Clive Hurford · Phil Wilson
Jonathan Storkey *Editors*

The Changing Status of Arable Habitats in Europe

A Nature Conservation Review

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"One of the penalties of an ecological education is that one lives alone in a world of wounds. Much of the damage inflicted on land is quite invisible to laymen. An ecologist must either harden his shell and make believe that the consequences of science are none of his business, or he must be the doctor who sees the marks of death in a community that believes itself well and does not want to be told otherwise."
— Aldo Leopold, A Sand County Almanac

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Preface

For a large proportion of the European population, our immediate encounter with the natural world is in the agricultural landscapes that surround our towns and cities. The plants and animals that are adapted to these habitats, poppies and cornflowers, skylarks and lapwings, take on a familiarity that gives us a sense of place and belonging to our local environments. For many years now, this rich cultural fabric that we associate with farmland has been systematically eroded with catastrophic declines in the diversity and abundance of plant and animal life documented across Europe. Seeking an escape from our urban environments in the surrounding countryside, many of us can now expect to encounter just a fraction of the wildlife our parents and grandparents enjoyed just five decades ago. The headlong rush for productivity in the post–World War II years has led to fewer crop species being grown, larger fields with less semi-natural habitat and the increasing use of inorganic fertilisers and chemical pesticides. Where once there was a fine scale patchwork of habitats supporting a rich diversity of plants and animals, the dominant characteristic of much of Europe's agricultural landscapes is now large homogenous areas of major crops in which only generalist fauna and flora can persist.

This volume celebrates the diversity of life adapted to arable habitats, the plants and animals that have been our travelling companions since we first learned to farm. For some of these species, they have been pushed to the fringes of our fields and arable landscapes and are hanging on in isolated populations and communities. Here, we show where they can still be found and the efforts being made to retain the rich cultural heritage they represent. But as well as the inherent value of biodiversity, we are increasingly realising that without the 'ecosystem services' it provides, crop production itself would not be possible. If we do not take the appropriate steps to conserve and enhance communities of natural predators of crop pests, pollinators and soil organisms, it is likely the current stagnation of crop yields will continue. It is, therefore, in all our interests to work towards diverse, functioning arable ecosystems that reconcile crop production with a healthy environment.

Harpenden, UK Jon Storkey

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Part I
Introduction

Chapter 1
Historical and Ecological Background to the Arable Habitats of Europe

Chris Stoate and Phil Wilson

Abstract Arable agriculture is the principal form of land use in Europe, occupying nearly 30% of the land area. While much of this is farmed very intensively, there are arable systems of high value to wildlife where cropping is diverse and interstitial habitats such as hedges, lines of trees, grassland patches and ponds are present.

Arable farming practices have changed greatly since the end of the nineteenth century, and particularly rapidly since the 1940s. These changes have included improvements to seed purity, the introduction of herbicides for control of non-crop plants, large increases in the application rates of fertilisers together with the development of high-yielding crop varieties and the ever-increasing size of farm machinery causing the removal of field boundary habitats. In recent years, irrigation has become more widespread, ploughing has been replaced by minimum cultivation and there has been an overall homogenisation of arable land. While these processes have been slower in the south and east of Europe, all countries are now affected.

These changes have had profound impacts on farmland wildlife through the direct and indirect effects and the loss of heterogeneity. These have included the catastrophic population declines of farmland birds such as corn bunting, little bustard and grey partridge, the loss of many formerly widespread plants characteristic of arable land, and declines of invertebrate numbers and diversity.

The rising demand for food to supply an increasing global population is the main driver of agricultural production. A slowing population growth and increasing agricultural efficiency may reduce pressures on arable land, while better understanding of the environmental costs of agricultural intensification coupled with payments to farmers will provide incentives to reduce inputs and mitigate their impacts.

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1 Arable Farming in Europe

Agricultural land covers almost half of the European land area. Within this is an enormous number of different farming systems, each associated with different species assemblages which have changed through time as the farming systems themselves have experienced changes. Although declines in biodiversity on farmland are well documented, the fact remains that many systems still support numerous species that have adapted to the farmed landscape as it has evolved over more than 10,000 years, and some species are primarily associated with this habitat (Stoate 2011).

