Enhancing biodiversity on arable farms in the context of environmental certification schemes

Manhoudt, A.G.E.

6

ENHANCING PLANT SPECIES RICHNESS ON DITCH BANKS: A COMPARISON OF FARMING PRACTICES AND MANAGEMENT REGIMES

Astrid Manhoudt, Andries Visser and Geert de Snoo

Submitted

Summary

Plant species richness of ditch banks under different farming practices and management regimes was compared. To this end, species richness was inventoried on several conventionally managed ditch banks on conventional and organic farms in two regions of the Netherlands and on ecologically managed ditch banks on a number of experimental farms.

Plant species richness was significantly higher on organic than conventional farms. On farms that had converted to organic agriculture more than 5 years ago, even more species were found, although this trend was not significant. Compared with the conventional farms in each region, there were 19% more plant species on recently converted organic farms (less than 5 years), and 34% (clay soil) and 48% (sandy soil) more on organic farms that had converted over 5 years ago.

On all farms, including the experimental farms, higher plant species numbers were found on sandy soils than on clay soils. This is also supported by the higher share of nitrogen poor plant species (Table 2) based on the Ellenberg values.

The combination of the increase in plant species richness and the change in plant species composition (based on the rarity index and the Ellenberg nitrogen values) was most marked in ecologically managed ditch banks (mowing and removal of the cutting in buffered ditch banks) on the experimental farms. This therefore indicated that the ecological management might enhance plant species richness more than organic farming alone in a 6-year period. In the context of an environmental label, criteria designed to enhance on-farm biodiversity should therefore specify an ecological management on ditch banks buffered with a pesticide and nutrient free zone.

6.1 Introduction

Europe has seen a historical decline in biodiversity on farms as well as in the wider agricultural landscapes, due largely to the intensification and industrialisation of traditional farming methods (e.g. Baldock, 1990; Fuller *et al.*, 1995; Andreasen *et al.*, 1996; Delbaere *et al.*, 1998). To reverse this trend less intensive agricultural practices are now being promoted, including organic farming, low-input farming, no-tillage farming and allied systems (European Council, 1997; Morris and Winter, 1999; European Commission, 1999; EUREP, 1999; SAI, 2002).

Many studies have compared the effects of organic and conventional farming systems on species diversity on arable fields, for example Albrecht and Mattheis (1998), Chamberlain *et al. (*1999), Hald (1999), Asteraki *et al. (*2004), Hole *et al. (*2005) and others. Most studies showed that organic farming benefits on-farm biodiversity more than conventional farming (Asteraki et a., 2004; Bengtsson *et al.*, 2005; Fuller *et al.*, 2005; Hole *et al.*, 2005). Differences in species diversity in the non-productive areas bordering arable fields have been less frequently studied, however, especially with regard to plant species diversity (Gardner and Brown, 1998).

The main goal of this study was to quantify differences in plant species richness on ditch banks on conventional and organic arable farms. Based on other studies as mentioned above, we expect to find a higher plant species richness in ditch banks on organic farms than in ditch banks on conventional farms. In addition, the effects of an ecological management regime designed specifically to enhance plant species richness on ditch banks were explored. In the Netherlands, ditch banks are the principal kind of semi-natural habitat on arable farms (Manhoudt and de Snoo, 2003).

The following research questions were addressed: 1) does ditch-bank plant species richness differ between organic and conventional arable farms on sandy and clay soils, 2) is plant species richness affected by the time elapsed since conversion to organic farming, and 3) does ecological management of ditch banks (i.e. mowing with removal of cuttings and a buffer zone between crop and ditch bank) enhance plant species richness over time compared with the current situation? There is also discussion of the criteria that might be employed in environmental certification schemes to improve ditch-bank plant species richness.

6.2 Methods

Field work

A series of conventional arable farms (in 2002) and organic arable farms (in 2003) on clay and sandy soils were visited (Table 1). Among the organic farms a distinction was made between those that had recently switched to organic methods (less than 5 years ago) and those that had done so longer ago (on average 16 ± 7.6 years). On each farm, 10 surveys of 25 metres of ditch bank were carried out on a transect to inventory the plant species presence (Nomenclature: van der Meijden, 1996). These covered the entire gradient of ditch banks, which had an average width of 1.9 ± 0.4 m in Zeeland and 1.5 ± 0.3 m in Noord-Brabant.

