Farmers' fears and agro-economic evaluation of sown grass strips in France

Cordeau, Reboud, Chauvel

Agronomy Sust. Developm. (2011) 31:463–473
DOI 10.1007/s13593-011-0004-6

ORIGINAL PAPER

Farmers' fears and agro-economic evaluation of sown grass strips in France

Stéphane Cordeau · Xavier Reboud · Bruno Chauvel

Accepted: 27 July 2010 / Published online: 16 February 2011

Abstract Since 2005, French farmers must set up sown grass strips along rivers in order to decrease pesticide levels and soil erosion. Farmers have thus parcelled out their fields, set aside 3% of their farm size and managed grass without herbicide. Consequently, this environmental policy may cause farmers' fears due to economic losses and weed infestations of their field margins. Here, we studied farmers' perception of sown grass strips. First, we interviewed 29 farmers in two French regions. Second, we evaluated the economic loss of gross margin when replacing crop by grass. Third, we evaluated the weed risk using flora surveys in sown grass strips. Our results showed that two thirds of interviewed farmers thought that sown grass strips affected their farm revenue and represented a weed risk. Concerning economy, we found that farmers loose from 358 to 853€/ha the year of installation and from 126 to 641€/ha next years. This economic loss is mainly due to the loss of crop production, with a minor impact of grass management cost. At the farm level, 3% of sown grass strips decreased the farm revenue by 7%. Concerning the weed risk, the farmers' perception was linked with the presence of some competitive perennial weeds, e.g. *Cirsium arvense*, and wind-dispersing weeds, e.g. *Asteraceae*. Sown grass strips with high weed species richness of 26 species on average, or with dominance of non-sown species (16.7% of sown grass strips) did not affect the farmers' perception. In our study, the economic loss was weak and acceptable at the farm level.

Keywords Field margin · Weed risk · Gross margin · Agri-environmental measure · Farmers' acceptance

Selected article from the International Conference on Weed Biology, Dijon, France, 2009.

S. Cordeau · X. Reboud · B. Chauvel
INRA, UMR1210, Biologie et Gestion des Adventices,
21000 Dijon, France

B. Chauvel (✉)
INRA, UMR1210, Biologie et Gestion des Adventices,
21065 Dijon cedex, France
e-mail: chauvel@dijon.inra.fr

1 Introduction

Reforms of European and national agricultural policies have generated changes in the arable landscape. Agricultural reforms have encouraged farmers to reorganise and manage differently their fields by diversifying crop rotations or stopping some cultural practices detrimental to the environment (straw burning). Since the Common Agricultural Policy reform in 2003, 5-m wide sown grass strips have been the only compulsory type of set-aside. Their environmental functions have been largely explored. They act as buffer zones between fields and watercourses by limiting pesticide drift (de Snoo and de Wit 1998) and reducing soil erosion (Montanarella et al. 2003). Moreover, these new elements of the arable landscape could in many ways enhance auxiliaries (Marshall and Moonen 2002), acting, for instance, as a refuge for pest predators (Sotherton 1985), crop pollinators, and farmland birds (Vickery et al. 2004). However, they have long been known to be a source of crop infestation of different pests, such as molluscs (Frank 1998), viruses (Henry et al. 1993), or weeds (Marshall 1989). In this sense, sown grass strips could cause farmers' fears. This agri-environmental policy compels farmers to parcel out their fields. Therefore, sown grass strips could be considered as new microfields where farmers try to minimise economic losses and limit weed development.

Concerning the economic aspects, sown grass strips could be considered as microfields where an annual crop is replaced by perennial grasses which sometimes are exported for cattle feeding. These non-cropped microfields account for 3% of the farm size. French farmers do not receive compensation payment to set up sown grass strips even if it has often been identified as making the farmers' acceptance of agri-environmental measures easier (Herzon and Mikk 2007; Defrancesco et al. 2008). Moreover, farmers have to sow a mixture of recommended species. In spite of the reduction in operating costs (no pesticide, no soil tillage), farmers have to spend money so as to manage their sown grass strips, since they are under the obligation to mow the grass at least once a year in order to control the development of woody species. Therefore, despite the saving of pesticides and tillage, sown grass strips could potentially represent a cost for farmers because of the loss of production and the cost of management (Carpy-Goulard et al. 2006).

Concerning the weeds, farmers manage them in order to limit weed infestation. In fact, the unique selection pressure on weed is the mowing of the sown grass strips and it seems to change the community in terms of composition, promoting pernicious species (Westbury et al. 2008). Moreover, sown grass strips have been installed on the field margins, which are known to harbour many weeds (Marshall 1989; Fried et al. 2009). Finally, sown grass strips could become a refuge for weeds due to the ban on pesticide and fertiliser use. The multitude of seeds or buds contained in the seed bank could raise the number and abundance of weed species (Amiaud and Touzard 2004).

The farmers' fears over weed risk and economic cost still need to be quantified and set alongside to economic evaluations or field observations. Moreover, in addition to economic (Hooks et al. 1983) or agronomic aspects, the behaviour of the growers must be taken into account in the process of adoption of innovations. Through interviews with farmers, the first aim of this work was to know whether sown grass strips caused economic and agronomic fears to farmers. Secondly, the consequences of the establishment of sown grass strips were evaluated by studying two criteria: (1) the economic cost of sown grass strips and (2) its potential weed risk. Using cost estimations of the farmers' practices and weed surveys in their sown grass strips, we have tried to estimate the loss of gross margin when farmers replace crops by grass and to describe the weed flora harboured by sown grass strips.

