Synthesis of the Research and Development Protocols related to High Nature and Cultural Value Agroforestry

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Contents

1. Context.....2
2. Synopsis of research and development protocols.....2
3. Specific research areas.....5
4. Experimental protocols to test innovations.....6
5. Assessment of tree effects on understory productivity and soil carbon.....16
6. Final remarks.....17
7. Acknowledgement.....17
8. References.....17

Annex A. Location and physical characterization of the experimental sites.....19

Annex B. Set of observations planned to estimate indicators of ecosystem services.....22

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1. Context

The AGFORWARD research project (January 2014-December 2017), funded by the European Commission, is promoting agroforestry practices in Europe that will advance sustainable rural development. The project has four objectives:

1. to understand the context and extent of agroforestry in Europe,
2. to identify, develop and field-test innovations (through participatory research) to improve the benefits and viability of agroforestry systems in Europe,
3. to evaluate innovative agroforestry designs and practices at different spatial scales, and
4. to promote the wider adoption of appropriate agroforestry systems in Europe through policy development and dissemination.

This report contributes to the second objective where innovations are being field tested within four agroforestry sectors; this report from work-package 2 focuses on agroforestry of high nature and cultural value (HNCV). This Particpatory Research and Development Network (PRDN) was initiated by ten stakesholder meetings (Milestone 2) organised by ten partners (Table 1). Each group then identified the key innovations or improvements to be examined (Milestone 3; Moreno et al 2015). This report (Milestone 4) synthesises the research and development protocols including both individual activities and activities shared among partners. Full details of the individual protocols are available on the AGFORWARD website (Table 2, Table 3).

Table 1. Acronyms of partners used in this report

Acronym	Full name of partner
BTU	BTU Cottbus-Senftenberg, Germany
CNR- ISPAAM	Consiglio Nazionale delle Ricerche, Italy
CRAN	Cranfield University, UK
EFI+SLU	European Forest Institute and Sveriges Lantbruksuniveritet
INRA	Institut National de la Recherche Agronomique, France
ISA	Instituto Superior de Agronomia, University of Lisbon, Portugal
NYME	Nyugat-Magyarorszagi Egyetem Kooperacios Kutatasi Kozpont Nonprofit KFT, Hungary
TEI	TEI Stereas Elladas, Greece
UBB	University of Santiago de Compostela, Spain
UEX	Universidad de Extremadura, Spain

2. Synopsis of research and development protocols

Work-package 2 is focused on a range of high nature and cultural value agroforestry systems which retain important biodiversity and other nature and cultural values, even though they are often marginal in terms of farming (Table 2). Innovation is needed as the economic viability of most systems is threatened by agricultural modernization and globalization. In some cases traditional practices, such as tree conservation, shaping and harvesting are being abandoned; in other cases intensification of farming undermines the continued presence of trees.

The systems vary in terms of tree species, their spatial arrangement, management practices, marketable products and current economic and social interest (Table 1 and Annex A). The selected innovations or improvements also vary between groups. They include technical innovations (e.g. artificial thorny protectors, invisible fencing), systemic technical innovations (e.g. 3D adaptive design and management of hedgerows) and organizational innovations (e.g. participatory forest management plan participated by Sami community of Njaarke). This report outlines the innovations in terms of topic areas together with a shared protocol for the characterization of tree effects on pasture/crop understory yield and soil carbon in the ten study systems.

Table 2. List of the high nature and cultural value agroforestry systems studied in work-package 2 (mostly wood pastures), with indication of the respective partner

Country	Partner	System	Main Concerns
Portugal	ISA	Montado: grazed open oak woodlands	Possible negative consequences of shrub encroachment of cork oak woodlands for cork yield and quality
Spain	UEX	Dehesa: grazed and intercropped oak woodlands	Low profitability, marked seasonality of fodder resources and deficient tree regeneration
Italy	CNR-ISPAAM	Grazed oak woodlands in Sardinia	The lack of forage availability and quality
Greece	TEI	Grazed valonia oak woodlands	Oak regeneration and poor pasture understory yield/quality
Romania	UBB	Grazed wood pastures and grasslands with ancient non-productive trees in Transylvania	Conservation of veteran non-productive trees and of tree species diversity. Need of economically and socially viable strategies to increase tree regeneration
Hungary	NYME	Grazed wood pastures and grasslands with ancient non-productive trees	Infilling of abandoned wood-pastures, and lack of public awareness of their nature and cultural values
Germany	BTU	Flood plain meadows with tree hedgerows	Hedgerows abandonment Lack of interest of farmers for trees
France	INRA	Bocage agroforestry in Brittany (hedgerows integrated with grassland and arable land)	Decrease of hedgerow density and their reduced importance in farming management and ecological services
UK	CRAN	Wood pasture and Parkland	Re-instituting tree management, balancing the prevention of wood pasture infilling with sufficient natural regeneration
Sweden	EFI + SLU	Wood pastures and grazed forests devoted to reindeer husbandry	Adaptation of forest operations to reindeer husbandry

Table 3. List of the ten research and development protocols in work-package 2

Franca A, Seddaiu G, Porqueddu C (2015). Research and Development Protocol for Grazed Oak Woodland in Sardinia, Italy. EU FP7 research project: AGFORWARD 613520. 8 pp. http://www.agforward.eu/index.php/en/grazed-oak-woodlands-in-sardinia.html Hartel T, Popa R, Rákosy L (2015). Research and Development Protocol for Wood-pasture Systems in Southern Transylvania, Romania. EU FP7 research project: AGFORWARD 613520. 12 pp. http://www.agforward.eu/index.php/es/wood-pastures-in-southern-transylvania-romania.html Moreno G, Cáceres Y, Juárez E, Bertomeu M, Pulido F, Gaspar P, Mesías FJ, Escribano M, Bustos P (2015). Research and Development Protocol for Iberian Dehesas in Spain. EU FP7 research project: AGFORWARD 613520. 71 pp. http://www.agforward.eu/index.php/en/dehesa-farms-in-spain.html Papadopoulos A, Pantera A, Mantzanas K, Papanastasis V (2015). Research and Development Protocol for the Valonia Oak Silvopastoral System, Greece. EU FP7 research project: AGFORWARD 613520. 12 pp. http://www.agforward.eu/index.php/en/valonia-oak-silvopastoral-systems-in-greece.html Paulo JA, Pacheco Faias S, Tomé M, Palma JHN (2015). Research and Development Protocol for Cork Oak Woodland in Portugal. EU FP7 research project: AGFORWARD 613520. 10 pp. http://www.agforward.eu/index.php/es/montado-portugal.html Thenail C, Viaud V, AviRon S (2015). Research and Development Protocol for Bocage Agroforestry in France. EU FP7 research project: AGFORWARD 613520. 13 pp. http://www.agforward.eu/index.php/en/bocage-agroforestry-in-brittany-france.html Tsonkova P, Mirck J (2015). Research and Development Protocol for Agroforestry in the Spreewald Floodplain, Germany. EU FP7 Research Project: AGFORWARD 613520. 11 pp. http://www.agforward.eu/index.php/en/agroforestry-in-the-spreewald-flood-plain-germany.html Upson M, Burgess PJ (2015). Research and Development Protocol for Wood Pasture and Parkland in the UK. EU FP7 Research Project: AGFORWARD 613520. 9 pp. http://www.agforward.eu/index.php/en/wood-pasture-and-parkland-in-the-uk.html Valinger E, Lind T, Berg S (2015). Research and Development Protocol for Wood Pastures and Reindeer in Sweden. EU FP7 Research Project: AGFORWARD 613520. 9 pp. http://www.agforward.eu/index.php/en/wood-pastures-and-reindeer-in-sweden.html Vityi A, Varga A (2015). Research and Development Protocol for the Wood Pastures in Hungary. EU FP7 research project: AGFORWARD 613520. 10 pp. http://www.agforward.eu/index.php/en/wood-pasture-in-hungary.html

