind.

How to establish poplars within open range systems

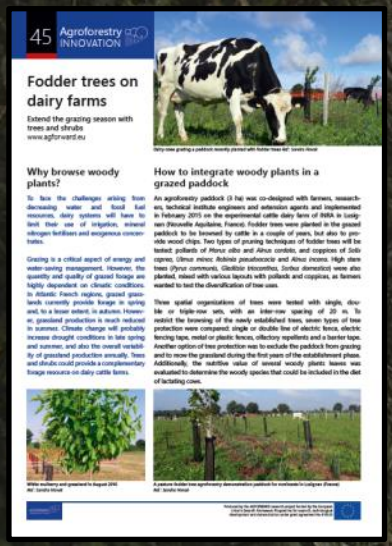
To assess different options, experimental trials were developed within an organic free range pig unit in an agroforestry system located in the northeast of Italy-Padania plane. (Veneto Agricoltura Azienda Sasse-Rami, Ceregnano – Rovigo; 45.050760° N; 11.880257° E)

Poplar is a fast growing species well-suited for tree range pig production in plain alluvial deep-soil where groundwater is normally present (1.5-2.0 m underneath). Spacing, intra-inter row distance and the final number of trees per hectare depends on soil type, field range design, pigs' categories, stoking expected during the production, and the wood destination at harvesting. In sandy soil types, tree density should be higher than those with loamy-clay textures; which have a better root-net capacity of minaure nutrients' absorption.

Under normal conditions, the harvesting cycle of poplar for packaging wood (main logs) or firewood (woodchip) could be every 10-12 years with a medium density plantation (200-300 trees/ha), but as short as 5-6 years (woodchip) with high density "short rotation" (1500-2000 trees/ha). Spacing of low-density plantations may vary from 3.0-4.0 m between tree and 16-25 m between rows. For high-density planting, recommended for growing-fattening heavy pigs, the common spacing is between 1.5-2 m x 3.0-3.5 m (with sufficient spaces left without trees for locating huts or feeding and drinking points).

Planting should be done in late autumn or early spring, using one year old rods (3-4 m long), planted at a depth of 1.3-1.5 m. Newly planted poplars must be protected from pig damage (mainly bark biting and scratching) by proper shelters. The area cannot be used by pigs until the second year, by which time the trees will be more resilient. There are very few types of shelter that can be used to protect newly planted trees from damage by pigs. According to the findings, a metal cage of 60-70 cm high around the trees will provide the best protection. Nevertheless, a low percentage (5-12 %) of trees are still likely to be seriously damaged (Bondesan, 2016). Metal cages should be removed before the tree growth incorporates it within the bark: if that happens more labour will be required to pull it away before harvesting.

Tree fodder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Fodder trees on dairy farms

Extend the grazing season with trees and shrubs

www.agforward.eu

Why browse woody plants?

How to integrate woody plants in a grazed paddock

Tree fodder database: leaves of black locust, chestnut, white mulberry and ash have crude protein levels of 22%

On-line fodder tree database

Online fodder tree database for Europe

Please cite as: Luske B., Meir I. van, Altinalmazis Kondylis A., Roelen S., Eekeren N. van (2017). Online fodder tree database for Europe. Louis Bolk Institute and Stichting Duinboeren, the Netherlands.