Table 1: Number of ditch banks on conventional farms, organic farms and number of experimental farms with ecologically managed ditch banks on clay and sandy soils.

	Clay soil	Sandy soil
Ditch banks on conventional farms	12	6
Ditch banks on organic farms:		
< 5 years organic	8	
> 5 years organic	8	4
Ecologically managed ditch bank	2	2

The present, conventional management regime of these ditch banks varied with respect to first mowing date and mowing frequency (Manhoudt *et al.*, 2005), but on none of the farms were the cuttings removed. An earlier study by Manhoudt *et al. (*2005) indicates that on these conventional arable farms these variations make little difference to ditch-bank plant species richness. The influence of this conventional management regime was therefore excluded from the present analysis.

On a small number of experimental farms (Table 1) participating in Wageningen University research programmes, ditch banks are managed ecologically and buffered with field margin strips to assess how plant species richness can best be enhanced (Hopster *et al.*, 2002). The data collected in this research program were used in the present study. On these farms a field margin strip at least 3 metres wide is maintained along ditch banks to buffer the influences of farming practices (organic or conventional). The ditch bank vegetation is mowed at least once a year (in September) and the cuttings removed to reduce nutrient inputs and vegetation biomass. On each of these farms, a minimum of 7 plant species surveys of 100 metres of ditch bank (covering the entire ditch bank gradient) were carried, out spread out over the whole farm from 1999 to 2004 inclusive.

Data analysis

To permit inter-farm comparison and correction for differences in ditch-bank width and survey area, plant species numbers were calculated per 400 m^2 ditch bank after establishing species-area curves for each individual ditch bank (using the methodology proposed by Manhoudt *et al. (*2005) and the computer program Estimates (Colwell and Coddington, 1994; Colwell, 1997). For each type of farm and each region, the average number of plant species was calculated. On the ecologically managed ditch banks on the experimental farms, changes in plant species numbers were also followed over the period 1999-2004.

Differences in plant species numbers were analysed using GLM-univariate analysis and one-way ANOVA after logarithmic transformation (Sokal and Rohlf, 2000; SPSS 11.0). Farming practices and numbers of years under organic management were included in the statistical analysis. Differences between ecological and conventional management regimes were also analysed. The trends in plant species richness and average Ellenberg indicator values for nitrogen of the ecologically managed ditch banks for the period 1999 - 2004 were assessed using linear regression analysis.

To compare the species composition of the ditch-bank vegetation a Dutch rarity index was employed, based on species presence in the Netherlands on a 1 × 1 km grid (Tamis and van 't Zelfde, 2003), with species categorised as extremely rare, rare, fairly rare, fairly common, common or very common according to the number of grid cells in which they were recorded in the period 1988-1999. Also, the plant species composition was compared based on the Ellenberg indicator values for nitrogen per species found in the ditch bank vegetations (Ellenberg *et al.*, 1992; Wiertz, 1992; Hill *et al.*, 1999).

6.3 Results

Plant species numbers

The number of ditch-bank plant species was significantly higher on organic farms ($P < 0.001$) than on conventional farms (Figure 1). Although no significant difference was found between organic farms that had recently converted and those that had done so over 5 years' ago, a definite increase in plant species numbers could still be observed (Figure 1). Regional differences were also assessed ($P < 0.001$) and plant species numbers were found to be significantly higher on sandy soils than on clay soils on both conventional and organic farms.

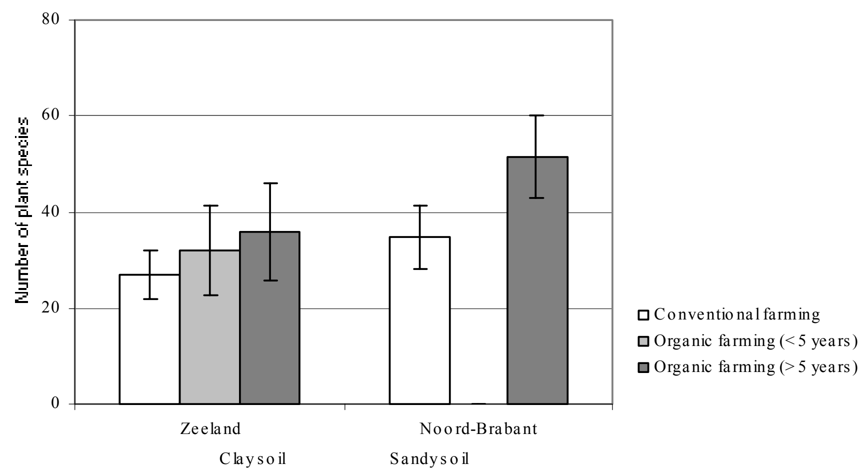

Figure 1: Average number of plant species per 400 m^2 ditch bank on conventional and organic farms in Zeeland (clay soil) and Noord-Brabant (sandy soil), showing standard deviation.