Within the total European farmland area, the proportion classed as arable varies between countries (Table 1.1), although the distinction between arable and other forms of land use is not always clear as arable land is integrated into livestock systems and the ratio between cropping and grassland changes through time. This is particularly the case where short-term grass leys form part of the arable rotation.

The proportion of arable land has fluctuated through history. In medieval Europe, much of the land was cultivated in rotation with fallow periods and common grazing land delivering yields that were very low by modern standards, both for direct human consumption and as winter feed for livestock. Taking the UK as an example, the combination of plague, which may have killed 50% of Europe's population in the mid fourteenth century alone, and subsequent enclosure of land by private land owners, caused a move from arable rotations to grazing ruminant systems, especially sheep for wool production, but later also cattle for beef and dairy production. The most dramatic changes in the UK were the result of parliamentary enclosure acts between 1760 and 1870 under which nearly 3 million ha of land previously farmed in common were brought under private management (Fairlie 2009). These in combination with high prices for arable produce which resulted from the Napoleonic Wars and subsequent agricultural subsidies under the 1815–1846 Corn Laws increased the arable area of the country to 3.8 million ha (Olson Jr and Harris 1959). The importation of cheap wheat from the USA from 1873 onwards caused a massive decline to around two million ha by 1900, which persisted with only a temporary increase during the First World War (Borchert 1948).

Although 'High Nature Value' farming systems are often associated with extensive grazing, some arable cropping systems are also categorised as such. Traditional low-input arable farming persists in many countries. Much of the arable area in Spain, Portugal and Hungary is managed extensively and supports high biodiversity. In Hungary it includes numerous small diverse Tanya farms on the Great Hungarian Plain. In Portugal and Spain, the agroforestry systems of montado and dehesa, comprising arable crops and livestock grazing under cork and holm oaks remains

Table 1.1 Areas of arable land in Europe

	Utilised agricultural area (X1000ha)	Arable land (X1000ha)	Percentage arable land
Estonia	892.7	597.1	76
Latvia	1838.2	1182.7	67
Lithuania	2711.9	1904.5	64
Poland	15815.2	12036.2	76
Finland	2288.7	2256.9	99
Belgium	1369.9	840.2	61
Czechia	3556.6	2595.9	73
Denmark	2682.2	2446.7	91
Germany	16930.2	11905.2	70
Ireland	4231.6	1100.8	26
France	31129.5	20019.9	65
Luxembourg	130.3	61.1	47
Netherlands	1902.3	1041.8	55
Austria	3204.5	1371.7	43
Sweden	3097.5	2627.6	85
United Kingdom	17573.9	6070.1	35
Norway	1030.2	852.5	83
Switzerland	1521.0	405.3	27
Greece	3963.9	2312.5	58
Spain	24663.8	12745.6	52
Italy	13914.0	7347.6	53
Cyprus	140.8	103.1	73
Malta	10.3	8.0	78
Portugal	3703.7	1161.6	31
FYR of Macedonia	1120.5	441.3	39
Albania	975.9	579.0	59
Montenegro	518.0	44.8	9
Bulgaria	4087.3	2467.9	60
Hungary	5797.3	4492.3	77
Romania	13758.1	8755.0	64
Slovakia	1931.6	1348.5	70
Slovenia	487.5	175.5	36
Croatia	1254.1	862.1	69
Bosnia-Herzegovina	2194.4	534.1	24
Serbia	5112.0	3329.0	65
Kosovo	369.0	136.1	37

From Hucorne (2012)

widespread although decreasing in area. Localised centres of “High Nature Value” arable farming are present in many other places throughout Europe. Even in the mountains of Transylvania, small arable fields close to villages produce winter food for livestock, alongside hay meadows further away, and summer-grazed pasture on the hill sides. In Scandinavia and the Baltic countries, a short growing season restricts arable land to spring sown crops, but these represent an important part of the farming systems.