3. Specific research areas

The ten stakeholder groups will test selected technical innovations or innovative integrated management, either in replicated experiments with controls or as participatory development projects with stakeholders. The research protocols described in Section 4 are here grouped into four categories with the relevant partner indicated in brackets.

3.1. Management

Design and management wood pastures to reinforce their potential for livestock husbandry (EFI-SLU)
Renewing of abandoned hedgerows and infilled wood pastures (BTU, UBB, NYME)
Integrating grazing with the persistence of trees in wood pastures

- Cost-efficient methods for protection of young trees: nursery shrubs, artificial wire thorny shelters, natural protectors (pruned branches) (BTU, UBB, NYME, UEX)
- Fencing for temporal grazing exclusion (BTU, TEI)

The application of new technologies for livestock management: GPS herding and invisible fencing

- GPS tracking of reindeer herds grazing open woodlands (EFI)
- Develop a web-based platform to allow farmers to interrogate GPS data from cattle collars (CRAN)
- Perform a simple cost benefit analysis of the invisible fencing system (CRAN)
- Development a low-energy-consuming GPS-collar as invisible fencing (UEX)

3.2. Production

Wood biomass, cork and fruits

- Production of timber, firewood and mulch (ramial chipped wood) by hedgerows (INRA)
- Evaluation of economical value of harvested biomass (BTU)
- Evaluation of cork oak production (and quality) in fuction of understory management (ISA)
- Evalution of acorn production under climatic change scenario (UEX)
- Recovery of panage (consumption of acorns by pigs freely ranching) (NYME)

Evaluation of livestock sheltering by hedgerows (INRA)
Fodder autonomy (reducing the need of supplementary feeding)

- Forest clearance and diversification to increase forage resources (EFI)
- Search of shade-adapapted fooder crops (legume-rich pastures) (CNR, TEI and UEX)
- Search of shade-adapapted fooder crops (triticale) (UEX)

Assessment of effects of trees on pasture/crop understory production (All partners)

3.3. Environment

Develop and apply a management tool for assessing the impact of grazing (CRAN)
Effect of different livestock on the vegetation structure and biodiversity (UBB)
Holistic (intensive fast-rotational) grazing for pasture, tree and soil restoration (UEX)
Participative programs of protection of ancient trees (UBB, NYME)
Design of hedgerow-based systems to reinforce their provision of ecosystems services (INRA , BTU)
Ecosystem services associated with biodiversity, and with soil and water (INRA)
Soil carbon pools (All partners) and evaluation of carbon sink strength at ecosystem level (UEX)

3.4. Socio-economic issues

Evaluation of the areas of high cultural value for tourism (BTU)
Explore the consumer acceptance for agroforestry products and services (NYME, UEX)
Attitude of local communities towards ancient trees and agreements to allow their persistence (UBB)

4. Experimental protocols to test innovations

In this section, the experimental protocols reported by partners are grouped by topics and summarized. Most of the studies refer to field experiments where innovations and/or management practices are tested (described below as 'Experimental layout + measurements'), but socio-economic studies are also included (described below as 'Study framework'). Modeling where planned as a further exercise that follows field measurements is also indicated.

4.1. Tree products

Different tree products will be studied in five study cases: cork oak in Portuguese montados, acorns in Spanish dehesas and Hungarian wood pastures, wood biomass in Spreewald hedgerows (Germany) and timber, firewood and ramial chipped wood in bocage (Britany, France).

4.1.1. *Cork oak production*

Innovations to be tested: control of shrub understory and sown lupins to improve cork production.
Central hypothesis: control of shrub understory improve cork production and quality.
Study site: montado located in Central Portugal (ISA).
Experimental layout: this work, inititated in 2002 in a private cork oak montado in Portugal, runs with two treatments replicated in two blocks (a total of 4 plots of 2 ha each). The treatments are i) no understorey removal and ii) periodical removal (every 3 years) of the understory.
Mesurements: tree and cork growth and quality every nine years.
Modeling excercise: Yield-SAFE biophysical model (Palma et al. 2014) will be used to assess if the cork grown is good enough to justify the cost of the understory removal and the sowing of lupins. To model the system, the model needs to be adapted to estimate cork allocation in the tree and/or the biomass of the extracted cork when debarking operations take place.

4.1.2. *Acorn production and utilization*

Study site 1: Majadas town dehesa, Spain (UEX)
Issue studied: evaluation of acorn production under different climatic scenarios.
Central hypothesis: increased intensity and length of drought periods negatively affect the acorn production of dehesa trees.
Experimental layout: litter traps hanging of 18 trees, randomly selected , have been used to collect acorn for 10 years. Each trees has six traps. The site is equiped with a automatic weather station.
Mesurements: acorns are collected, classified (aborted and mature), counted and weighed every autumn. Climatic variables (temperature, rainfall, wind, radiation) are registered continuously.
Modeling excercise: Yield-SAFE will be adapted to estimate acorn production as response to climatic conditions of the year.

Study site 2: Pénzesgyőr and Bogyiszló wood pastures and other wood pastures in Hungary
Innovations to be tested: recovering the pannage practice (NYME).
Central hypothesis: extensive pigs could benefit of feeding with acorns in wood pastures.
Study framework: interviews with farmers and herders at Pénzesgyőr and Bogyiszló wood pasture farms. Online questionnaire for mangalica (extensive pig) keeper about the pannage management.

4.1.3. ***Wood biomass***

Study site: Spreewald floodplain in Germany (BTU)

Issue studied: the use of excess of wood biomass produced by hedgerows to fund their maintenance.

Central hypothesis: the increasing price of biomass energy could reactivate the conservation and management plans of hedgerows.

Experimental layout: thinning of hedgerows density is too high or they are excessively width (> 15 m).