Table 2: Percentage of plant species per rarity class* and per class of Ellenberg nitrogen values in ditch banks on conventional farms, organic farms and the experimental farms Westmaas, OBS Nagele, Vredepeel and Kooijenburg with ecologically managed ditch banks.

Type of farm	*Conventional farms:*		*Organic farms:*			*Experimental farms:* *Westmaas*		*OBS Nagele*		*Vredepeel*		*Kooijenburg*	
Soil type	Clay	Sandy	Clay	Clay	Sandy	Clay		Clay		Sandy		Sandy	
Duration farm manag.			< 5 years	> 5 years	> 5 years								
Inventory year	2001 (n = 12)	2001 (n = 6)	2003 (n = 8)	2003 (n = 8)	2003 (n = 4)	1999	2004	1999	2004	1999	2004	1999	2004
Composition:													
extremely rare	0	0	0	0	0	0	0	0	0	0	2.1	0	1.0
rare	1.3	0	0.9	0	2.0	0	1.3	3.2	2.2	0	0	0	0
fairly rare	2.6	5.8	1.8	0.9	1.0	1.3	2.7	9.5	5.6	2.0	0	2.3	0
fairly common-common	10.3	4.7	21.6	22.4	15.8	10.0	12.0	14.3	14.4	14.0	13.3	5.8	9.1
very common	85.9	89.5	75.7	76.6	81.2	88.8	84.0	73.0	77.8	84.0	84.7	91.9	89.9
Ellenberg indicator:													
nitrogen poor (1-3)	4.2	6.9	12.2	3.3	13.1	9.0	9.5	7.8	9.5	16.7	16.5	13.3	14.8
intermediate (4-6)	42.3	36.1	38.9	43.3	42.9	37.3	44.4	29.4	40.5	38.1	44.3	37.3	44.4
nitrogen rich (7-9)	53.5	56.9	48.9	53.3	44.0	53.7	46.0	62.7	50.0	45.2	39.2	49.3	40.7

* Rarity class (based on the period 1988-1999)
- extremely rare species present in 31 - 100 km^2 of the Netherlands
- rare 101 - 300 km^2
- fairly rare 301 - 1000 km^2
- fairly common-common 1001 - 3000 km^2
- common 3000 - 10000 km^2
- very common > 10000 km^2

Compared with the conventional farms in each region, there were 19% more plant species on recently converted organic farms (less than 5 years), and 34% (clay soil) and 48% (sandy soil) more on organic farms that had converted over 5 years ago.

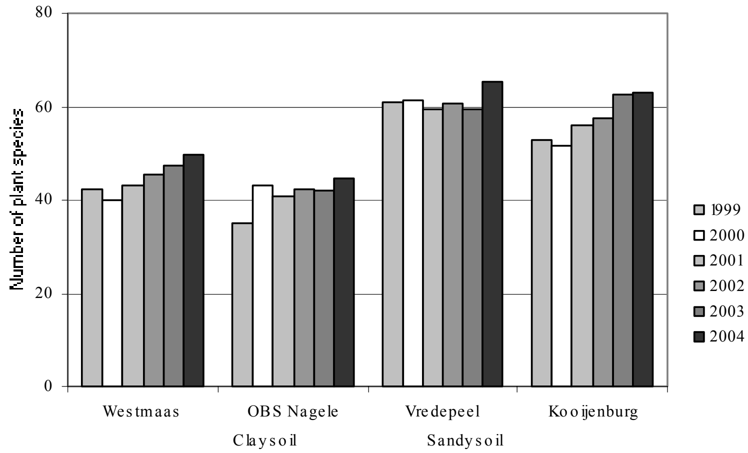

Figure 2: Trends in plant species numbers per 400 m^2 ecologically managed ditch bank with buffer zone per experimental farm over the period 1999 (initiation of the regime) to 2004.