Across most of lowland Europe, crops such as wheat, oilseed rape, barley, rye and field beans are mainly autumn-sown, but spring sown crops such as sugar beet, maize, peas, linseed, sunflower and some cereals are also grown in large-scale intensive arable systems. In small scale systems the diversity of crops grown can be much greater with minor crops such as buckwheat and borage also present in some areas, and small plots of horticulture and vegetables.

Within arable systems there are frequently considerable areas taken out of cultivation for one or more years, traditionally to help maintain fertility and to facilitate weed-control. In cool temperate regions where there is sufficient rainfall short-term grass leys are established, while in regions where rainfall is a limiting factor, land is frequently fallowed with vegetation allowed to regenerate naturally. Orchards and vineyards are also a feature of some arable landscapes. This diversity of cropping is extremely important in the maintenance of the biodiversity of cropped land.

Interstitial components of the agricultural landscape also influence its ecology. In the UK and parts of France, field boundary hedges are an obvious feature of landscapes, originally created to contain livestock. In today's arable systems these are recognised and maintained not only for their wildlife and aesthetic value but for many other agronomically important functions (Dover 2019). In the Netherlands and Baltic countries, land drainage channels form important components of the landscape which influence the wildlife present in otherwise arable landscapes. In many parts of Europe, field boundaries are marked by tree lines. In the remaining dry plains of Catalunya for example, old almond and olive trees in field margins are valuable nest sites for endangered birds (Mañosa et al., this volume – Chap. 19). In other countries such as Poland and Hungary however, both large and small fields have no clear boundary features creating an open landscape in which only the diversity of crops and size of fields contribute to the landscape scale heterogeneity.

2 Twentieth Century Changes in Arable Farming – Intensification and Homogenisation

Changes in European agricultural systems around the turn of the century have been reviewed from an environmental perspective by Stoate et al. (2001, 2009).

During and after the Second World War there was a substantial government-led change in the UK from livestock to arable systems to improve food security so that arable and livestock areas became more polarised into the east and west respectively. The Agriculture Act (1947) guaranteed prices and stability for British farmers. Similar arable expansion had occurred in other countries under fascist regimes in the 1930s. In Portugal, the 'Wheat Campaign' (Campanha do Trigo) and in Italy the

"Battle of Wheat" (Battaglia del Grano) (Saraiva 2010) resulted in the expansion of the arable area, even into large areas of hilly land with thin soils where production could not be maintained for more than a few years and the land was subsequently abandoned. Mechanisation increased rapidly in the post-war period in northwest Europe, and at a slower pace in the south and east, but the size of agricultural machinery used in most areas has continued to increase into the current century, initially with the consequent removal of non-cropped features such as hedges and ponds.

Most twenty-first century arable systems have high external inputs, based on crop cultivars developed to respond to these with high yields. Such inputs include herbicides, insecticides and fungicides, of which some are applied prophylactically, and others when weed, pest or disease thresholds are reached. The first modern selective herbicides, 2-4-D, 2-4-5-T and MCPA, were introduced in the mid-1940s (Makepeace 1980), and by the 1970s most arable land in lowland north-western Europe had received a herbicide treatment (Fryer and Chancellor 1970). The first modern insecticide, the organochlorine DDT, was introduced for agricultural use in 1945, followed by other organochlorines, carbamates, organophosphates, synthetic pyrethroids and other compounds (Oberemok et al. 2015).

Similarly, fertilisers (mainly nitrogen and phosphate) are applied according to nutrient availability in the soil and the estimated requirements of specific crops. Although nitrogen- and phosphorus-containing artificial fertilisers had been available since the late-nineteenth century, until the 1940s the bulk of nutrients were supplied to arable crops as animal manure. The availability and application of large quantities of cheap and concentrated manufactured fertilisers from the 1940s onwards (Fig. 1.1), was accompanied by the development of high-yielding and highly competitive crop varieties (Fischbeck 1990).

