Chapter 4
The Status of Arable Plant Habitats in Scandinavian Countries

Terho Hyvönen, Lars Andersson, and Christian Andreasen

Abstract Scandinavia is situated in the northern part of Europe where climate conditions limit both agricultural production and weed diversity. Scandinavian countries differ from each other in terms of climate conditions, land use intensity and agricultural production. In Finland and Denmark, the status of arable plant populations has been recorded by regular weed surveys covering several decades. In both countries, a tremendous decline in weed abundance was documented between 1960s and 1980s caused by the significant intensification of the cropping practices. The decline was attributed to the higher rate of nitrogen fertiliser application, more effective fertilisation methods, the increased use of crop monocultures and the application of herbicides. During the following decades, a slight increase in weed abundances was recorded in both countries probably mainly caused by stricter regulation of herbicide use decided nationally and by the EU. In the 1990s, agri-environmental support schemes to facilitate environmental issues were introduced, which resulted in, among other things, increasing area of organic farming. Organic farming has enhanced weed species diversity. However, conservation of rare arable weeds has not been a primary focus in Scandinavian countries and there are no specific conservation methods to protect rare plant species on arable land.

Keywords Denmark · Sweden · Norway · Finland · Cropping patterns · Weed diversity · Organic farming · European Union

T. Hyvönen (✉)
Natural Resources Institute Finland (Luke), Jokioinen, Finland
e-mail: terho.hyvonen@luke.fi

L. Andersson
Swedish University of Agricultural Sciences, Uppsala, Sweden
e-mail: lars.andersson@slu.se

C. Andreasen
University of Copenhagen, Taastrup, Denmark
e-mail: can@plen.ku.dk

C. Hurford et al. (eds.), *The Changing Status of Arable Habitats in Europe*,
https://doi.org/10.1007/978-3-030-59875-4_4

1 Introduction

Scandinavia is situated in the northern part of Europe where climatic conditions limit both agricultural production and weed diversity. However, Scandinavian countries (here Denmark, Sweden, Norway and Finland) also differ from each other in terms of climate conditions, land use intensity and agricultural production. The arable land area in Denmark, Sweden and Finland is similar, ca 2.2–2.5 million ha, but lower in Norway (0.8 million ha). Denmark has the most favorable climatic conditions for agriculture where the arable land constitutes about 56% of the total land area (https://tradingeconomics.com). In the other Scandinavian countries, the share of arable land varies between 2.2 and 7.6%. In these countries, the arable area is concentrated in the southern regions while other parts are either field-forest mosaic or entirely forested areas.

Weed flora composition and weed infestation are affected directly and indirectly by climatic factors, soil characteristics, and land use (Andreasen and Skovgaard 2009). In all countries the production of annual crops is dominated by cereals, ranging from 36% of arable land in Norway to 60% in Denmark. Grass clover leys are also an important part of the arable landscape covering 20, 30 and 45% of arable land in Denmark, Finland and Sweden, respectively. The proportion of leys increases toward the north in the two latter countries. Climatic conditions and soil characteristics have resulted in large differences in land use; while Danish cereal production is dominated by autumn sown cereals, spring barley and spring oat are the most common annual crops in Finland. In Sweden, with a mid-position, spring barley and winter wheat are the major annual crops. The proportion of organically managed land has increased substantially over the last decades. In 2018, the proportion of organic land (including under conversion) was 4.7, 9.8, 13.1 and 20.3% in Norway, Denmark, Finland and Sweden, respectively, as compared to an average of 7.5% in the European Union as a whole (Eurostat 2020).

As a probable consequence of the interaction between climate and land use, and the high proportion of organic farming, the use of herbicides is lower in the three Scandinavian countries than in EU 28 as a whole. The average sale of herbicides, including preharvest desiccation agents and moss killers, during the period 2013–2017 ranged from 0.5 kg ha^{-1} (Finland) to 0.8 kg ha^{-1} (Denmark) as compared to, for example, 1.4 kg ha^{-1} in Germany and 1.1 kg ha^{-1} across all the EU28 (Eurostat 2020).

Weed diversity declines along a south-north climate gradient in Europe (Glemnitz et al. 2006; Hyvönen et al. 2011) and in Scandinavia, the distribution of several weed species common in Central Europe (e.g., *Amaranthus retroflexus* and *Echinochloa crus-galli*) is limited by the climate (Hyvönen et al. 2012) or lack of crop species, that cover the ground late in the growing season such as beets and maize (Hyvönen and Ramula 2014). However, frequent reports from advisors and farmers indicate that *E. crus-galli* is a fast-increasing weed problem in southern Sweden, Denmark and Norway (L. Andersson (own observation), Andreasen et al. 1992; Andreasen and Streibig 2011; VKM 2016).

