Deliverable 7.3
Report on plot economics of European silvoarable systems
and
Deliverable 8.2
Economic feasibility of silvoarable agroforestry in target regions report

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EXECUTIVE SUMMARY

1. Aim

Deliverable 7.3 (plot-scale economic analysis of silvoarable systems in target regions) and Deliverable 8.2 (economic feasibility of silvoarable systems in target regions) have been combined into a single report because the former flows directly into the latter.

The aim of Deliverable 7.3 was to undertake an economic analysis at the plot-scale for selected target regions of Europe. It builds on task 7.5 which was "to determine the optimum silvoarable system for selected locations by using a model to assess the impact of changes in biophysical parameters on profitability".

The aim of Deliverable 8.2 was to assess the economic feasibility of silvoarable systems in target regions of Spain, France and the Netherlands. This builds on task 8.2 which was "to extrapolate plot-scale predictions to a farm-scale using existing national farm survey information and physical spatial databases of soils, topography and climate".

2. Selection of landscape test sites, creation of land units and hypothetical farms

Using a statistical analysis of climatic, topographic and land classification data, 19 landscape test sites (LTS), measuring 4 km x 4 km, were selected in Spain (9 sites), France (7 sites) and the Netherlands (3 sites). In Spain the sites ranged from Alcala la Real in the southern region of Andalucia to St Maria del Paramo in the northern region of Castille Leon. In France, the sites ranged from the Poitou Charentes region in the west to the Franche Comté region in the east. The sites in the Netherlands were located in the eastern part of the country.

Within each landscape test site, the land use was determined from aerial photographs and was digitised from onto a geographical information system. In addition spatial data on soil depth, soil texture and elevation were collated. The differences in solar radiation within the site were calculated from a digital elevation model. Using cluster analysis, the arable land within each site was then divided into between one and four land units on the basis of soil texture, soil depth and proportion of solar radiation.

For each landscape test site, the area of a typical "hypothetical" farm was derived from the Farm Accountancy Data Network (FADN) for Spain and the Netherlands and from ROSACE for France, assuming the most frequently occurring farm type for the region. The proportion of land in each land unit was then used to determine the area of each land type on the hypothetical farm.

Daily weather data (temperature, radiation and rainfall) were generated for each landscape test site using reference data from the closest weather station and a computer-based weather generator. The mean annual temperature ranged from 10.2 to 15.5°C in Spain, 8.5 to 11.0°C in France, and 8.8 to 9.0°C in the Netherlands. The annual solar radiation varied from 6600 MJ m^{-2} at one site in Spain to 3690 MJ m^{-2} at one site in the Netherlands. The mean annual rainfall (mm) varied from 316 to 530 mm in Spain, from 587 to 1084 mm in France, and between 729 and 818 mm in the Netherlands.

3. Biophysical analysis

During 2004, workshops were held in each of the three countries to determine the optimum forestry and arable system for each land unit (Palma and Reisner, 2004; Reisner, 2004; Herzog, 2004). The forestry systems in Spain were based on either holm oak (*Quercus ilex*) or stone pine (*Pinus pinea*). The forestry systems considered in France and the Netherlands were wild cherry (*Prunus avium*), walnut (*Juglans* spp.), and poplar (*Populus* sp.). The agricultural systems in Spain were assumed to be based on wheat, sunflower and fallow. The systems in France were based on wheat and sunflower in the Poitou Charentes and Centre regions, and wheat, oilseed and grain maize in the eastern Franche Comté region. The systems in the Netherlands were based on wheat and forage maize. Full details of the rotations assumed at each site are presented in Deliverable 6.4 (Burgess et al. 2005)

During the workshops, a reference tree and crop yield was determined for each landscape test site assuming 100% radiation and a specified depth of soil (Burgess et al. 2005). These values were then used to calibrate the tree and crop components of a biophysical model called Yield-SAFE (van der Werf et al. 2005), implemented in Microsoft Excel© in a worksheet called Plot-SAFE (Burgess et al. 2004). The calibrated model, together with the radiation soil depth and texture data specific to each land unit, was used to calculate daily values of tree and crop growth within a forestry and arable system for each land unit. The Yield-SAFE model was also used to calculate the tree and crop yields within silvoarable systems with a density of 50 and 113 trees per hectare. The results of biophysical modeling are described in Deliverable 6.4 (Burgess et al., 2005).

The land equivalent ratio (LER) for each silvoarable system with 113 trees ha^{-1} was above 1.0, indicating improved land productivity from integrating crops and trees in a single system, rather than having separate areas of trees and crops. The land equivalent ratio was always higher for the 113 tree ha^{-1} system than the 50 tree ha^{-1} system. The highest land equivalent ratio on a landscape test site was found with the deciduous tree and autumn-planted crops in France and the Netherlands, systems where the tree and crop had complementary patterns of light use. The trees selected in Spain, holm oak and stone pine, were both evergreen.

4. Plot-scale economic results

Financial data for tree and crop production at each landscape test site were collated and stored on electronic templates (Graves et al. 2004). A combined plot- and farm-scale economic model called Farm-SAFE was then used to undertake a plot-scale cost-benefit analysis of the arable, silvoarable and forestry systems on each land unit. For the silvoarable systems, it was assumed that the farmer would continue cropping until the five year moving average of the net margin became zero; thereafter the intercrop area was left fallow. Since time is important in determining the value of long-term systems, the results from the analyses were compared in terms of their effect on the net present value (discount rate = 4%) and the corresponding equivalent annual value.

An important factor determining the relative profitability of the different systems to a farmer is the level of grants. The effect of six grant scenarios was therefore examined; the first of which was a no grant scenario. In this scenario, the equivalent annual value (at a 4% discount rate) of each forestry system in Spain and the Netherlands, and forestry with wild cherry in France was negative. The only forestry systems showing a positive return were the poplar and walnut systems in France. The profitability of the arable system was positive at five of the nine landscape test units in Spain, at four of the seven landscape units in France, and at each site in the Netherlands. There were no sites in Spain where silvoarable agroforestry (without grants) showed a positive return which was greater than the arable system. By contrast in France, silvoarable agroforestry with walnut in each of the three regions, agroforestry with poplar in the Centre region, and agroforestry with cherry in the Poitou Charentes and Franche Comté regions were predicted to be more profitable than the arable and forestry systems. In the Netherlands, the poplar silvoarable systems had a marginally greater equivalent annual value than that for the arable system, but the walnut system was unprofitable.

With the 2004 grant scenario, forestry in Spain received a higher level of grants that both the arable and silvoarable systems, while in France and the Netherlands, the greatest level of support was obtained by the arable systems. The level of support for silvoarable agroforestry in Spain and the Netherlands was substantially less than that for either arable or forestry systems. Hence under the 2004 grant regime, in Spain and the Netherlands there were no land units where the 113 tree ha^{-1} silvoarable system had a higher equivalent annual value than both the forestry and arable system. In France, at those sites where the chosen tree species was cherry, the arable system was predicted to more profitable than both the forestry and the silvoarable system. Only the poplar and walnut systems in France produced a greater return than both the forestry and the arable system.

During 2005 a new method of support for arable areas based on single farm payments was introduced in the European Union. Hence for each landscape test site, the level of the single farm payment was predicted. Since the exact nature of the future grant scheme is uncertain, four scenarios were examined for the silvoarable system with differing levels of single farm payment and the presence or absence of tree-related grants.

Under the 2005 grant regime, the relative profitability of silvoarable agroforestry relative to forestry and arable system remained broadly similar to that under the 2004 grant regime. The effect of the four different scenarios on the relative profitability was also small. At each site in Spain, the arable system remained more attractive than the silvoarable option. In France, the silvoarable systems with walnut and poplar continued to be more profitable than the arable and forestry systems, and under the most optimistic grant scenario (i.e. full single farm payment plus tree-related grants), silvoarable system with cherry could become more profitable than both arable and forestry systems in the Franche Comté region. In the Netherlands, under each of the scenarios, the arable systems continued to out-perform both the silvoarable and the forestry systems.

5. Farm-scale feasibility

The plot-scale results for each land unit were integrated using the hypothetical farms to allow a farm-scale analysis. Farm fixed costs were developed from the Farm Accountancy Data Network (FADN) (Graves, 2002) and ROSACE for each farm. The status quo net present value (NPV) of the net margin (4% discount rate) on each farm was then compared with the predicted value following the introduction of silvoarable and forestry systems on 10% of the highest and lowest quality land.

The feasibility of introducing silvoarable or forestry systems at a farm-scale was primarily determined by the economics at a plot-scale. In Spain, there was no case, where grants were available, where introducing silvoarable agroforestry would increase the farm net margin relative to the status quo. Assuming the 2004 grant regime, on 90% of the Spanish farms profitability could have been increased with the introducing forestry; this decreased to 50% under the 2005 grant scenarios. There appeared to be some advantage from locating such forestry systems on the lowest quality land.

In France, under each of the grant scenarios, silvoarable systems with poplar (short-rotation) and walnut (high-value timber) could increase the farm net margin. Because these systems tended to be allocated to the best land, the analysis suggested that planting agroforestry on the best land was preferable to planting on poor quality land, which tended to be allocated a cherry-based system. In a similar way, the walnut and poplar forestry systems, allocated to the best land, tended to increase farm profitability, whereas the cherry systems, allocated to the lowest quality land, tended to reduce farm profitability. In the Netherlands, both silvoarable and forestry systems reduced farm profitability in comparison with the status quo. Forestry was particularly disadvantageous because of the opportunity cost of having to find alternative sites for applying manure from the assumed livestock enterprises on the farm.

6. Conclusions and recommendations

Plot-scale economics

1. Without grants, in France, the equivalent annual value (at a 4% discount rate) of poplar and walnut silvoarable systems (113 trees ha^{-1}) was higher than that for the arable and forestry systems. Wild cherry in Poitou Charentes and Franche Comté, and poplar in the Netherlands was also more profitable than arable and forestry systems.

2. Under the 2004 grant scenario, only the walnut and poplar silvoarable systems in France were more profitable than the competing forestry and arable systems. The situation was similar under the 2005 grant scenarios. Therefore, walnut and poplar silvoarable systems can be promoted in France as an alternative to both arable and forestry systems.

3. A high land equivalent ratio, profitable arable and forestry production and an equitable balance between the profitability of the tree and crop components appear to produce the optimal conditions for a successful silvoarable system.

4. Within the silvoarable system, the predicted relative yields of spring-planted crops were less than those for autumn-planted crops. This has implications for crop selection. The predicted land equivalent ratios were higher in systems with deciduous rather than evergreen trees because of the greater complementarity of light use between the tree and crop.

Farm-scale feasibility

1. In France, introducing silvoarable systems with walnut and poplar increased farm profitability on both poor and good quality arable land. The main reasons for this are the high value of walnut timber and the short rotation for poplar. In Spain and the Netherlands, there was no economic benefit from introducing silvoarable systems to arable land.

2. With the stated grant scenarios, in France and the Netherlands, trees could be introduced more profitably through silvoarable agroforestry rather than through forestry. Thus, if the farmer's objective is to establish trees on the farm, silvoarable systems provide a more profitable means of doing so than forestry systems.

3. In Spain under the 2004 grant scenario, forestry was the more profitable means of establishing tree cover on farms; this benefit was reduced under the 2005 grant scenarios. The location of forestry on low quality rather than high quality land is marginally preferable.

4. The Farm-SAFE model provides a platform which could be used for further evaluations of farm-scale economics. These could include the value of acorns and pine-nuts in Spain, and an assessment of labour demands, current price trends and the effect of multi-planting schemes in different years.

1. OBJECTIVES AND GENERAL APPROACH

A task within work-package 7 of the Silvoarable Agroforestry For Europe (SAFE) project was to "determine the optimum silvoarable system for selected locations by using a model to assess the impact of changes in biophysical parameters on profitability". A task within work-package 8 was to "to extrapolate plot-scale predictions to a farm-scale using existing national farm survey information and physical spatial databases of soils, topography and climate". This report combines these two tasks into one document. The economic assessments were investigated for characteristic sites of three European countries and different management scenarios. The economic analysis was done from a farmer's perspective.

A statistical approach was used to select 19 landscape test sites across three countries in Europe. These landscape test sites were divided into up to four land units on the basis of soil depth and type and radiation receipts. Within each land unit a typical forestry and agricultural system with a defined yield was specified. A biophysical model called Yield-SAFE was then used to determine the yields of trees and crops from a silvoarable system with 113 and 50 trees per hectare. Workshops were held in each country to determine the costs associated with tree and crop production, the value of the tree and crop products and the level of grant payments in 2004. These and the yield calculations were then used to undertake a cost-benefit analysis of the forestry, agricultural and silvoarable system in each land unit. The relative profitability of the systems was defined in terms of the Net Present Value (NPV) and the Equivalent Annual Value (*EAV*). The results were then aggregated at a farm-level to determine if the planting of silvoarable systems was most likely to occur on the best land or poor land.

2. SELECTION OF LANDSCAPE TEST SITES AND CREATION OF LAND UNITS

The countries selected for analysis were France, Spain and the Netherlands. The climate patterns in these locations range from a Mediterranean climate in Spain to an Atlantic climate in the selected regions of France and the Netherlands (Figure 1).

Within these three countries, nineteen landscape test sites (LTS), measuring 4 km x 4 km, were selected from an environmental classification of Europe based on statistical analysis of climate and topographic data (Mücher et al. 2003) and filtered for arable land using the PELCOM land cover classification. From this selection, landscape test sites were randomly selected on each of the most dominant environmental classes in France and Spain. In the Netherlands, only one environmental class was available and therefore only three sites were selected.

Meteorology

Daily weather data (temperature, radiation and rainfall) was generated for each LTS using Cligen 5.2 (United States Department of Agriculture) using reference data from the closest weather station to the LTS. The eight landscape test sites in Spain ranged from Alcala in the Andalucia region where the mean temperature was 15.3°C and the mean annual rainfall is 355 mm, to St Maria del Paramo in the Castille-Leon region, where the mean temperature is about 10°C and the mean rainfall in 519 mm (Table 1; Figure 2). In Andalucia, the rainfall in Spain primarily occurs between October and May, and although the majority of rainfall still occurs in the winter, the rainfall distribution is more even in the North (Figure 3). In France, each of the landscape test sites are at the same latitude. Hence the mean temperature at the seven sites (8.5-11.0°C) is broadly consistent. However the annual rainfall totals at the sites range from about 600-650 mm at the three most westerly sites to about 1080 mm at the two most easterly sites. The three sites in the Netherlands have a mean annual temperature of about 9.0°C and a mean rainfall of 700-820 mm.

Further layers of data were developed for soil depth, soil texture and elevation using pre-existing electronic data or by digitising the information where necessary. Land use was digitised from aerial photographs and non-arable land excluded from further analysis.