On the experimental farms with ecologically managed ditch banks plant species numbers rose significantly ($P < 0.01$) over a 6-year period (Figure 2). The largest increase (27%) was found on the farm 'OBS Nagele', on clay soil, and the smallest (7%) on 'Vredepeel', on sandy soil. However, on the Vredepeel farm plant species were already relatively high at the initiation of the ecological management regime in 1999.

Plant species composition

On the organic farms, 75.7% (clay) to 81.2% (sandy) of the plant species found were very common, with about 20% fairly common or common species. Also, some fairly rare or rare plant species were found on these farms (Table 2). In comparison with the conventional farms, on the organic farms a small shift was seen from very common to more fairly common or common species.

Analysis of the species presence of the ecologically managed ditch banks over the period 1999-2004 (Table 2) showed a small shift on most farms from very common to fairly common and common or fairly rare and rare plant species. On two of the experimental farms (both on sandy soils) some extremely rare plant species were recorded in 2004.

Based on the plant species found in the ditch banks, no difference was found between the average Ellenberg nitrogen values on the organic and conventional farms in Zeeland and Noord-Brabant: the average Ellenberg nitrogen value was 6.1 ± 1.5 for all farms. On both organic and conventional farms on sandy soils, the relative share of nitrogen poor species (class 1-3) is larger than on clay soils (Table 2). On the recently converted organic farms on clay soil, an increase in nitrogen poor species was noticed compared with the conventional farms. However, this trends was not found on the organic farms that had converted over 5 years ago. On sandy soil, an increase in nitrogen poor plant species was seen on organic farms compared with conventional farms.

On the experimental farms, a significant negative trend was seen in the average Ellenberg nitrogen values based on the found plant species was seen over 6 years ($P < 0.01$; Figure 3). On all experimental farms, there was also a shift in plant species composition (Table 2) from nitrogen rich plant species (class 7-9) to the intermediate nitrogen values (4-6) and the nitrogen poor values (1-3).

For the specific plant species found in ditch banks on the conventional, organic and experimental farms, see appendix of this thesis.

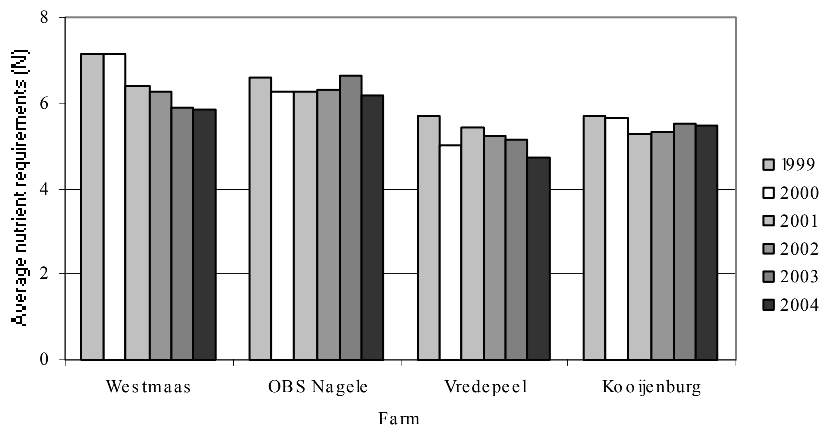

Figure 3: Average Ellenberg nitrogen values of ecologically managed ditch bank flora per experimental farm in the period 1999 (initiation of the regime) to 2004.

6.4 Discussion

Three groups of ditch banks were compared: on conventional and organic farms and ditch banks under ecological management on experimental farms. Plant species numbers and composition of the ditch bank vegetation (rarity and nutrient status) were analysed for all groups.

Ditch banks on conventional and organic farms

Plant species richness was significantly higher on organic farms compared with conventional farms. On farms that had converted to organic agriculture more than 5 years ago, even more species were found, although this trend was not statistically significant.

There was little difference in the species composition of ditch bank vegetation on conventional farms, as published in Manhoudt *et al.* (2005), and the organic farms in this study, although the latter showed a relatively small shift from very common to fairly common or common and fairly rare or rare species. Similar changes have been recorded in other studies, too, with more endangered arable plant species being found on organic farms than conventional farms (Cobb *et al.*, 1998; Kay and Gregory, 1998 and 1999).