2 Materials and methods

2.1 Study area

The study was carried out in two agricultural landscapes (Fig. 1a) located in western France (site 1, Zone Atelier CNRS "Plaine & Val de Sèvres"; Fig. 1b) and eastern France (site 2, Fig. 1c) so as to explore different farm types and cropping systems (Table 1). No significant gradient in the soil (clay loam soils and deep marly soils) and weather was detected within either studied area. On site 1, fields are mainly devoted

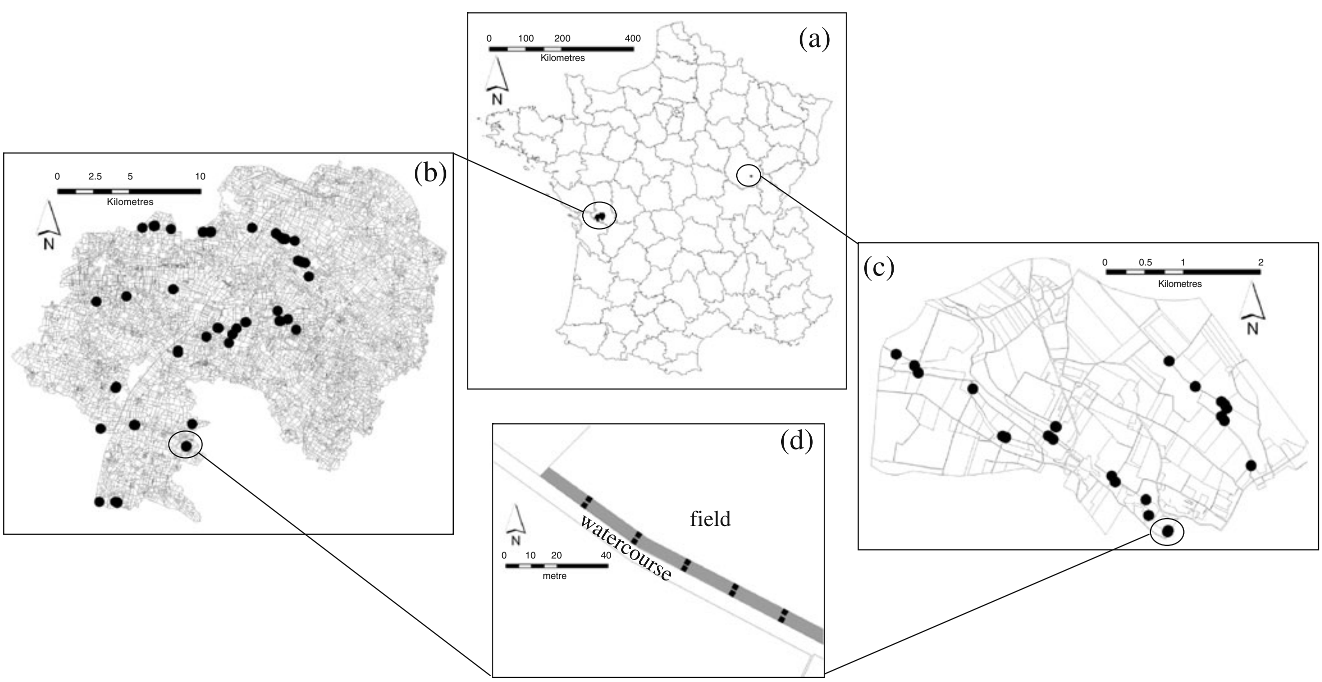

Fig. 1 **a** Location of the studied areas in France. **b** Site 1 in the south of the Deux-Sèvres department; **c** site 2 in the south of the Côte d'Or department. The *black dots* in **b** and **c** show the sown grass strips sampled in 2008; **d** represents the sampling design in sown grass strips (*grey*). The ten plots (0.36 m²) are indicated by the *black squares*

Table 1 Description of sites and surveyed farms

	Site 1		Site 2	
	Chizé		Fénay	
Location	Deux-Sèvres, Western France		Côte d'Or, Eastern France	
Coordinates	46°11N 0°28W		47°13N 5°03W	
Site area	500 km² (19,000 fields)		8.9 km² (140 fields)	
Typical rotations	Oilseed rape/wheat/barley Oilseed rape/wheat/sunflower/wheat Monoculture of maize		Oilseed rape/wheat/spring barley	
Average area (ha) of farms on the site	80		130	
Orientation of the main production	Cereal farms	Breeding farms	Cereal farms	Breeding farms
Average size (s.d.) of surveyed farms	109 (58)	191 (167)	144 (83)	380
Number of interviewed farmers	7	15	6	1

to autumn cereals (i.e. 70% of fields) and a few to maize. Few fields were devoted to temporary meadows (alfalfa and ray grass). On site 2, fields are devoted to autumn cereals (i.e. 42%) and oilseed rape (c.a. 13%). A total of 29 farmers (site 1, N=22; site 2, N=7) were interviewed. Sixteen of them were polyculture-breeding farmers and 13 were cereal farmers. The major part (89.6%) was constituted by quite big farms in comparison with the average size of large-scale arable French farms (i.e. 65 ha).

2.2 Interviews with farmers

2.2.1 Farmers' perception of sown grass strips

We interviewed 33 farmers about their perception of the economic and weed-related risks linked to sown grass strips. Interviews focused on two yes/no questions dealing with the economic cost perception—"Do the sown grass strips impact your farm revenue?"—and with the weed risk perception—"Have you encountered weed problems in your sown grass strips?" In addition, farmers tried to identify the origin of the loss of revenues and mentioned weed species which emerged in their sown grass strips, assuming they migrate through landscape elements (from the boundary to the sown grass strip, from the sown grass strip to the field, etc.). With Khi-2 tests on crossed tables of strength (table of contingency), we tried to find out whether there was a relationship between the farmers' answers and farm descriptors (farm size and cereal or breeding farm) and between the farmers' answers and their installation and management practices on sown grass strips.

2.2.2 Practices on sown grass strips

Farmers were interviewed about their practices so as to estimate the cost of installing and managing sown grass strips and to show links between their perceptions, their practices and weed indicators. We identified five setting-up variables and two management variables (Table 2). The installation variables were: strip age (1–5 years), mouldboard ploughing (yes or no), sowing type (conventional, sowing drill only; combined, sowing drill combined with

Table 2 Number of sown grass strips at each level of factors (installation and management variables) detailed by site

Factor	Level	Site 1 (N=46)	Site 2 (N=20)
Age (year)	1	2	5
	2	6	1
	3	23	11
	4	12	0
	>5	3	3
Ploughing	Yes	28	17
	No	18	3
Sowing type	Conventional	7	7
	Combined	30	12
	Direct	9	1
Sowing period	Autumn	21	7
	Spring	25	13
Sown seed mixture	GL	4	2
	GFrLp	20	6
	GFa	22	12
Mowing pratices	Cutting with removal of cuttings	6	5
	Cutting without removal of cuttings	40	15
Mowing frequency	1	14	5
	2	27	13
	3	5	2