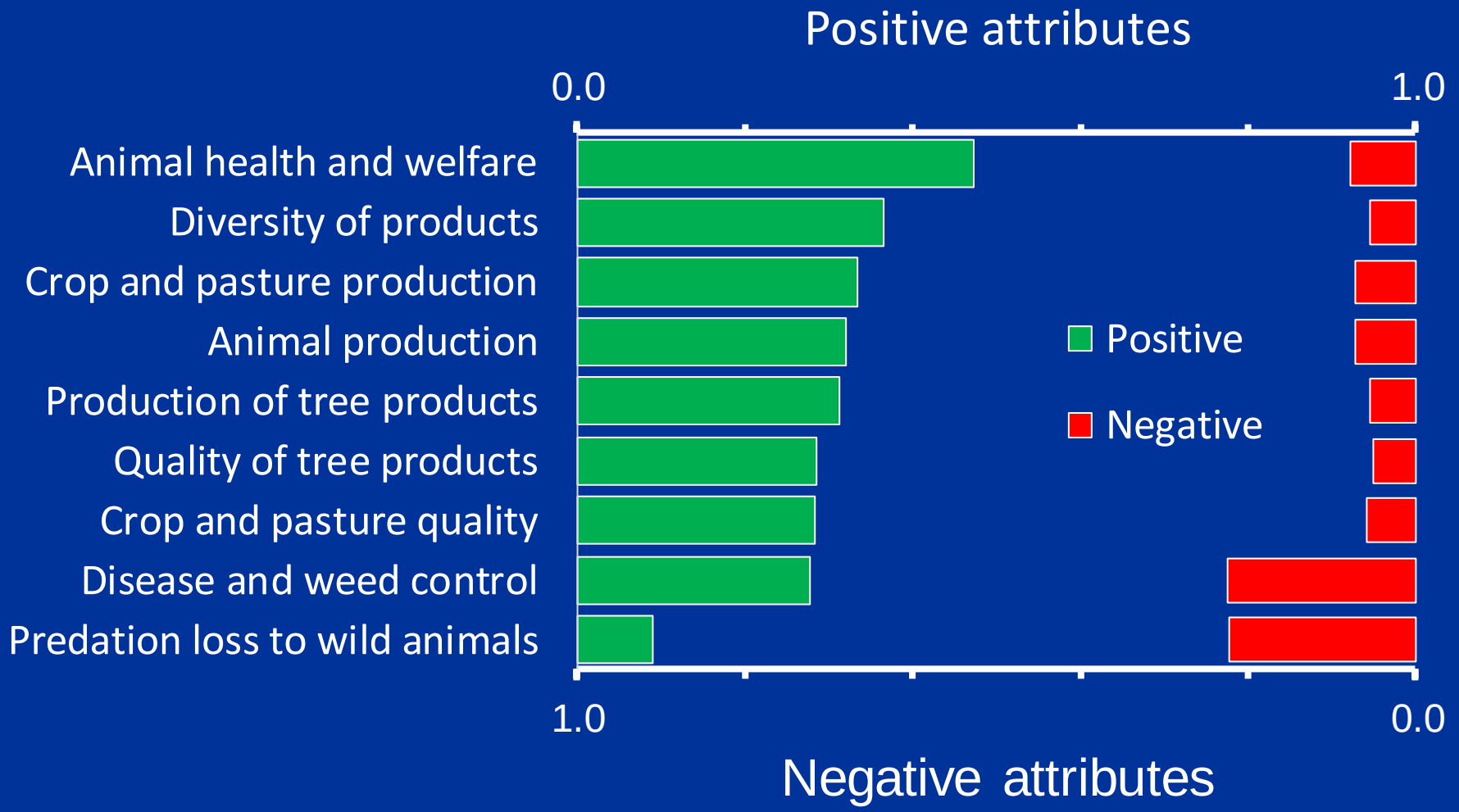
note: of some trees/shrubs, several analysis values are known. For completeness, all are mentioned

Choose one of the following selection criteria

Group/Genus:	Willow
Species:	----
Species (Latin):	----
Sorted on analysis value: (Descending)	----