2 The Status of Arable Plant Diversity in Scandinavian Countries

In Finland and Denmark, the status of arable plant populations has been recorded by regular weed surveys covering several decades (Mukula et al. 1969; Erviö and Salonen 1987; Haas and Streibig 1982; Andreasen et al. 1996, 2018; Salonen et al. 2001, 2011; Andreasen and Stryhn 2008, 2012). The major aim of these weed surveys has been to record changes in the abundance of harmful weed species in terms of crop production. However, they also provide useful information on changes in weed species diversity. In both countries, dramatic declines in weed abundance were documented between the 1960s and 1980s (Andreasen et al. 1996; Erviö and Salonen 1987) caused by the significant intensification of the cropping practices. During the following decades, a slight increase in weed abundances was recorded in both countries (Andreasen and Stryhn 2008, 2012; Salonen et al. 2001, 2011) probably mainly caused by stricter regulation of herbicide use decided nationally and by the EU.

The total numbers of weed species recorded in the weed surveys in the two countries are not directly comparable due to different sample sizes and sampling methods. However, in both countries, the total number of weed species is relatively high compared to the number of species that are targeted for weed control. In the two latest weed surveys of Finnish spring cereal fields the total numbers of weed species recorded were 160 and 148 (from 690 and 595 sampled fields), respectively (Salonen et al. 2001, 2011). In the countrywide survey in Denmark in 1987–1989, 199 weed species were found in nine crops in 213 fields (Andreasen 1990), while 224 species were found in 11 crops during 2001–2004 distributed on 240 fields (Andreasen and Stryhn 2008). These data do not indicate that the total number of weed species has decreased on a country level as different species occur in different regions. However, the number of species in a single field was observed to have declined.

Average species numbers per sampled area are easier to compare between the two countries. In Denmark, long-term changes in average species numbers have followed the trend of weed abundance: declining between the 1960s and the 1980s followed by a slight increase, but not fully recovering by the 2000s. In cereal fields (winter wheat, rye and spring barley), the species numbers in a random selected circular sample plot of 0.1 m^2, varied between 5.8 and 6.9 in the 1960s, 2.1 and 2.9 in the 1980s and 3.4 and 4.9 in the 2000s (Andreasen and Stryhn 2008). Average species numbers of grass leys were lower than in cereal fields in all decades (e.g., 3.4 species in the 1960s) and did not differ between the two latest weed surveys (1.5 species in both). In these surveys, the average number of species was calculated based on the 67 weed species observed across all the sampled plots. In the Finnish weed surveys, determination of average number of weed species was based on records of all species, but it is available only from the two latest weed surveys (Salonen et al. 2001, 2011). The comparison between the weed surveys showed a decline in the average number of weed species (per 10×0.1 m^2) both in conventionally (16 vs. 12 species) and in organically managed (24 vs. 21 species) fields between the 1990s and 2000s. Conventionally grown fields included both fields sprayed and unsprayed with herbicides during the growth season. This increased the variation of average species number among conventional fields (e.g., variation of 3–26 species in the 2000s). This is an indication of the impact of weed control measures on weed species numbers.

In both countries, seed banks of weeds have also been studied (Salonen et al. 2011; Andreasen et al. 2018). Surveys of the same fields in Denmark, showed that the mean soil seed bank per m^2 in the uppermost 20 cm of the ploughing layer was estimated to be 19,390 seeds in 1964, 10,120 in 1989 and 20,455 in 2014. Thus, the size of seed bank had recovered to the level of 1960s in the 2010s. However, a few common species made up most of the soil seed bank in all years (e.g., *Poa annua*, *Juncus bufonius* and *Capsella bursa-pastoris*) but diversity has declined over time. Relatively few species have been able to adapt to modern cultivation practice reflecting the narrowing of the ecological niche for weeds in arable fields. In Finland, the number of seeds were 1684 per m^2 when samples were taken at the depth of 5 cm. The majority of the seeds were either *Chenopodium album* (66.2%) or *Spergula arvensis* (10.6%) Finnish samples were taken on spring cereal fields while Danish ones represented several crop species.