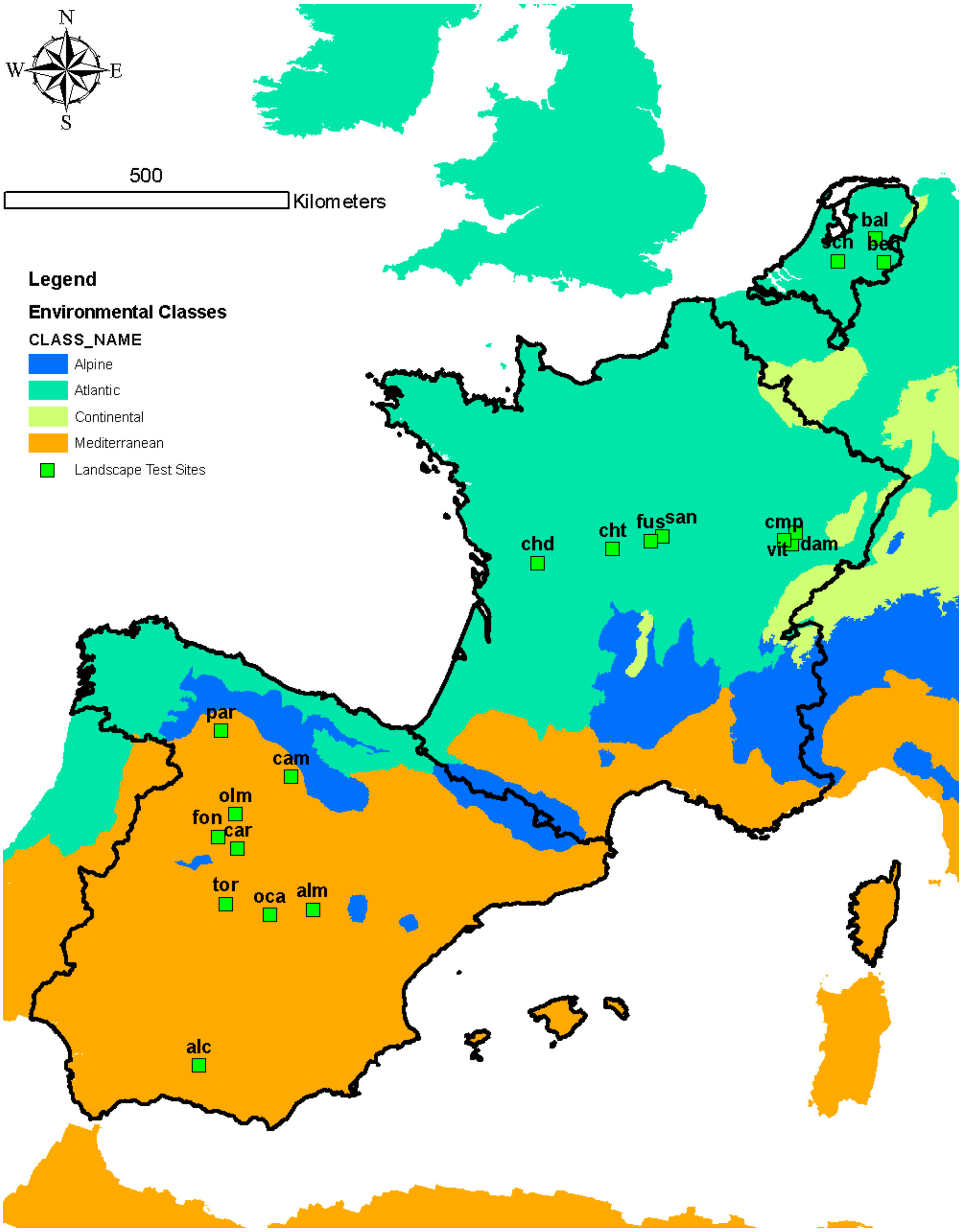

Figure 1 Location of the landscape test sites in Spain, France and the Netherlands

Table 1 Summary of the annual rainfall, solar radiation and mean temperature at each site

Country and region	Site name	Latitude	Long.	Altitude (m)	Mean temp (°C)	Solar radiation (MJ m^{-2})	Annual rainfall (mm)
Spain							
Andalucia	Alcala la real	37.36N	3.88W	1000	15.3	5490	355
Castilla La Mancha	Torrijos	39.89N	4.39W	500	15.5	5560	348
	Ocaña	39.94N	3.44W	700	14.7	5780	316
	Almonacid de Zorita	40.23N	2.61W	900	12.6	6610	404
Castille-Leon	Cardenosa El Espinar	40.78N	4.53W	1000	12.0	5700	404
	Fontiveros	40.86N	5.00W	900	12.0	6170	393
	Olmedo	41.28N	4.80W	750	12.5	5480	410
	St Maria del Campo	42.11N	3.91W	800	na	5630	530
	St Maria del Paramo	42.44N	5.69W	800	10.2	6600	519
France							
Poitou Charentes	Champdeniers	46.41N	0.02E	200	11.0	4740	648
Centre	Chateauroux	46.92N	1.65E	150	11.0	4750	587
	Fussy	47.18N	2.47E	200	10.6	4800	626
	Sancerre	47.30N	2.72E	400	10.7	4590	724
France Comté	Champlitte	47.64N	5.58E	300	8.5	4940	773
	Dampierre	47.61N	5.82E	300	10.0	5090	1072
	Vitrey	47.81N	5.78E	400	9.5	4900	1084
The Netherlands	Balkbrugg	52.57N	6.34E	0	8.9	4830	818
	Bentelo	52.22N	6.67E	0	8.8	3690	729
	Scherpenzeel	52.57N	6.34E	0	9.0	3710	801

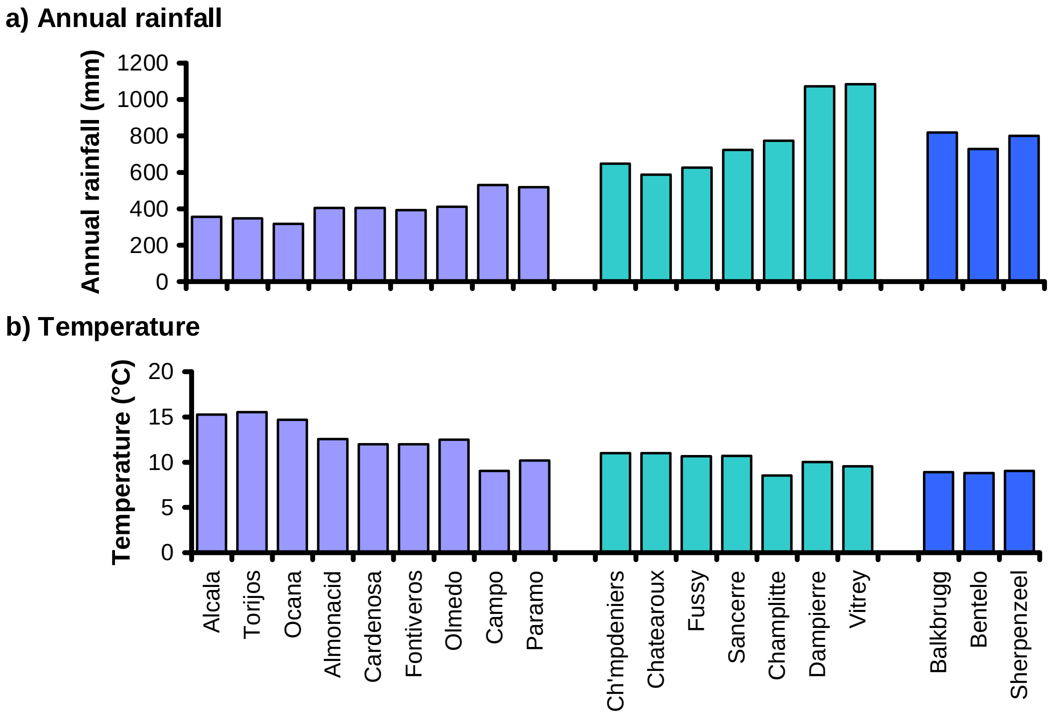

Figure 2 Summary of the rainfall and temperature across the landscape test sites

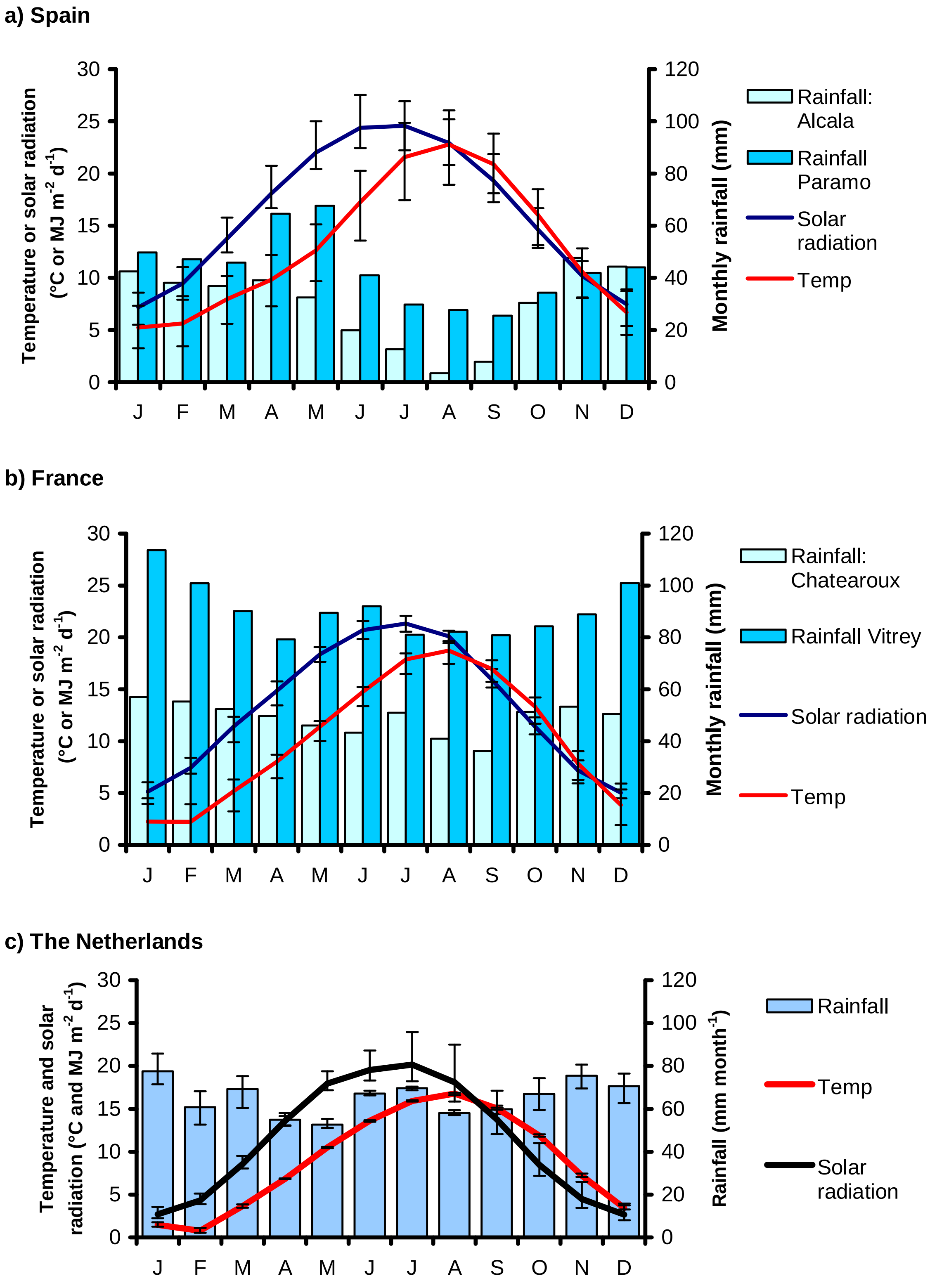

Figure 3 Seasonal distribution of solar radiation, temperature and rainfall for the landscape test sites in a) Spain, b) France and c) the Netherlands.

Creation of land units

Each landscape test site was divided into between one and four land units using cluster analysis on available water content and percentage radiation, calculated from the digital elevation model (Figure 4; Table 2). Areas of land that were not available for arable production were excluded.

For each landscape test site, the area of a hypothetical farm was derived from the Farm Accountancy Data Network (FADN) for Spain and the Netherlands and from ROSACE for France, assuming the most frequently occurring farm type for the region. The proportion of land in each land unit was then used to represent the proportion of each land unit on the hypothetical farm.

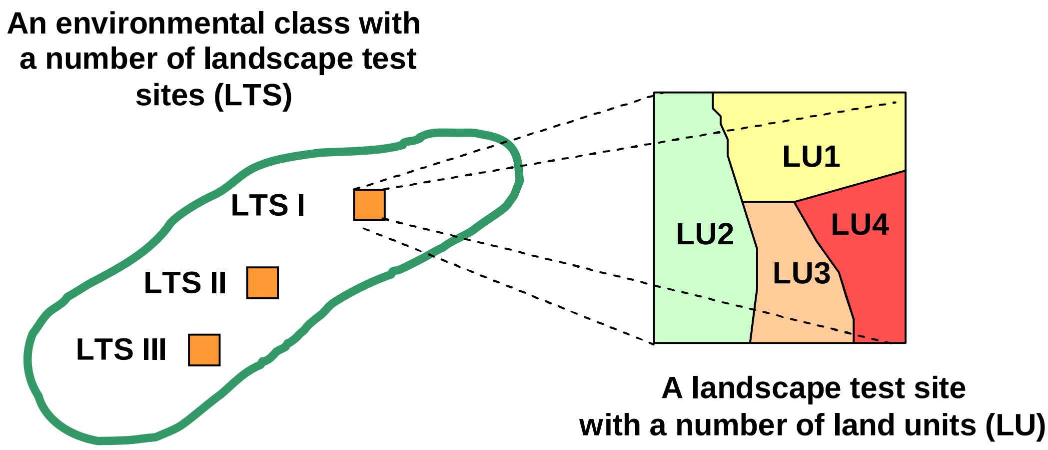

Figure 4 Schematic diagram showing the concept of creating land units within each landscape test site

Table 2 Total area and the area of each land unit, the fixed costs and the gross margin from any other enterprise for each landscape test site

Country	Landscape test site	Area (ha)	Land unit 1 (ha)	Land unit 2 (ha)	Land unit 3 (ha)	Land unit 4 (ha)
Spain	Alcala	73	58	15	0	0
	Torrijos	66	10	56	0	0
	Ocaña	66	66	0	0	0
	Almonacid	66	59	7	0	0
	Cardenosa	58	23	35	0	0
	Fontiveros	58	49	9	0	0
	Olmedo	57	5	34	18	0
	Campo	58	44	14	0	0
	Paramo	59	4	34	21	0
France	Champdeniers	94	67	27	0	0
	Chateauroux	152	32	86	23	11
	Fussy	80	10	43	27	0
	Sancerre	98	37	44	7	10
	Champlitte	130	68	62	0	0
	Dampierre	130	64	43	23	0
	Vitrey	120	46	74	0	0
The Netherlands	Balkbrugg	40	40	0	0	0
	Bentelo	40	40	0	0	0
	Scherpenzeel	10	10	0	0	0

3. Biophysical analysis

Choice of modelled forestry and arable systems

During 2004, workshops were held in each of the three countries to determine the optimum forestry system for each land unit (Palma and Reisner, 2004; Reisner, 2004; Herzog, 2004). The forestry systems in Spain were based on either holm oak (*Quercus ilex*) or stone pine (*Pinus pinea*). The forestry systems considered in France and the Netherlands were wild cherry (*Prunus avium*), walnut (*Juglans* spp.), and poplar (*Populus* spp.) (Figure 5). Full details of the tree rotations used at each site are presented in Deliverable 6.4 (Burgess et al. 2005).

a) Holm oak b) Stone pine c) Wild cherry d) Walnut e) Poplar

Figure 5 Photos of a) holm oak, b) stone Pine (Arboretum de Villardebelle, 2003), c) wild cherry, d) walnut and e) poplar

At the same workshops, an agricultural system was also selected for each land unit (Table 3). The agricultural systems in Spain were assumed to be based on wheat, sunflower and fallow. The systems in France were based on wheat and sunflower in the Poitou Charentes and Centre regions, and wheat, oilseed and grain maize in the eastern Franche Comté region. The systems in the Netherlands were based on wheat and forage maize. Full details of the rotations assumed at each site are presented in Deliverable 6.4 (Burgess et al. 2005).

Reference yields

For each landscape test site, normal tree timber volumes were determined for the selected forestry systems. At each site in Spain, the reference yield for the holm oak and stone pine at 60 years was assumed to be 0.22 m^3 and 0.26 m^3 per tree respectively. In France, the timber volume of wild cherry, after 60 years, was assumed to be either 1.04 or 1.06 m^3 per tree. The timber volume of walnut was assumed to 1.04 m^3 per tree in France and 0.80 m^3 per tree in the Netherlands. The timber volume of the poplar, after 20 years, was assumed to be 1.46 and 1.51 m^3 per tree in France and the Netherlands respectively. Full details of the reference yield at each site are presented in Deliverable 6.4 (Burgess et al. 2005).

Reference arable yields were also determined for each crop at each land unit assuming 100% radiation and a specified soil type and depth. In Spain, reference wheat and sunflower yields ranged from 1.62 to 3.71 t ha^{-1} and 0.60 to 1.09 t ha^{-1} respectively Unlike the network site analysis, the landscape site analysis did not include a livestock component. In France, in the western and central regions, the reference sunflower yield was 2.3-2.5 t ha^{-1}. Wheat yields ranged from 6.5 to 8.0 t ha^{-1} and oilseed yields ranged from 3.2 to 4.0 t ha^{-1}. In the eastern part of France, the reference grain maize yield was 7.5-8.0 t ha^{-1}. In the Netherlands, the mean yield of wheat and forage maize (dry weight basis) was assumed to be 7.8 and 12.0 t ha^{-1} respectively. Full details of the reference yield at each site are presented again by Burgess et al. (2005).

As described by Burgess et al. (2005), the Yield-SAFE model was calibrated against the reference forestry and arable for each landscape test site. The Yield-SAFE model was then used to determine the specific forestry and arable yield on each land unit in response to changes in radiation levels, soil type and depth.