Irrigation has become more widely adopted for high value crops in the north, and for a wider range of crops in the south. In southern Europe, the area of irrigated crops has increased considerably since the 1960s. In Italy for example 25% of the arable land area was irrigated in 2000 and 55% of arable produce was from irrigated land (Bazzani et al. 2004). Pivot irrigation of crops such as maize is associated with increased fertiliser and pesticide applications and the environmental impacts of irrigation are at least partially those of these inputs, but also include the loss of fallows from the rotation. Mañosa et al. (this volume – Chap. 19) describe the loss of some of the remaining areas of dry arable land to irrigation in Catalunya.

Cultivation systems have also changed in recent decades, with adoption of reduced tillage using discs and tines, and direct drilling using specialised drills in many parts of Europe instead of the traditional plough and associated cultivations to produce a seedbed. The development of these systems throughout the world has been documented by Derpsch (1998). In 2015 it was estimated that approximately 55% of arable crops in the UK were established by minimum or no-tillage (Alskaf et al. 2019). These changes have had substantial impacts on the above and below ground ecology of the farmed environment, and the effects of these on soil organisms are described by Crotty (this volume – Chap. 10).

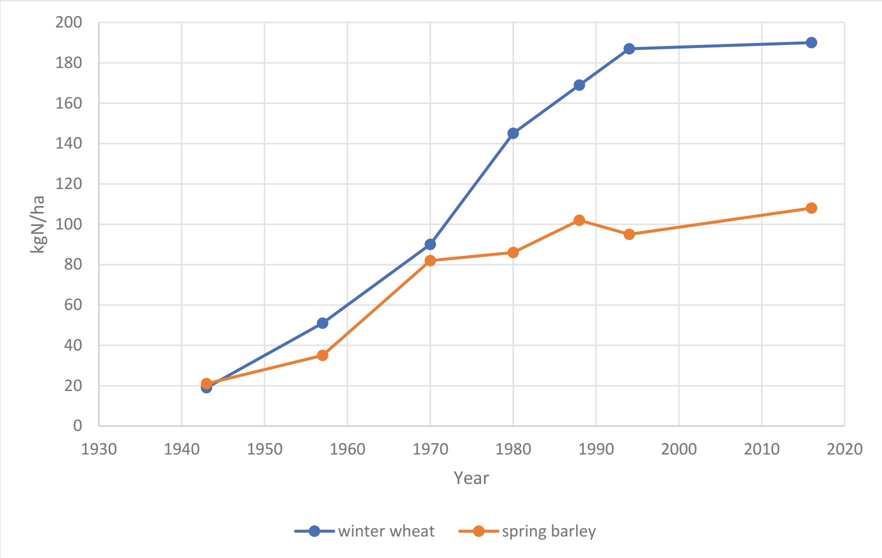

Fig. 1.1 Application rates of synthetic nitrogen fertilisers to cereal crops (Church 1981; Anon 2017)

Homogenisation of farmland landscapes has been characteristic of Eastern Europe, especially in the period of collectivisation in the 1950s and '60s. Socialist agriculture supported through state ownership and planning in the 1970 – 1990s was as intensive as in western countries in terms of use of inputs but received less financial support than in the EU. In many eastern European countries however the economic drivers, poor communications and mountainous terrain permitted the localised survival of a rich arable biodiversity (Pinke, this volume – Chap. 2). Most collectivised land was privatised in the 1990s, input costs increased, and livestock numbers declined.

Enlargement of the EU in 2004 and 2007 incorporated 12 eastern and southern European countries including much high nature value extensively-managed farmland and EU agricultural policy was therefore extended. This has resulted in convergence of agricultural intensification across east and western Europe, and this has been compounded by the general drift of the rural population to the cities, resulting in abandonment of farmland and intensification of management on the remainder. Agricultural commodity prices showed an unprecedented increase in 2007/8, partly in response to demand for biofuels, and partly because of global food insecurity associated with climate change and increasing human population and per capita consumption. Global commodity prices subsequently declined, reducing the profitability of farm businesses, but continue to be the main driving force for the management of crops in European countries.