Sowing type: *conventional* sowing drill only, *combined* sowing drill combined with harrow, *direct* sowing directly with superficial soil tillage. Sown seed mixture: *GL* grasses and legumes, *GFrLp* grass mixtures with *F. rubra* and *L. perenne*, *GFa* grass mixtures dominated by *F. arundinacea* harrow; direct, sowing directly with superficial soil tillage), sowing period (autumn or spring) and sown seed mixture (grasses and legumes, grass mixtures with *Festuca rubra* L. and *Lolium perenne* L., grass mixtures dominated by *Festuca arundinacea* L.). The sown grass strips were mainly sown with two or three species, among which *L. perenne*, *Dactylis glomerata* L., *F. rubra* and *F. arundinacea* L., sometimes associated with legumes such as *Trifolium repens* L. or *Medicago sativa* L. Considering the frequency of occurrence *L. perenne* was the most frequent sown species (42% of the sown grass strips). Some of these species will be considered as spontaneous species if they were not sown (e.g. *D. glomerata*, *T. repens*). The management variables were: mowing practices (cutting with or without removal of cuttings) and mowing frequency (1–3). The interviews revealed that the majority of sown grass strips were ploughed and sown with sowing drill combined with harrow (Table 2). Then, sown grass strips were generally cut with or without removal of the cuttings, most often twice a year.

2.3 Economic evaluation

The main combination of practices was firstly evaluated with six scenarios (Table 3). Scenarios were built in relation to the crop replaced by grass (winter wheat or winter barley, winter oilseed rape, maize) and in relation to the grass management (with or without removal of cuttings). During the first year, farmers installed their sown grass strips and managed them. During the following years, they only managed them. Consequently, the economic evaluation of each scenario was estimated in the first year and in the following years.

The economic evaluation was based on the comparison of gross margins between the crop and the sown grass strips, the gross margin being defined as the difference between the sale of products and the operating costs. The crop production represents an income in the estimation of the crop gross margin while hay represents a potential income (Table 3 scenarios 2, 4, and 6) in the estimation of the gross margin of the sown grass strip. The production cost includes mechanization (soil tillage, sowing, pesticide and fertiliser application, harvesting) and input (seeds, pesticides, fertilisers) costs. The mowing costs was calculated for two cuttings (25€/h each). Moreover, the removal costs included wilting (2x30€/ha), raking up (25€/ha) and baling (18€/ha) costs. The quantity of hay was estimated using the interviews with farmers, and its value was reduced by 30 % (Gokkus et al. 1999; Schellberg et al. 1999) because of its low quality (no fertiliser).

Table 3 Description of field scenarios (crop+removal of cuttings) and cropping systems (rotation of crops+removal of cuttings) economically evaluated

	Crop	Removal of cuttings
Scenario 1	Winter wheat or winter barley	No
Scenario 2	Winter wheat or winter barley	Yes
Scenario 3	Winter oilseed rape	No
Scenario 4	Winter oilseed rape	Yes
Scenario 5	Maize	No
Scenario 6	Maize	Yes
	Rotation	Removal of cuttings
Cropping system 1	Oilseed rape/wheat/barley	No
Cropping system 2	Oilseed rape/wheat/barley	Yes
Cropping system 3	Maize/maize/maize	No
Cropping system 4	Maize/maize/maize	Yes

The loss of gross margin in each scenario was integrated in two typical rotations operated on both sites (Table 3). Combined with the grass management (with or without removal of cuttings), the loss of gross margin was estimated in four cropping systems (Table 3). Finally, the loss of gross margin in the cropping systems was estimated at the farm level. We considered a 168-ha farm (average farm size on both sites), including 5.04 ha of sown grass strips, where the farmer set up the cropping systems 1 and 3 (Table 3) on two thirds and on one third of his farm area, respectively. We decided to evaluate this case because all the practices and cropping systems could occur in all surveyed farms.

2.4 Weed risk evaluation

2.4.1 Flora surveys

In June and July 2008, flora surveys were conducted on 46 and 20 sown grass strips on sites 1 and 2, respectively. Flora assessments were carried out on both sites with two complementary methods. Firstly, the presence and abundance of species on five pairs of 0.36-m² plots 25 m apart (Fig. 1d) were noted. Plots were located 1 m from the boundary or from the crop edge. The abundance was visually estimated adapting Braun–Blanquet cover abundance method (Mueller-Dombois and Ellenberg 1974) to sown grass strips. The cover percentage of each species was considered with the following scale intervals: 5 by more than 75% of cover of the plot, 4 by between 50% and 75%, 3 by between 25% and 50%, 2 by between 5% and 25%, 1 by less than 5%, 0.1 by more than two individuals with insignificant cover, 0.01 by one individual with insignificant cover. Secondly, species were listed walking across a 500-m² area of the sown grass strip (5×100 m, from the first to the last pair of plots). Plants were identified and named using available floras (Fournier 1947; Jauzein 1995), except for a few taxa for which small seedling size needed the identification at genus level (*Bromus* spp., *Cardamine* spp., *Carduus* spp., *Carex* spp., *Lolium* spp., *Luzula* spp., *Mentha* spp., *Melilotus* spp., *Rubus* spp.). The description of biological characteristics (life form, life span, potential frequency in field) was based on the flora of cultivated fields (Jauzein 1995).

Sown species were extracted from our dataset and considered as an explanatory variable (cover percentage of sown species, sown mixture). The dataset only contains non-sown species named weeds.

2.4.2 Indicators of the weed risk

Three weed risk indicators were used so as to set the farmers' perception with regard to our flora relevés: presence of particular weed species (e.g. potentially competitive or high dispersing weed), weed species richness and weed species cover abundance. Firstly, the ranking list of the weeds mentioned most frequently by the farmers was set alongside the ranking list of the weeds most frequently found in our surveys, using Kendall rank correlation coefficient. Secondly, we tried to explain the variability in the weed species richness of the sown grass strips by the installation and management practices, using Kruskal–Wallis tests. The normality of the distribution of the weed species richness was previously tested (Shapiro–Wilk test, W=0.9626, P=0.022). Finally, the abundance of weed species was illustrated using a dominance ratio defined as:

$$\text{Weed dominance ratio} = \log 10\left(\frac{\textit{total cover of weeds species}}{\textit{total cover of sown species}}\right)$$

Thus, this dominance ratio is positive when the weed species dominate the sown species. We tried to explain the variability in the dominance ratio of the sown grass strips by the installation and management practices, using one-way ANOVA. The normality of the values distribution of the dominance ratio was previously tested (Shapiro–Wilk test, W=0.9791, P=0.3296). Then we tested whether sown grass strips (for which weed-related problems were reported by the farmers) showed higher weed species richness or/and higher dominance ratio, using Mann–Whitney test and one-way ANOVA, respectively.

