AGROFORESTRY SYSTEMS OF HIGH NATURAL AND CULTURAL VALUE IN EUROPE: STRUCTURE, MANAGEMENT, GOODS AND SERVICES

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Introduction

High nature and cultural value (HNCV) agroforestry includes semi-natural farming systems valuable for biodiversity where cultivation and/or grazing is practiced among trees. HNCV agroforestry comprises a range of farming systems and practices that have often co-developed with regional livestock breeds and crops and resulted in distinctive "cultural landscapes" adapted to specific climate and geographic areas. The processes leading from "natural" environments to "cultural landscapes" make a major contribution to the world heritage of biodiversity and are an appropriate focus for scientific research.

Although in the past they formed mosaics of agro-silvo-pastoral systems and landscapes, with different spatial and temporal scales of integration, currently they are managed mostly as extensive silvopastoral systems. They are mostly located in marginal areas of different European regions, where orography, low soil fertility and climate constraints have hampered the development of intensive agriculture. However even so, HNVC areas also provide multiple woody and non-woody plant products, high-quality food, livestock and game products, recreational or cultural services through multiple activities conducted with a comparatively low environmental impact[1]. This includes important regulating services such as carbon sequestration, soil fertilization, microclimate amelioration, and control of atmospheric contamination and soil erosion[2]. The capacity of HNVC agroforestry systems to sustain multiple functions and products has been emphasized as new needs and challenges emerge in modern society[3,4,5].

However, many HNCV agroforestry systems in Europe are facing both environmental and economic threats that might compromise their long-term persistence. Technological and socio-economic change and land use policies are resulting in a loss of traditional empirical knowledge, and a decrease in the profitability and hence the ongoing management of extensive agroforestry systems. Therefore, an important issue in European landscape conservation is the preserve semi-natural traditional HNCV agroforestry systems, preventing both agricultural intensification and land abandonment.

In the European project AGFORWARD (www.agforward.eu), a wide international research team is working to: (i) inventory the extension and geographical distribution of these systems[6]; (ii) identify in close collaboration with stakeholders the main constraints, challenges and innovations needed to increase the resilience of the HNVC agroforestry systems[7]; and (iii) evaluate and visualize the role of these systems in terms of provision of goods and services. This work aims to compile information on the diversity of HNCV agroforestry in Europe, describing the structure, components and management practices of these systems, and identifying the variety of goods and services provided by them.

Methods

Ten HNCV agroforestry systems were selected as representative of the different European biogeographical regions and agroforestry practices (Table 1). They ranged from forest habitats that are (partially) farmed (e.g. extensive grazing with reindeers) to mixed farming (e.g. bocage). They include silvopastoral (SP) systems such as grazed woodlands, wood pastures, and parklands and are frequently associated with low-intensity livestock rearing.

All ten HNCV agroforestry systems have been described in detail using a common template aimed at recording: (i) distribution and extension; (ii) main environmental conditions (climate and soil); (iii) components (trees, pasture/forage crops and livestock); (iv) management practices; (v) main marketable products; (vi) ecosystem services scientifically measured; and, where available, (vii) current trends and economic value of these systems. The description is based on the revison of international and local literature available for the ten selected HNVC agroforestry systems.

Main findings

The cases described here vary in structure, components, farming activities and management practices (see Table 1 for a summary). The list of goods produced in the European HNCV agroforestry systems that are still marketed is long. While high quality livestock-based foods (meat, cheese, milk, eggs) are common to most of the systems studied, some goods are regionally specific. For instance, cork is the main marketable products of Portuguese montado, and Valonian acorn cups is used for tanning in Greece. Other goods include timber and firewood, charcoal, mulch, wild fruits (e.g., syrup and jam from rosehips and mulberry), honey, mushrooms, wild edible, medicinal and aromatic plants, and recreational activities such as hunting and fishing, education and leisure activities. In some cases, specific labels are identified for the products of the HNCV agroforestry systems (e.g. Iberian jam, Sardinian cheeses).