EU financial support for farmers is another major influence on the way arable land is managed. Successive reforms of the CAP from the 1980s onwards, but particularly in 2005 and 2008 included decoupling of payments from production, introduction of cross-compliance, modulation, and extension of the Rural Development Programme. Cross-compliance comprised a range of basic environmental criteria for land management, while agri-environment schemes under the Rural Development Regulation provided funding for more targeted management of the farmed environment to meet specific environmental objectives, including those associated with biodiversity. The first agri-environment schemes were introduced in 1985 (in the UK, Environmentally Sensitive Areas, but subsequently a series of stewardship schemes). Adoption of these was at the discretion of member states and consequently differed across the continent, but numerous studies have demonstrated their importance in the conservation of arable biodiversity.

3 Impacts of Changes in Arable Management on Farmland Ecology

These changes in structure and management of the arable environment have influenced farmland ecology in several ways. These include loss of crop and non-crop habitat heterogeneity, loss of intrinsic habitat value at a range of scales, and intensification in the form of increased external inputs such as nutrients which change the composition of vegetation through competition, herbicides, fungicides and insecticides all of which have direct toxicity towards target organisms and some also to non-target organisms. Adoption of highly nitrogen-responsive crop varieties, abandonment of arable land, including the conversion to forestry and intensively managed grassland, irrigation, land drainage and changes to tillage systems have all had profound effects on the arable ecosystem.

Brown hare (Tapper and Barnes 1986), lapwing (Henderson et al. 2012), yellowhammer (Stoate et al. 1998; McHugh et al. 2016) and little bustard (Mañosa, this volume – Chap. 19) are all examples of vertebrate species that use different features of the arable landscape for different purposes or at different times of the year and consequently rely on landscape-scale heterogeneity. Santana et al. (2017) demonstrate that both habitat diversity and complexity can influence landscape scale avian biodiversity across Portuguese farming systems. Headage payments for livestock provide an example of how economic support can influence the composition of the landscape, in this case by reducing the arable area in favour of grazing livestock, and increasing livestock density, to the detriment of regenerating trees in traditional agroforestry systems such as Montado and Dehesa. Payments under agri-environment schemes for the enhancement of habitats for wildlife can be important as drivers in agricultural systems where profit margins are small.

Intensification of management has contributed to biodiversity loss in many ways. Increased fertiliser use, and the vigorous crop cultivars developed for high input systems, radically change the plant assemblage associated with crops, while misplaced fertiliser in field edges has also resulted in eutrophication of field margin habitats and a decline in plant species richness. These competitive effects, together with direct toxicity from herbicides, have combined to transform and impoverish the species-rich and diverse plant communities formerly associated with arable cultivation thoughout Europe.

The plant species which have suffered most are those segetal species with life-cycles most closely synchronised with traditional cereal growing. They are often poorly competitive with a fully fertilised modern cereal variety and very susceptible to a wide range of herbicides. Some of these such as *Agrostemma githago* (Firbank 1988), *Ranunculus arvensis* and *Scandix pecten-veneris* (Wilson 1990) produce relatively few seeds with limited dormancy in the soil and are consequently particularly vulnerable to change. Many of these species have experienced massive declines throughout Europe. In Britain for instance, of the 100 species of plant exhibiting the greatest declines in the latter half of the twentieth century, 47 were typical species of arable land (Preston et al. 2002) (Storkey, this volume – Chap. 2). These declines were noted as early as the 1900s as improved methods of seed-cleaning removed contaminants such as *Agrostemma githago, Centaurea cyanus*, *Lolium temulentum* and *Adonis spp* (Meyer, this volume – Chap. 6) and the suite of species associated with flax cultivation (Kornas 1961). Declines continued through the end of the twentieth century and into the 21st with the near-disappearance by the 1970s from many northern European countries and the collectivised parts of eastern Europe of segetal communities associated with nutrient-poor soils such as the *Teesdalio-Arnoseridetum* and *Caucalido-Adonidetum*. Intensification of arable management in much of southern Europe occurred later (Meyer and Bergmeier, this volume – Chap. 8; Recasens, this volume – Chap. 5) and parts of Eastern Europe (Pinke, this volume – Chap. 3), but even in these areas, there have been great losses of species diversity and of individual species in recent years.