Table 3 Description of the 42 different land units and the respective assumed tree species and crop rotation

Country and region	Site	Code	Rad (%)	Soil type	Soil depth (cm)	Tree species	Crop rotation
Spain							
Andalucia	Alcala	ALC1	97	Medium	140	Oak	w/w/f
	Alcala	ALC2	86	Medium	50	Oak	w/w/f
Castilla La Mancha	Torrijos	TOR1	101	Medium	140	Oak	w/f
	Torrijos	TOR2	100	Medium	140	Oak	w/w/f
	Ocaña	OCA1	100	Medium	140	Oak	w/w/f
	Almonacid	ALM1	97	Medium	140	Oak	w/f
	Almonacid	ALM2	83	Fine	140	Oak	s/s/s/s/s/w/f
Castille-Leon	Cardenosa	CAR1	93	Medium	140	Oak	w/w/w/f
	Cardenosa	CAR2	101	Fine	140	Oak	w/w/w/f
	Fontiveros	FON1	99	Coarse	140	Oak	w/w/w/w/f
	Fontiveros	FON2	98	Coarse	140	Pine	w/w/w/w/f
	Olmedo	OLM1	100	Coarse	140	Pine	w/s/f
	Olmedo	OLM2	100	Medium	140	Oak	w/s/f
	Olmedo	OLM3	99	Coarse	140	Oak	w/s/f
	Campo	CAM1	99	Coarse	140	Pine	w/w/w/f
	Campo	CAM2	99	Medium	140	Oak	w/w/w/w/w/f
	Paramo	PAR1	100	Medium	140	Oak	w/w/w/s/f
	Paramo	PAR2	100	Medium	140	Oak	w/w/w/s/f
	Paramo	PAR3	101	Medium	140	Oak	w/w/w/s/f
France							
Poitou Charentes	Champdeniers	CMD1	100	Fine	80	W. cherry	w/w/s/w/o/s
	Champdeniers	CMD2	100	Medium	120	Walnut	w/w/s/w/o/s
Centre	Chateauroux	CHT1	102	Fine	80	Walnut	w/w/o/w/o/s
	Chateauroux	CHT2	102	Fine	40	W. cherry	w/w/o/w/o/s
	Chateauroux	CHT3	102	Medium	120	Walnut	w/w/o
	Chateauroux	CHT4	100	Fine	40	W. cherry	w/w/o/w/o/s
	Fussy	FUS1	101	Fine	40	W. cherry	w/o
	Fussy	FUS2	103	Medium	80	Poplar	w/w/o
	Fussy	FUS3	102	Fine	120	W. cherry	w/o
	Sancerre	SAN1	103	Fine	40	W. cherry	o/w/s/w/w/o
	Sancerre	SAN2	102	V fine	140	Poplar	o/w/s/w/w/o
	Sancerre	SAN3	101	V fine	120	W. cherry	o/w/s/w/w/o
	Sancerre	SAN4	100	Coarse	80	W. cherry	o/w/s/w
France Comté	Champlitte	CMP1	103	Medium	140	W. cherry	w/w/o
	Champlitte	CMP2	103	Md-fine	35	Walnut	w/w/w/w/w/gm
	Dampierre	DMP1	98	Medium	140	W. cherry	w/w/gm
	Dampierre	DMP2	97	Fine	35	W. cherry	w/w/w/gm
	Dampierre	DMP3	95	Md-fine	60	Poplar	w/gm
	Vitrey	VIT1	103	Medium	60	W. cherry	w/w/o
	Vitrey	VIT2	103	Md-fine	60	Poplar	w/w/gm
Netherlands	Bentelo	BAN1	100	Coarse	140	Walnut	w/w/fm
	Balkbrugg	BAL1	100	Coarse	140	Poplar	fm
	Scherpenzeel	SHR1	100	Coarse	140	Poplar	fm

Crop rotation key: w = wheat; s = sunflower; f = fallow ; o = oilseed; fm = forage maize; gm = grain maize

The yields predicted by the Yield-SAFE model for the arable and forestry systems could have been modified by changes in soil type, solar radiation level and soil depth. In practice, there were minimal changes in predicted yield due to soil type because the available water contents of different soils as predicted by Wösten et al. (1999) were relatively similar. The level of solar radiation within a land unit was assumed to range from 83% for northerly-facing slopes (Almonacid Land Unit 2) to 103% for southerly-facing slopes (Fussy land unit 2, Sancerre land unit 2, Champlitte land units 1 and 2, and Vitrey land units 1 and 2). However the effect of these differences was confounded by other factors. The major changes in tree and crop yields across the sites appeared to result from differences in soil depth. For example in France, the predicted yield from wheat was predicted to decline by 20 kg ha^{-1} per 1 cm decrease in soil depth (Figure 6). Similarly the timber yield of cherry was predicted to decline by 0.31 m^3 ha^{-1} per 1 cm decline in soil depth (Figure 6).

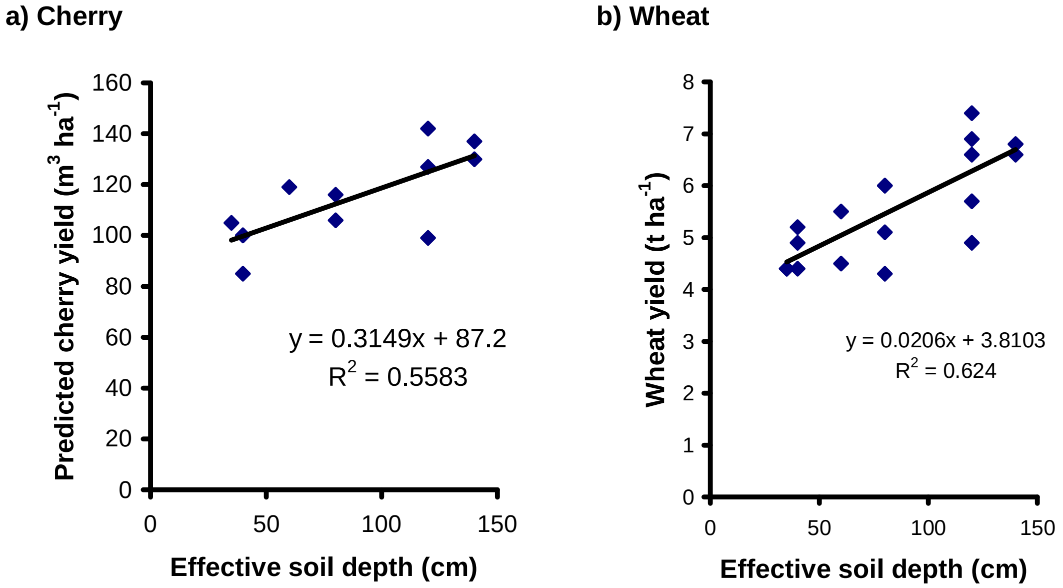

Figure 6 Predicted effect of soil depth (*d*) on the predicted yield (*Y*) monoculture a) wild cherry ($Y = 0.32\ d + 87$; $R^2 = 0.55$) and b) wheat yields ($Y = 0.021\ d + 3.8$; $R^2 = 0.62$) at the Land Units in France

Selection of modelled silvoarable systems

The assumed silvoarable system at each land unit integrated the tree species in the forestry system with the crop rotation used in the arable system. The tree and crop yields from two silvoarable systems (50 and 113 trees ha^{-1}) were then established for each land unit using the Yield-SAFE model. The Yield-SAFE model assumes a uniform distribution of trees and does not take into account rectangularity. However for any tree density there is a range of possible tree spacings. For the purpose of the initial analysis it was assumed that the area cropped was 95% and 90% at densities of 50 and 113 trees ha^{-1} respectively. However in estimating the land equivalent ratio, it is was assumed that the rectangularity should not be greater than about 2:1 and therefore lower proportions of cropped area were assumed (Table 4).

Table 4 Summary of tree densities and proposed orientation and cropped area

Tree density	Original calibration			LER calculations		
	Tree spacing (m)	Crop width (m)	Proportion of area cropped (%)	Tree spacing (m)	Crop width (m)	Proportion of area cropped (%)
113 trees ha^{-1}	22 x 6.3	20	90.0	14 x 6.3	12	85.7
50 trees ha^{-1}	40 x 5	38	95.0	20 x 10	18	90.0

The full set of results from the Yield-SAFE model are presented by Burgess et al. (2005) in Deliverable 6.4. As an example, the results are presented for an oak system, a wild cherry, a walnut and a poplar system (Figure 9).

The Yield-SAFE model predicted different growth patterns for the five tree species. In France, the initial growth of the cherry was generally slow, and hence the level of crop yields tended to be greater than that in the walnut system, where initial tree growth was rapid (Figure 7; Figure 9). Although the poplars showed the fastest growth rate, the relative crop yields over the tree rotation were intermediate because it was assumed that the tree would be harvested after 20 years.

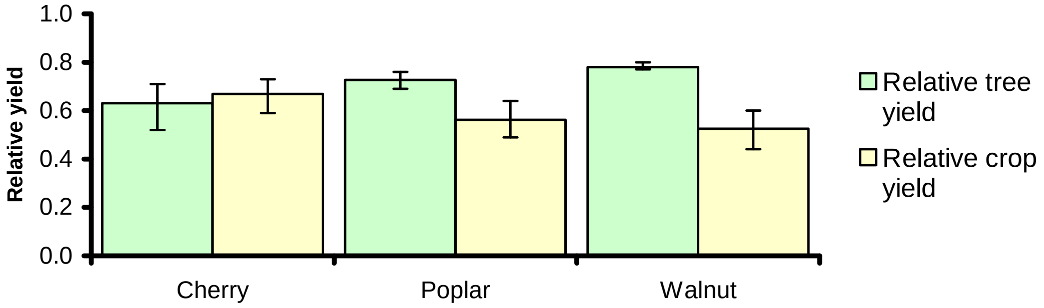

Figure 7 Predicted effects of tree species in a silvoarable system (113 trees ha^{-1}) on the yield of the tree and the crop components relative to a monoculture

In Spain, the relative yield of autumn-planted wheat tended to be greater than that for spring-planted sunflower (Figure 8a). As the trees were evergreen, it is assumed that this is a result of the greater competition experienced by the spring-planted crop for water. Within the silvoarable systems with deciduous trees in France, the difference in the relative yield of the autumn- (i.e. wheat and oilseed) and spring-planted (sunflower and grain maize) crops was greater (Figure 8b). This is because of the reduced shading of the autumn-planted crops, which can be harvested before or soon after the trees have fully unfurled their leaves.

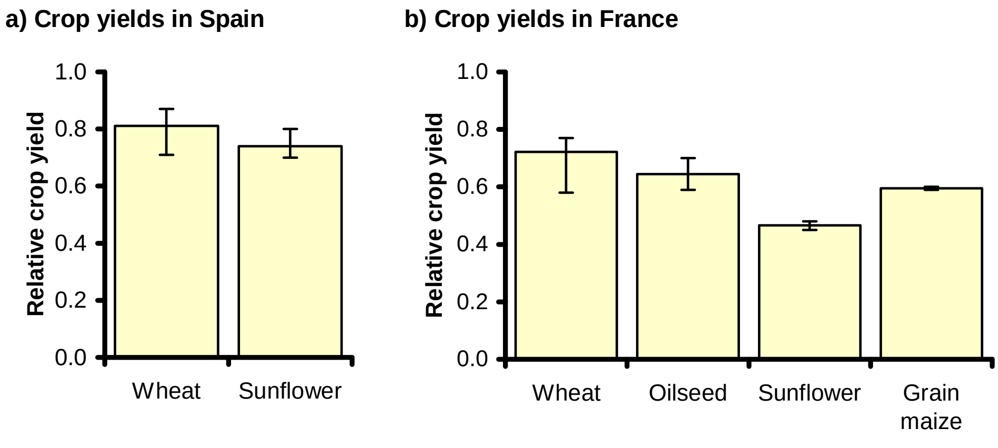

Figure 8 Effect of crop species on the relative crop yield over a complete tree rotation below (a) oak in Spain and (b) below cherry trees in France at 113 trees ha^{-1}.

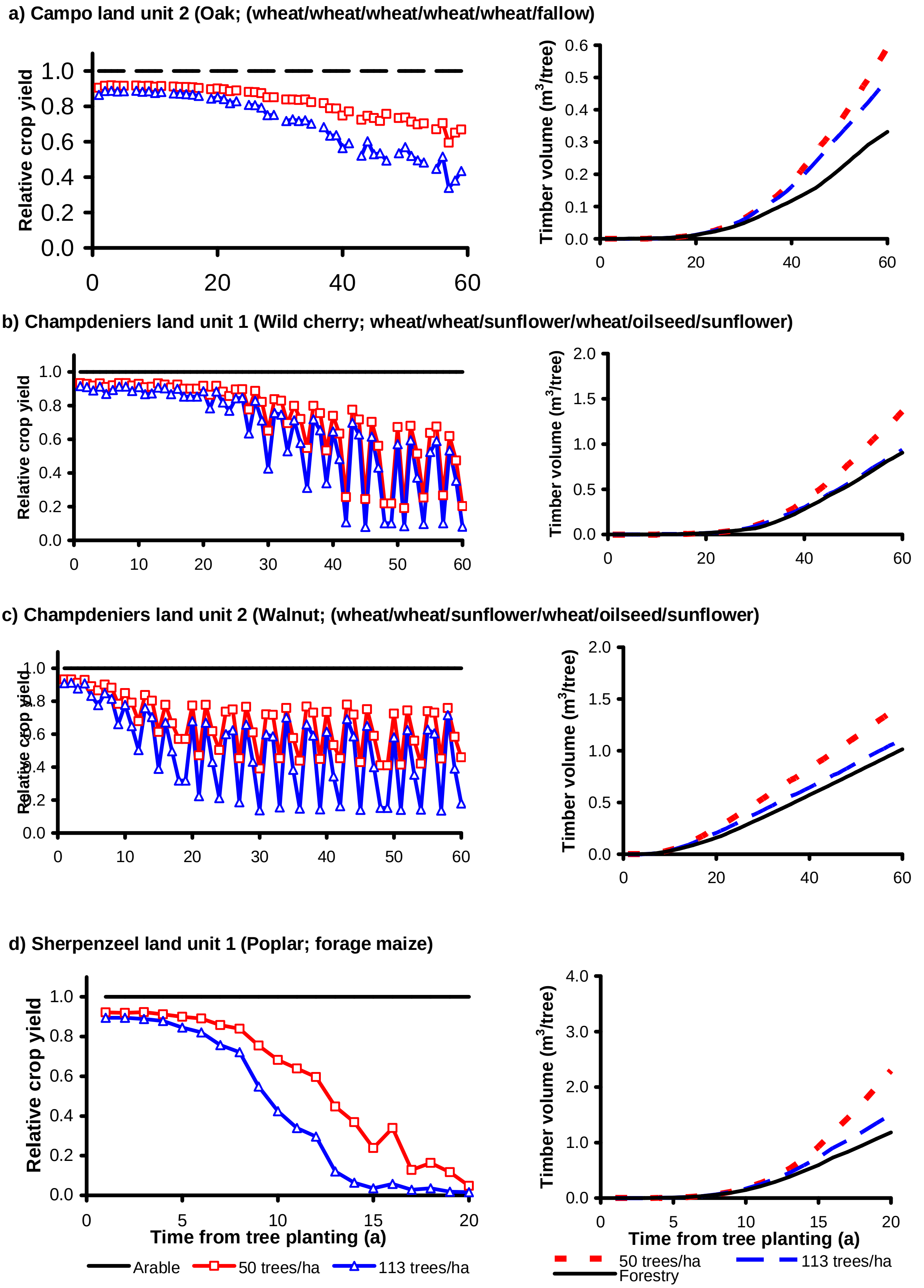

Figure 9 Relative crop yields and the timber volume for (a) an oak, b) a wild cherry, c) a walnut and a d) poplar silvoarable agroforestry system for selected land units

Land equivalent ratios

From the biophysical yields, it was possible to estimate a land equivalent ratio (LER) for each system. This is defined as “the ratio of the area under sole cropping to the area under the agroforestry system, at the same level of management that gives an equal amount of yield” (Ong, 1996). The LER can therefore be expressed as:

$$LER = \frac{Tree\ silvoarable\ yield}{Tree\ monoculture\ yield} + \frac{Crop\ silvoarable\ yield}{Crop\ monoculture\ yield} \qquad \textbf{Equation 1}$$

Because some of the crop rotations contained more than one species, the yield ratio of each crop type was determined separately and then weighted to provide an overall value. The LER for each system was then calculated. Ong (1996) notes that the choice of the denominator or the monoculture yields for the tree and the crop should be the optimal for that site. One of the potential advantages of the Yield-SAFE model is the possibility of determining if this is the case.