Measurement: a cost-benefit analysis of the harvested biomass will be performed.

Study site: Les Ecoupées Farm (La Motte) and Coacovec Farms (Saint-Barnabé), Bocage in Britany, France (INRA)

Issue studied: design and planting of new hedgerows as source of wood resources.

Central hypothesis: hedgerows can provide commercially valuable timber, firewood and mulch.

Experimental layout: Study carried out in two farms with hedgerows planted recently (2005 and 1999-2000) and surrounding farms with old hedgerows. Comparison aims to discern the provision of wood products (together with other ecosystems services reported in 4.3.1).

Measurement: detailed survey to farmers of management practices and harvests at the hedgerow and field scale.

4.2. **Tree regeneration**

Different techniques to facilitate the natural and artificial regeneration of trees in wood pastures and hedgerow-based systems are being studied, including young tree protectors, nursery plants, chemical repellents and grazing exclusion, with field tests in four study cases (Spain, Romania, Hungary and Greece).

4.2.1. ***Young tree protection***

Innovations to be tested: low-cost methods of tree regeneration in wood pastures, based on oak seedling protection and on acorn sowing.

Central hypothesis: propensity of farmers to restore trees without subsidies increases when costs are reduced.

Measurements: plant survival and size and evidence of shelter deterioration.

Study site 1: Five Spanish dehesa farms (La Parra, Monteviejo, Atoquedo, Valdesequera, Dehesilla) (UEX).

Experimental layout (site 1): use of a diverse array of techniques using natural materials and/or mimicking natural processes by which plant survival is increased. They include seedling shelters (natural shelter made with dead branches, thorny wire shelter and nursery shrubs) and acorns treated with natural repellents againts vertebrate predators. In all cases the reference control is the conventional seedling shelters, combining Tubex and wire shelters (ca. 30 € / unit). Thorny wire shelter is tested in four farms with and without Tubex shelter and with and without antigrass mesh. Natural shelter is tested in three farms. As nursery shrubs, *Retama spaherocarpa*, *Cistus ladanifer* and *lavandula stoechas* are studied in two farms planting seedlings and sowing acorns with and without chemical repellent in three positions: beneath the shrub plant, in open interspaces between shrubs, and in open pastures.

Study site 2: Rupea wood pastures, Transylvania, Romania. (UBB)

Study framework (site 2): the work includes the clearance of shrubs and young hornbeam and use of cleared shrubs for fencing oak saplings, but also the conservation of thorny shubs in the wood pastures to facilitate natural oak regeneration while grazing management is maintained. The study includes one wood-pasture grazed by sheep (and/or goats) and other traditionally grazed by cattle and/or buffalo. Lessons will be the base for a socailly agreed and participated program of tree regeneration at local wood pastures

Study site 3: Bogyiszló wood pastues, Hungary (NYME)

Experimental layout (site 3): testing at field different protection practices (nursery shrubs vs artificial thorny protectors). Interview with herders on local knowledge.

4.2.2. ***Grazing exclusion***

Innovations to be tested: the combination of grazing exclusion and nursery shrub species to facilitate tree natural regeneration on grazed oak woodlands.

Central hypothesis: livestock grazing and trampling hamper natural tree regeneration.

Study site: Xeromero forest -Aitoloakarnania Prefecture (Greece) (TEI).

Experimental layout: two microhabitats (beneath vs out of the canopy) x two grazing levels (grazed vs fenced) x two shrub understory (intact shrubs vs cleared shrubs) x 12 replicated random blocks.

Measurements: number of acorns; seedling emerged (end spring); seedling survival (seedlings alive in successive autumns); shrub species and cover.

4.3. **Trees/hedgerows management**

This section includes protocols for new adaptive designs and management of wood pastures and hedgerows to optimize the grazing potential and provision of ecosystem services, for the renewing of abandoned hedgerows and wood pastures, and for the protection of ancient non-productive trees. Studies are conducted in five countries: France, Sweden, Hungary, Romania and Germany.

4.3.1. ***Adaptive design and management of hedgerows***

Innovations to be tested: 3D adaptive design and management of hedgerows (examined in an integrative way including the establishment sequence, the shaping and maintenance, the type of ground and vegetation structure, the mixing of species and of trees of high and medium stems, the number of lines, and the connections between hedgerows) to reinforce ecosystem services at plot, farm and landscape scales.

Central hypothesis: hedgerows design, management and degree of integration with field management determine significantly support, regulating and provisioning ecosystem and cultural services.

Study site: Les Ecoupées Farm (La Motte) and Coacovec Farms (Saint-Barnabé), France (INRA)

Experimental layout: Study carried out in two farms with hedgerows planted recently (2005 and 1999-2000), similar in climate, physiography, soil and farming system, and surrounding farms with old hedgerows. Comparison aims to discern what ecosystem services change with the aging of trees and of the overall hedgerows ground and vegetation structure.

Measurements: The study is based on the evaluation of a set of indicators of key ecosystems services related to biodiversity (flora and ground beetles, not specialized butterflies as pollinators, weed flora and ground beetles and spiders as indicators of natural control of pests), related to soil/water quality (C and NO_3^- soil content) and related to provisioning of goods (livestock sheltering, crops and grass production, timber, firewood and ramial chipped wood). To measure/estimate these indicators 5 levels of measurements will be conducted at filed, farm and landscape scales: i) transect of observation plots from hedgerows perpendicular to slope, toward the center of fields; ii) succession of observation plots in and alongside hedgerows; iii) further description of hedgerows ground and vegetation structure; iv) mapping of the landscape structure and topography; v) detailed survey to farmers of management practices and harvests at the hedgerow and field scale. Annex B summarizes the indicators derived from each type of the measurement.

4.3.2. ***Forest thinning and diversification to promote grazing***

Innovations to be tested: new forest management schemes to facilitate reindeer husbandry.

Central hypothesis: the sustainability of the traditional reindeer husbandry in open woodland deserves adaptation of current forest management.

Study site: Njaarke Same Village, Sweden (EFI-SLU)

Experimental layout: the design involves one reference case (current forest management practices) and an innovative scenario that adapts forest management to promote better conditions for reindeer husbandry. Adaptation includes less soil scarification, no planting with Lodgepole Pine, more and harder pre-commercial thinning, and forests with longer rotation periods in some areas.

Measurements: i) forest conditions (stem diameter, growth and age distribution), ii) forest operation data (e.g., thinning, wood market), and iii) reindeer production chain (stocking rate, seasonal movement, animal slaughtered and losses).

Modeling exercise: to compare the outcomes of different scenarios the software Heureka RegWise, a forestry decision support system will be used (http://www.slu.se/sha). RegWise simulates the forest development and output of goods (e.g. timber, biofuel) and services (carbon sequestration, recreation, habitat) in periods of 5 years from 2015 to 2035. The results for each scenario will be an input to the Tool for Sustainability Impact Assessment (ToSIA) (Lindner et al. 2012). Calculations allow to assess economic (gross value addes, prodcution costs), social (full time employment, fata accidents) and environemantal (greenhouse gases) indicators.