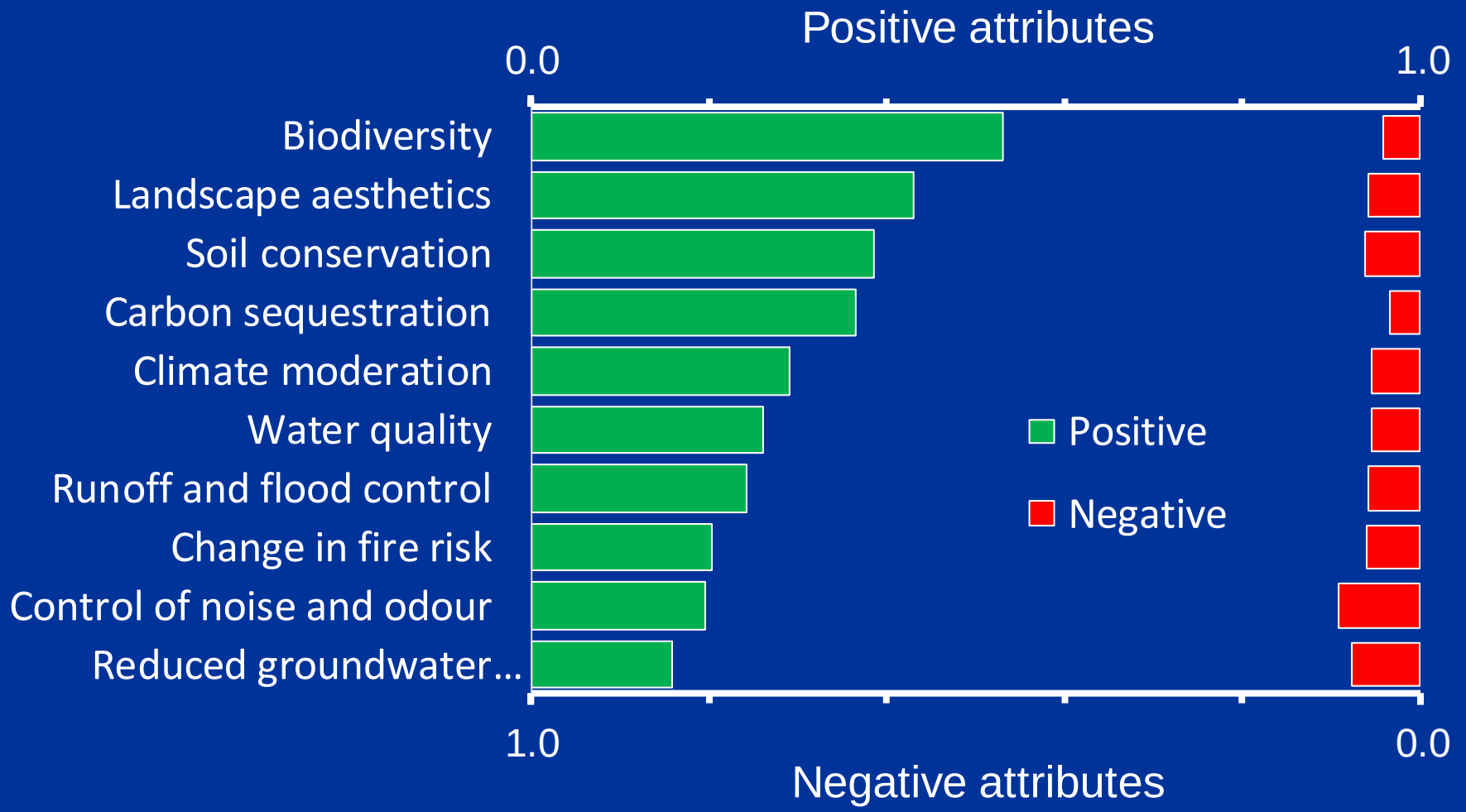
				General analysis					Specific analysis Hide								
Group	Species	Tree part	Moment of sampling	DM Dry Matter [%]	Crude Ash [%DM]	Crude protein [%DM]	Crude Fat [%DM]	Crude Fibre [%DM]	NDF neutral detergend fiber [%DM]	ADF acid detergent fibre [%DM]	Lignin [%DM]	Condensed Tannins [%DM]	OK [%DM]	NfE nitrogen-free extract [%DM]	Digestible Organic Matter [%]	Digestible Crude Protein [%]	Digestible Crude Fat [%]
Willow	Willow *Salix spec*	bark			8.0	5.0			36.0			9.0			66.0		
"	"	"			10.0	4.0			48.0			7.0			59.0		
Average analysis results bark Willow (*Salix spec*)																	
Willow	Willow *Salix spec*	bud	march	34.0													
Willow	Willow *Salix spec*	leaf	winter	55.0	10.0	9.0			34.0	21.0							
"	"	"	spring	54.0	7.0	12.0			33.0	22.0							
"	"	"			10.0	17.0	4.0	20.0						47.0		47.0	
"	"	"	april														
"	"	"	november			9.0		39.0	50.0	16.0	18.0						
"	"	"	october			16.0		14.0									
"	"	"	june	38.0	8.0	23.0		13.0							70.0		
"	"	"	june	25.0	6.0	21.0		13.0							54.0		