A potential difference on weed species richness between the two sites was tested using Mann–Whitney test. No significant effect was found on weed richness (H=0.103, P=0.7483). More than two thirds of the observed species on each site (90 species) were common to the two sites. Therefore, the data sampled on both sites were pooled. Dataset analyses were carried out with Past software version 1.87b (Hammer et al. 2001).

3 Results and discussion

3.1 Farmer's perception of sown grass strips

3.1.1 Decrease of farm revenue

Concerning the economic point of view, 63.6% of the farmers (N=21) thought that sown grass strips affect their farm revenue, whereas 36.4% (N=12) observe no impact on their revenue. The economic point of view was not linked with the farm type (Khi2-test on contingency table, P(no assoc)=0.1691) or with the farm size (Mann–Whitney test, T=113.5, P=0.6534). More generally, interviewed farmers regret that France is the only European country which does not compensate them for environmental measures through compensatory payment. In fact, the success and durability of agri-environmental measures depend on the farmers' acceptance (Burton et al. 2008). Farmers are willing to implement agri-environmental measures in exchange for compensatory payment to do it (Herzon and Mikk 2007; Defrancesco et al. 2008). Farmers said that the decrease in their revenue came from the loss of production (17.3% of answers) or from investments in new equipment (3.4% of answers). However, most of the farmers (79.3%) were not able to explain the source of the loss. In fact, interviews and economic evaluation conducted by the French Ministry of Agriculture (Carpy-Goulard et al. 2006) showed that the losses are caused by the management of sown grass strips, the reduction in the crop area and the cost of installation (e.g. grass seed mixture). These authors mentioned that the time allocated to manage sown grass strips could increase with weed infestation.

3.1.2 Weed risk

The interviews indicated that 69.7% of the farmers (N=23) encountered weed problems in their sown grass strips. Sown grass strips for which weed-related problems were reported by the farmers were mainly sown in spring (Khi2-test on contingency table, P(no assoc)<0.01) and were less frequently managed every year (Khi2-test on contingency table, P(no assoc)<0.05). No relationship was shown with the others variables (e.g. mowing practices, age, mixture). Farmers mainly mentioned perennial and competitive weeds e.g. *Cirsium arvense* (65.2% of the farmers having weed problems), that could decrease the crop yield in their fields (Donald and Khan 1996). Besides, they mentioned 26 weed species among which several are very frequent in sown grass strips (Table 4), e.g. *Elytrigia repens*, *Convolvulus arvensis*, *Bromus sterilis* and *Taraxacum sect. Vulgaria,* and high dispersing weeds (e.g. *Asteraceae*). Concerning weed dispersion, farmers feared that sown

Table 4 Frequency of occurrence (percentage on each site), averaged cover abundance (mean of cover percentage in the ten plots) of weed species in the 46 and 20 sown grass strips (site 1 and 2, respectively), classified by their total frequency ranks (both sites)

				Site 1		Site 2	
Frequency rank	Taxa	Total frequency (%) of occurrence	Farmers' citation (% of farmers)[a]	Frequency (%) of occurrence	Cover abundance if presence (%)	Frequency (%) of occurrence	Cover abundance if presence (%)
1	*Cirsium arvense*	87.9	65.2	82.6	1.19	100.0	1.98
2	*Convolvulus arvensis*	86.4	13.0	89.1	0.82	80.0	0.60
	Sonchus asper	86.4	4.3	84.8	0.65	90.0	0.17
4	*Taraxacum sect. Vulgaria*	81.8	4.3	82.6	0.80	80.0	0.75
5	*Picris hieracioides*	75.8		82.6	1.64	60.0	0.18
6	*Rubus* spp.	65.2	8.7	67.4	0.16	60.0	0.01
7	*Picris echioides*	57.6		78.3	4.63	10.0	0.01
8	*Dipsacus fullonum*	51.5		54.3	0.48	45.0	1.88
9	*Lactuca serriola*	47.0		54.3	0.13	30.0	0.00
10	*Arrhenatherum elatius*	45.5		54.3	2.69	25.0	8.37
	Cirsium vulgare	45.5	8.7	45.7	1.00	45.0	0.08
	Crepis vesicaria	45.5		52.2	0.20	30.0	0.00
	Verbena officinalis	45.5		56.5	0.16	20.0	0.01
14	*Calystegia sepium*	43.9		34.8	0.96	65.0	0.29
	Rumex obtusifolius	43.9	8.7	45.7	0.02	40.0	0.09
	Torilis arvensis	43.9		60.9	0.36	5.0	–[b]
17	*Elytrigia repens*	42.4	8.7	41.3	3.27	45.0	0.86
18	*Bromus sterilis*	40.9	4.3	34.8	0.61	55.0	0.26
	Rumex crispus	40.9		47.8	0.01	25.0	0.01
20	*Daucus carota*	39.4		41.3	0.64	35.0	0.07
	Epilobium tetragonum	39.4		45.7	0.33	25.0	0.00

[a] Percentage of weed species mentioned as problematic by farmers

[b] No abundance because the species was not observed in plots but while walking across the sown grass strips

grass strips would become a source of crop infestation and help weed to disperse into the adjacent field. All farmers suggested dissemination of weeds through landscape features. In fact, 15.2% of the farmers thought that species could come from the field. However, 69.6% thought that weed species could also disperse from the boundary to the sown grass strip, and 51.5%, from the sown grass strip to the cultivated area. This point is not evaluated in this paper, but studies showed long-distance dispersal by wind for some *Asteraceae* species and others by seed rain (de Cauwer et al. 2008). The literature shows that margins have little influence on the weed flora of crop edges and no impact on the flora of field cores (Marshall 2009); even if in our study, farmers' fears were related to the presence of some perennial and wind-dispersing weed species.