Across the 42 land units, the land equivalent ratio was calculated to show a convex pattern, equal to 1 within the forestry and arable systems, and in general values above 1 in the silvoarable treatments. The land equivalent ratio with a density of 113 trees ha^{-1} was greater than that at 50 trees ha^{-1} (Figure 10). The land equivalent ratio for cherry, poplar and walnut also tended to higher than those for the oak and pine (Figure 11).

a) 113 trees per hectare **b) 50 trees per hectare**

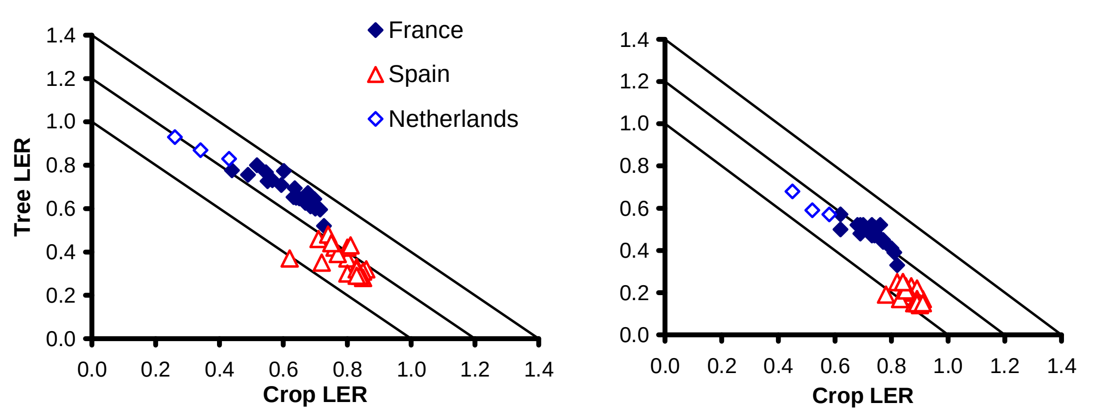

Figure 10 Effect of country of the predicted Land Equivalent Ratio at the 19 Land Units

a) 113 trees per hectare **b) 50 trees per hectare**

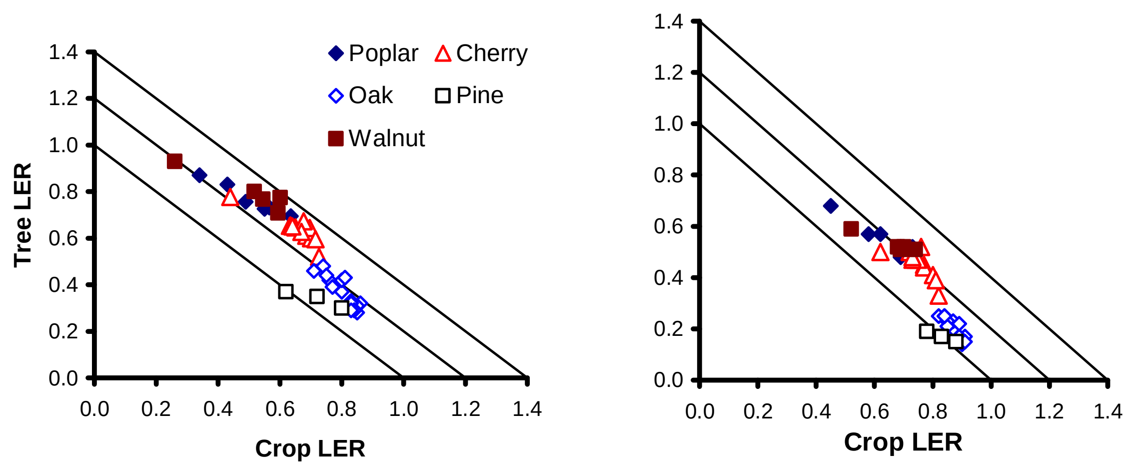

Figure 11 Effect of country of the predicted Land Equivalent Ratio at the 19 Land Units

4. BASIS OF THE ECONOMIC ANALYSIS

Objective of the economic analysis

The aim of the economic analysis was to compare the net returns over a period of years from arable, silvoarable and forestry enterprises, and to express this as a single value. Cost benefit analysis provided a convenient way of making such comparisons through the comparison of aggregated revenue and costs, and the expression of these in terms of a net present value.

In Europe, arable farms are typically composed of a range of "enterprises", such as wheat, barley and oilseed rape production, which generate revenue (*R*; units: € ha^{-1}) and costs expressed on a per unit area basis. Those costs which are directly related to the area of an enterprise, such as the costs of fertilizer, seed and sprays in an arable enterprise, are termed variable costs (*V*; units: € ha^{-1}) (Nix, 1999; Ministry of Agriculture, Fisheries and Food, 1983). For annual-crop enterprises, the net value of enterprises to the farm can be compared on the basis of their gross margins (units: € ha^{-1}) (revenue minus variable costs).

Gross margin = $R - V$ **Equation 2**

Two other costs associated with most enterprises are labour and machinery. Such costs can be termed 'assignable fixed costs' (*A*; units: € ha^{-1}) in that they are "fixed" over short time periods but they can nevertheless be assigned to specific enterprises. Because agroforestry systems exist over a long time period and because labour and machinery costs are typically included in analyses of forestry systems, economic comparisons of agricultural, agroforestry and forestry systems are typically undertaken on the basis of their net margins (units: € ha^{-1}) (revenue minus variable costs minus assignable fixed costs) (Equation 2) (Willis et al. 1993; Burgess et al. 1999; 2000).

Net margin = $R - V - A$ **Equation 3**

Whereas an economic comparison of arable crops can be undertaken on an annual basis using the gross and net margin, the economics of a forestry plantation need to be considered over the rotation of the tree crop which may last many years. Within the model, the aggregation of the benefits and costs from each enterprise over time was based on discounted cost benefit analysis (Faustmann, 1849). Discounting is a method that allows the user to directly compare money realised at different periods of time. Most people have a preference for immediate income, because of inflation, the opportunity cost of money and flexibility. Hence a net "present" value of future benefits and costs was determined by dividing them by a pre-determined discount rate (*i*; typically a value between 0.0 and 0.1). At a plot scale, the net present value (*NPV*; units: € ha^{-1}) of an arable, forestry or silvoarable enterprise can therefore be expressed as (Equation 3):

$$NPV = \sum_{t=0}^{t=T} \frac{(R_t - V_t - A_t)}{(1+i)^t}$$ **Equation 4**

Where: *NPV* is the net present value of the arable, forestry or silvoarable enterprise within a unit (€ ha^{-1}), R_t is the revenue from the enterprise (including subsidies) in year *t* (€ ha^{-1}), V_t is the variable costs in year *t* (€ ha^{-1}), A_t is the assignable fixed costs in year *t* (€ ha^{-1}), *t* is the time horizon (years), and *i* is the discount rate.

In order to compare systems with different rotation lengths, it is possible to calculate an infinite net present value. This is defined as today's value of an infinite system in which each replication has a rotation of *n* years. The infinite *NPV* was defined as:

$$Infinite\,NPV = NPV \frac{(1+i)^n}{(1+i)^n - 1}$$ **Equation 5**

The infinite net present value can also be expressed as an equivalent annual value (*EAV*). This is the infinite net present value converted to an annual payment at the end of year for the life of the investment. It is calculated at an appropriate discount rate using the following formula:

EAV = infinite $NPV \times i$ **Equation 6**

Use of the Farm-SAFE model

The analysis of the net present values and the equivalent annual values were determined using the Farm-SAFE model developed as part of the EU-SAFE project. The model is a spreadsheet-based model comprising numerous worksheets. A full description of the model is provided by Graves et al. (2003). The outline structure of the model is showed in Figure 12.

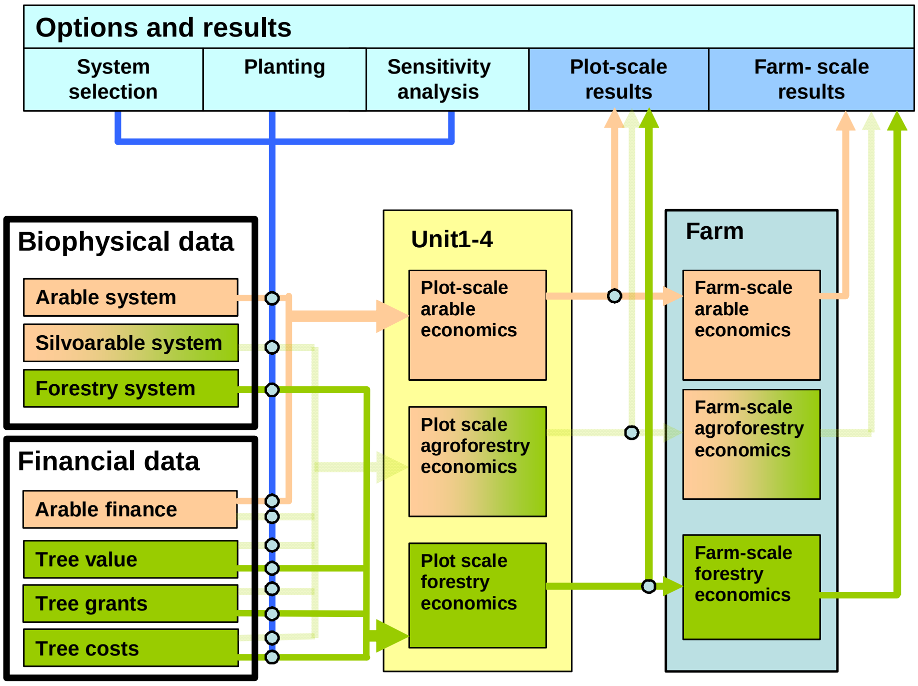

Figure 12 Outline of the Farm-SAFE model

Financial data for the crop components

The financial data for the crop components were obtained from the Farm Accountancy Data Network or ROSACE (Table 5). For the 2004 grant scenario, it was assumed that direct payments on the arable area were dependent on the crop. For the 2005 scenario, a single Farm Payment was assumed for each land type (Table 6).

Financial data for the tree components

The financial data for the tree components comprise the timber revenue, the costs of woodland establishment and management and grants

Timber revenue

Values for the long-term relationship between the standing value of the tree and the average tree volume were established for each examined species in each country (Table 7). The predicted value of oak in Spain was estimated to be worth 17 € m^{-3} irrespective of the timber size. By contrast, the value of clear-felled walnut in France was estimated to be worth 40 € m^{-3} at a volume of 0.1 m^3, to 900 € m^{-3} at a volume of 1 m^3. There were significant differences in the perceived value of the timber between the different regions. For example the value of walnut timber in the Netherlands, where there were no established mills, was estimated to be only 2% of that for 1 m^3 of timber in France.

Table 5 Values of crop revenue, grants and costs used in the analysis

		Landscape test site	Grain price (€ t^{-1})	Straw price (€ t^{-1})	Variable costs (€ ha^{-1})	Non-labour costs (€ ha^{-1})	Labour (€ hr^{-1})	(hr ha^{-1})
Wheat	Spain	All sites	142	0	189	33	7.8	8.5
	France	Champdeniers	110	0	302	252	7.8	6.0
		Chateauroux	110	0	297	223	7.8	4.4
		Fussy	110	0	278	315	7.8	7.0
		Sancerre	110	0	289	210	7.8	6.0
		Champlitte	102	30	278	315	7.8	7.0
		Dampierre	102	30	394	300	7.8	7.0
		Vitrey	110	30	278	300	7.8	7.0
	NL	Bentelo	130	50	457	144	13.0	9.6
Sunflower	Spain	All sites	231	na	45	41	7.8	9.1
	France	Champdeniers	280	na	262	252	7.8	5.5
		Chateauroux	280	na	165	223	7.8	5.0
		Sancerre	280	na	214	210	7.8	5.5
Oilseed	France	Champdeniers	220	na	391	252	7.8	5.5
		Chateauroux	220	na	318	223	7.8	5.0
		Fussy	215	na	302	207	7.8	5.5
		Sancerre	220	na	294	210	7.8	5.5
		Champlitte	220	na	390	315	7.8	5.5
		Vitrey	220	na	390	329	7.7	5.5
Grain maize	France	Champlitte	85	na	434	315	7.8	7.0
		Dampierre	88	na	460	300	7.8	7.0
		Vitrey	85	na	322	329	7.8	7.0
Forage maize	NL	All sites	112	na	479	611	13.0	5.6

Table 6 Summary of the arable grants (€ ha^{-1}) in each landscape test site

Country	Landscape test site	2004 arable area payments				2005
		Wheat	Sunflower	Oilseed	Maize	Single Farm Payment
Spain	Alcala	129	176	na	na	330
	Torrijos	129	176	na	na	136
	Ocaña	129	na	na	na	138
	Almonacid	129	176	na	na	149
	Cardenosa	129	176	na	na	116
	Fontiveros	129	176	na	na	149
	Olmedo	129	176	na	na	144
	Campo	129	na	na	na	169
	Paramo	129	176	na	na	193
France	Champdeniers	345	361	361	na	353
	Chateauroux	340	360	360	na	349
	Fussy	343	na	360	na	351
	Sancerre	339	359	359	na	346
	Champlitte	328	na	348	348	333
	Dampierre	344	364	364	na	329
	Vitrey	324	na	344	324	330
NL	Balkbrugg	350	na	512	400	586
	Bentelo	350	na	512	400	353
	Scherpenzeel	350	na	512	400	400

Table 7 Assumed value of standing timber at each location (€ m^{-3})

Size of wood (m^3)	Spain		France					Netherlands	
	Oak	Pine	Walnut		Cherry		Poplar	Walnut	Poplar
			final	thin	final	thin			
Firewood	17	8	10	10	10	10	10	10	18
0.1	17	8	40	20	10	10	7	18	19
0.5	17	8	450	150	150	22	28	18	29
1	17	19	900	400	350	65	41	18	40
2	17	19	1100	1100	380	175	53	41	62
4	17	19	1300	1300	380	200	55	41	97

Costs of the tree component

The costs associated with the forestry system and the tree component of the silvoarable systems were based on numerous sources. These are reported in Table 8 and Table 9. A major cost of the forestry systems in the Netherlands was the loss of a location for applying manure from the assumed livestock enterprise on the farm and the need to find alternative arrangements (408 € $ha^{-1}a^{-1}$).

Table 8 Summary of costs associated with the tree component of the systems

		Spain				The Netherlands	
Pricing system		Oak	Oak	Pinus	Pinus	Walnut	Poplar
Minimum tree density		400	50	600	50	50	50
Maximum tree density		800	113	800	113	113	204
Establishment							
Plant	(€ $tree^{-1}$)	0.36	0.36	0.76	0.76	5.00	1.30
Tree protection	(€ $tree^{-1}$)	0.5	0.5	0.5	0.5	0.29	0.29
Ground preparation	(hr ha^{-1})	5.2-7.0	1.2-1.8	6.3-7.0	1.2-1.8	6.05	6.05
Full weeding	(hr ha^{-1})	-	-	-	-	6.60	6.60
Marking out	(hr ha^{-1})	-	-	-	-	1.87	1.87
Planting trees	(min $tree^{-1}$)	2.7	2.7	2.7	2.7	3.18	3.18
Tree protection	(min $tree^{-1}$)	2.7	2.7	2.7	2.7	0.78	0.78
Localised weeding	(min $tree^{-1}$)	-	-	-	-	2.76	2.76
Maintenance							
Weeding							
Year of first weeding	(year)	1	1	1	1	2	2
Year of last weeding	(years)	3	5	3	5	2	2
Annual weeding	(min $tree^{-1}$)	0.06-0.12	0.53	0.06-0.08	0.53	1.09	1.09
Annual herbicide	(€ $tree^{-1}$)	-	0.14	-	0.14	0.81	0.81
Grass sward establishment							
First year	(year)	12	-	12	-	1	1
Final year	(year)					60	20
Labour required	(hr ha^{-1})	3.88	-	3.88	-	3.2	3.2
Establishment materials	(€ ha^{-1})					347.5	347.5
Maintenance labour	(hr ha^{-1} a^{-1})					2.4	2.4
Maintenance materials	(€ ha^{-1} a^{-1})					83.2	83.2
Epicormics							
Year of 1^{st} removal	(year)						6
Year of last removal	(years)						11
Labour	(min $tree^{-1}$)						1.2
Pruning							
First prune							
Height	(m)	1.8	1.8	3.0	3.0	1.0	1.0
Time	(min $tree^{-1}$)	5.4	5.4	17.0	17.0	6.6	1.4
Last prune							
Height	(m)	5.6	5.6	8.0	8.0	6.5	8.0
Time required	(min $tree^{-1}$)	47.0	47.0	92.0	92.0	12.6	3.3
Removal of prunings	(min $tree^{-1}$)					1.2	1.2
Administration							
Administrative cost	(€ ha^{-1})					19.0	19.0
Insurance management	(€ ha^{-1})					3.0	3.0
Thinning							
Marking up & labour	(min $tree^{-1}$)	2		3.3		6.8	10.1
Removal of tree	(min $tree^{-1}$)					3.8	2.2
Clear felling							
Labour	(min $tree^{-1}$)	23	23	12	12	5.6	9.3
Other costs							
First year	(year)					1	1
Last year	(year)					60	20
Amount	(€ ha^{-1})					408	408

Note: per hectare costs are per tree area

Table 9 Costs associated with the tree component of the systems in France

		France					
Pricing system		Cherry	Cherry	Walnut	Walnut	Poplar	Poplar
Minimum tree density		816	50	210	50	204	50
Maximum tree density			113		113		113
Establishment							
Plant	(€ tree^{-1})	0.5	1	6	6	4	4
Tree protection	(€ tree^{-1})	0.5	1.5	0.5	1.5	0.5	0.5
Ground preparation	(hr ha^{-1})	6.5	4	6.5	4	16	12
Full weeding	(hr ha^{-1})	1.5	0.5	1.5	0.5	1.5	0.5
Marking out	(hr ha^{-1})	4	7	4	7	4	7
Planting trees	(min tree^{-1})	2	2	2	2	2	2
Tree protection	(min tree^{-1})	1	2	1	2	1	2
Localised weeding	(min tree^{-1})	0.5	0.5	0.5	0.5	0.5	0.5
Maintenance							
Weeding							
Year of first weeding	(year)	1	1	1	1	1	1
Year of last weeding	(years)	3	3	3	3	3	3
Annual weeding	(min tree^{-1})	0.5	0.5	0.5	0.5	0.5	0.5
Annual herbicide	(€ tree^{-1})	0.14	0.14	0.14	0.14	0.14	0.14
Grass sward establishment							
First year	(year)	0	0	0	0	0	0
Final year	(year)	12		15		6	
Labour required	(hr ha^{-1})						
Establishment materials	(€ ha^{-1})						
Maintenance labour	(hr ha^{-1} a^{-1})	4.0	2.0	4.0	2.0	4.0	2.0
Maintenance materials	(€ ha^{-1} a^{-1})	90.0	30.0	90.0	30.0	90.0	30.0
Epicormics							
Year of 1st removal	(year)						
Year of last removal	(years)						
Labour	(min tree^{-1})						
Pruning							
First prune							
Height	(m)	1.0	1.0	1.0	1.0	1.5	1.5
Time	(min tree^{-1})	0.2	1.0	0.2	1.0	1.0	1.0
Last prune							
Height	(m)	6.0	6.0	4.5	4.5	8.0	8.0
Time required	(min tree^{-1})	6.4	6.4	7.0	7.0	10.0	10.0
Removal of prunings	(min tree^{-1})	4.0	4.0	4.0	4.0	4.0	4.0
Administration							
Administrative cost	(€ ha^{-1})						
Insurance management	(€ ha^{-1})	20.0	20.0	20.0	20.0	20.0	20.0
Thinning							
Marking up & labour	(min tree^{-1})	7.0	7.0	7.0	7.0	7.0	7.0
Removal of tree	(min tree^{-1})	5.0	5.0	5.0	5.0	5.0	5.0
Clear felling							
Labour	(min tree^{-1})	4.0	4.0	4.0	4.0	4.0	4.0
Other costs							
First year	(year)	51	1	51	1	11	1
Last year	(year)	60	60	60	60	60	60
Amount	(€ ha^{-1})	30-39	44-58	30-39	44-58	30-39	44-58