Regarding the nutrient status, on sandy soils more nitrogen poor species were found on the organic farms compared with the conventional farms. However, these results were not consistent on clay soils, since on farms that were converted to organic for more than five years only a small percentage of nitrogen poor plant species was found. Little is known about the long-term effects of organic farming on biodiversity and further research is required (Gardner and Brown, 1998; Hole *et al.*, 2005). However, an increase in species richness is to be expected, as observed in this study.

This enhanced species richness on organic compared with conventional farms was also apparent along hedgerows (Stopes *et al.*, 1995; Aude *et al.*, 2003 and 2004), and in arable fields (Hald, 1999; Norton, 2002; Albrecht and Mattheis, 1998; Hyvönen *et al.*, 2003) and also holds for other species groups in arable fields such as insects and birds (Feber *et al.*, 1997; Wilson *et al.*, 1997; Azeez, 2000; Shepherd *et al.*, 2003; Hole *et al.*, 2005). Likely explanatory factors include the rejection of artificial pesticides and fertilisers on organic farms (Hald, 1999; Norton, 2002; Albrecht and Mattheis, 2003; Hyvönen *et al.*, 2003). Other studies have shown that unsprayed crop edges in cereals led to higher plant species diversity in the adjacent habitat (Fischer and Milberg, 1997; de Snoo and van der Poll, 1999). This might be a possible explanation for the increase in plant species richness in ditch banks on organic farms. However, no difference was found between the types of farm regarding the Ellenberg nitrogen values. Probably even higher plant species diversities in ditch banks can be achieved, if negative impacts of the on-field nutrient applications, such as nutrient leaching (Orleans *et al.*, 1994) or fertiliser misplacement (Tsiouris and Marshall, 1998), on the adjacent habitats can be avoided.

Ditch banks under ecological management

On the ecologically managed ditch banks that were buffered with field margin strips, plant species numbers were almost twice as high as on conventional farms (cf. Figure 1 and 2). Species numbers were in fact already higher at the outset of the new regime. Also, on two experimental farms (on sandy soils), relatively smaller average Ellenberg nitrogen values were found at the outset of the new regime. These differences are probably owed to the farm participation in research programmes in which new technologies are being explored and nutrients and pesticides judiciously applied according to state-of-the-art practice. However, these differences in plant species numbers between the experimental farms and the other farms might also be influenced by a sampling effect, since the sampling on the experimental farms was not performed on a transect but sampling areas were spread out on the whole farm area, this can result in higher overall species numbers (Higgs and Usher, 1980; Margules *et al.*, 1982).

On the experimental farm Vredepeel, plant species numbers were from the start of the ecological management regime considerably higher than on the other sites and over the 6-year period the change was relatively small. Therefore, it can queried if continuation of ecological management is likely to result in a higher plant species richness over time.

Studies of the application of ecological management in other semi-natural habitats have also yielded increases in species richness (Berendse *et al.*, 1992; Marrs, 1993; Bakker and Olff, 1995; Schippers and Joenje, 2002).

On all farms, including the experimental farms, higher plant species numbers were found on sandy soils than on clay soils. This is also supported by the higher share of nitrogen poor plant species (Table 2) based on the Ellenberg values.

Due to a large variation in plant species richness of ditch banks on organic farms, some of the organic farms had species numbers that are almost comparable to the plant species numbers found on the experimental farms (cf. the organic farms on sandy soil). However, these results were only obtained after an average period of 16 years under organic farming. As well as the increase in plant species richness in 6 years, a change in the vegetation composition was also seen from plant species indicative for nitrogen rich vegetation types to more plant species indicative for the intermediate and nitrogen poor vegetation types. The combination of the increase in plant species richness and the change in plant species composition (based on the rarity index and the Ellenberg nitrogen values) was most marked in ecologically managed ditch banks on the experimental farms, therefore, indicated that the ecological management might enhance plant species richness more than organic farming alone in a 6-year period.