3.2 Economic evaluation

Only one case (scenario 1, Table 3, i.e. sown grass strip replacing winter wheat without removal of cuttings) was fully detailed (Table 5). The others were summed up in Table 6. During the first year, farmers installed sown grass strips, which generally did not require investment in new equipments (e.g. plough, harrow, sowing drill).

The gross margin in wheat production was estimated at 159 Euros (€) per hectare (Table 5, (A)=(1)–(2)). After farmers replaced wheat by sown grass strips the gross margin is negative (Table 5, (B)=(3)–(4)=–282€/ha) because of the absence of revenue (Table 5, (3)). Consequently, for the first year, the loss of gross margin was estimated at −441€/ha (Table 5, (B)–(A)), mainly because of the loss of wheat production. The reduction in operating

Table 5 Cost estimation to instal sown grass strips (first year) and to manage sown grass strips by cutting without removal of cuttings (first year and next year), in a preceding wheat field, based on the comparison of gross margins (€/ha) of wheat (A, C) and sown grass strip (B, D)

	Winter wheat				Sown grass strips			
	Revenues	cost (€/ha)	Operating costs	cost (€/ha)	Revenues	cost (€/ha)	Operating costs	cost (€/ha)
First year	Wheat[a]	840	Ploughing[b]	57			Ploughing[b]	57
			Combined sowing[b]	45			Combined sowing[b]	45
			Crop seeds[c]	120			Sown grass strip seeds[c]	130
			Fertilisers and fertiliser applications[b,c]	146			Cutting[b]	50
			Pesticides and pesticide applications[b,c]	228				
			Harvesting[b]	85				
	Total (1) =	840	Total (2) =	681	Total (3) =	0	Total (4) =	282
	wheat gross margin (A)=(1)–(2)=+159 €/ha				sown grass strip gross margin (B)=(3)–(4)=–282 €/ha			
	loss of gross margin=(B)–(A)=(–282)–(159)=−441 €/ha							
Next year	Wheat[a]	840	Ploughing[b]	57			Cutting[b]	50
			Combined sowing[b]	45				
			Crop seeds[c]	120				
			Fertilisers and fertiliser applications[b,c]	146				
			Pesticides and pesticide applications[b,c]	228				
			Harvesting[b]	85				
	Total (5) =	840	Total (6) =	681	Total (7) =	0	Total (8) =	50
	wheat gross margin (C)=(5)–(6)=+159 €/ha				sown grass strip gross margin (D)=(7)–(8)=−50 €/ha			
	loss of gross margin=(D)–(C)=(–50)–(159)=−209 €/ha							

Mowing costs was calculated for two cuttings per year. Gross margins were calculated as the difference between revenues (1, 3, 5 and 7) and operating costs (2, 4, 6 and 8). The loss of gross margin has been defined as the sown grass strip gross margin minus the wheat gross margin (i.e. (B)–(C) or (D)–(C))

Sources of costs:

[a] Average crop prices between 2000 and 2006 (French technical institutes dedicated to each crop: AGPM, Association Générale des Producteurs de Maïs and CETIOM, Centre Interprofessionnel des Oléagineux Métropolitains; personal communication)

[b] Equipment costs work sheet (Anonymous 2009)

[c] Data obtained from agricultural cooperatives of the two sites

Table 6 Losses of gross margins (€/ha/year), in the first year and the next years, in the 6 scenarios, i.e. when sown grass strips replace winter wheat (or winter barley), oilseed rape or maize, with or without hay-making and export for cattle

			Loss of gross margin (€/ha/year)	
	Crop	Removal of cuttings	First year	Next year
Scenario 1	Wheat or barley	No	−441	−209
Scenario 2	Wheat or barley	Yes	−358	−126
Scenario 3	Oilseed rape	No	−696	−464
Scenario 4	Oilseed rape	Yes	−613	−381
Scenario 5	Maize	No	−853	−641
Scenario 6	Maize	Yes	−770	−558
	Rotation	Removal of cuttings	Loss of gross margin (€/ha/year)	
Cropping system 1	Oilseed rape/wheat/barley	No	−371	
Cropping system 2	Oilseed rape/wheat/barley	Yes	−288	
Cropping system 3	Maize/maize/maize	No	−712	
Cropping system 4	Maize/maize/maize	Yes	−629	

Mowing and removal of cuttings were calculated for two cuttings per year. The removal costs included wilting (2×30€/ha), raking up (25€/ha) and baling (18€/ha) costs. The losses of gross margin were integrated within 3-year rotations, that is, 1 year of installation (first year cost) and 2 years of management (next year cost) costs (e.g. pesticides and fertilisers), from 681€ to 282€, is not sufficient to compensate for the loss of production and the additional operating costs (seed mixture, 130€/ha; cutting, 50€/ha). This loss largely depends on the prices of agricultural goods, which can fluctuate over the years. Furthermore, the farmers could loss more money if they install sown grass strips in field previously cropped with high-value-added crop (e.g. sugar beet). Concerning the impact on the farm revenue, about 15% of the farmers thought that the loss of revenue came from the loss of production. This perception was proven by our economic evaluation.

The estimation of the wheat gross margin still remained identical during the second year (Table 5, (C)). The operating costs in the sown grass strip decreased (Table 5, (8)=50€/ha). Nevertheless, the loss of gross margin remained negative during the second year (Table 5, (D)–(C)=–209€/ha). The installation of sown grass strips in a cultivated field implies a loss of gross margin in all the scenarios that varied from –126 to –853€/ha/year (Table 6). So, considering the loss of gross margin within the rotation (Table 6), farmers lost money in all evaluated cropping systems. The loss varied from 371€/ha/year for the oilseed rape/wheat/barley rotation without removal of cuttings to 712€/ha/year for a monoculture of maize without removal of cuttings.

Even if it makes the loss of gross margin less severe (i.e. by 83€/ha/year), hay making seems to be economically non-viable (Shield et al. 1996) because of the low quality of the forage (produced without fertilisers) that decreases year after year (de Cauwer et al. 2006). Besides, in some cases, farmers had to rent or purchase new equipment and hay making could exclusively be performed by polyculture-breeding farmers.