4.3.3. ***Wood pastures rejuvenation***

Issue studied: renewing encroach-abandoned wood pastures.

Central hypothesis: encroached or abandoned wood pastures can easily be reverted to their original silvopastoral use.

Study site: Pénzesgyőr wood pasture in Hungary (NYME)

Study framework: vegetation survey, landscape history, interview with local farmers and herders, and interviews at the local food market. From here, the following questions are addressed: i) what are the best practices and steps to renew an abandoned and infilled wood pasture? ii) how does it influence the management of the vegetation in a wood pasture?, and iii) why is it worthwhile to renew or establish a wood pasture (e.g. products, goods and other values)?

4.3.4. ***Hedgerow rejuvenation***

Issue studied: best and cost-efficient method for hedgerows rejuvenation that include both harvesting the excess of biomass and protection or regeneration (natural or planted).

Central hypothesis: hedgerows have important ecological and aesthetic values, which are only guaranteed through their periodical rejuvenation.

Study site: Spreewald floodplain in Germany (BTU)

Experimental layout: the following treatments will be tested in two experimental plots: i) tree harvesting to reduce hedgerow width or density and subsequently left for natural regeneration; ii) same as i) plus regeneration protected with fences; iii) gaps and/or harvested single trees filled/replaced with combination of long lived trees, fast growing trees and shrubs; iv) same as iii) plus planted trees protected with fences, and v) unmanaged hedgerows. The study will include also the search of cost-effective fencing for planted trees and natural regeneration, including the use of dead/cut branches.

Measurement: i) vegetation (dead and alive) inventory; (ii) hedge structure; iii) cattle damage to hedges (by photograpic record); iv) cost and revenue of harvesting, and v) cost of fencing material, including labour. The social and ecosystem services provided by the hedge structure such as wind reduction, wildlife habitat, and areas of high cultural value for tourism will be disucussed with stakeholders.

4.3.5. ***Conservation of veteran non-productive trees***

Innovations to be tested: attitude of local communities towards ancient trees

Central hypothesis/idea: local people still has multiple reasons to conserve ancient trees

Study site: Rupea wood pastures, Transylvania, Romania (UBB)

Experimental layout: semi-structured interviews in up to six villages with ancient trees on wood-pastures.

Measurements: i) cultural, aesthetic, economic values perceived by local people, ii) extent at which people tolerate the ancient trees, iii) perception of locals about the origins of the ancient trees on pastures, iv) perception of locals about the main threats to the ancient trees, and v) perception of locals about ways and possibilities to protect the ancient trees.

Study site: Bogyiszló wood pasture in Hungary (NYME)

Study framework: participatory methods, collaboration with the local school, interviews with different age groups of the local people. Establish a model project for local school. From here, the following questions are addressed: i) what does the local community know about the ancient trees of the closest wood pasture? ii) what are the values of the ancient trees for the local community?, and iii) what are the best methods to improve their awareness of the ancient trees on wood pastures?

4.4. **Pasture understory products**

Three Mediterranean case studies (Spain, Italy and Greece) will focus on the search of new pasture resources to reduce the increasing dependence of commercial fodder resources. Studies search forage sources reach in protein (legumes and triticale) to characterize their attitude to grow and persist under tree shade and grazing pressure.

4.4.1. ***Legume-rich pastures: selection of varieties best adapted to tree shade***

Innovations to be tested: to identify pastures rich in legumes adapted to oak shade and grazing pressure.

Central hypothesis: forage legume species respond distinctively to tree shade.

Study sites: Italy (Sardinia, CNR-ISPAAM), Spain (Casablanca and Ahigaleja dehesa farms, UEX) and Greece (Kea island, TEI).

Experimental layout: three pasture types (natural pasture, pasture oversown with Fertiprado mixture, pasture oversown with ISPAAM mixture; Table 4) x two microhabitats (beneath and beyond tree canopy). The number of replicated blocks and plot size varied among study sites (Table 5). Additonally in a second spanish dehesa farm (La Higaleja), eight different forage combinations were compared (one 0.5 ha plot per combination), with different richness of legume species (Table 6).

Measurements (2-3 consecutive years): persistence and productivity of different pasture legume species (soil seed bank, cover and biomass of different legume species). Build-up of soil organic matter and nitrogen (labile Soil organic matter and mineral N at the beginning of fast growing season).

Table 4. Description of the two seed mixtures rich in forage legumes

Seed mixture name	Composition
ISPAAM (native species)	40% *Trifolium subterraneum* cv Campeda, 40% *Medicago polymorpha* cv Anglona, 10 % *Lolium rigidum* cv Nurra
Fertiprado (commercial mixture)	60.6% *Trifolium subterraneum*, 4.5% *T. michelianum* var balansae, 3%*T. vesiculosum*, 3% *T. resupinatum*, 6.1% *T. incarnatum*. 1.5% *T. istmocarpus*, 1.5% *T. glanduliferum*, and 19.7% *Ornithopus sativus*. For *T subterraneum*, the subspecies include brachycalycinum (6.1%) and yaninnicum (3%), and early maturing (13.6%), mid-season (19.7%) and late-maturing (18.2%) cultivars.

Both mixtures were sown at a density of 20 kg seed/ha, buried around 0.5-1.0 cm.

Table 5. Details of plot size and replications used in the three countries where FERTIPRADO and ISPAAM legume seed mixtures are tested

Parameter	CNR, Italy	TEI, Greece	UEX, Spain
Plot size	5 x 3 m	1 x 1 m	4 x4 m
Number of blocks	3	5	4
Tree species	Quercus suber	*Quercus ithaburensis* ssp *macrolepis*	*Quercus ilex*
Fertilization	200 kg ha^{-1} diammonium phosphate		144 kg ha^{-1} monopotassium phosphate 52-34

Table 6. Description of eight forage seed mixtures tested in the dehesa farm “La Higaleja” (Spain)

Number	Description
T0	Native pasture
T1	Native pasture with phosphoric fertilization
T2	Simplified mixture of pasture legume seeds (15 kg ha^{-1} *Trifolium subterraneum* + 3 kg ha^{-1} *Ornithpus sativus* + 2 kg ha^{-1}*T. michilianum*)
T3	T2 + Ryegrass (10 kg ha^{-1})
T4	T2 + Triticale (50 kg ha^{-1})
T6	Mixture of short duration pasture legume species (8 kg ha^{-1} *Trifolium subterraneum* + 5 kg ha^{-1} *Ornithopus sativus* + 3 kg ha^{-1} *T. granduliferum* + 2 kg ha^{-1} *T. michilianum* + 2 kg ha^{-1} *T. vesiculosum*).
T7	Mixture FERTIPRADO I for permanent pastures (*Trifolium subterraneum* + *T. michilianum* + *T. vesiculosum* + *T. resupinatum* + *T. incarnatum* + *T. repens* + *O. sativus* + T. *isthmocarpum* + *Lolium multiflorum* + *Lolium perenne* + *Dactylis glomerata*).
T8	Mixture FERTIPRADO II for short duration pastures (*Trifolium suaveolens* + *T. michilianum* + *T. vesiculosum* +*Lolium multiflorum*).