Protection for livestock (shelter) and crops/pastures (windbreaks) were identified as an important ecosystem service of HNCV agroforestry. The higher capacity of these systems to store carbon compared to treeless systems has been highlighted[8]. Soil organic carbon contents measured in topsoil under old hedgerows can be up to 2.5 times higher than those in the adjacent crop field[9]. The importance of grazing wood pastures to control wildfires is highlighted by Mediterranean cases[10].

The capacity to improve water infiltration and prevent soil erosion is mentioned for Mediterranean case studies but also for the Continental Spreewald floodplain and the Atlantic bocage. Several studies demonstrated also the anti-erosive effect of hedgerows, with high spatial variability at the landscape scale[11]. Especial emphasis on the regulation of the nitrate and phosphorus pollution is done in Britany where hedgerows are designed to improve the groundwater quality. At a watershed scale, the nitrate flux brought by water surface decreased when the hedge tree density increased[12].

To enhance biodiversity is a common goal to all the HNCV agroforestry studied. For instance, ancient trees of British, Hungarian and Romanian wood pastures are especially rich in fungi, epiphyte, macroinvertebrates, bats and birds. Indeed, wood pastures have been identified as a priority habitat in the UK. In Portugal, a comprehensive biodiversity survey on a 220 ha montado farm has identified 264 fungi, 75 bryophytes, 304 vascular plants and 121 vertebrate species were recorded[13]. In Spain, 135 species in 0.1 ha in holm oak dehesas and 60–100 species per 0.1 ha in cork oak stands have been described[14]. The importance of grazing in wood pastures for flora biodiversity has been demonstrated in Sardinia where the Shannon biodiversity index was 2.5-4.8 in grazed areas and 1.3-3.8 in ungrazed areas[15]. The diversity of butterflies in bocage was found to be higher in hedgerow banks than other herbaceous habitats, in relationships with a high diversity of plant species[16]. Le Feon[17] found that the diversity of pollinators such as solitary bees increased with hedgerow density in farming landscapes, due to the high quality of nectar and nesting resources in these elements. Regarding the communities of natural enemies of crop pests, the diversity of predatory carabid beetles, of ladybugs and of aphid parasitoids in cereals fields was found to be positively related to the density of hedgerows and/or their proximity to crops in the surrounding landscape[18]. Although high biodiversity values found in Iberian dehesas can be partly explained by the existence of a habitat dominated by scattered trees, the intimate mix of tree and treeless pastures and marginal habitats has also a significant role[19].

The objective for some systems is the maintenance of the cultural landscape of high aesthetic value and their associated traditional knowledge and potential for tourism. Indeed, for the Iberian dehesas, environmentally-related income streams are more important than income from agricultural products which often hardly compensates labour costs[20]. Unfortunately, disaggregated results for HNCV agroforestry systems are not available yet, but results of the stakeholders meeting held for the ten cases studies show clearly that the low profitability of these agroforestry systems could compromise seriously their future persistence[7].

With the exception of Iberian dehesas and montados, and in some way the Sardinian agro-silvo-pastoral landscapes, the rest of the HNCV agroforestry systems studied experienced an important regression and/or abandonment of the farming practices during the 20th century. This has led to programs to restore traditional farming practices. For instance, in Britany in France, new hedge planting schemes have been implemented since the 1990s. A plan for the

rejuvenation of the abandoned hedgerows in the German Spreewald floodplain has also been initiated. In both cases the hedges can be a source of biomass energy. In Hungary formerly abandoned areas are being farmed again as wood pastures to supply the demand the organic and high quality foods. In Sweden forest plans of intensive timber plantations are being adapted to compatibilist timber production with the reindeer husbandry. In UK, pollarding and grazing activities in old abandoned wood pastures is re-introduced to maintain the cultural landscape mostly used for public recreational activities.