Note: per hectare costs are per tree area

Tree-related grants-forestry systems

The woodland grants tended to be based on a planting grant and a compensation payment. In the 2004 grant scenario and dependent on the tree species, Spanish farmers could receive a woodland planting grant of 849 to 1593 € ha^{-1} (Table 10). Farmers could also receive a compensation grant of 225-325 € ha^{-1} a^{-1} over the first 20 years and a maintenance grant (180-288 € ha^{-1} a^{-1}) for the first five years. In the Poitou Charentes and Centre regions of France, the woodland planting grant was assumed to cover 50% of the costs incurred over the first four years. Farmers were also eligible to a compensation grant of 240-300 € ha^{-1} over 10 (walnut and cherry systems) or 7 years (poplar). In the French region of Franche Comté, where there is already a substantial area of woodland, there were no woodland grants. In the Netherlands, a woodland planting grant of 95% of costs was available up to a maximum of 1500 € ha^{-1}. Farmers were also eligible to a planting grant of 240 € ha^{-1} a^{-1} for five years and a maintenance payment of 545 € ha^{-1} a^{-1} for the first 18 years. In the 2005 scenario, it was assumed that the planting grant at each site is on a 50% cost basis. In the Netherlands, it was assumed that the maintenance grant would only be payable for ten years at the rate of €500 ha^{-1} a^{-1}.

Local experts were used to determine the status of agroforestry grants related to the tree component in 2004. In Spain and the Netherlands, the experience was that no grants were available for the tree component of the agroforestry system. However a woodland planting grant was available in the Poitou Charentes and Centre regions of France (Table 10). In the 2005 grant scenario, it was anticipated that 50% of the first four years of the tree-related costs would be payable in each region, except Franche Comté in France.

Table 10 Forestry grants in a) the 2004 and b) the 2005 scenario at each landscape test site

Country	Region	System	Planting		Compensation		Maintenance	
			Year	Grant (€ ha^{-1})	Year	Grant (€ ha^{-1})	Year	Grant (€ ha^{-1})
a) Forestry grants in the 2004 scenario								
Spain	Andalucia	Oak (400 ha^{-1})	1	1149	1-20	225	1-5	240
	Castilla La Mancha	Oak (600 ha^{-1})	1	1593	1-20	325	1-5	258
		Pine (800 ha^{-1})	1	1262	1-20	312	1-5	180
	Castille-Leon	Oak (800 ha^{-1})	1	1017	1-20	320	1-5	288
		Pine (800 ha^{-1})	1	849	1-20	313	1-5	180
France	Poitou Charentes	Broadleaf	1-4	50% costs	1-10[b]	300	0	0
	Centre	Broadleaf	1-4	50% costs	1-10[b]	240	0	0
	Franche Comté	Broadleaf		0		0	0	0
Netherlands		Broadleaf	1	1500[a]	1-5	100	1-18	545
b) Forestry grants in the 2005 scenario								
Spain	Andalucia	Oak (400 ha^{-1})	1	50% costs	1-10	225	1-5	240
	Castilla La Mancha	Oak (600 ha^{-1})	1	50% costs	1-10	325	1-5	258
		Pine (800 ha^{-1})	1	50% costs	1-10	312	1-5	180
	Castille-Leon	Oak (800 ha^{-1})	1	50% costs	1-10	320	1-5	288
		Pine (800 ha^{-1})	1	50% costs	1-10	313	1-5	180
France	Poitou Charentes	Broadleaf	1-4	50% costs	1-10[b]	300	0	0
	Centre	Broadleaf	1-4	50% costs	1-10[b]	240	0	0
	Franche Comté	Broadleaf		0		0	0	0
Netherlands		Broadleaf	1	50% costs	1-5	100	1-10	500
c) Tree-related agroforestry grants in the 2004 scenario								
Spain	All departments	All systems		0		0		0
France	Poitou Charentes	Broadleaf	1-4	50% costs		0		0
	Centre	Broadleaf	1-4	50% costs		0		0
	Franche Comté	Broadleaf		0		0		0
Netherlands		Broadleaf		0		0		0
d) Tree-related agroforestry grants in the 2005 scenario								
Spain	All departments	All systems	1-4	50% costs		0		0
France	Poitou Charentes	Broadleaf	1-4	50% costs		0		0
	Centre	Broadleaf	1-4	50% costs		0		0
	Franche Comté	Broadleaf		0		0		0
Netherlands		Broadleaf	1-4	50% costs		0		0

[a]: 95% of total costs not exceeding €1500 ha^{-1}

[b]: Compensation payments for poplar in France, where paid, are only paid for 7 years.

5. PLOT-SCALE ECONOMIC RESULTS

The Farm-SAFE model was first used to determine the actual net present value (assumed discount rate of 0%) for each land unit over the length of the tree rotation (Appendix A: Table 17). From these results it was also possible to determine the predicted level of grant that would be accrued by each system during the length of the tree rotation (Appendix A: Table 18). The model was also used to calculate the equivalent annual value (at a discount rate of 4%) for each system with the 2004 grant scenario and for the situation with no grants (Table 11). For this plot-scale analysis, the optimum rotation for the silvoarable system with no-grants system was allowed to be different from that for the grant scenario (Table 17).

Table 11 Equivalent annual value (€ ha^{-1} a^{-1}) at 4% discount rate, with the no grant and 2004 grant scenarios, assuming optimised rotations in the silvoarable system

Species	Site	No grant				2004 scenario		
		Forest	Arable	SAF	Crop (a)	Forest	Arable	SAF
Oak	Alcala 1	-57	99	67	*28*	184	191	125
	Alcala 2	-50	47	30	*28*	190	139	97
	Torrijos 1	-36	-13	-5	*7*	290	56	23
	Torrijos 2	-37	-39	-9	*6*	289	53	11
	Ocaña 1	-37	-32	-11	*6*	289	59	29
	Almonacid 1	-40	-20	-13	*7*	286	48	19
	Almonacid 2	-46	18	0	*13*	280	172	108
	Cardenosa 1	-59	113	98	*60*	245	215	172
	Cardenosa 2	-55	115	98	*60*	248	218	169
	Fontiveros 1	-56	100	72	*32*	248	210	162
	Olmedo 2	-54	58	38	*30*	250	149	105
	Olmedo 3	-55	8	-9	*9*	248	115	62
	Campo 2	-57	-54	-25	*5*	247	61	8
	Paramo 1	-51	196	176	*60*	253	315	258
	Paramo 2	-51	196	176	*60*	253	315	258
	Paramo 3	-50	195	175	*60*	253	314	257
Pine	Fontiveros 2	-80	100	57	*32*	190	210	129
	Olmedo 1	-80	7	-15	*9*	190	115	34
	Campo 1	-80	-73	-34	*5*	190	30	-9
Cherry	Champdeniers 1	-111	14	68	*19*	63	380	353
	Chateauroux 2	-152	35	40	*22*	0	398	353
	Chateauroux 4	-153	31	37	*22*	-2	395	349
	Fussy 1	-166	114	79	*32*	-14	479	399
	Fussy 3	-90	317	277	*35*	62	682	607
	Sancerre 1	-155	18	15	*12*	-3	380	327
	Sancerre 3	-59	249	262	*35*	92	610	580
	Sancerre 4	-146	24	31	*11*	6	387	341
	Champlitte 1	-73	127	187	*24*	-73	474	435
	Dampierre 1	-79	48	120	*21*	-79	412	408
	Dampierre 2	-144	-207	-37	*5*	-144	156	131
	Vitrey 1	-108	-61	16	*5*	-108	283	256
Walnut	Champdeniers 2	227	91	296	*12*	394	458	535
	Chateauroux 1	182	154	287	*13*	327	517	578
	Chateauroux 3	231	269	354	*22*	376	629	691
	Champlitte 2	224	-166	227	*5*	224	178	296
Poplar	Fussy 2	232	219	318	*13*	417	581	634
	Sancerre 2	414	271	508	*12*	599	632	803
	Dampierre 3	309	-132	270	*5*	309	236	401
	Vitrey 2	262	-128	250	*5*	262	215	358
Walnut	Bentelo	-1063	248	-161	*12*	-659	646	-16
Poplar	Balkbrugg	-521	187	216	*7*	151	603	356
	Sherpenzeel	-756	131	140	*9*	-84	547	310

Profitability with no grants

In the no grant scenario, the equivalent annual value (*EAV)* (at 4% discount rate) of the forestry systems at each site in Spain and the Netherlands was negative (Figure 13). The *EAV* of each wild cherry forestry system in France was also negative. The only forestry systems showing a positive return were the walnut and poplar systems in France. In Spain, the *EAV* of the arable system was positive in Alcala, Cardenosa, Fontiveros, Olmedo and Paramo, and negative in Torrijos, Ocaña and Campo. In France, the profitability of the arable system was positive in Poitou Charentes and Centre, but negative in the majority of sites in the Franche Comté region (i.e. at Dampierre and Vitrey). In the Netherlands the arable system showed positive returns without grants.

There were no sites in Spain where silvoarable agroforestry (without grants) showed a positive return that was greater than the arable system. By contrast in France, silvoarable agroforestry with walnut in each of the three regions, agroforestry with poplar in the Centre region, and agroforestry with cherry in the Poitou Charentes and the Franche Comté regions were predicted to be more profitable (4% discount rate) than the arable and forestry systems. In the Netherlands, the poplar silvoarable systems were predicted to have a marginally greater *EAV* (140-216 € ha^{-1} a^{-1}) than that (131-187 € ha^{-1} a^{-1}) for the arable system. However the walnut silvoarable system was unprofitable because of the relatively low value of walnut timber in the Netherlands.

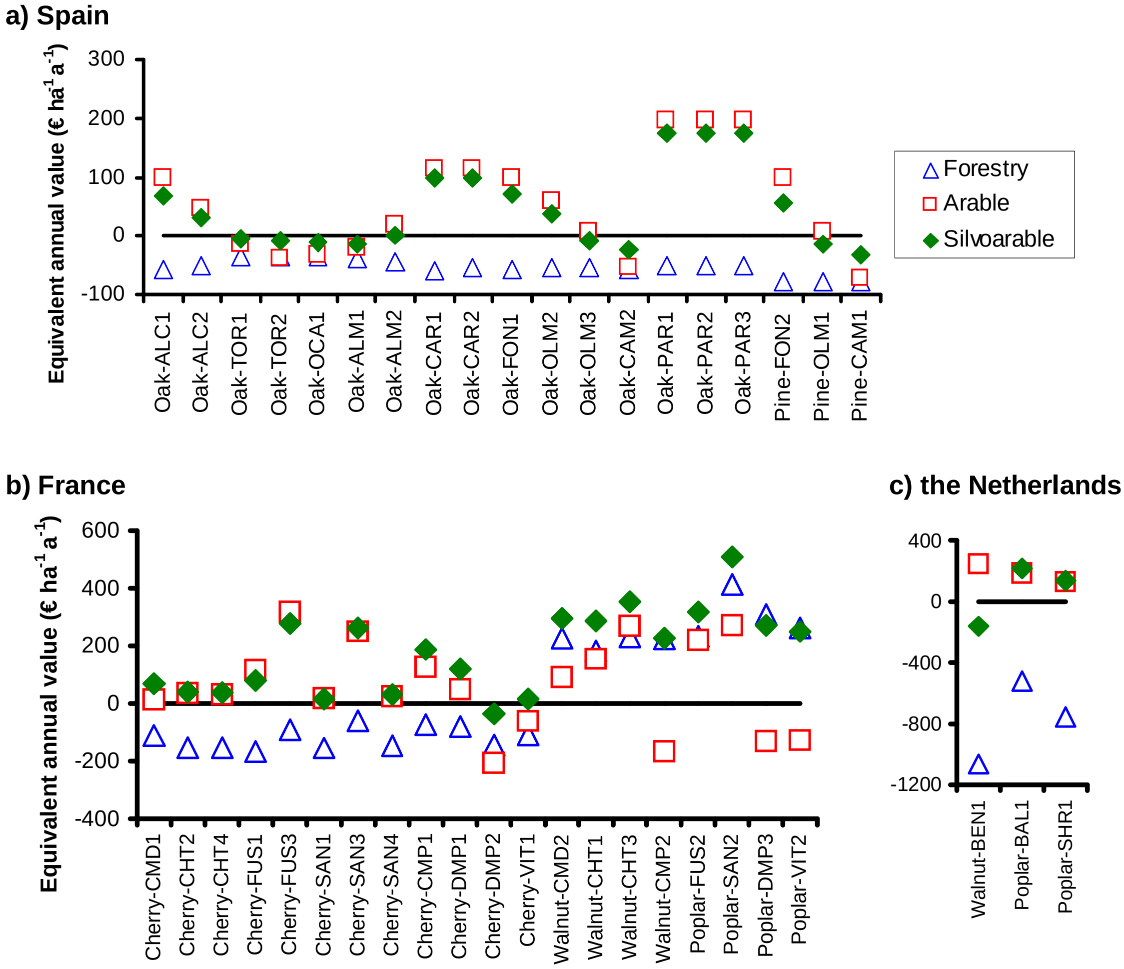

Figure 13 Equivalent annual value (discount rate of 4%) without grants of the arable, forestry and silvoarable (113 trees ha^{-1}) system in a) Spain, b) France and c) the Netherlands

Value of grants with the 2004 grant scenario

In Spain, the predicted level (6860-9380 € ha^{-1}) of forestry grant, where available, was greater than that (3870-8770 € ha^{-1}) predicted for the arable systems (Figure 14). At each site, the lowest level of grant (1380-4080 € ha^{-1}) was predicted for the silvoarable system.

In the Poitou Charentes and Centre regions of France, the predicted level of grant available for the arable system, predicted forward over 60 years based on 2004 levels, was at least five-times available for forestry (Figure 14). The level of grant for the silvoarable systems in these regions was broadly similar to, but still less than, that for arable agriculture. At Champlitte, Dampierre and Vitrey in the Franche Comté region, there were no forestry grants and hence the greatest level of support was for arable agriculture. The predicted level of arable grants for the poplar system was low because a 20 year, rather than a 60 year, time period was assumed.

In the Netherlands, the support for forestry was similar for the walnut and poplar systems, and that for agriculture was dependent on the assumed rotation of the tree species. In each case the support for silvoarable agroforestry was less than for forestry and arable agriculture.