4.4.2. *Legume-rich pastures: evaluation of long-term persistence*

Innovations to be tested: to identify pastures rich in legumes adapted to oak shading conditions that persist under Mediterranean conditions and grazing pressure.

Central hypothesis: long persistence of forage legume species is hampered by summer drought and grazing pressure, what could be modulated by tree shade.

Study site: the Spanish dehesa farms (Atoquedo, Las Casillas, La Cabra) (UEX)

Experimental layout: the study is based on the study of chronosequences of pastures rich in legumes sown in different years with the FERTIPRADO mixtures of legume seeds (Table 6). The trial follows a simple design with only one plot per age and farm. 12 wire exclusion cages (60 x 60 x 60 cm) are installed, one half beneath tree canopy and the other half beyond the canopy projection (> 20 m distance).

Measurements: pasture biomass is measured in exclusion cages (n=6 per plot and microhabitat). In the same locations, soil samples will be taken to detemine mineral-N availability and soil carbon (labile and non-labile fractions).

4.4.3. ***High productive fodder crop: Selection of shade-adapted Triticale of double use***

Innovations to be tested: the use of triticale as fooder crop under tree cover

Central hypothesis: Triticale varieties respond distinctively to tree shade.

Study site: three Spanish dehesa (Varales, Los Llanos and Atoquedo farms) (UEX)

Experimental layout: on each dehesa, an experimental area of ~ 5 ha is divided in three plots sowing a Triticale cultivar in each plot (Fronteira , Verato and Montijano). Within each plot, four homogeneous holm oak adult trees are selected for further sampling campaings. The crop is grazed at approximately January-February (growth stage (GS) 31 of the Zadocks scale) and mowed by early June.

Measurements: soil samples for the determination of mineral N and extractable P and K just before sowing (October) and during the fast-growing season (April). Crop yield (biomass and grains) before the two grazing/mowing periods (January and June). In herbage samples the crude protein, neutral detergent fibre, acid detergent fibre and acid detergent lignin will be determined. Samples are taken beneath tree canopy and out of the influence of tree canopy (> 20 m distance to nearest tree).

4.5. **Pasture management/conservation**

The effect of livestock and grazing scheme on pasture and soil quality will be tested in four case studies (Romania, Hungary, UK and Spain).

4.5.1. ***Assessing the effect of different livestock type on vegetation structure and biodiversity***

Study site 1: Rupea wood pastures, Transylvania, Romania (UBB)

Innovations to be tested: substitution of sheep by local cattle and buffalo

Central hypothesis: local pastures are better conserved when grazed with both local cattle and buffalo.

Experimental layout: comparison of the effects of sheep (and/or goats) and cattle and/or buffalo on the vegetation structure and biodiversity of grazed wood pastures.

Measurements: i) structural heterogeneity of the pasture (i.e. scrub, tree cover in the study plots), ii) number of plant species, with mention to threatened species, iii) richness of plant functional groups, iv) biomass production across a year, v) vegetation cover in different seasons. The study include also the social aspect exploring the rationale behind selecting sheep or cattle for grazing (e.g. economic incentives, market possibilities, personal preferences, potential conflicts).

Study site 2: Pénzesgyőr and Bogyiszló wood pasture farms, Hungary (NYME)

Innovations to be tested: application of local knowledge to improve grazing practice in wood pastures

Central hypothesis: local and traditional knowledge will help to the better conservation of wood pastures.

Study framework: vegetation survey, landscape history, interviews with local farmer and herders.

4.5.2. ***Assessing the impact of grazing***

Innovations to be tested: development and apply a management tool for assessing the impact of grazing.

Central hypothesis: cattle exert an uneven grazing pressure and impact in (spatially heterogeneous) wood pastures

Study site: Epping Forest and Knepp Castle Estate, UK (CRAN).

Experimental layout: the existing Grazing Impact Assessments (GIAs) will be reviewed to produce and apply a more specific assessment to wood pasture and parkland systems. GPS data recorded in 2014 at the two study sites will be used to identify and comapre areas that received different grazing pressure.

Measurements: this comparison will include the measure of a set of indicators such as i) sward height, diversity, and structure; ii) positive and negative (e.g. thistles, bracken, ragwort) indicator species; iii) quantity and distribution of scrub, iv) presence of bare ground; and v) recruitment of new trees.

4.5.3. ***Fast-intensive rotational grazing (FIRG)***

Innovations to be tested: to assess the adaptability of FIRG management to the strong seasonality of Spanish dehesas

Central hypothesis: FIGR will not only increases productivity but also implies ecosystem improvements: improving soil properties (soil structure, amount of organic matter, water efficiency, and availability soil nutrients), pasture species cover and composition, and tree regeneration.

Study site: the Spanish dehesa farm Los Llanos (UEX).

Experimental layout: a factorial experimental project has been designed (4 treatments x 2 sites). Four different managements (fast-intensive rotational grazing (FIRG), continuous grazing, sown pasture rich in legumes, and phosphate fertilization) will be implemented in two different sites (plots of 1 ha each). The FIRG approach will be developed through high animal density in a short grazing time period and an adequate pasture rest.

Measurements: two set of indicators will be measured after two years of the implementation of the different treatments. Soil indicators: compaction, water infiltration rate, mineral N and available P, soil organic matter, bulk density, and soil respiration. Vegetation indicators: productivity, functional diversity, vegetation cover, and tree recovery. Measurements will be compared in all cases in two positions, beneath tree canopy and out of the influence of the trees.

4.6. **Livestock management for trees and/or pasture conservation**

Invisible fencing and GPS tracking are two new technological facilities that could be applied to the management of livestock grazing in wood pastures. However, the high cost still hampers their general use by farmers. This section proposes different advances that aim to increase the utility of these facilities and/or to reduce the cost. Studies are carried out in UK, Sweden and Spain.

4.6.1. ***Invisible fencing***

Study site: Epping Forest and Knepp Castle Estate, UK (CRAN)

Innovations to be tested: a simple cost benefit analysis of the invisible fencing system.

Central hypothesis: invisible fencing is a very practical facility to manage herds to more efficient use of forage resources and protect areas devoted to tree regeneration and/or pasture restauration.