Table 1: Ten types of HNCV agroforestry systems of Europe classified by biogeographical regions

Bio-region	System	Components and Management
MEDITERRANEAN	Montado, Portugal (737 000 ha)	Oak (mainly cork oak in montado and holm oak in dehesas) at < 80 trees ha^{-1} + grass understory + livestock (0.2–0.5 LU ha^{-1}) Planting and/or natural regeneration, shrub control, periodical cropping and regular grazing. Periodical debarking of cork oaks.
	Dehesa, Spain (2.3 millions ha)	
	Agrosilvopastoral mosaics, Italy (Sardinia: 806 228 ha of potential silvopastoral systems)	*Quercus* spp. + grass understory + dairy sheep in more open stands and cattle in more dense stands (0.3 LU ha-1). Forest policy applied in Sardinia are very restrictive of grazing in the woods and seasonally limited
	Valonian oak silvopastures, Greece (29632 ha)	*Q. ithaburensis and other Quercus + grasses and bushes +* sheep, goats, pigs, cows (< 1 LU ha-1). Grass can be grazed directly by livestock or cut in more productive areas to provide animal feed (silage or hay)
ATLANTIC	Bocage, Bretagne, France (183000 km over 2.7 millions ha)	Lines of high- and medium-stem trees (multispecific; hardwoods) contouring crop fields (included fodder crops) and pastures. Hedgerow density varies between 16 and 94 $m.ha^{-1}$. Planting hedges, with or without bank, pruning, thinning and harvesting
	Wood pastures and parklands, UK (estimated 10000-20000 ha)	Traditional land use in the UK comprising open-grown Trees (often pollarded), grazing livestock, and an understorey of grassland or heathland.
CONTINENTAL	Hedgerows contouring meadows, Germany (example: Spreewald Biosphere Reserve)	Tree and shrubs hedgerows (native flood plain species such as *Alnus glutinosa*) contouring meadows and field crops. Inter-row spacing ~50 m. Grass managed by grazing with cattle (3 per ha) and mowing. Traditionally regular harvest of hedgerow biomass. Currently need special permission and are almost abandoned. *Deadwood up to 50% of stand trees.*
	Transylvanian wood pastures, Romania (~7000 ha)	*Quercus robur*, *Q. petraea*, *Pyrus communis, P. pyraster* + Natural grass + Cattle + sheep ~ 0.3 LU ha^{-1}
PANONIAN	Wood pastures, Hungary (~8000 ha)	Mosaic of open grassland, wood pastures with ancient trees and forest. Sheep, cattle, buffalo, goat. Mostly traditional breeds for the Carpathian-basin. Grazing is officially prohibited in forests, but livestock use woody species as fodder.
BOREAL	Forests devoted to reindeer husbandry (up to 24 million ha are used by Sami villages)	Conifers + birch forest: 1500-2000 trees/ha Understory rich in herbs, berries and terrestrial and arboreal lichens. Grazed by migrating reindeer herds. Stoking rate < 0.01 ha^{-1} Soil scarification, planting/seeding, and natural regeneration , with further cleaning, thinning and clear-cut (cycles of 100-130 years)

Conclusions

Most of the traditional HNCV agroforestry systems and associated agro-silvo-pastoral practices were under-valued in the XX century and the systems have either evolved in dense forests and

shrublands or been deforested by the gradual loss of trees. Recently, HNCV agroforestry systems have acquired interest again for their ecological, cultural and recreational value, through the support of agri-environment programmes and the rising demand for high quality food. Numerous projects of rejuvenation or restoration have emerged to preserve ancient trees, hedgerows, tree cover, and practices such as grazing forest, pannage, and pollarding. However, there is still important uncertainties on how to restore and maintain these systems, and ultimately to guarantee an economic and ecological sustainable management of these systems. Research on the best agroforestry management practices to optimise more demanded public services and high quality and low-carbon-emission products are still needed.

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