Weed species abundance and diversity affects the higher trophic levels using weeds as food sources. Based on such interactions, Hyvönen and Huusela-Veistola (2008) developed an indicator for farmland birds, pollinators and phytophagous insects. The indicator showed the decline in the weed abundance between 1960s and 1980s to have been harmful for all species groups in terms of decline of food sources. However, the increase of weed abundance between 1980s and 1990s benefitted more farmland birds and phytophagous insects than pollinators. This was due to lower abundance of weed species important for pollinators such as *Galeopsis speciosa* and *Galeopsis bifida*. Recognition of decline in the arable biodiversity has led to research on the measures for enhancing agrobiodiversity. For pollinators, rotational fallows (Kuussaari et al. 2011) and long-term set-asides (Alanen et al. 2011) as well as wildflower strips (Korpela et al. 2013) have been found to be most effective. Long-term set asides also provide important food sources for farmland birds. (Hyvönen and Huusela-Veistola 2011). In Finland, these measures have already been introduced in an agri-environmental support scheme.

3 The Specific Drivers of Change

Intensification of agricultural practices has negatively affected weed abundance and species diversity. In both Denmark and Finland, a tremendous decline in weed abundance took place between the1960s and 1980s. The decline was attributed to the higher rate of nitrogen fertilizer application, more effective fertilization methods, the increased use of crop monocultures and the application of herbicides. Large-scale application of herbicides was probably the most important single factor responsible for the decline in weed abundance (Andreasen and Streibig 2011). Sub-surface draining also became more common which affected the landscape structure in terms of increased field size, reducing field margins and hedges. Furthermore, the landscape became dominated by a few crop species with a simplified crop rotation system. These landscape scale impacts reduced habitat heterogeneity and the richness of the regional species pool that is able to colonise cultivated fields.

After decades of intensification, concerns about the environmental problems related to use of pesticides and fertilizers were raised, which led to political initiatives to reduce their use. For example, a Danish action plan required a 50% reduction in pesticide use by 1997 compared with 1981–1985. Both the quantity of ingredient sold and the spraying intensity were reduced (Haas and Streibig 1994). The average amount of active ingredient of herbicide used per hectare declined from 1.5 to 1.0 kg, while the spraying intensity declined from 1.5 to 1.3 applications per hectare (Anon 2006).

In 1995, Finland and Sweden joined the EU, which affected agricultural policy in many ways. One of the consequences was an introduction of agri-environmental support schemes to facilitate environmental issues. In Finland and Sweden, enrollment in agri-environmental schemes has been high (https://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-_commitments). This resulted in, among other things, an increasing area of organic farming, which in 2017 constituted 19.2% of the total utilized agricultural area in Sweden and 11.4% in Finland (https://ec.europa.eu/eurostat/statistics-explained/index.php/Organic_farming_statistics). In Denmark, conversion from conventional to organic farming has been politically and economically encouraged in order to obtain more sustainable agricultural practices, and the area of registered organic land increased from 0.2% in 1989 to 5.6% in 2004 (Anon 2005). Organic farming generally enhances weed species diversity (Hyvönen et al. 2003; Andreasen and Andresen 2011).

A decrease in the profitability of agriculture has led to an increase in the farm and field sizes. For example, in Denmark, the average farm size increased from 33.1 ha to 53.7 ha from 1987–89 to 2001–04 (Anon 2006). In 2018, 22% of the farms were larger than 100 ha and the number of farms was reduced from 81,267 in 1989 to 34,114 in 2018 (Anon 1990, 2020). In Sweden, the number of agricultural holdings decreased from 96,000 in 1990 to 63,000 in 2016, and the average farm size increased from 20 to 41 ha during the same period. There is a tendency towards greater pesticide use per unit area on large farms (Jensen 2003), and the sale of herbicides has increased in Sweden since the 1990's. The average sale during the period 2011–2017 was 18% higher than the period 1991–1995 (KEMI 2020). In Finland, the use of glyphosate has increased due to direct drilling (Salonen et al. 2011).

4 Conservation of Rare Plant Species

There has been little consideration given to the conservation of rare arable weeds in Scandinavian countries and there are no specific conservation methods to protect rare plant species on arable land. However, there are several weed species whose conservation status has been identified as being of concern (Table 4.1). Many of these species occurred on agricultural fields before the introduction of herbicides in the 1950's were introduced (Suominen 1986; Svensson and Wigren 1986). Some of these weed species are associated with cultivation of flax (*Camelina alyssum*, *Cuscuta epilinum* and *Spergula arvensis* subsp. *maxima*) or rye (e.g., *Bromus secalinus*). Cropping practices of these crops have changed (e.g., combine harvesting, more competitive cultivars) or the cropping area has declined (flax) tremendously which caused a decline in the populations. *Centaurea cyanus* is also a weed species associated with rye which declined in abudance during earlier

Table 4.1 Red-listed plant species occurring in arable habitats and their conservation status in Scandinavian countries