Study framework: invisible fencing' systems work by emitting cues (audible or electrical) to deter an animal from crossing a pre-defined boundary (Anderson 2007). The boundaries are typically defined by wires (located above or belowground) which generate an radio signal which is received by an electrical device located on the animal (typically on a collar). The cost of the invisible fencing will be compared with traditional enclosures to quantify how much the cost would need to fall to be more a more attractive prospect to farmers. This analysis will be weighed with an assessment of the effectiveness of the invisible fencing, and the risk of cattle breaching the enclosures.

Study site: Spanish dehesas (UEX)

Innovations to be tested: new advanced livestock wearable devices and collars that will extend the virtual fencing paradigm with new, high-value uses, such as the prevention of contagious diseases from wildlife to livestock and the protection of scattered saplings in semi-natural rangelands facing environmental and economic threats.

Central hypothesis: information and communication (Global System for Mobile Communications (GSM) and General Packet Radio Service (GPRS)) technologies can provide a reliable assistance to this complex situation by helping to improve the efficient use of the available natural resources and reducing the risks of further degradation.

Study framework: the work program is based on consecutive steps that contemplate alternative solutions: i) selection of valid technology for embedded computation, communications, energy, GPS, discharge generation and GSM/GPRS; ii) testing current intensity and discharge frequency with remote controlled dog collars in controlled environments; iii) test of GPRS/GSM and intra-herd transmission reliability and reach in laboratory conditions; iv) test of energy consumption in laboratory conditions: v) test of energy consumption with GPRS/GSM transmission with a selected animal in controlled conditions; vi) test of energy consumption with intra-herd transmission with selected animals in controlled conditions; vii) test of intra-herd communications through the router-collar getaway with selected animals in controlled conditions, and viii) experiments in open field for increasing periods of time. At this point of the development process most of the technology should be validated. Longer term experiments will show additional aspects to be corrected to approach a pre-industrial prototype.

4.6.2. ***GPS tracking***

Study site: Epping Forest (and possibly also Essex County Council), UK (CRAN)

Innovations to be tested: development a web-based platform to interrogate GPS data

Central hypothesis: GPS data produced by cattle collars is a powerful source of information to adopt best grazing strategies

Study framework: development a web-based platform to allow farmers to interrogate GPS data from cattle collars. By using GPS collars, thousands of records of cattle movements are produced, which are of value to analyze the behavior of animals in interaction with plant communities, weather, invisible fencing. To interrogate GPS data and produce valuable information for managers, a GPS data platform will be produced using the R package 'shiny' (RStudio Inc. 2014) and 'ggmap' (Kahle & Wickham 2013).

Study site: open forest gazed with reindeers, Sweden (EFI-SLU)

Innovations to be tested: the use pf GPS based devices for reindeer movements
Central hypothesis: GPS devises will facilitate the use of fodder resources and safety of reindeer herds.
Study framework: reindeer herds grazing in different scenarios described in 4.3.2 will be managed through the use of GPS collars to decide when and where to move the herds.

4.7. **Branding HNCV agroforestry products**

Two partners, NYME in Hungary and UEX in Spain, will conduct specific studies to explore the consumer interest for new or underused products of agroforestry systems of HNCV, and their willingness to pay an extra-price for the quality of the products and the ecosystem services provided by these systems.

Innovations to be tested: i) to identify products and services, new demands and emerging products, ii) to assess the willingness to pay a premium price for different products and services, and iii) to identify mechanisms to promote efficient marketing of high value products and ecosystem services.
Central hypothesis: products coming from agroforestry systems of high nature an cultural value can be sold with an extra-price.

Study site 1: Pénzesgyőr and Bogyiszló wood pasture farms and whole country level, Hungary (NYME)
Study framework: interview with farmers, producers and consumer at local food market and festival, online questionnaire, and a database of the products. From here the following questions are addressed i) what kind of products are related to HNCV agroforestry in Hungary?, ii) where could customer buy HNCV agroforestry products in Hungary?, (iii) why are customers not buying HNCV agroforestry products?, and iv) what are the best branding and marketing methods to improve customer awareness?

Study site 2: Spanish deheas (UEX)
Study framework: collection of primary data through focus groups, interviews and in-depth surveys. The process will be organized with different types of stakeholders according to the methodology selected. New agroforestry derived products and services will be identified through focus groups (~ 40 participants), a qualitative research technique suitable for the initial stages of an exploratory research. Projective techniques (questionnaire to 150-200 citizens of different areas of the dehesa territory) will be used to determine the degree of knowledge, perception of new products, attributes identification and association with agroforestry. Choice experiments (on-line survey with inclusion of several options of the same product carrying different attributes, with the subject selecting the option which better reflects his preferences) will be used to estimate willingness to pay and the importance of each of the attributes identified by consumers. New marketing channels will be evaluated through a Delphi study with an Expert Panel Selection from different backgrounds (20-30 stakeholders linked to product marketing and valuation of ecosystem services).

5. Assessment of tree effects on understory productivity and soil carbon

Apart of the study of innovations identified, the role of trees on pasture understory production and on soil carbon accumulation will be studied in the ten study cases[1].

Common (low-time and low-resources consuming) protocols are followed for a quick assessment of these parameters, using the same sampling points for both parameters. To facilitate the field work, the characterization of both parameters, soil and pasture, will follow the same sampling design (location of samples and sampling date). Samples will be taken beneath canopy (x /2) and out of the canopy (3 x), being x the tree canopy radius. The sampling should include a minimum of six trees (six pairs of sampling points). Where several tree species are present, the sampling could be extended to the three more representative species, with six paired sampling points per species. If the study include control reference plots, either forest and/or open pasture controls, a minimum of six randomly selected points per control would be included in the sampling design.

At each sampling point, pasture will be harvested at ground level in a quadrat of 50 cm x 50 cm at the period of maximum pasture biomass (end of spring in Mediterranean countries and by mid-summer in other countries). Immediately after, in the middle of the quadrats, a soil core 30 cm depth will be taken. Soil core will be divided in three sections, 0-10, 10-20 and 20-30 cm. Both pasture and soil samples could be dried at ambient temperature for some days, but then need to be oven-dried (105°C for 24 h) before weighting. Both labile and non-labile organic will be measured by dry combustion[2]. Labile fraction will be determine by difference between total and non-labile organic carbon, being the latter determined in sample treated previously with 333 mM potassium permanganate (Blair et al. 1995).

Additionally, data of three Eddy covariance stations of the international network FLUXNET located in the dehesa farm of Majadas are available for model exercises and calibration of yieldSAFE and/or HiSAFE models. These stations register continuously the fluxes of CO_2 and water vapour exchanged in around 25 ha of wood pastures for each of stations. One of the tower is operating since 2003 and the other two towers together with an additional tower placed a 1.5 m height records gases exchange for pasture layer started in 2014. Other data recorded are soil temperature and moisture, tree and pasture evapotrasnpiration, stem tree growth, acorn production, tree and pasture phenology, tree leaf production, tree LAI, nutrient content in tree leaves and pasture, soil nutrient content (both beneath tree canopy and out of the canopy), soil respiration, botanical composition of pasture, pasture production (both beneath tree canopy and out of the canopy), pasture LAI. Two specific questions that could be modeled from these data:

a) The effects of trees on pasture understory production under different scenarios of nutrient availability and water availability.
b) The effects of tree carbon sequestration under different scenarios of nutrient availability and water availability.