Environmental certification

The results of this study are of potential interest for environmental certification schemes. The existing environmental certification schemes do have criteria relating to on-farm biodiversity (de Snoo and van de Ven, 1999; Manhoudt *et al.*, 2002), however these are without farmer engagement. Criteria to actively enhance on-farm biodiversity might therefore usefully be included in these schemes (Udo de Haes and de Snoo, 1997). Based on the results of this study, we recommend implementing criteria keyed to ditch-bank management and physical design. To actively promote diversity of plant species growing on ditch banks, the vegetation should be mown at least once a year and the cuttings being removed. Based on this study, this should be joint with the creation of a buffer zone between the ditch bank and crop to prevent species richness being eroded by pesticide drift and nutrient leaching (de Snoo, 1997; Fischer and Milberg, 1997; Kleijn and Snoeijing, 1997; de Snoo and van der Poll, 1999), since the effect of the ecological management or the buffer zones on plant species richness on the experimental farms have not been studied independently. As it takes several years before the ecological management begins to have an impact, it is recommended that habitat management criteria be set for a minimum of 5 years to guarantee results.

6.5 Conclusions

On organic farms, plant species richness on ditch banks was significantly higher than on conventional farms. On farms that had converted to organic agriculture more than 5 years ago, even more species were found, although this trend was not significant.

On all farms, including the experimental farms, higher plant species numbers were found on sandy soils than on clay soils. This was supported by a higher share of nitrogen poor plant species (Table 2) based on the Ellenberg nitrogen values.

The results showed that active ecological management of ditch banks already leads to a increase in plant species richness and a change in the plant species composition (based on the rarity index and the Ellenberg nitrogen values) within a period of six years. In these ditch banks under ecological management the vegetation was mown and the cuttings were removed to reduce nutrient input and vegetation biomass and a buffer zone was created between the ditch bank and crop to shield them from the negative impacts of pesticide and nutrient drift.

In the context of an environmental label, criteria designed to enhance on-farm biodiversity should therefore specify an ecological management on ditch banks buffered with a pesticide and nutrient free zone.

Acknowledgement

We wish to thank the farmers for their co-operation in this research project, Paul Vos for his statistical support and Nigel Harle for editing the text.

References

Albrecht, H., Mattheis, A., 1998. The effects of organic and integrated farming on rare arable weeds on the Forschungverbund Agrarokosysteme Munchen (FAM) research station in southern Bavaria. Biological Conservation 86, 347-356.

Andreasen, C., Stryhn, H., Streibig, J.C., 1996. Decline of the flora in Danish arable fields. Journal of Applied Ecology 33, 619-626.

Asteraki E.J., Hart B.J., Ings T.C., Manley W.J., 2004. Factors influencing the plant and invertebrate diversity of arable field margins. Agriculture, Ecosystems and Environment 102 (2), 219-231.

Aude, E., K. Tybirk, Bruus Pedersen, M., 2003. Vegetation diversity of conventional and organic hedgerows in Denmark. Agriculture, Ecosystems and Environment 99, 135-147.

Aude, E., Tybirk, K., Michelsen, A., Ejrnæs, R., Hald, A. B., Mark, S., 2004. Conservation value of the herbaceous vegetation in hedgerows – does organic farming make a difference? Biological Conservation, 118 (4), 467-478.

Azeez, G., 2000. The biodiversity benefits of organic farming. Soil Association, UK.

Baldock, D., 1990. Agriculture and habitat loss in Europe. CAP Discussion Paper. Gland, Switzerland.

Bakker, J.P., Olff, H., 1995. Nutrient dynamics during restoration of fen meadows by haymaking without fertiliser application. In: Wheeler, B.D., Shaw, S.C., Fojt, W.J., Robertson, R.A., 1995. Restoration of temperate wetlands. John Wiley & Sons Ltd.

Bengtsson, J., Ahnström, J., Weibull, A.-C., 2005. The effects of organic agriculture on biodiversity and abundance: a meta-analysis. Journal of Applied Ecology 42, 261-269.

Berendse, F., Oomes, M.J.M., Altena, H.J., Elberse, T., 1992. Experiments on the restoration of species-rich meadows in the Netherlands. Biological Conservation 62, 59-65.

Chamberlain, D.E., Wilson, A.M., Browne, S.J., Vickery, J.A., 1999. Effects of habitat type and management on the abundance of skylarks in the breeding season. Journal of Applied Ecology 36, 856-870.

Cobb, D., Feber, R., Hopkins, A., Stockdale, L., 1998. Organic farming study. Global Environment Change Programme Briefings No. 17, University of Sussex, UK. Source: www.susx.ac.uk.

Colwell, R.K., 1997. EstimateS: Statistical estimation of species richness and shared species from samples. Version 5. User's guide and application published at: viceroy.eeb.uconn.edu/estimates.