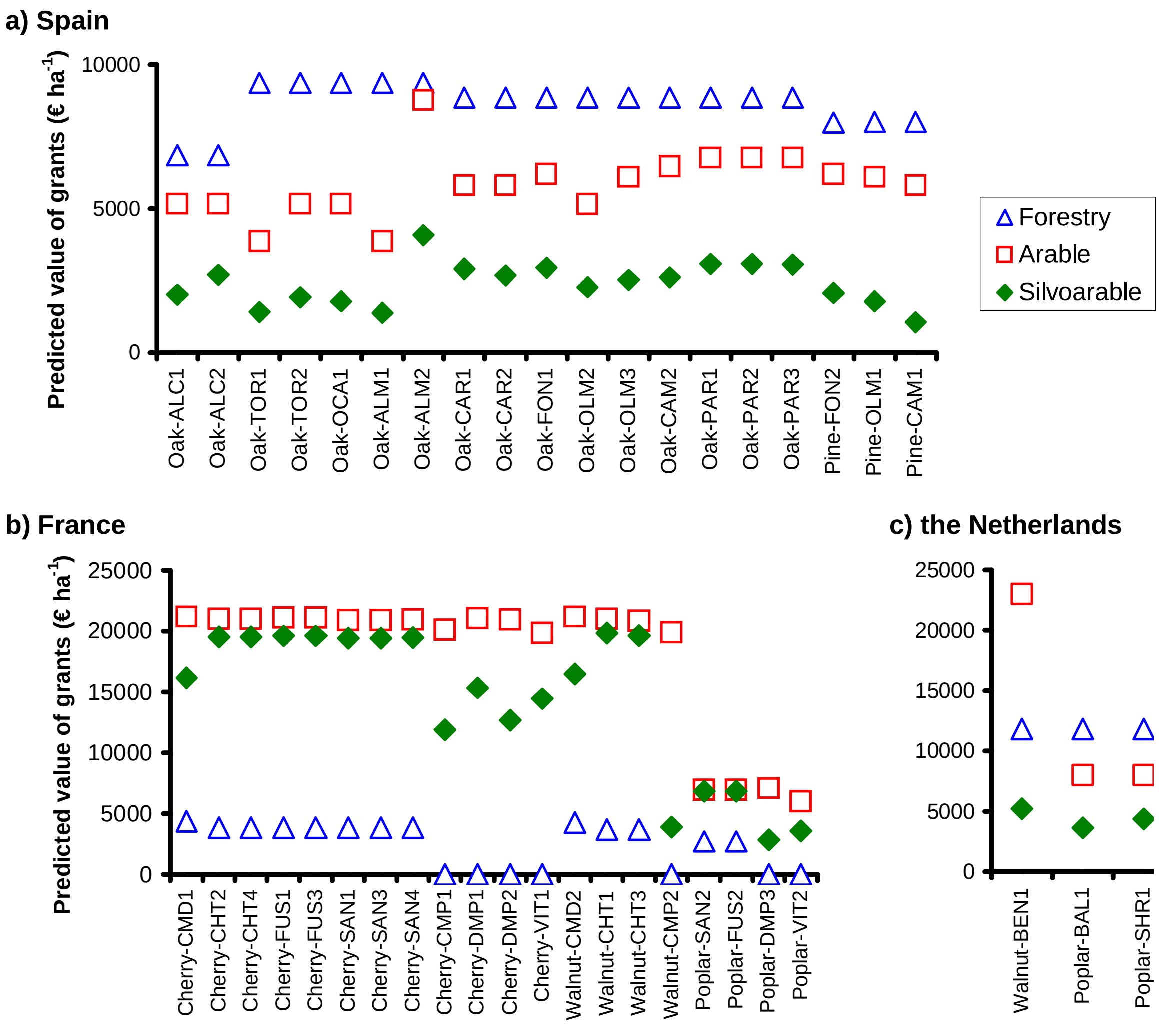

Figure 14 Predicted actual value of grants (2004 grant scenario) for the forestry, arable and silvoarable (113 trees ha^{-1}) system in a) Spain and b) France and c) the Netherlands

Equivalent annual value with the 2004 grant scenario

Under the 2004 grant regime, in Spain and the Netherlands, there were no land units where the 113 tree ha^{-1} silvoarable system had a higher equivalent annual value (at a 4% discount rate) than both the forestry and the agricultural system (Figure 15).

In France, at those sites where the chosen tree species was cherry, the arable system was predicted to be more profitable than both the forestry and the silvoarable system. However it is apparent that silvoarable agroforestry offers the most profitable means of establishing cherry trees at these sites. By contrast, both the poplar and the walnut systems in France produced a greater return than both the forestry and the arable system.

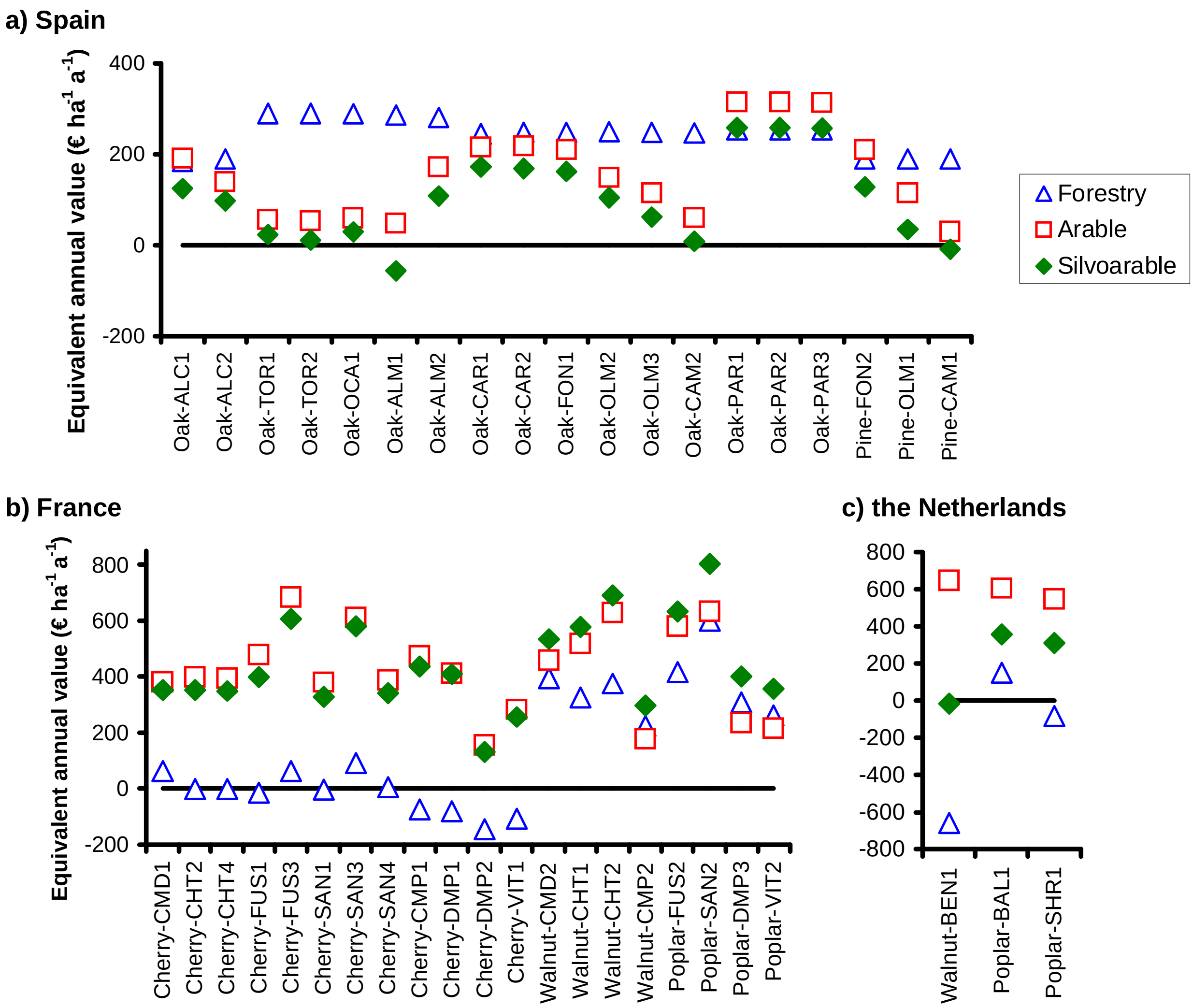

Figure 15 Equivalent annual value (4% discount rate) of the arable, forestry and silvoarable (113 trees ha^{-1}) system in a) Spain and b) France and c) the Netherlands, assuming the 2004 grant regime.

Value of grants and equivalent annual value with the 2005 grant scenario

Four grant scenarios termed the "2005 grant scenario" were determined to determine the relative profitability of silvoarable agroforestry following the reforms to the Common Agricultural Policy agreed in September 2003 (Table 12). The grant scenarios for the forestry system and the tree component of the silvoarable system are described in Table 10. The arable system and the arable component of the silvoarable system were assumed to be eligible for the appropriate level of a single farm payment.

Table 12 Summary of the four 2005 grant scenarios

Grant scenario	Description	Arable payment	Tree payment
1.1	% arable; 0 tree	Cropped area	None
1.2	full arable; 0 tree	Total area	None
2.1	% arable; full tree	Cropped area	Specified level
2.2	full arable; full tree	Total area	Specified level

Under the 2005 grant regime, in Spain the profitability of the arable systems at Alcala and Paramo were predicted to increase because of the assumed value of the new single farm payment were particularly high at these sites (Table 6; Figure 16). However at the other Spanish sites and in France and the Netherlands, the *EAV* of each system was generally similar to that for the 2004 grant scenario. The effect of the different 2005 grant scenarios on the predicted *EAV* was relatively small. Full details are provided in Table 20.

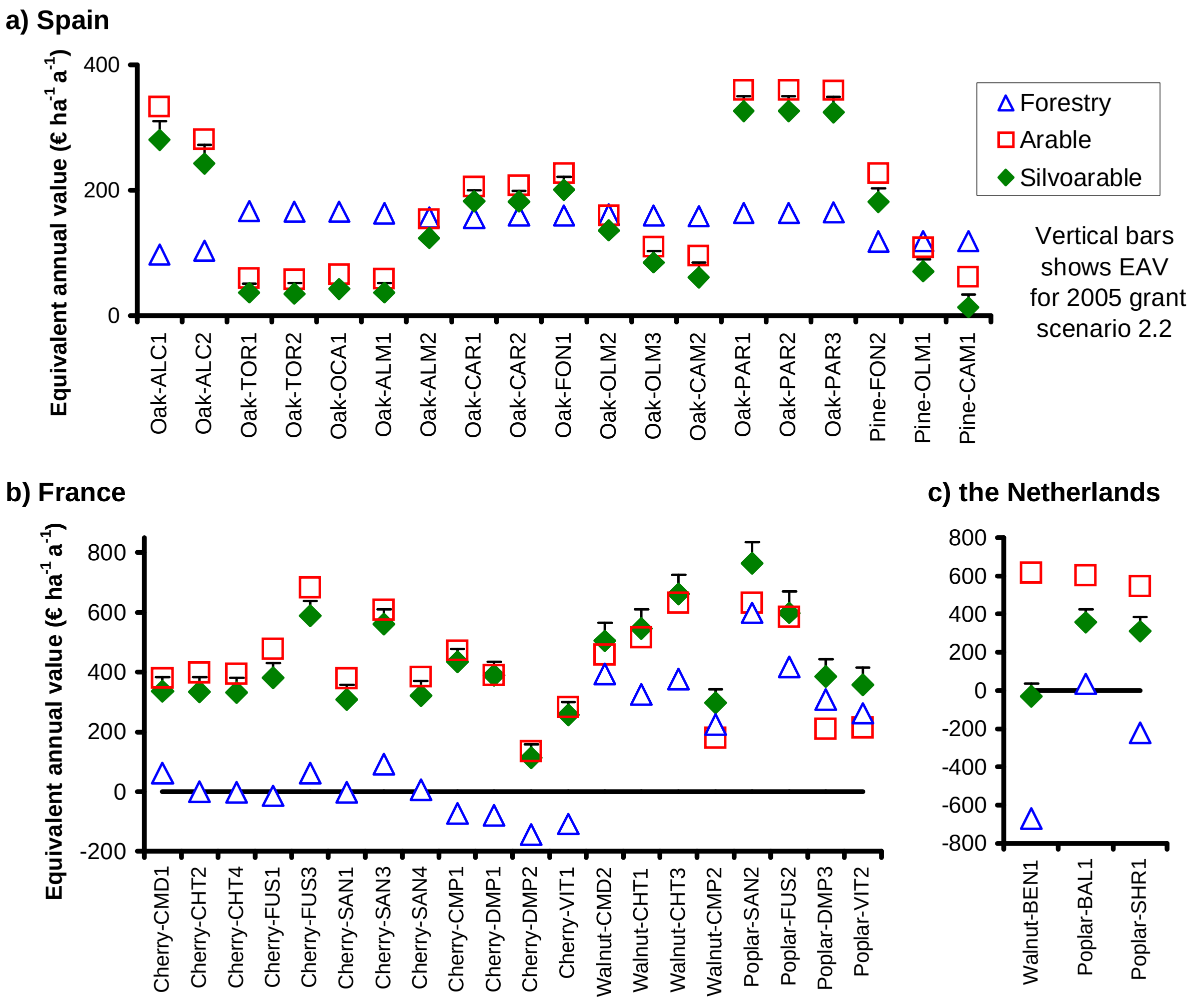

Figure 16 Equivalent annual value (4% discount rate) of a forestry, arable, and silvoarable (113 tree ha^{-1}) system in a) Spain and b) France and c) the Netherlands, assuming the 2005 grant scenario 1.1

6. FARM-SCALE FEASIBILITY

Using the Farm-SAFE model, the plot-scale results for each land unit were combined and weighted according to their area within the specified hypothetical farms (Graves et al. 2005). The fixed costs for each farm were derived for Spain and the Netherlands from the Farm Accountancy Data Network, and for France from ROSACE (Table 13).

Table 13 Area of each land unit, the fixed costs and the gross margin from any other enterprise for the hypothetical farm at each landscape test site

Country	Landscape test site	Total area (ha)	Unit 1 (ha)	Unit 2 (ha)	Unit 3 (ha)	Unit 4 (ha)	Fixed costs (€ farm^{-1})	Other net margins (€ farm^{-1})
Spain	Alcala	73	58	15	0	0	1910	0
	Torrijos	66	10	56	0	0	2345	0
	Ocaña	66	66	0	0	0	2345	0
	Almonacid	66	59	7	0	0	2345	0
	Cardenosa	58	23	35	0	0	2650	0
	Fontiveros	58	49	9	0	0	2650	0
	Olmedo	57	5	34	18	0	2650	0
	Campo	58	44	14	0	0	2650	0
	Paramo	59	4	34	21	0	2650	0
France	Champdeniers	94	67	27	0	0	28785	0
	Chateauroux	152	32	86	23	11	44789	0
	Fussy	80	10	43	27	0	41305	0
	Sancerre	98	37	44	7	10	34174	0
	Champlitte	130	68	62	0	0	40370	0
	Dampierre	130	64	43	23	0	42135	0
	Vitrey	120	46	74	0	0	44120	0
Netherlands	Balkbrugg	40	40	0	0	0	31923	113591
	Bentelo	40	40	0	0	0	25937	0
	Scherpenzeel	10	10	0	0	0	32726	79920

The effect of prioritizing the planting silvoarable and agroforestry systems on the 10% worst land and the 10% best land was investigated. The ranking of the land units at each site is described in Table 14. In France, the general pattern was to plant poplar on the best land, and cherry on the worst. The one exception was Champdeniers where the "low" quality land was used for walnut.

It was assumed that planting would be completed in year 1. Holm oak, stone pine, wild cherry and walnut were "harvested" to provide revenue in year 60. A rotation of 20 years was assumed for poplar, and hence by assuming replanting in years 21 and 41, three full rotations of poplar could be completed within 60 years. It was assumed for poplar that the tree related grants in year 21 and 41 would be the same as for year 1.

Table 14 Ranking of the quality of the land units at each site

		Best land	Tree species	2nd best	Tree species	3rd best	Tree species	4th best	Tree species
Spain	Alcala	LU1	Oak	LU2	Oak				
	Torrijos	LU2	Oak	LU1	Oak				
	Almonacid	LU2	Oak	LU1	Oak				
	Cardenosa	LU2	Oak	LU1	Oak				
	Fontiveros	LU2	Pine	LU1	Oak				
	Olmedo	LU2	Oak	LU1	Pine	LU3	Oak		
	Campo	LU2	Oak	LU1	Pine				
	Paramo	LU2	Oak	LU1	Oak	LU3	Oak		
France	Champdeniers	LU1	Cherry	LU2	Walnut				
	Chateauroux	LU3	Walnut	LU1	Walnut	LU2	Cherry	LU4	Cherry
	Fussy	LU2	Poplar	LU3	Cherry	LU1	Cherry		
	Sancerre	LU2	Poplar	LU3	Cherry	LU1	Cherry	LU4	Cherry
	Champlitte	LU2	Walnut	LU1	Walnut				
	Dampierre	LU3	Poplar	LU2	Cherry				
	Vitrey	LU2	Poplar	LU1	Cherry				

Effect of grants on farm profitability

Farm profitability with the 2004 grant scenario

Under the 2004 grant scenario in Spain, the farm-scale analysis shown that in no case was it profitable for the farmer to replant arable land with a silvoarable system (Table 15). This is primarily because of the low volume and value of the timber, the lack of tree-related payments (Table 10) and the proportional loss of the crop area payment. By contrast, the analysis suggested that, assuming the forestry grants were available, farm profitability would increase by establishing forestry, particularly on poor land. This is because the standard payments for woodland establishment (assuming satisfactory establishment) was independent of land quality.

In France at each landscape test site except Champdeniers, farm profitability was predicted to increase by establishing a silvoarable agroforestry on the best land (Table 15). This was primarily an effect of where the experts chose to place the poplar and walnut systems. For example in Champdeniers, where the poorest land was planted with walnut, then planting an agroforestry system on poor land improved farm profitability. In the Netherlands, under the 2004 grant scenario, planting a forestry or silvoarable system would reduce farm profitability.