[1] Where data are already available in the literature or produced in previous projects, field works would not needed: this is the case of soil C in UK, soil carbon and pasture yield in Spanish dehesa and Portuguese montados.
[2] Soil analysis could be centralised in UEX laboratory, Spain. Partners should sent soils dried at ambient temperature.

6. Final remarks

This report has presented a list of protocols to test innovations identified by stakholders groups, following many different approaches. it is important to highlight that if the research is to be relevant in this changing social-ecological system, then it should not be purely experimental and technical but it should also incorporate local communities. The list of studies reported include field experiments that include reference systems as control and/or contrasted treatments, and replicated plots and/or samples. By contrast other studies are designed as cases studies, without replicated blocks and/or without contrasted treatments/systems. They are rather development projects to be implemented together with the local farmers/stakeholders, to produce more eficient forms of participative system management. There are also studies that consist on the development of new facilities (new technologies) for the daily system/livestock management. Finally, some studies are based on questionnaires and discussions with focus groups to find out new proposals / products to be developed in the coming years. It should also be noted that the protocols presented here continue to evolve. Some studies have already been ongoing for some years; others are only recently started.

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Annex A. Location and physical characterization of the experimental sites

Page 1/3

Partner	EFI, Sweden	CRAN, UK		BTU, Germ	NyME, hungary		INRA, France	
System	Wood pastures with reindeer husbandry	Wood pastures and Parklands		Mosaic of features including hedgerows	Wood pastures		Britany bocage	
Site Name	Njaarke Same Village	Epping Forest	Knepp Castle Estate	Filower	Tűzkövesbörc	Bogyiszlói	Les Ecoupées Farm, la Motte	Coacovec Farms, Saint-Barnabé
Coord.(N,E)	63.5000, 14.2000	51.6580, 0.0409	50.9834, -0.3547	51.8719, 14.0710	47.2132, 17.7914	46.3928 18.8641	48.2457, -2.6954	48.1238, -2.7393
Area, ha	100000	450	1400	109	120	87	20	30
AMT, ºC	2.5			9.4	8.5	10.7	10.7	10.7
AMP, mm	543			570	750 (± 50 SD)	600 (± 50 SD)	735	749
Soil	Depth soils, with 40%, sand, 48% silt and 3 % clay	Eutric Luvic Planosol, 100 cm depth, fine loamed		Floodplain with gleysols. Groundwater at 10-80 cm depth	Cambisol, Leptosols	Gleysols, alluvial soil	over micaschist, sometimes altered	over soft shale often altered
							Moderately deep to deep. Clay-loam	
Tree component	*Picea abies* (50%), *Pinus sylvestris* (33%), *Betula* spp. (12%), *Pinus contorta* (2%), other broadleaves (2%), *Populus tremuloides* (1%). 2500 stems ha^{-1} (1580 stems > 100 y ha^{-1})	*Carpinus betulus* 30-60 trees ha^{-1} *Fagus sylvatica* 30-50 trees ha^{-1} *Quercus robur* and *petraea. Pollarded trees.*	Mixed broadleaves at variable density. Seedlings emerging.	*Alnus glutinosa*, *Populus nigra*, *Prunus padus, Salix* spp., *Quercus petraea, Frangula alnus, Rhamnus alaternus*	*Quercus petrea, Fagus sylvatica, Pyrus pyraster, Carpinus betulus, Prunus avium, Acer campestre, Fraxinus spp., Sorbus spp*	*Quercus robur, Pyrus pyraster, Salix alba, Populus spp, Pyrus pyraster, Prunus spinosa, Crataegus spp., Rosa spp*	*Castanea sativa*, *Fagus sylvatica*, *Pinus sylvestris*, *Quercus pedunculata*, *Q. sessiliflora*, *Carpinus betulus*, *Coryllus avellana*, *Acer campestre*, *Prunus cerasifera*, *Crataegus monogyna.* Planted in lines	
Understory	Herbs (49%), Bilberry (24%), Lingonberry and Crowberry (13%), Grass (12%), Sedge and horsetail (1%), Lichens (< 1 %)	Predominantly grass, wild forbs, and brambles		Grass managed by grazing with cattle and mowing	Diverse grass species (217 sp.), dominated by *Anthyllido-Festucetum rubrae*	Mesotrophic wet meadows, uncharacteristic semi-dry grassland and mesic meadow communities	Permanent grassland	Silage maize, cereals, grassland rotations
Animal	2000 reindeers at winter (> in the control system)	Red polls and Longhorn cattle	Longhorn cattle	Cattle, 3 per ha	Traditional breeds of the Carpathian-basin: Hungarian great grey cattle, Hucul horse, Racka sheep, Cikta sheep, Cigája sheep, Buffalo, Goat	Merino sheep, Cattle	Dairy heifers	Suckler cows and dairy cattle
Contact	Torgny Lind, Torgny.lind@slu.se	Paul Burgess P.Burgess@cranfield.ac.uk		Michael Petschick, michael.petschick@lugv.brandenburg.de	Tibor Nagy; FB: Tűzkövesbörc Tanya	www.bogyiszlo.hu	Claudine Thenail Claudine.thenail@rennes.inra.fr	

Annex A. Location and physical characterization of the experimental sites

Page 2/3

Partners	UBB, Romania	TEI, Greece		CNR, Italy	ISA, Portugal
System	Transylvanian wood pastures	Grazed Valonian oak silvopastures		Grazed Oakwood pastures	Cork oak montados
Site Name	Rupea	Xeromero forest -Aitoloakarnania Prefecture	Kea Islands		Montargil
Coordinates (N, E)	46.0147, 25.2259	38.6078, 21.2156 / 38.6068, 21.2163 38.6056, 21.2156 / 38.5969, 21.2101 38.5980, 21.2080 / 38.5959, 21.2077 38.5853, 21.1940 / 38.5842, 21.1941 38.5834, 21.1943 / 38.5670, 21.1968 38.5663, 21.1954 / 38.5666, 21.1952	37.5797, 24.3259	40.8229, 9.3217	Not permission
Area, ha	393	120	0.5	100 (2.32)	12
AMT, ºC	8.2	18.8	17.9	14.5	15.4
AMP, mm	650/700	938	700.4	629	554
Soil	Brown forest soils, argilo-aluvial podzolic and clay aluvial regosols.	Leptosols, ≤1 m, pH 7.1	Cambisols, ≤1 m, pH 6.65	Typic Dystroxerept, 100 cm depth, sandy-loam	Sandy Podzols
Tree component		*Quercus ithaburensis* ssp *macrolepis*), 60 trees ha-1		*Quercus suber*, 10-40 trees ha^{-1}	*Quercus suber*
Understory	*Quercus robur*, *Q. petraea*, *Pyrus communis, P. pyraster*	Natural grass		Natural pastures + annual forage crops (*Lolium multiflorum*, *Trifolium michelianum*)	Shrub (*Cistus ladanifer*), seeded leguminous grass (*Lupinus luteus*)
Animal	Grass managed by grazing	5.5 sheep/goats ha-1		5 dairy sheep ha^{-1}	
Contact	Cattle (50) and sheep (400-500 sheep) ~ 0.3 LU ha^{-1}	Andreas Papadopoulos, ampapadopoulos@teiste.gr		Sebastiano Mu, a.franca@cspm.ss.cnr.it	Joana Amaral Paulo, joanaap@isa.ulisboa.pt