Let us consider an average-sized farm (5.04 ha of sown grass strips), where the farmer set up the cropping systems 1 and 3 (Table 3) on two thirds and one third of his farm area respectively. The farmer has earned 60,813€/year since 2005. But now, with 3% of sown grass strips, he loses 2,457€/year and earns 58,990€/year from the rest of his farm (i.e. 168–5.04=162.96 ha), so he earns 56,533€/year. Consequently, 3% of sown grass strips decreased his revenue by 7.04%. The economic losses seemed to be important but were weak in comparison to crop yield losses caused by insects (Lerin 1995), by hailfall (Changnon 1971) or by harvesters (Sausse et al. 2006). At the farm-scale level, sown grass strips had low economic impact but management practices in sown grass strips could hinder the farm planning. Moreover, the presence of a sown grass strip adjacent to a field could be beneficial for some aspects, e.g. decreasing the costs for pest control by enhancing auxiliaries populations (Marshall and Moonen 2002) or increase the soil quality (reduction of erosion). However, these positive effects could be balanced by negative ones, e.g. presence of ergot on grasses (Bailey and Gossen 2005).

3.3 Weed risk evaluation

3.3.1 Presence of some weed species

In the 66 sown grass strips, 167 taxa were identified. The most frequent species (Table 4) were perennials (*E. repens* (L.) Nevski, *Verbena officinalis* L.), including geophytes (*C. arvense* (L.) Scop.) or hemicryptophytes (*Taraxacum* Sect. *Vulgaria* Dahlst., *Crepis vesicaria* L., *Rumex obtusifolius* L.), some were anemochores such as *Asteraceae* species (*Sonchus asper* (L.) Hill, *Picris hieracioides* L., *Picris echioides* L., *Lactuca serriola* L.), grasses (*D. glomerata* L., *Arrhenatherum elatius* (Willd.) Dumort.) and creeper plants (*C. arvensis* L., *Calystegia sepium* (L.) Brown, *Rubus* spp.). We showed that sown grass strips harboured as many grasses as forbs, whereas—as shown by Marshall and Arnold (1995)—forbs are in a majority in field–core areas.

Considering the life form, 41.0% of the recorded non-sown species were hemicryptophyte plants and 43.3% therophyte plants. Besides, 44.0% were annual plants. Comparing with other habitats of the landscape, there were fewer annual species in sown grass strips than in fields (e.g. 88%, Fried et al. 2009), crop edges (e.g. 73%, Fried et al. 2009) or herbaceaous boundaries (e.g. 79%, Walker et al. 2007). However, annual plants were more frequent in sown grass strips than in perennial habitats like set-asides (e.g. 5–20%, Nemeth 2001). Besides, 87.3% of the species observed in the strips can also be found as weeds in fields, 50.0% of them being frequently found in fields. Among rare or non-arable plants, we observed common species of moist habitats (ditches or river banks) like *Dipsacus fullonum* L., *Phragmites australis* Cav. Steudel. or boundary-specific species like *Arctium lappa* L., *Salvia pratensis* L., *Galium mollugo* L., *Achillea millefolium* L. and *Sambucus ebulus* L. No invasive species were observed and only a few individuals of one segetal weed (*Legousia speculum-veneris* (L.) Chaix) were observed in a sown grass strip on site 1.

Among the 20 most frequent species (Table 4), *C. arvense* was observed in all the sown grass strips of site 2 (Table 4), while 50.2% of the species were observed in fewer than five sown grass strips. Interviewed farmers actually mentioned the most frequent weed species found in sown grass strips as a significant problem. The ranking classification of the weed most frequently mentioned by the farmers (Table 4) were correlated with the ranking classification of frequencies of weed species occurrences in our surveys (Kendall's tau=0.3796, $P<0.01$).

3.3.2 Weed species richness

The median weed species richness was 26 species (quartile=22, third quartile=31) per 500 m² of sown grass strip supporting a previous estimation of Critchley et al. (2006). Species richness varied from six to 50 weed species per sown grass strip. Sown grass strips for which farmers mentioned weed problems did not harbour more weed species than the others (Mann–Whitney test, P=0.8796).

Species richness in sown grass strips could be three times higher than in field areas (i.e. about nine and 12 species in the field core and field edge, respectively (Fried et al. 2009)). We recorded high values as early as the first year (median=25, quartile=22, third quartile=31; Table 7). The high species richness of 1-year-old sown grass strips revealed that a multitude of seeds or buds were in the soil seed bank or dispersed by the wind from the boundaries. The ban of herbicide spraying allowed them to go past the seedling stage. Our results showed that the weed species richness did not increase with the age of sown grass strips, unlike set-asides (Forche 1991) or mown and occasionally grazed grasslands (Jongepierova et al. 2004).

Moreover, in our study, the age, the sowing type, sowing period, sown mixture, mowing pratices and mowing frequency were found to have no effect on the weed species richness (Table 7). However, in experimental sown grass strips, de Cauwer et al. (2005) showed interactions between mowing treatments and sown mixtures. The mowing seemed to change the community in terms of composition, affecting pernicious or desirable species, depending on their biological traits (Westbury et al. 2008).

Table 7 Effects (P value) of each installation and management variables (factors) on two indicators of weed species: weed species richness (number of weed species observed) and weed dominance ratio (i.e. the total abundance of all weed species were divided by the total abundance of the sown species, log10 transformed)

Factor	Weed species richness (P)[a]	Weed dominance ratio (P)[b]
Age	0.56	<0.05
Ploughing	<0.05	0.62
Sowing type	0.84	0.45
Sowing period	0.66	0.27
Sown seed mixture	0.42	0.16
Mowing pratices	0.79	0.39
Mowing frequency	0.21	0.98

[a] Kruskall–Wallis test

[b] One-way ANOVA

However, the ploughing structured the weed species richness (Table 7), and the sown grass strips which were ploughed at the installation harboured 27 weed species (quartile=24, third quartile=34.5), whereas non-ploughed strips harboured 23 species (quartile=19, third quartile=31). The ploughing rise to the soil surface old seeds which were able to rapidly germinate. However, the effect of the ploughing seems relevant to be studied only for 1-year old grass strips, as the effects of all installation practices.