Table 15 The predicted net present value (4% discount rate) of the farm net margin ('000 €) under the status quo arable system, and the change in that net margin ('000 €) from planting silvoarable agroforestry (113 trees ha^{-1}) or forestry on the 10% worst or best land on each of the landscape test sites, assuming the 2004 grant scenario

Country	Landscape test site	Status quo	Net change			
			Agroforestry 10% worst	Agroforestry 10% best	Forestry 10%worst	Forestry 10%best
Spain	Alcala	279	-8	-12	9	-1
	Torrijos	26	-5	-7	39	39
	Ocaña	37	-5	-5	38	38
	Almonacid	40	-5	-11	39	18
	Cardenosa	245	-6	-7	4	4
	Fontiveros	235	-7	-12	6	-3
	Olmedo	124	-8	-6	19	15
	Campo	-15	-6	-8	23	27
	Paramo	395	-8	-8	-9	-9
France	Champdeniers	198	18	-6	-15	-75
	Chateauroux	576	-17	23	-152	-97
	Fussy	131	-16	9	-99	-33
	Sancerre	362	-11	40	-94	-8
	Champlitte	32	-13	38	-178	15
	Dampierre	-133	-8	54	-97	24
	Vitrey	-424	-8	43	-117	14
Netherlands	Balkbrugg	2727	-25	-25	-53	-53
	Bentelo	-28	-66	-66	-130	-130
	Scherpenzeel	1364	-6	-6	-18	-18

Farm profitability with the 2005 grant scenario

The effect of the 2005 grant regime on farm profitability was determined for four possible scenarios (Table 12). As for the 2004 grant regime, at each site in Spain the introduction of silvoarable systems resulted in lower farm profitability (Table 16). There was no clear benefit to introducing silvoarable systems on high quality land in preference to low quality land. The introduction of forestry was predicted to result in higher farm NPVs than the arable status quo in Torrijos, Ocaña, Almonacid, Olmedo and Campo. It was also found that forestry systems performed better than silvoarable systems at these locations, although the opposite was true for the remaining sites.

In France, under each of the 2005 grant scenarios, the introduction of silvoarable systems on the best land generally improved farm profitability. The introduction of silvoarable systems on the worst land was predicted generally to result in lower farm NPV than the status quo farm. This was primarily an effect of where the experts chose to place the poplar and walnut systems. For example in Champdeniers, where the poorest land was planted with walnut, then planting an agroforestry system on poor land improved farm profitability. The introduction of forestry reduced farm profitability at each site except when walnut and poplar were planted on the best land at the three sites in the Franche Comté region (i.e. Champlitte, Dampierre and Vitrey). In each case, silvoarable agroforestry improved farm profitability relative to planting the same area of forestry.

In the Netherlands there was no advantage to the introduction of silvoarable systems or forestry in comparison with the status quo. Forestry in particular was particularly disadvantageous due to the opportunity cost of the nitrogen levy and silvoarable systems, although reducing overall profitability were preferable to forestry.

Table 16 The predicted net present value (4% discount rate) of the farm net margin ('000 €) under the status quo arable system, and the change in that net margin ('000 €) from planting silvoarable agroforestry (113 trees ha^{-1}) or forestry on the 10% worst or best land on each of the landscape test sites, assuming the 2005 grant scenarios

Landscape test site	Status quo 2005 scenario	Change in net margin									
		Scenario 1.1		Scenario 1.2		Scenario 2.1		Scenario 2.2		Forestry future	
		10% worst	10% best	10% worst	10% best	10% worst	10% best	10% worst	10% best	10% worst	10% best
Spain											
Alcala	538	-7	-10	-3	-6	-5	-8	-2	-4	-32	-43
Torrijos	34	-4	-4	-3	-2	-2	-2	-1	-1	18	18
Ocaña	47	-4	na	-2	na	-2	na	-1	na	16	na
Almonacid	53	-4	-5	-3	-3	-2	-3	-1	-1	17	0
Cardenosa	230	-3	-4	-2	-2	-2	-2	-1	-1	-7	-7
Fontiveros	259	-4	-7	-2	-5	-2	-5	-1	-3	-10	-16
Olmedo	130	-4	-4	-2	-2	-2	-2	-1	-1	7	0
Campo	32	-7	-5	-6	-3	-6	-4	-4	-2	8	9
Paramo	461	-5	-5	-3	-3	-4	-4	-2	-2	-28	-28
France											
Champdeniers	199	11	-11	18	-3	18	-6	25	1	-15	-75
Chateauroux	576	-24	12	-11	24	-17	23	-5	36	-152	-98
Fussy	134	-20	2	-13	8	-16	9	-10	16	-98	-33
Sancerre	359	-16	31	-8	39	-11	40	-3	48	-93	-8
Champlitte	33	-13	38	-4	43	-7	48	2	53	-177	14
Dampierre	-206	-7	57	2	64	-1	70	8	76	-91	32
Vitrey	-425	-8	43	0	49	-3	54	6	61	-117	14
The Netherlands											
Balkbrugg	2727	-25	na	-22	na	-20	na	-18	na	-64	na
Bentelo	-59	-64	na	-63	na	-60	na	-58	na	-128	na
Scherpenzeel	1364	-6	na	-5	na	-5	na	-4	na	-21	na

na = not applicable because only one land unit was considered

Frequency analysis

Improved profitability

The frequency with which the introduction of the silvoarable and forestry systems on 10% of the best and 10% of the worst land, improved farm profitability was calculated for the 2004 grant scenario and the least and most optimistic scenarios within the 2005 grant regime (Figure 17).

In Spain, in the 2004 and 2005 grant scenarios, there were no sites where profitability was increased by introducing silvoarable agroforestry. Instead the grant regimes favour the establishment of forestry. With the 2004 grant scenario, forestry would be attractive on about 80% of the cases. The 2005 grant scenarios reduced the relative attractiveness of forestry, but forestry still improved farm profitability in about 50% of cases.

In France, with the 2004 grant regime, planting an agroforestry system increased farm profitability in about half of the sample cases. This was similar to the situation under the 2005 grant scenario 1.1. However the proportion of cases increased to 80% with the most optimistic scenario 2.2. For each grant regime, the frequency of forestry increasing farm profitability was less than that for agroforestry. The proportion of cases where it was profitable to introduce forestry was about 20%, and this was not altered by the grant regime. There were no sites in the Netherlands where the introduction of silvoarable or forestry systems improved farm profitability under the 2004 or 2005 grant regimes.

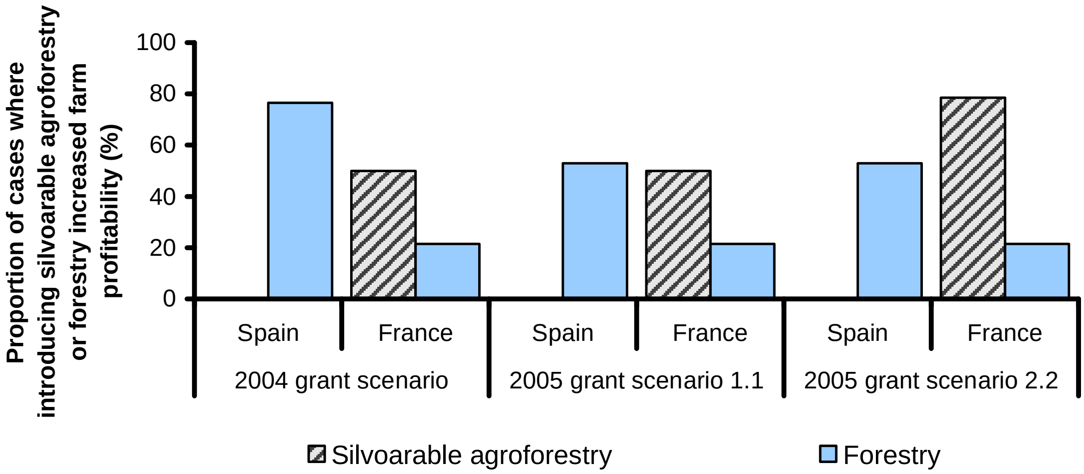

Figure 17 Frequency with which farm net present value was improved compared with the status quo farm by the introduction of silvoarable systems or forestry (Spain: n =17; France: n = 14)

Effect of land type

In Spain, under the 2004 and 2005 payment schemes and irrespective of land type, introducing silvoarable agroforestry did not improved farm profitability. Under the 2004 grant regime, the proportion of farm showing a benefit of forestry on low quality land (90%) was greater than that (65%) on high quality land (Figure 18). However under the 2005 grant scenarios, the difference from planting on high or low quality land was not evident.

In France, under the 2004 grant regime, 86% and 14% of farms showed an increase in profitability when silvoarable agroforestry was established on good and poor land respectively. The same apparent advantage to planting on good land also existed with the forestry systems. However further analysis suggests that these results are not due to the effect of land quality, but simply that the high value timber species, such a walnut and poplar, were assumed to be planted on good land and low value species, such as cherry, were assumed to be planted on poor land. In the Netherlands, because the land on each farm was assumed to be uniform, the effect of land type was not evaluated.

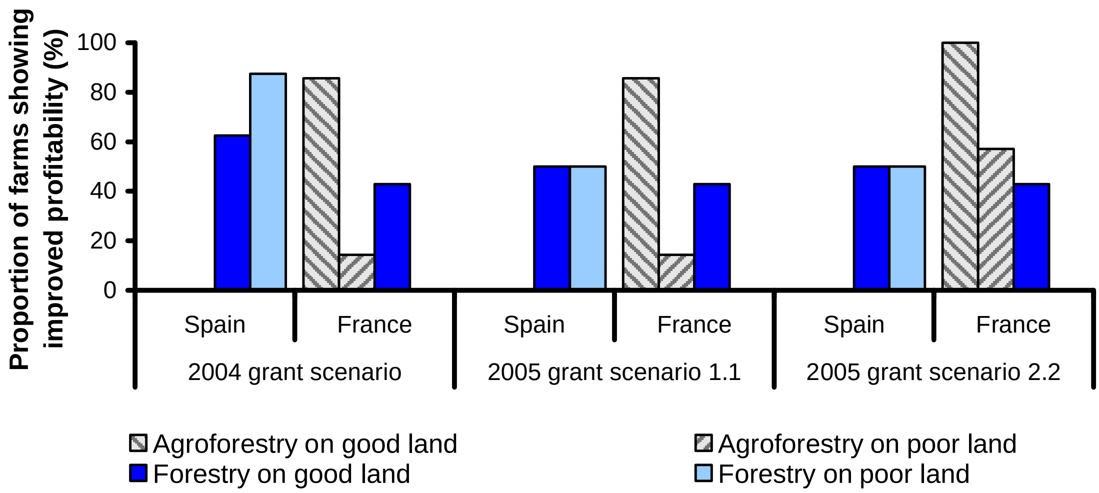

Figure 18 Frequency with which farm net present value was improved compared with the status quo by introducing silvoarable or forestry systems on good or poor land (Spain: n =8; France: n = 7)

Comparison of forestry and agroforestry
Assuming that a farmer wishes to establish trees, one question is whether it is better to plant them in an agroforestry or a forestry system. Where grants were available, land type had no effect on whether silvoarable agroforestry was better than forestry. With grants, silvoarable agroforestry was also predicted to be more attractive than forestry on all farms in France and the Netherlands. In Spain the proportion of cases where silvoarable agroforestry was more profitable than forestry increased from 12% under the 2004 grant scenario, to about 50% under the 2005 grant scenarios.

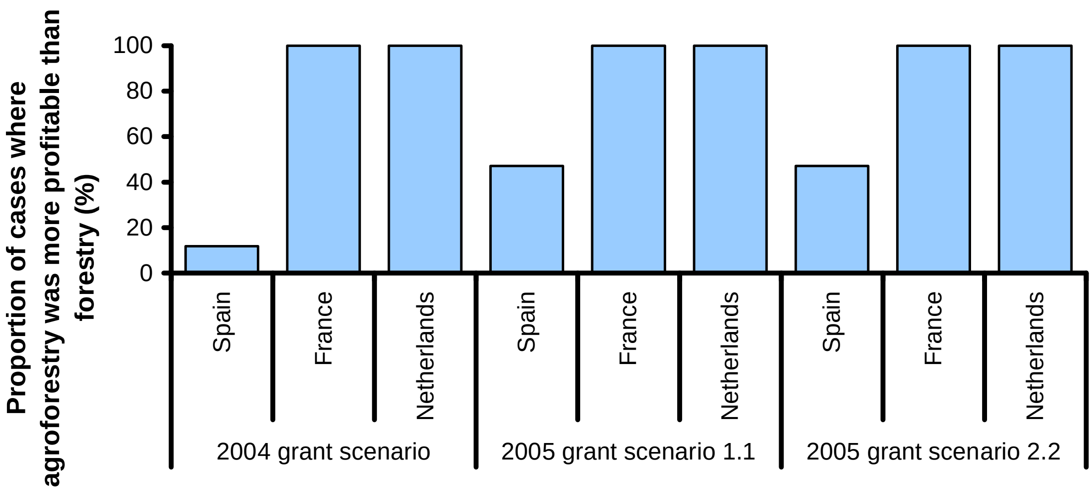

Figure 19 Frequency with which silvoarable systems outperformed forestry (Spain: n = 17; France: n = 14; the Netherlands: n = 3)

7. CONCLUSIONS

Arising out of this report, a number of conclusions and recommendations can be made.

Plot-scale economic analysis

1. Assuming no grants, the silvoarable systems with poplar in France and the Netherlands, with walnut in France, and with cherry in Poitou Charentes and Franche Comté were more profitable at a discount rate of 4% than the described forestry and arable systems. For these systems, the equivalent annual value (at a discount rate of 4%) for a silvoarable system with 113 trees ha^{-1} was on average 74 (range : 3 to 107), 70, and 19 € ha^{-1} a^{-1} greater than for the competing forestry and arable system in France and the Netherlands respectively. This analysis shows that without grants, there can be a financial incentive for silvoarable agroforestry.

2. Without grants, four conditions that seem to favour silvoarable agroforestry, relative to competing arable and forestry systems, are:

- A high land equivalent ratio (LER) improves the relative profitability of silvoarable agroforestry. This could be the result of complementary tree and crop growth patterns or a poorly optimised forestry system. Hence, assuming 113 trees ha^{-1}, the systems with deciduous tree species in France (mean LER = 1.30) tended to be more profitable than the systems with oak and pine (mean LER = 1.15) in Spain.
- Forestry without grants should be profitable. This requires a tree species with either high quality wood (e.g. walnut) or a short rotation (e.g. poplar). However the value of timber appears to be country dependent. For example, the assumed value of walnut timber in France was almost twenty-times that determined in the Netherlands. It is recommended that the reasons for such differences should be determined, in what should be a free-trade area.
- Arable agriculture without grants should also be profitable. For example arable agriculture is not particularly profitable in the Franche Comté region in France and hence without grants poplar production is more profitable in a forestry rather than an agroforestry system.
- The profitability of forestry and arable agriculture should ideally be similar. If one particular system is substantially more profitable than the other, the farmer would tend to plant monocultures of that system than an agroforestry system combining the two.

3. Assuming the 2004 grant regime of the Common Agricultural Policy and that arable area payments were only paid when the land was cropped, the length of the optimal crop rotation in the presence of grants tended to be longer than in the situation with no grants. This means that the optimal silvoarable management regime with grants tends to be different from that without. With the 2004 grant scenario, the only silvoarable systems that were more profitable (at a discount rate of 4%) than the agricultural and forestry system were the poplar and walnut systems in France. The systems with cherry in France, and poplar in the Netherlands became less profitable than the arable or forestry systems. It is clear that the current separation of agriculture-related payments within the Common Agricultural Policy from tree-related payments within a rural development policy is hindering the uptake of silvoarable agroforestry. In addition it creates non-optimal silvoarable management regimes where the farmer may seek to maximise grant income rather than non-grant-related profitability.

4. The 2005 grant scenario, based on the new single farm payments, generally gave similar results to the 2004 grant scenario. This is because it was assumed that the single farm payment would not be received on uncultivated land. The distortions present in the 2004 grant regime in relation to agroforestry appear to remain in the predicted future grant scenarios.

5. The above analyses are based on an analysis of predicted benefits and costs. Additional considerations, such as potential damage to machinery against the trees, which may prevent the uptake of silvoarable systems were not considered. Similarly possible environmental benefits from agroforestry such as soil erosion control (Palma et al. 2004) were not included.

Economic feasibility

1. The importance of the value of timber (walnut) or of high timber production over a short rotation (poplar) is reflected in the farm-scale results. In the presence of grants, the only situation where the addition of a silvoarable system on arable land increased farm profitability was with the walnut and poplar systems in France.

2. In France and the Netherlands, silvoarable agroforestry was a more cost-effective way of establishing trees than forestry. In the Netherlands, forestry systems are particularly affected by the opportunity cost (the nitrate levy) assumed as a result of not being able to apply manure to arable land. Under the 2004 grant scenario, forestry was the generally the most profitable means of establishing tree cover on farms in Spain, although this advantage was reduced under the 2005 scenario.

3. In France, silvoarable agroforestry and forestry appeared to increase farm profitability most, or reduced farm profitability least, when planted on good rather than poor quality land. However this effect was due to the high (i.e. walnut and poplar) and low (i.e. cherry) value tree species being allocated to the high and poor quality land respectively. In Spain, forestry tended to increase farm profitability most when planted on poor rather than good land. Land quality had no overall effect on the frequency with which silvoarable systems out-performed forestry.