Direct effects of insecticides on vertebrates have been greatly reduced since the phasing out of organochlorines in the 1980s (Newton 2015). However, long-running research in southern England demonstrates that direct effects on non-target invertebrates persist, and direct effects of fungicides on invertebrates have also been documented (Ewald et al., this volume – Chap. 11). Indirect effects of herbicide use on farmland invertebrates have been demonstrated in the same study. Other work has implicated the most widely used modern insecticides, the neo-nicotinoids, in the continuing global declines in farmland invertebrates and vertebrates (Goulson 2013).

Sotherton et al. (this volume – Chap. 19) describe the strong link between grey partridge chick survival and subsequent breeding abundance and the abundance of arable invertebrates and their plant hosts. Throughout Europe, nestling survival and breeding abundance of other characteristic birds of arable farming systems such as corn bunting (Brickle et al. 2000) and little bustard (Mañosa et al., this volume – Chap. 19) have been shown to be higher in extensively managed areas supporting weeds and invertebrates.

4 Current Threats and Opportunities

The key influences on arable biodiversity are therefore heterogeneity at a range of scales and the intensity of management in terms of use of external inputs. Loss of heterogeneity and intensification are major threats, while abandonment to other land uses is an increasing threat in marginal areas.

Demand for food is increasing globally as the human population increases, alongside increasing consumption, especially of meat. Intensive production of the latter requires a large arable area for animal feed, compounding pressure on land from other markets, including biofuels such as maize for anaerobic digestion. High input costs and low global commodity prices contribute to the loss of small farms, amalgamation into larger units, increased use of contractors, and adoption of methods that take little account of site-specific circumstances or environmental considerations including biodiversity. Increases in farm, field and equipment size have combined to simplify arable landscapes, while the increasing prevalence of contractors rather than owner occupiers on enlarged holdings can contribute to reduced attention to detail and increased prophylactic use of pesticides.

On the other hand, economic drivers for nutrient use efficiency can also result in reduced nutrient emissions to the environment and therefore a decline in negative impacts on biodiversity as well as other externalities such as aquatic eutrophication and climate change. A combination of regulation and high input costs can also encourage adoption of holistic approaches to crop management such as integrated pest control and organic systems. Encouraging invertebrate predators of crop pests can potentially reduce insecticide use with benefits to farmland biodiversity resulting both from the habitats created and from less frequent use of insecticides. Crop cultivars are also being developed that are resistant to some insect pests (e.g. orange wheat blossom midge in wheat), as well as the well-established breeding of resistance to or tolerance of fungal diseases. Although challenging on some soil types, the widespread move towards reduced tillage and direct drilling can also have benefits to the ecology of aquatic and terrestrial habitats, as well as to the soil itself. In addition, reduced tillage can reduce costs and soil erosion, while also reducing fossil fuel use and carbon dioxide flux, and allowing the accumulation of carbon stores in the soil. At the same time however it can lead to impeded drainage, accumulation of perennial weeds and grasses, the loss of uncommon segetal species and an increase in the use of broad-spectrum herbicides.

There remains a considerable need to support farmers to achieve both specific and systemic environmental objectives through agri-environment schemes such as those demonstrated in this volume (Meyer – Chap. 6; Mañosa et al. – Chap. 19; Swan – Chap. 21) to benefit wildlife associated with arable habitats. There is increasing interest amongst policy makers in the potential of 'payments by results' in which the level of payments received by farmers is determined by the quantified delivery of wildlife, rather than, or in addition to, management-based payments made for creating and managing habitats. Such an approach encourages a genuine understanding by farmers of the life cycle requirements of species and the management required to meet these, and can stimulate innovation to achieve targets. However, this approach may be more readily applied to segetal plant communities than to mobile and less easily measurable animals associated with arable landscapes.