Agroforestry can create production benefits



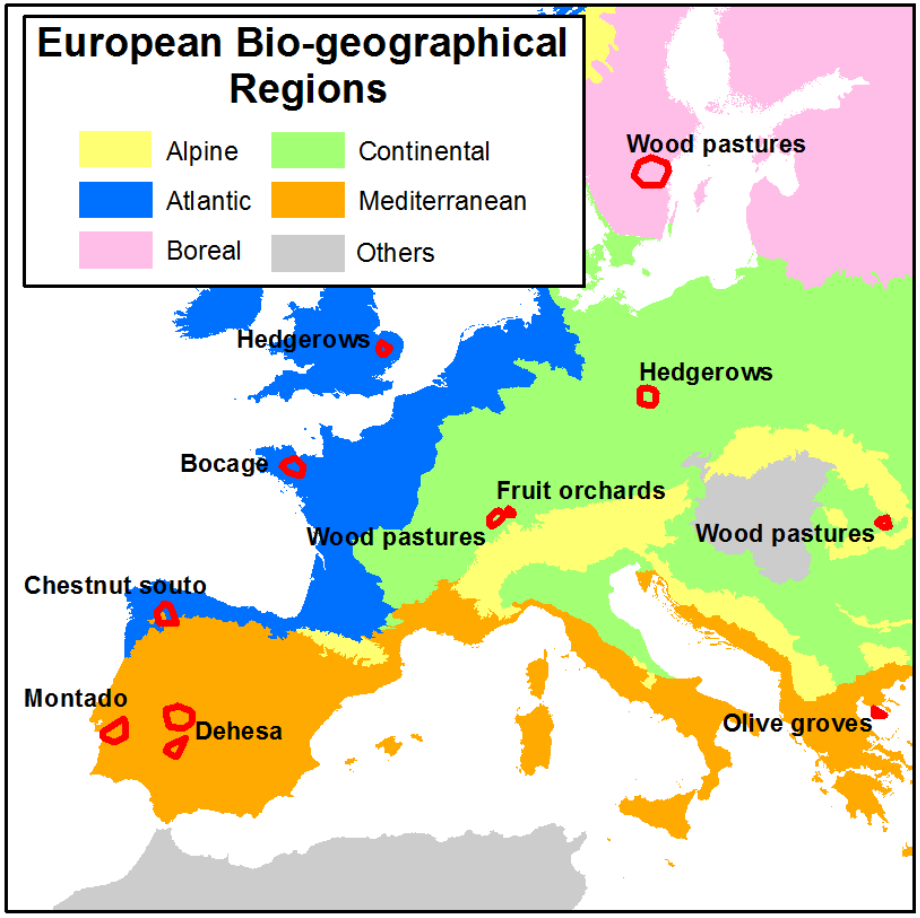
Analysis of 30 stakeholder groups and 344 stakeholders (Garcia de Jalon et al. 2017)

Agroforestry provides environmental benefits



Analysis of 30 stakeholder groups and 344 stakeholders (Garcia de Jalon et al. 2017)