Annex A. Location and physical characterization of the experimental sites (Spanish dehesa farms; UEX)

Page 3/3

Site Name	Las Parras	Monteviejo Moraleja	Atoquedo	Valdesequera	Dehesilla	Los Varales	Casablanca	La Higaleja	La Casilla valencia	La Cabra Fregenal	Los Llanos	Majadas
Coordinates (N, E)	40.1324 -6.5199	40.0312 -6.6326	39.7694 -5.9340	39.0598 -6.8516	39.8200 -5.5164	38.7720 -6.8536	40.1500 -6.1110	40.1635 -6.2875	39.4858 -7.1413	39.1908 -6.7055	38.9831 -5.0165	39.9403 -5.7746
Area, ha	24	3	275	6	1.5	5.5	15	2.5	100	6	6.5	50
AMT, ºC	15.4	16.0	15.8	16.6	15.8	15.9	15.2	15.0	15.8	14.9	15.6	16.1
AMP, mm	739	649	546	523	640	543	715	771	577	721	628	753
Soil	Haploxeralf Xerochrept Acid, Very low SOC Clay-Loam	Xerochrept Acid Low SOC Sandy-Loam	Ochraqualf Palexeralf Very acid Moderate SOC Sand-clay-loam	Ochraqualf Palexeralf Mid acid Moderate SOC Sand-clay-loam	Xerochrept Very acid Very low SOC Sand-loam	Haploxeralf Rhodoxeralf Neutral Very low SOC Sandy-clay-loam	Xerochrept Very acid Low SOC Sandy-loam	Xerochrept Very acid Moder. SOC Sandy-loam	Xerochrept Mid acid Low SOC Sandy-loam	Xerochrept Mid acid Very low SOC Sandy-loam	Xerochrept Mid acid Very low SOC Sandy-loam	Haplaquept Ochraqualf Very acid Very low SOC Sandy-clay-loam
Tree component (Q. = *Quercus*) (t= tree)	*Q. ilex* < 10 t ha^{-1}	*Q. ilex* < 10 t ha^{-1}	*Q. ilex* 25 t ha^{-1}	*Q. ilex* 20 t ha^{-1}	*Q. ilex* 25 t ha^{-1}	*Q.ilex* 20 t ha^{-1}	*Q.ilex* 30 t ha^{-1}	*Q. pyrenaica* 16 t ha^{-1}	*Q ilex* (50%) *Q. suber* (50%) ???? t ha^{-1}	*Q. ilex* ?? t ha^{-1}	*Q. ilex* 10 t ha^{-1}	*Q. ilex (90%)* Q. faginea (8%) Q. Suber (2%) 26 t ha^{-1}
Understory	Natural Pasture and shrublands with *Retama sphaerocarpa* and *Cytisus* spp.	Natural Pasture	Natural Pasture and sown pasture rich in legumes	Natural Pasture	Natural Pasture and shrublands with *Retama sphaerocarpa*	Natural pasture and cereal crops	Natural pasture	Natural pasture, sown pasture rich in legumes and shrublands of *Cytisus* spp.	Natural pasture and sown pasture rich in legumes	Natural pasture and sown pasture rich in legumes	Natural pasture and sown pasture rich in legumes	Natural pasture
Animal	Cattle 0.5 LU ha-1	Fighting bulls 0.45 LU ha^{-1}	1.67 ewes and 0.05 goat ha^{-1}	Sheep and pigs	Cattle, 0.4 LU ha-1	Sheep and pigs, 4 ewes and 0.5 pigs ha^{-1}	0.37 cows, 1.5 calves ha^{-1} and 0.25 pigs ha^{-1}	Cattle	Cattle	Cattle	Sheep	Cattle 0.3 LU ha-1
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Annex B. Set of observations planned to estimate indicators of ecosystem services

[1]Ecosystem Service associated to		Design of observation at plots and landscape level and on-farm surveys				
		Transect of observation plots from hedgerows toward the center of fields	Succession of observation plots in and alongside hedgerows	Further description of hedgerows dimensions and vegetation structure	Mapping of the landscape structure and topography	Detailed survey of management practices and harvests
Biodiversity	ES 1-1. Favour species richness: Flora species characteristics of forest-edges and low fertile grassland; forest ground beetles	Exhaustive sampling of flora			Descriptors of landscape structure as Indicators of services when upscaling	
Biodiversity	ES 1-2. Favour pollination: Broadleaf flora; non specialized butterflies	sampling of butterflies by visual observations				
Biodiversity	ES 1-3. Favour natural control of pests: Weed flora; open-field ground beetles, spiders	collect of ground beetles and spiders by the mean of pitfall traps				
soil & water	ES 2-1. NO_3^- content in soil	Measurements in soil samples at different depths				
soil & water	ES 2-2. C content in soil					
soil & water	ES 2-3. Limit excess of water and/or favour water availability: water table height				Indicator taking into account hedgerows and landscape structure (density, connectivity) and water table height	
Provisioning services field	ES 3-1. Livestock sheltering from wind and inclement weather			Indicator based on the structure of hedgerows vegetation and orientation		Observations with farmers of grazing cattle behavior
Provisioning services field	ES 3-2. Abundance of quality fodder species in grassland; Crop yield compare to farm references	Exhaustive sampling of flora				Assessment with farmers of crop and grass yields compare to farm comparable references (e.g. similar soils)
Provisioning services field	ES 3-3. Indicators of biomass: i) potential for timber, ii) produced for firewood, iii) produced for mulch					Measurement of harvested biomasses of firewood and mulch; estimation of potential for timber from high stem trees frequency and trunk diameters.

[1]After the implantation of "3 dimensions adaptive design and management of hedgerows in Les Ecoupées (La Motte) and Coacovec (Saint-Barnabé) farms (Britany, France)