Colwell, R.K., Coddington, J.A., 1994. Estimating terrestrial biodiversity through extrapolation. Philosophical Transactions of the Royal Society London 345, 101-118.

Delbaere, B., Drucker, G., Lina, P., Rientjes, S., Vinken, H., Wascher, D., 1998. Facts & figures on Europe's biodiversity. State and trends 1998-1999. ECNC The Netherlands.

Ellenberg, H., Weber, H.E., Düll, R., Wirth, V., Werner, W., Paulissen, D., 1992. Zeigerwerte von Pflanzen in Mitteleuropa. Scripta Geobotanica 18, 1-258.

European Commission, 1999. Directions towards sustainable agriculture, Communication to the Council, the European Parliament, the Economic and Social Committee of the Regions, COM (1999) 22 Final, January 1, 1999.

European Council, 1997. Council Regulation (EEC) No. 2092/91 on organic production of agricultural products and indications referring hereto on agricultural products and foodstuffs (OJ L 198, 22.7.1991; Bull. 6-1991), as last amended by Regulation (EEC) No 1488/97: OJ L 202, 30.7.1997.

EUREP (Euro-Retailer Produce Working Group), 1999. GB-GAP Protocol 2000. Eurohandels-institute e.V., Cologne.

Feber, R.E., Firbank, L.G., Johnson, P.J., Macdonald, D.W., 1997. The effects of organic farming on pest and non-pest butterfly abundance. Agriculture, Ecosystems and Environment 64, 133-139.

Fischer, A., Milberg, P., 1997. Effects on the flora of extensified use of field margins. Swedish Journal of Agricultural Research 27, 105-111.

Fuller, R.J, Gregory, R.D., Gibbons, D.W., Marchant, J.H., Wilson, J.D., Baille, S.R., Carter, N., 1995. Population declines and range contractions among lowland farmland birds in Britain. Conservation Biology 9 (6), 1425-1441.

Fuller, R.J., Norton, L.R., Feber, R.E., Johnson, P.J., Chamberlain, D.E., Joys, A.C., Mathews, F., Stuart, R.C., Townsend, M.C., Manley, W.J., Wolfe, M.S., Macdonald, D.W., Firbank, L.G., 2005. Benefits of organic farming to biodiversity vary among taxa. Biology Letters published online.

Gardner, S.M., Brown, R.W., 1998. Review of the comparative effects of organic farming on biodiversity. ADAS and R & D Associates, UK.

Hald, A.B., 1999. The impact of changing the season in which cereals are sown on the diversity of weed flora in rotational fields in Denmark. Journal of Applied Ecology 36, 24-32.

Higgs, A.J., Usher, M.B., 1980. Should nature reserves be large or small? Nature 285, 568-569.

Hill, M.O., Mountford, J.O., Roy, D.B., Bunce, R.G.H., 1999. Ellenberg's indicator values for British plants. Technical Annex, Institute of Terrestial Ecology/Department of Environment, Transport and Regions (NERC), Grange-over-Sands, UK.

Hole, D.G., Perkins, A.J., Wilson, J.D.,Alexander, I.H., Grice, P.V., Evans, A.D., 2005. Does organic farming benefit biodiversity? Biological Conservation 122, 113-130.

Hopster, G.K., Visser, A.J., Beek, A.J.C.M., 2002. Agrarisch natuurbeheer op proefbedrijven. Tussentijdse evaluatie 1998-2001. PPO Wageningen University.

Hyvönen, T., Ketoja, E., Salonen, J., Jalli, H., Tiainen, J., 2003. Weed species diversity and community composition in organic and conventional cropping of spring cereals. Agriculture, Ecosystems and Environment 97, 131-149.

Kay, S., Gregory, S., 1998. Rare arable Flora Survey 1998. Northmoor Trust. Little Wittenham, Abingdon Oxfordshire, UK

Kay, S., Gregory, S., 1999. Rare arable Flora Survey 1999. Northmoor Trust. Little Wittenham, Abingdon Oxfordshire, UK

Kleijn, D., Snoeijing, G.I.J., 1997. Field boundary vegetation and the effects of agrochemical drift: botanical changes caused by low levels of herbicide and fertiliser. Journal of Applied Ecology 34 (6), 1413-1425.

Manhoudt, A.G.E., Ven, G.W.J. van de, Udo de Haes, H.A., Snoo, G.R. de, 2002. Environmental certification in the Netherlands; a framework for integrated farming. Journal of Environmental Management 65 (3), 269-283.