Modelling ecosystem services for landscapes with and without agroforestry

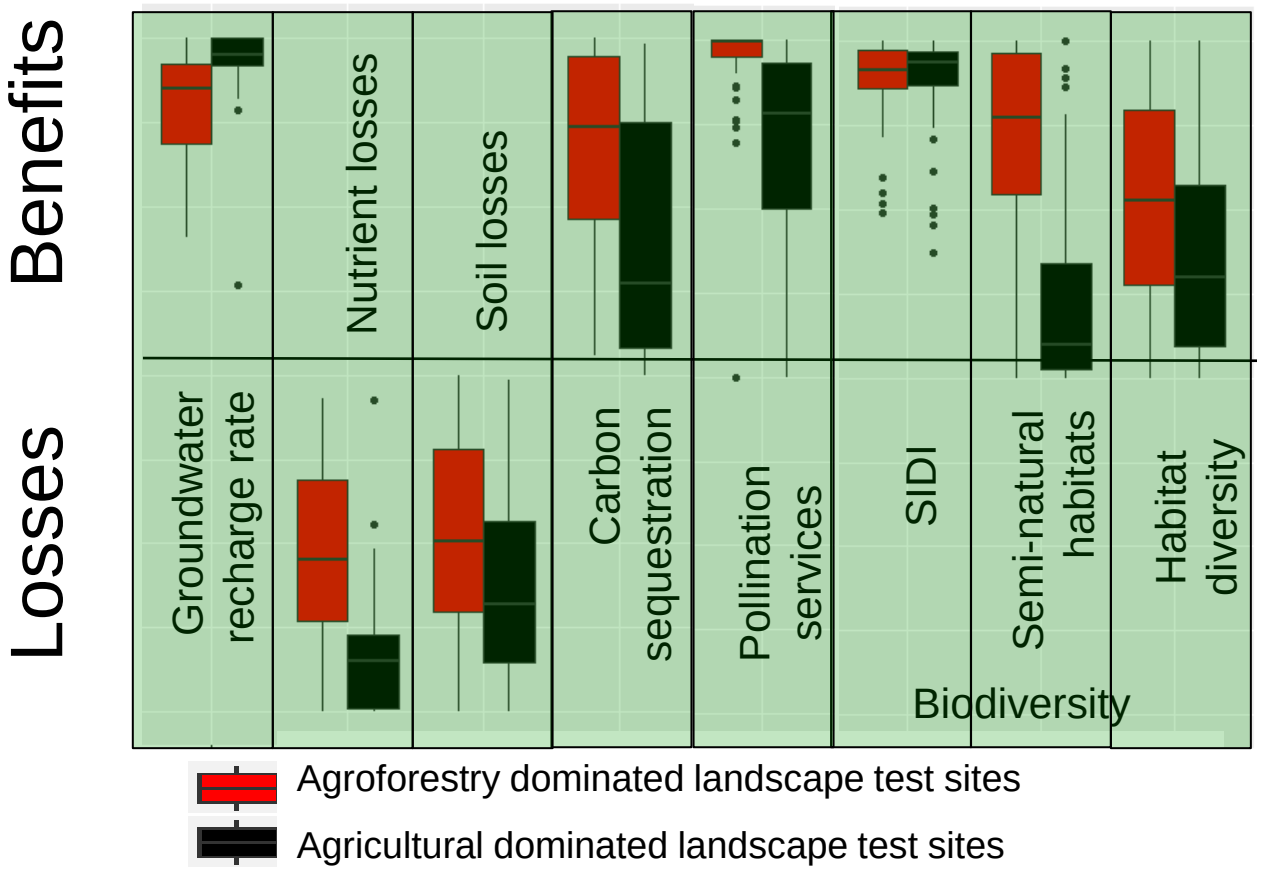


Ecosystem services modelled:

- Crop biomass yield
- Groundwater recharge rate
- Nutrient retention
- Soil conservation
- Carbon sequestration
- Biodiversity
  - Functional biodiversity (Pollination)
  - Habitat diversity

Kay et al. (2017) Agroforestry Systems

Comparison of agroforestry and agricultural landscapes across 12 sites



Agroforestry landscapes

Higher:

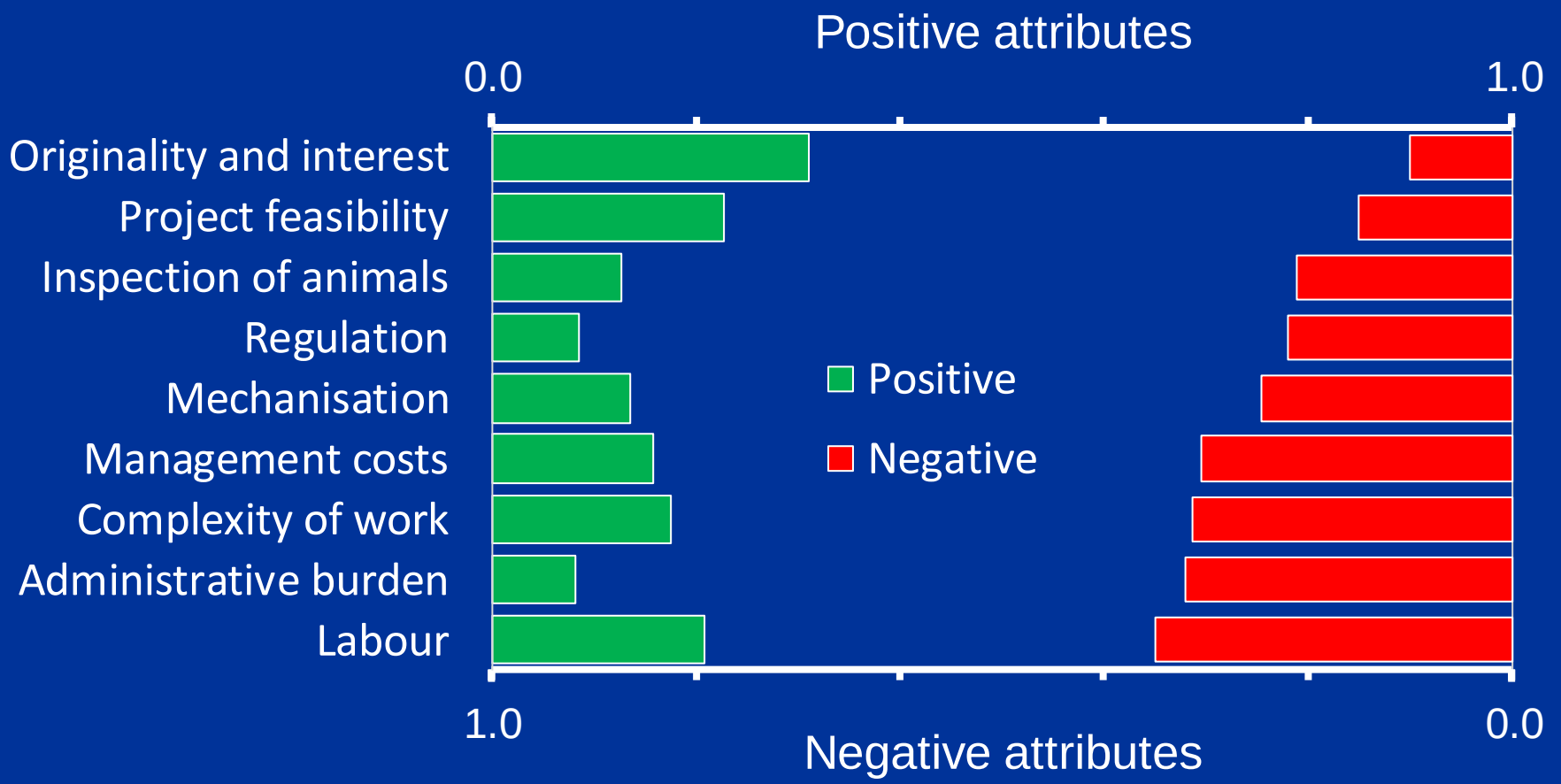
- Nutrient retention
- C sequestration
- Soil conservation
- Pollination services
- Proportions of semi-natural habitats

Lower:

- Groundwater recharge

Kay et al. (2017) Agroforestry Systems

Farmers indicate that agroforestry has labour and administrative costs



Analysis of 30 stakeholder groups and 344 stakeholders (Garcia de Jalon et al. 2017)

Agroforestry for livestock farmers

1. Is an important land use
2. Established animal welfare and seasonal grass production benefits
3. Interest in trees as fodder
4. Wider environmental benefits for society
5. Importance of manager's mind set: do you focus on the positive innovations or the costs?
6. Visit: www.agforward.eu

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