3.3.3 Relations between sown and weed species: weed dominance ratio

The total plant cover averaged 77.3% (SD=14.9%) ranging from 23.4% to 98.7%. There was no sown grass strip with 100% of vegetation cover. Furthermore, 95% of sown grass strips had a total vegetation cover higher than 50%. We observed only one extreme case (i.e. 23.4%). Sown grass strips for which farmers mentioned weed problems did not show higher ratio dominance than the others (one-way ANOVA, df=1, F=0.19, P=0.66). The dominance of weed species was not structured by installation and management variables (Table 7), except for the age of sown grass strips

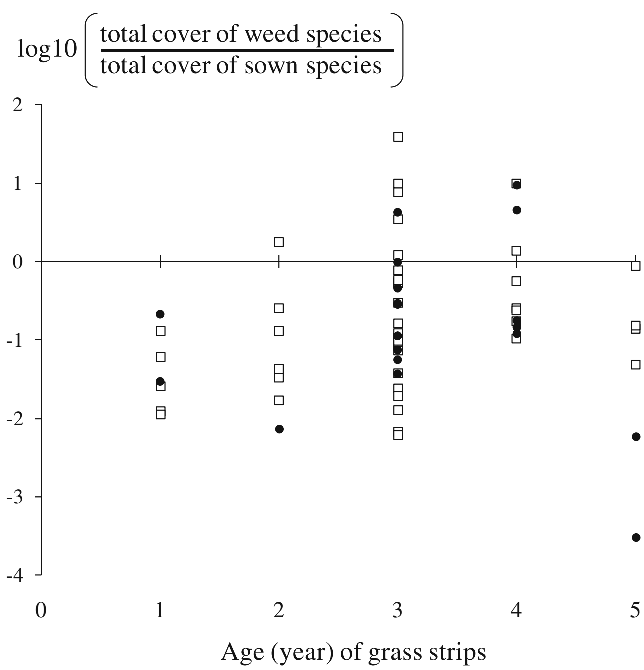

Fig. 2 Weed dominance ratio, i.e. the total cover percentage of weed species divided by the total cover percentage of sown species, log10 transformed, related to the age of sown grass strips. Sums of weed and sown species were performed per plot. On the graph, each point accounts for the average of the 10 plots performed per sown grass strip. Datasets were grouped using the farmers' answers to the yes-no question: "do you have weed problem in your sown grass strip?" (*black dot* no weed problem, *white square* weed problems). All points above the x-axis represent sown grass strips where weed species dominated sown species in terms of abundance

(one-way ANOVA, df=4, F=3.47, P<0.05). In most sown grass strips (N=55), the very competitive sown grass species dominated the weed species (Fig. 2). The number of sown grass strips with positive weed dominance ratio increased over the time and fell down after 3 years. Farmers weed problems were not associated to strips showing dominance of non-sown species because farmers can manage them or could plough the grass strips to re-sow it. In that sense, they did not take into account the overall weed community but focused on some species.

4 Conclusion

Concerning weed risk, the results showed that the farmers' fears were linked with the presence of particular species, but not with a high richness or weed dominance. These three aspects and the views the farmers had on each of them suggested that they could accept high weed richness and the high biodiversity level it entails. Sown grass strips were set up for environmental reasons. In the process of innovations like sown grass strips, scientists and policy makers must study the consequences and the acceptability of their findings. Concerning cost of sown grass strips, they decrease the farmers' revenue even if they consider the losses as acceptable at the farm level. Moreover, field margins could be a highly biodiverse and acceptable habitat, keeping fields to produce crops. Sown grass strips could act in favour of flora and fauna biodiversity at the local or landscape level. However, the sown grass strips were set up for environmental purposes and farmers understood and accepted to lose 3% of their farm area to these objectives. Consequently, with long-term considerations, the sown grass strips will have to keep their environmental functions to remain a sustainable measure and acceptable for farmers. However, the weed risk could increase over the time even if the economic fears could decrease.

Acknowledgements This work was funded by grants from ANR Ecoger, ANR-STRA-1 08-02 and INRA. The authors thank Fabrice Dessaint and Sandrine Petit for their help. We also thank Rémi Bonnot and the farmers of the two sites for their assistance in the sown grass strips surveys. We thank Jean-Luc Demizieux and the anonymous reviewers for their help in reviewing the manuscript.

References

Amiaud B, Touzard B (2004) The relationships between soil seed bank, aboveground vegetation and disturbances in old embanked marshlands of Western France. Flora 199:25–35. doi:10.1078/0367-2530-00129

Anonymous (2009) Barème d'entraide 2009 Nord Est : Evaluez le coût de vos matériels, Entraid' Est n°185 supplement

Bailey KL, Gossen BD (2005) Boundary areas and plant diseases. In: Thomas AG (ed) Field boundary habitats: implications for weed, insect and disease management, topics in canadian weed science, Canadian weed science soc. Soc Canadienne Malherbologie, Quebec, pp 165–169

Burton RJF, Kuczera C, Schwarz G (2008) Exploring farmers' cultural resistance to voluntary agri-environmental schemes. Sociol Rural 48:16–37. doi:10.1111/j.1467-9523.2008.00452.x

Carpy-Goulard F, Daniel K, Kephaliacos C, Mosnier C, Ridier A, van De Moortel C (2006) Conditionnalité des aides directes: impact de la mise en oeuvre de certaines BCAE et de la mesure de maintien des pâturages permanents. Notes et études économiques 25:137–164

Changnon SA (1971) Hailfall characteristics related to crop damage. J Appl Meteorol 10:270–274

Critchley CNR, Fowbert JA, Sherwood AJ, Pywell RF (2006) Vegetation development of sown grass margins in arable fields under a countrywide agri-environment scheme. Biol Conserv 132:1–11. doi:10.1016/j.biocon.2006.03.007

de Cauwer B, Reheul D, D'Hooghe K, Nijs I, Milbau A (2005) Evolution of the vegetation of mown field margins over their first 3 years. Agric Ecosyst Environ 109:87–96. doi:10.1016/j.agee.2005.02.012

de Cauwer B, Reheul D, Nijs I, Milbau A (2006) Dry matter yield and herbage quality of field margin vegetation as a function of vegetation development and management regime. NJAS Wagening J Life Sci 54:37–60. doi:10.1016/S1573-5214(06)80003-5

de Cauwer B, Reheul D, Nijs I, Milbau A (2008) Management of newly established field margins on nutrient-rich soil to reduce weed spread and seed rain into adjacent crops. Weed Res 48:102–112. doi:10.1111/j.1365-3180.2007.00607.x

de Snoo GR, de Wit PJ (1998) Buffer zones for reducing pesticide drift to ditches and risks to aquatic organisms. Ecotoxicol Environ Saf 41:112–118. doi:10.1006/eesa.1998.1678