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APPENDIX A PLOT-SCALE RESULTS FROM EACH LAND UNIT

Table 17 Net present value (assumed discount rate of 0%) (€ ha^{-1}) of the forestry, arable and silvoarable system within each land unit in the 2004 grant and the no grant scenarios

Country, tree species And land unit		Rotation (a)	2004 grant scenario			No grant		
			Forest	Arable	Silvo-arable	Forest	Arable	Silvo-arable
Spain								
Oak	Alcala 1	60	6890	9830	5150	30	4660	3140
	Alcala 2	60	6220	7460	4480	-640	2290	1790
	Torrijos 1	60	11670	2650	2070	2290	-1220	660
	Torrijos 2	60	11640	2590	1070	2260	-2580	-850
	Ocaña 1	60	11550	2880	2230	2170	-2290	460
	Almonacid 1	60	11190	2610	1880	1810	-1260	500
	Almonacid 2	60	10240	9250	4490	870	480	410
	Cardenosa 1	60	9780	11900	8760	920	6090	5860
	Cardenosa 2	60	10360	12040	8470	1500	6230	5800
	Fontiveros 1	60	10230	11390	7810	1380	5190	4870
	Olmedo 2	60	10560	7910	5020	1700	2750	2760
	Olmedo 3	60	10320	6450	3060	1460	350	540
	Campo 2	60	10160	3340	620	1300	-3120	-1990
	Paramo 1	60	11050	17210	13160	2190	10450	10080
	Paramo 2	60	11050	17210	13160	2190	10450	10080
	Paramo 3	60	11130	17170	13090	2270	10410	10030
Pine	Fontiveros 2	60	7500	11410	5630	-500	5210	3570
	Olmedo 1	60	7550	6430	1140	-460	330	-640
	Campo 2	60	7530	1780	450	-480	-4030	-600
France: Poitou Charentes								
Cherry	Champdeniers 1	60	27190	21600	34780	22750	420	18650
Walnut	Champdeniers 2	60	91800	25570	89420	87530	4390	72980
France: Centre								
Cherry	Fussy 3	60	32450	39890	51640	28610	18800	32050
	Sancerre 3	60	38780	35380	53830	34940	14520	34450
	Fussy 1	60	16040	28360	32010	12200	7270	12420
	Chateauroux 2	60	17410	23090	30750	13570	2090	11240
	Chateauroux 4	60	16800	22880	30330	12956	1880	10820
	Sancerre 4	60	18740	22200	32080	14890	1260	12630
	Sancerre 1	60	17150	22010	29200	13310	1150	9820
Walnut	Chateauroux 3	60	92070	35700	96240	88400	14900	76610
	Chateauroux 1	60	80930	29870	88740	77250	8870	68920
Poplar	Sancerre 2	20	17550	12180	19560	14830	5240	12710
	Fussy 2	20	12360	11100	14870	9640	4140	8000
France: Franche Comté								
Cherry	Champlitte 1	60	32220	26710	47120	32220	6630	35240
	Dampierre 1	60	28960	23540	41820	28960	2500	26500
	Vitrey 1	60	22890	16390	28950	22890	-3450	14500
	Dampierre 2	60	14170	9190	17320	14170	-11750	4620
Walnut	Champlitte 2	60	87600	10100	76960	87600	-9780	73040
Poplar	Dampierre 3	20	11810	4470	11630	11810	-1610	7760
	Vitrey 2	20	10510	4190	10790	10510	-2410	7180
The Netherlands								
Walnut	Bentelo	60	-30530	37400	2420	-42340	14000	6420
Poplar	Balkbrugg	20	7210	11660	10060	-4600	3660	-2810
Poplar	Sherpenzeel	20	370	10670	8340	-11440	2670	3970

Table 18 Actual value (discount rate = 0%) (€ ha^{-1}) of the grants in the 2004 scenario and 2005 scenario 1.1 for the forestry, arable and silvoarable system in each land unit

	Rotation	2004 scenario			2005 scenario 1.1		
	(a)	Forest	Arable	Silvo-arable	Forest	Arable	Silvo-arable
Spain							
Alcala 1	60	6860	5170	2010	3920	13200	12020
Alcala 2	60	6860	5170	2690	3920	13200	12010
Torrijos 1	60	9380	3870	1410	5190	4080	2230
Torrijos 2	60	9380	5170	1920	5200	5440	3710
Ocaña 1	60	9380	5170	1770	5190	5520	2530
Almonacid 1	60	9380	3870	1380	5190	4470	2420
Almonacid 2	60	9370	8770	4080	5190	7740	7060
Cardenosa 1	60	8860	5810	2900	5480	5220	4750
Cardenosa 2	60	8860	5810	2670	5470	5220	4750
Fontiveros 1	60	8850	6200	2940	5470	7150	6510
Olmedo 2	60	8860	5160	2260	5470	5760	5250
Olmedo 3	60	8860	6100	2520	5480	5760	5240
Campo 2	60	8860	6460	2610	5480	8450	6000
Paramo 1	60	8860	6760	3080	5470	9260	8430
Paramo 2	60	8860	6760	3080	5470	9260	8430
Paramo 3	60	8860	6760	3060	5470	9260	8430
Fontiveros 2	60	8000	6200	2060	5040	7150	6510
Olmedo 1	60	8010	6100	1780	5040	5760	5250
Campo 1	60	8010	5810	1050	5040	7600	1810
France: Poitou Charentes							
Champdeniers 1	60	4440	21180	16130	4440	21180	15740
Champdeniers 2	60	4270	21180	16440	4270	21180	15740
France: Centre							
Fussy 3	60	3840	21090	19590	3840	21060	19160
Sancerre 3	60	3840	20860	19380	3840	20790	18920
Fussy 1	60	3840	21090	19590	3840	21060	19170
Chateauroux 2	60	3840	21000	19510	3840	20950	19070
Chateauroux 4	60	3840	21000	19510	3840	20950	19070
Sancerre 4	60	3850	20940	19450	3850	20790	18920
Sancerre 1	60	3840	20860	19380	3840	20790	18920
Chateauroux 3	60	3670	20800	19630	3670	20950	19060
Chateauroux 1	60	3680	21000	19820	3680	20950	19070
Sancerre 2	20	2720	6940	6850	2720	6930	6310
Fussy 2	20	2720	6960	6870	2720	7020	6390
France: Franche Comté							
Champlitte 1	60	0	20080	11880	0	19980	11820
Dampierre 1	60	0	21040	15320	0	19740	14460
Vitrey 1	60	0	19840	14450	0	19780	14400
Dampierre 2	60	0	20940	12700	0	19740	11970
Champlitte 2	60	0	19880	3920	0	19980	3940
Dampierre 3	20	0	7080	2870	0	6580	3590
Vitrey 2	20	0	6600	3610	0	6590	3600
The Netherlands							
Bentelo	60	11810	23000	5230	9830	21180	4820
Balkbrugg	20	11810	8000	3640	8500	8000	3640
Sherpenzeel	20	11810	8000	4370	8170	8000	4370

Table 19 Net present values (discount rate of 0%) (€ ha^{-1}) for the forestry, arable and silvoarable systems within each land unit under the 2005 grant scenarios

Country, tree species and land unit		Rotation (a)	Forest	Arable	Silvoarable (113 trees ha^{-1})			
					Scenario 1.1	Scenario 1.2	Scenario 2.1	Scenario 2.2
Spain								
Oak	Alcala 1	60	3950	17860	15160	16340	15370	16560
	Alcala 2	60	3280	15490	13800	14990	14020	15200
	Torrijos 1	60	7480	2860	2890	3110	3110	3330
	Torrijos 2	60	7460	2860	2860	3230	3080	3450
	Ocaña 1	60	7360	3230	2990	3440	3210	3660
	Almonacid 1	60	7000	3210	2920	3270	3140	3490
	Almonacid 2	60	6060	8220	7470	8160	7680	8380
	Cardenosa 1	60	6400	11310	10610	11080	10830	11290
	Cardenosa 2	60	6970	11450	10550	11020	10770	11240
	Fontiveros 1	60	6850	12340	11380	12020	11600	12240
	Olmedo 2	60	7170	8510	8010	8520	8220	8740
	Olmedo 3	60	6940	6110	5780	6300	6000	6520
	Campo 2	60	6780	5330	4010	4790	4230	5010
	Paramo 1	60	7660	19710	18510	19340	18730	19560
	Paramo 2	60	7660	19710	18510	19340	18730	19560
	Paramo 3	60	7740	19670	18460	19290	18680	19510
Pine	Fontiveros 2	60	4540	12360	10080	10720	10320	10960
	Olmedo 1	60	4580	6090	4610	5120	4850	5370
	Campo 2	60	4560	3570	1210	1650	1450	1890
France: Poitou Charentes								
Cherry	Champdeniers 1	60	27190	21600	34390	35950	34790	36350
Walnut	Champdeniers 2	60	91800	25570	88720	90270	89430	90980
France: Centre								
Cherry	Fussy 3	60	32450	39860	51210	53110	51610	53500
	Sancerre 3	60	38780	35310	53370	55240	53770	55640
	Fussy 1	60	16040	28330	31590	33480	31980	33880
	Chateauroux 2	60	17410	23040	30310	32190	30700	32590
	Chateauroux 4	60	29889	22830	29890	31770	30280	32170
	Sancerre 4	60	18740	22050	31550	33420	31940	33810
	Sancerre 1	60	17150	21940	28740	30610	29130	3100
Walnut	Chateauroux 3	60	92070	35850	95670	97560	96380	98270
	Chateauroux 1	60	80930	29820	87990	89870	88690	90580
Poplar	Sancerre 2	20	17550	12170	19020	19640	19550	20170
	Fussy 2	20	12360	11160	14390	15020	14920	15550
France: Franche Comté								
Cherry	Champlitte 1	60	32220	26610	47060	48290	47460	48690
	Dampierre 1	60	28960	22240	40960	42290	41360	42690
	Vitrey 1	60	22890	16330	28900	30210	29300	30610
	Dampierre 2	60	14170	7990	16590	17780	16990	18170
Walnut	Champlitte 2	60	87600	10200	76980	77320	77690	78030
Poplar	Dampierre 3	20	11810	3970	11350	11710	11890	12240
	Vitrey 2	20	10510	4180	10780	11130	11310	11660
The Netherlands								
Walnut	Bentelo	60	-32510	35580	2010	2480	3140	3610
Poplar	Balkbrugg	20	3900	11660	10060	10420	10730	11090
Poplar	Sherpenzeel	20	-3270	10670	8340	8770	9010	9940

Table 20 Equivalent annual values (at a 4% discount rate) (€ ha^{-1} a^{-1}) for the forestry, arable and silvoarable systems for the 2005 grant scenarios

Country and species	Land unit	Forest	Arable	Silvoarable (113 trees ha^{-1})			
				Scenario 1.1	Scenario 1.2	Scenario 2.1	Scenario 2.2
Spain							
Oak	Alcala 1	97	333	279	300	289	310
	Alcala 2	103	281	242	263	251	272
	Torrijos 1	166	59	36	42	46	51
	Torrijos 2	166	57	35	43	44	52
	Ocaña 1	166	66	42	51	51	60
	Almonacid 1	163	59	36	43	46	52
	Almonacid 2	157	154	124	136	133	145
	Cardenosa 1	156	205	182	190	191	200
	Cardenosa 2	160	207	181	190	191	199
	Fontiveros 1	159	226	200	212	210	221
	Olmedo 2	161	160	136	145	145	154
	Olmedo 3	160	109	85	94	94	103
	Campo 2	158	96	61	74	70	84
	Paramo 1	164	360	325	340	335	349
	Paramo 2	164	360	325	340	335	349
	Paramo 3	165	359	324	339	334	348
Pine	Fontiveros 2	118	227	181	193	192	203
	Olmedo 1	118	109	71	80	81	90
	Campo 1	118	61	13	24	24	34
France: Poitou Charentes							
Cherry	Champdeniers 1	63	381	336	367	353	384
Walnut	Champdeniers 2	394	459	504	535	535	566
France: Centre							
Cherry	Fussy 3	62	682	589	622	606	639
	Sancerre 3	92	609	561	594	578	611
	Fussy 1	-14	479	381	414	398	431
	Chateauroux 2	0	398	335	368	352	385
	Chateauroux 4	-2	394	332	364	349	382
	Sancerre 4	6	384	321	354	338	371
	Sancerre 1	-3	379	309	341	326	359
Walnut	Chateauroux 3	376	632	662	695	693	726
	Chateauroux 1	327	517	547	579	578	610
Poplar	Sancerre 2	599	631	764	796	802	835
	Fussy 2	417	584	598	631	637	670
France: Franche Comté							
Cherry	Champlitte 1	-73	473	434	461	451	478
	Dampierre 1	-79	390	390	418	407	435
	Vitrey 1	-108	282	256	284	273	301
	Dampierre 2	-144	135	115	142	132	159
Walnut	Champlitte 2	224	180	297	311	328	342
Poplar	Dampierre 3	309	210	385	406	424	445
	Vitrey 2	262	215	357	378	396	417
The Netherlands							
Walnut	Bentelo	-669	615	-30	-13	20	36
Poplar	Balkbrugg	35	603	356	378	404	426
Poplar	Sherpenzeel	-221	547	310	336	358	384

APPENDIX B FREQUENCY RESULTS FROM THE FARM-SCALE ANALYSIS

Table 21 Frequency (%) with which agroforestry and forestry provide higher farm net present values than the status quo farm under six grant scenarios

		Agroforestry	Forestry
No grants	France	79	50
	Netherlands	0	0
	Spain	12	6
	Total	38	24
2004 scenario	France	50	21
	Netherlands	0	0
	Spain	0	76
	Total	21	47
2005 scenario 1.1	France	50	21
	Netherlands	0	0
	Spain	0	53
	Total	21	35
2005 scenario 1.2	France	64	21
	Netherlands	0	0
	Spain	0	53
	Total	26	35
2005 scenario 2.1	France	50	21
	Netherlands	0	0
	Spain	0	53
	Total	21	35
2005 scenario 2.1	France	79	21
	Netherlands	0	0
	Spain	0	53
	Total	32	35

Table 22 Frequency (%) with which agroforestry and forestry provide higher farm net present values than the status quo farm on high and low quality land, under six grant scenarios

		Agroforestry		Forestry	
		Better on bad land	Better on good land	Better on bad land	Better on good land
No grants	France	57	100	29	71
	Spain	13	0	0	13
	Total	33	47	13	40
2004 scenario	France	14	86	0	43
	Spain	0	0	88	63
	Total	7	40	47	53
2005 scenario 1.1	France	14	86	0	43
	Spain	0	0	50	50
	Total	7	40	27	47
2005 scenario 1.2	France	43	86	0	43
	Spain	0	0	50	50
	Total	20	40	27	47
2005 scenario 1.3	France	14	86	0	43
	Spain	0	0	50	50
	Total	7	40	27	47
2005 scenario 1.4	France	57	100	0	43
	Spain	0	0	50	50
	Total	27	47	27	47

Table 23 Frequency (%) with which agroforestry and forestry provided higher farm net present values when located on high or low quality land under six grant scenarios

		Agroforestry		Forestry	
		Better on bad land	Better on good land	Better on bad land	Better on good land
No grants	France	14	86	14	86
	Spain	75	25	63	38
	Total	47	53	40	60
2004 scenario	France	14	86	14	86
	Spain	75	25	63	38
	Total	47	53	40	60
2005 scenario 1.1	France	14	86	14	86
	Spain	50	50	63	38
	Total	33	67	40	60
2005 scenario 1.2	France	14	86	14	86
	Spain	50	50	63	38
	Total	33	67	40	60
2005 scenario 2.1	France	14	86	14	86
	Spain	50	50	63	38
	Total	33	67	40	60
2005 scenario 2.2	France	14	86	14	86
	Spain	50	50	63	38
	Total	33	67	40	60

Table 24 Frequency (%) with which agroforestry provided higher net present values than forestry under six grant scenarios

Grant scenario	Spain	France	The Netherlands	Total
No grants	64	88	100	79
2004 scenario	12	100	100	56
2005 scenario 1.1	47	100	100	74
2005 scenario 1.2	47	100	100	74
2005 scenario 2.1	47	100	100	74
2005 scenario 2.2	47	100	100	74

Table 25 Frequency (%) with which agroforestry provided higher farm net present values than forestry on high and low quality land, without payments, under the prevailing 2004 payments and under 4 future payment scenarios

		Agroforestry		Forestry	
		Better on bad land	Better on good land	Better on bad land	Better on good land
No grants	France	71	57	29	43
	Spain	100	75	0	25
	Total	87	67	13	33
2004 grant	France	100	100	0	0
	Spain	13	13	88	88
	Total	53	53	47	47
2005 scenario 1.1	France	100	100	0	0
	Spain	50	50	50	50
	Total	73	73	27	27
2005 scenario 1.2	France	100	100	0	0
	Spain	50	50	50	50
	Total	73	73	27	27
2005 scenario 2.1	France	100	100	0	0
	Spain	50	50	50	50
	Total	73	73	27	27
2005 scenario 2.2	France	100	100	0	0
	Spain	50	50	50	50
	Total	73	73	27	27