Manhoudt, A.G.E., Snoo, G.R. de, 2003. A quantitative survey of semi-natural habitats on Dutch arable farms. Agriculture, Ecosystems and Environment 97, 235-240.

Manhoudt, A.G.E., Udo de Haes, H.A, Snoo, G.R. de, 2005. An indicator of plant species richness of semi-natural habitats and crops on arable farms. Agriculture, Ecosystems and Environment 109, 166-174.

Margules, C., Higgs, A.J., Rafe, R.W., 1982. Modern biogeography theory: are there any lessons for nature reserve design. Biological Conservation 24, 115-128.

Marrs, J.H., 1993. Soil fertility and nature conservation in Europe: theoretical considerations and practical solutions. Advances in Ecological Research 24, 241-300.

Meijden, R. van der, 1996. Heukels' Flora van Nederland. Wolters-Noordhoff Groningen.

Morris, C., Winter, M., 1999. Integrated farming systems: the third way for European agriculture? Land Use Policy 16, 193-205.

Norton, L.R., 2002. Factors influencing biodiversity within organic and conventional systems of arable farming-methodologies and preliminary results. In: Powell *et al. (*eds), UK Organic Research 2002: Proceedings of the COR Conference, 2002, Aberystwyth, pp. 231-236.

Orleans, A.B.M., Mugge, F.L.T., Meij, T. van der, Keurs, W.J. ter, 1994. Minder nutriënten in het oppervlaktewater door bufferstroken. Een literatuuranalyse. Milieubiologie Rijksunversiteit Leiden, p. 88.

SAI, 2002. Sustainable Agriculture Initiative (SAI), a Food Industry Initiative: Position Paper, Principles, Strategy and Organisation. Source: www.saiplatform.org

Schippers, P., Joenje, W., 2002. Modelling the effect of fertiliser, mowing, disturbance and width on the biodiversity of plant communities of field boundaries. Agriculture, Ecosystems and Environment 93, 351-365.

Shepherd, M., Pearce, B., Cormack, B., Philipps, L., Cuttle, S., Bhogal., A., Costigan, P., Unwin, R., 2003. An assessment of the environmental impacts of organic farming. A reviewfor Defra-funded project OF0405, ADAS, UK.

Snoo, G.R. de, 1997. Arable flora in sprayed and unsprayed crop edges. Agriculture, Ecosystems and Environment 66, 223-230.

Snoo, G.R. de, Ven, G.W.J. van de, 1999. Environmental themes in ecolabels. Landscape and Urban Planning, 46, 179-184.

Snoo, G.R. de, Poll, R.J. van der, 1999. Effect of herbicide drift on adjacent boundary vegetation. Agriculture, Ecosystems and Environment 73, 1-6.

Sokal, R.R., Rohlf, F.J., 2000. Biometry: second edition. W.H. Freeman and Company, New York.

Stopes, C., Measures, M., Smith, C., Foster, L., 1995. Hedgerow management in organic farming-impact on biodiversity. In: Isart, J., Llerena, J.J. (eds.) 1995. Biodiversity and Land Use: the role of organic farming. Proceedings of the First ENOF Workshop, Germany.

Tamis, W.L.M., Zelfde, M. van 't, 2003. KilometerhokFrequentieKlassen, een nieuwe zeldzaamheidsschaal voor de Nederlandse flora. Gorteria 29, 57-83.

Tsiouris, S., Marshall, E.J.P., 1998. Observations on patterns of granular fertiliser deposition beside hedges and its likely effects on the botanical composition of field margins. Annals of Applied Biology, 132, 115-127.

Udo de Haes, H.A., Snoo, G. R. de, 1997. The Agro-production chain. Environmental management in the agricultural production-consumption chain. International Journal of Life Cycle Assessment 2 (1), 33-38.

Wiertz, J., 1992. Schatting van ontbrekende vocht- en stikstofindicatiegetallen van Ellenberg (1979).Instituut voor Bos- en Natuuronderzoek (IBN-DLO), Wageningen, Nederland.

Wilson, J.D., Evans, J., Browne, S. J., King, J.R., 1997. Territory distribution and breeding success of skylarks *Alauda arvensis* on organic and intensive farmland in southern England. Journal of Applied Ecology 34, 1462-1478.