Defrancesco E, Gatto P, Runge F, Trestini S (2008) Factors affecting farmers' participation in agri-environmental measures: a northern Italian perspective. J Agric Econ 59:114–131. doi:10.1111/j.1477-9552.2007.00134.x

Donald WW, Khan M (1996) Canada thistle (*Cirsium arvense*) effects on yield components of spring wheat (*Triticum aestivum*). Weed Sci 44:114–121

Forche T (1991) Changing vegetation and weed floras during set-aside and afterwards. Proc Brighton Crop Prot Conf; pp. 377–386

Fournier P (1947) Les quatre flores de France, 1990th edn. Lechavalier, Paris

Frank T (1998) Slug damage and numbers of the slug pests, *Arion lusitanicus* and *Deroceras reticulatum*, in oilseed rape grown beside sown wildflower strips. Agric Ecosyst Environ 67:67–78. doi:10.1016/S0167-8809(97)00108-4

Fried G, Petit S, Dessaint F, Reboud X (2009) Arable weed decline in Northern France: crop edges as refugia for weed conservation? Biol Conserv 142:238–243. doi:10.1016/j.biocon.2008.09.029

Gokkus A, Koc A, Serin Y, Comakli B, Tan M, Kantar F (1999) Hay yield and nitrogen harvest in smooth bromegrass mixtures with alfalfa and red clover in relation to nitrogen application. Eur J Agron 10:145–151. doi:10.1016/S1161-0301(98)00061-6

Hammer Ø, Harper DAT, Ryan PD (2001) Past: paleontological statistics software package for education and data analysis. Palaeontol Electronica 4:1–9

Henry M, George S, Arnold GM, Dedryver CA, Kendall DA, Robert Y, Smith BD (1993) Occurrence of barley yellow dwarf virus (BYDV) isolates in different farmland habitats in western France and south-west England. Ann Appl Biol 123:315–329

Herzon I, Mikk M (2007) Farmers' perceptions of biodiversity and their willingness to enhance it through agri-environment schemes: a comparative study from Estonia and Finland. J Nat Conserv 15:10–25. doi:10.1016/j.jnc.2006.08.001

Hooks GM, Napier TL, Carter MV (1983) Correlates of adoption behaviors—the case of farm technologies. Rural Sociol 48:308–323
Jauzein P (1995) Flore des champs cultivés. SOPRA-INRA, Paris
Jongepierova I, Jongepier JW, Klimes L (2004) Restoring grassland on arable land: an example of a fast spontaneous succession without weed-dominated stages. Preslia 76:361–369
Lerin J (1995) Assessment of yield losses caused by insects in winter oilseed rape, a critical review, in: IOBC/WPRS Working Group 'Integrated control in oilseed crops', Zurich, Switzerland, 24–25 February 1994, pp. 95–101
Marshall EJP (1989) Distribution patterns of plants associated with arable field edges. J Appl Ecol 26:247–257
Marshall EJP (2009) The impact of landscape structure and sown grass margin strips on weed assemblages in arable crops and their boundaries. Weed Res 49:107–115. doi:10.1111/j.1365-3180.2008.00670.x
Marshall EJP, Arnold GM (1995) Factors affecting field weed and field margin flora on a farm in Essex, UK. Landsc Urban Plan 31:205–216. doi:10.1016/0169-2046(94)01047-C
Marshall EJP, Moonen AC (2002) Field margins in northern Europe: their functions and interactions with agriculture. Agric Ecosyst Environ 89:5–21. doi:10.1016/S0167-8809(01)00315-2
Montanarella L, van Rompaey A, Jones R (2003) Soil erosion risk in Europe. European Commission report, Joint Research Centre, Institute for Environment and Sustainability, pp. 15
Mueller-Dombois D, Ellenberg H (1974) Aims and methods of vegetation. Wiley, New York
Nemeth I (2001) Weed flora of fields set-aside for a long period in Northern Hungary. Novenytermeles 50:217–230
Sausse C, Wagner D, Lucas JL, Estragnat A, Mangenot O, Garric B, Reau R, Devaux C, Champolivier J, Messean A (2006) Estimate of losses at harvest of winter oilseed rape (*Brassica napus*) under varying conditions. OCL-Ol Corps Gras, Lipides 13:431–438
Schellberg J, Moseler BM, Kuhbauch W, Rademacher IF (1999) Long-term effects of fertilizer on soil nutrient concentration, yield, forage quality and floristic composition of a hay meadow in the Eifel mountains, Germany. Grass Forage Sci 54:195–207. doi:10.1046/j.1365-2494.1999.00166.x
Shield IF, Godwin RJ, Smith DLO (1996) The costs of alternative methods of managing 'set-aside' land within the European Community. Soil Tillage Res 37:273–287. doi:10.1016/0167-1987(96)01007-0
Sotherton NW (1985) The distribution and abundance of predatory coleoptera overwintering in field boundaries. Ann Appl Biol 106:17–21
Vickery JA, Bradbury RB, Henderson IG, Eaton MA, Grice PV (2004) The role of agri-environment schemes and farm management practices in reversing the decline of farmland birds in England. Biol Conserv 119:19–39. doi:10.1016/j.biocon.2003.06.004
Walker KJ, Critchley CNR, Sherwood AJ, Large R, Nuttall P, Hulmes S, Rose R, Mountford JO (2007) The conservation of arable plants on cereal field margins: an assessment of new agri-environment scheme options in England, UK. Biol Conserv 136:260–270. doi:10.1016/j.biocon.2006.11.026
Westbury DB, Woodcock BA, Harris SJ, Brown VK, Potts SG (2008) The effects of seed mix and management on the abundance of desirable and pernicious unsown species in arable buffer strip communities. Weed Res 48:113–123. doi:10.1111/j.1365-3180.2007.00614.x