	Finland[a]	Sweden[b]	Norway[c]	Denmark[d]
Primarily or solely on arable habitat				
Agrostemma githago	RE	CR	NKR	NA
Anthemis arvensis	NT	NT	LC	NA
Bromus secalinus	VU	EN	NE	NA
Camelina alyssum	RE	RE	NE	NA
Cuscuta epilinum	RE	RE	NE	NA
Delphinium consolida	EN	NT	NE	–
Fumaria vaillantii	CR	NT	NE	NA
Galeopsis ladanum	NT	NT	EN	NA
Lolium remotum	RE	RE	NE	NA
Odontites vernus	RE	NT	SE	LC
Papaver dubium	NT	LC	NA	NA
Spergula arvensis subsp. *maxima*	RE	RE	RE	–
Vicia villosa subsp. *villosa*	RE	NA	NA	NA
Primarily on other habitats				
Buglossoides arvensis	EN	NE	CR	–
Epilobium lamyi	EN	LC	–	LC
Hyoscyamus niger	NT	NT	EN	NA
Oxybasis urbica	RE	RE	NE	–
Urtica urens	NT	NT	VU	NA

The categories of conservation status: *RE* Regionally Extinct, *CR* Critically Endangered, *EN* Endangered, *VU* Vulnerable, *NT* Near Threatened, *LC* Least Concern, *NA* Not Applicable, *NE* Not Evaluated, *SE* Severe Risk, *NKR* No Known Risk - = not found from the database
[a]Ryttäri et al. (2019)
[b]Artfakta från ArtDatabanken
[c]Artsdatabanken (Norwegian Biodiversity Information Centre)
[d]Wind and Pihl (2004)

decades in Finland and Sweden (Suominen 1986; Svensson and Wigren 1986). The likely reasons for the decline are denser crop stands and the use of herbicides. Many of the threatened species have already gone extinct. The highest number of extinct species is found in Finland (Table 4.1). However, the information on the status of rare weed populations of arable fields is often insufficient to evaluate their status. This is true especially in Denmark where only two of the species have been systematically evaluated.

References

Alanen E-L, Hyvönen T, Lindgren S, Härmä O, Kuussaari M (2011) Differential responses of bumblebees and diurnal Lepidoptera to vegetation succession in long-term set-aside. J Appl Ecol 48:1251–1259

Andreasen C (1990) The occurrence of weed species in Danish arable fields. PhD thesis, Department of Agricultural Sciences, The Royal Veterinary and Agricultural University, Frederiksberg, Copenhagen. 125 pp

Andreasen C, Andresen LC (2011) Managing farmland flora to promote biodiversity in Europe. CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources 6, No. 047

Andreasen C, Skovgaard IM (2009) Crop and soil factors of importance for the distribution of plant species on arable fields. Agric Ecosyst Environ 133:61–67

Andreasen C, Streibig JC (2011) Evaluation of changes in weed flora in arable fields of Nordic countries – based on Danish long-term surveys. Weed Res 51:214–226

Andreasen C, Stryhn H (2008) Increasing weed flora on Danish arable fields and its importance for biodiversity. Weed Res 48:1–9

Andreasen C, Stryhn H (2012) Increasing frequency of weed species in Danish beet, pea and winter barley fields. Crop Prot 36:11–17

Andreasen C, Jensen JE, Haas H (1992) Grøn Skærmaks (*Setaria víridis*) og Hanespore (Echinochloa sp.): Nye græsukrudtsarter i Danmark. (*Setaria viridis* and *Echinochloa*: New grass weed species in Denmark) 9th Danish Plant Protection Conference/Weeds. Statens Planteavlsforsøg, beretn S 2178−1992. 49–60

Andreasen C, Stryhn H, Streibig JC (1996) Decline of the flora in Danish arable fields. J Appl Ecol 33:619–626

Andreasen C, Jensen HA, Jensen SM (2018) Decreasing diversity in the soil seed bank after 50 years in Danish arable fields. Agric Ecosyst Environ 259:61–71

Anon (1990) Agricultural Statistics 1990. Danmarks Statistik ISSN 0070-3559

Anon (2005) Statistik over økologiske jordbrugsbedrifter 2004. Autorisation og produktion. Juli 2005, 2. Plant Directorate. Ministry of Food, Agriculture and Fishery, Denmark

Anon (2006) Agricultural Statistics 2006. Danmarks Statistik. ISSN 1602-4550

Anon (2020) Danmarks Statistik. https://www.dst.dk/. Accessed 6 Jan 2020

Erviö L-R, Salonen J (1987) Changes in the weed population of spring cereals in Finland. Ann Agric Fenniae 26:210–226

Eurostat (2020). https://ec.europa.eu/eurostat/statistics-explained/index.php/Organic_farming_statistics

Glemnitz M, Radics L, Hoffmann J, Czimber G (2006) Weed species richness and species composition of different arable field types – A comparative analysis along a climate gradient from south to north Europe. J Plant Dis Prot Sonderheft 20:577–586

Haas H, Streibig JC (1982) Changing patterns of weed distribution as a result of herbicide use and other agronomic factors. In: Lebaron HM, Gressel J (eds) Herbicide resistance in plants. Wiley, New York, pp 57–79

Haas H, Streibig JC (1994) Policy and research strategies to reduce herbicide use in northern Europe. Rice pest science and management. In: Teng PS, Heong KL, Moody K (eds) Selected papers from the International Rice-Research Conference. IRRI, Los Ban˜os/Laguna, pp 245–254

Hyvönen T, Huusela-Veistola E (2008) Arable weeds as indicators of agricultural intensity – A case study from Finland. Biol Conserv 141:2857–2864

Hyvönen T, Huusela-Veistola E (2011) Impact of seed mixture and mowing on food abundance for farmland birds in set-asides. Agric Ecosyst Environ 143:20–27

Hyvönen T, Ramula S (2014) Crop–weed competition rather than temperature limits the population establishment of two annual C4 weeds at the edge of their northern range. Weed Res 54:245–255

Hyvönen T, Ketoja E, Salonen J (2003) Changes in the abundance of weeds in spring cereal fields in Finland. Weed Res 43:348–356

Hyvönen T, Glemnitz M, Radics L, Hoffmann J (2011) Impact of climate and land use type on the distribution of Finnish casual arable weeds in Europe. Weed Res 51:201–208

Hyvönen T, Luoto M, Uotila P (2012) Assessment of weed establishment risk in a changing European climate. Agric Food Sci 21:348–360

Jensen JE (2003) Behandlingsintensitet 2000, 2001 og 2002 (*Treatment intensity* in 2000, 2001 and 2002). DJF-rapportnr. Danske Planteværnskonference, Danmarks JordbrugsForskning, Foulum, Danmark, 88–2003:20, 143–153

KEMI (2020). https://kemi.se/kemikaliestatistik/statistik-om-bekampningsmedel

Korpela E-L, Hyvönen T, Lindgren S, Kuussaari M (2013) Can pollination services, species diversity and conservation be simultaneously promoted by sown wildflower strips on farmland? Agric Ecosyst Environ 179:18–24

Kuussaari M, Hyvönen T, Härmä O (2011) Pollinator insects benefit from rotational fallows. Agric Ecosyst Environ 143:28–36

Mukula J, Raatikainen M, Lallukka R, Raatikainen T (1969) Composition of weed flora in spring cereals in Finland. Ann Agric Fenniae 8:59–109

Ryttäri T, Reinikainen M, Hæggström C-A, Hakalisto S, Hallman J, Kanerva T, Kulmala P, Lampinen J, Piirainen M, Rautiainen V-P, Rintanen T, Vainio O (2019) Vascular plants. In: Hyvärinen E, Juslén A, Kemppainen E, Uddström A, Liukko U-M (eds) The 2019 red list of Finnish species. Ministry of the Environment & Finnish Environment Institute, Helsinki, pp 263––312

Salonen J, Hyvönen T, Jalli H (2001) Weeds in spring cereal fields in Finland – a third survey. Agric Food Sci Finland 10:347–364

Salonen J, Hyvönen T, Jalli H (2011) Composition of weed flora in spring cereals in Finland – a fourth survey. Agric Food Sci 20:245–261

Suominen J (1986) The vanishing element of Finnish field weeds. Memoranda Soc. Fauna Flora Fennica 62:79–82. (In Finnish)

Svensson R, Wigren M (1986) Observations on the decline of some farmland weeds. Memoranda Soc Fauna Flora Fennica 62:63–67

VKM (2016). Risk assessment of cockspur grass (Echinochloa crus-galli). Scientific Opinion of the Panel on Plant Health of the Norwegian Scientific Committee for Food Safety, ISBN: 978-82-8259-213-0, Oslo, Norway. https://vkm.no/download/18.2994e95b15cc54507161c7ae/1498204990105/c2542ec415.pdf. Accessed 6 Jan 2020

Wind P, Pihl S (eds) (2004) The Danish Red List – The National Environmental Research Institute, Aarhus University. redlist.dmu.dk (updated April 2010)