Increasingly, food processors are providing incentives to their farmer suppliers to adopt management practices that benefit wildlife or have other environmental benefits, and some products from farming systems that support wildlife continue to attain a premium that provides farmers with an economic incentive. There is also a move towards collaboration between farmers to manage their land to benefit certain iconic species such as wading birds in the Netherlands and a range of species that are valued by Farmer Clusters in the UK. Such 'ownership' of species at the farm level is fundamental to their conservation. In the end, it is farmers working individually and collaboratively within a robust, scientifically-guided regulatory and funding system who will determine the future of arable ecosystems.

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Part II
National and International Nature Conservation Reviews

Chapter 2
A Weed's Eye View of Arable Habitats

Jonathan Storkey

Abstract The diversity of plant communities adapted to arable habitats has declined across Europe with many species becoming nationally rare or extinct since the 1960s. Common trends in the response of these communities can be understood in the context of plant ecological principles. The assembly of plant communities is driven by the interaction of the frequency of disturbance with the availability of resources; determining the prevalence of contrasting plant strategies. Arable plants are characterised by traits that make them well adapted to the highly disturbed environment of cultivated fields (being dominated by annuals) and can be negatively impacted by changes in the disturbance regime either through shifts in cropping patterns or land abandonment. The intensification of agricultural production has also seen a dramatic increase in the amount of fertiliser applied to crops to realise the greater yield potential of modern cultivars. This has selected against more 'stress tolerant' arable plants that are less able to compete with the crop for above ground resources and for faster growing, more competitive species that are adapted to soils with high fertility. When combined with the increased use of herbicides, these changes in crop management have effectively narrowed the available habitat niche for arable plants with a tendency for more specialized species to decline and generalists to increase. In seeking to conserve the ecological value and cultural heritage that arable plant communities represent, space needs to be found in intensively farmed landscapes to support the range of species that are currently excluded from our fields.

Keywords Rare arable weeds · Plant ecological strategies · Fertilisers · Cultivation · Herbicides · Broadbalk long-term experiment

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1 Introduction

Arable fields are a novel habitat for floral communities that represent a combination of environmental conditions not previously encountered by plants and animals in evolutionary history. However, the inherent diversity of life and its capacity to adapt has meant that these new environments have become a new opportunity for colonisation for a group of plants we now call 'weeds' such that they have become our constant travelling companions since the advent of agriculture in Europe (Jones et al. 2005). In some cases, this has even meant that weed species have co-evolved with agriculture (Vigueira et al. 2013) to the extent that they include some examples of anecophytes (plants that are only found in human-created habitats). Previous generations had no choice but to learn to accommodate and live with these hitchhikers in their crops (Shakespeare's King Lear was "*Crowned with rank fumiter and furrow-weeds, with burdocks, hemlock, nettles, cuckoo-flowers, Darnel, and all the idle weeds that grow in our sustaining corn*"). However, in more recent history, in the face of the growing world population and need to increase productivity, they have been perceived almost exclusively as a problem that needs to be removed (Oerke 2006). As a result, the diversity and abundance of weeds in arable fields has declined dramatically across Europe, especially in the post World War II era after the advent of herbicides, and specialist weed floras of national cultural and ecological importance are now under threat across the continent (Storkey et al. 2012). These declines have refocussed attention on the inherent cultural value of weeds and their potential contribution to maintaining ecosystem function by providing resources for higher trophic groups (Marshall et al. 2003).

This collection of chapters has been written by agricultural botanists and weed scientists representing different regions in Europe all of whom share a concern for the conservation of arable floras. Because of the negative connotations associated with the term 'weed' (implying it is unwanted), these species tend to be referred to henceforth as 'arable plants'. However, whatever we decide to call them, these plants are defined by the fact that their fortunes are closely wedded to human activity. The historical trends in arable plant communities can, therefore, only be understood in the context of changes in the management of arable fields and associated impacts on their habitat. In this introductory chapter, this concept is explored in the context of general ecological principles that underlie the region-specific patterns discussed in subsequent chapters. Additional examples and case studies are introduced from a UK perspective to illustrate these principles.

2 Monitoring the Status of Arable Plants

If our starting point is that conserving arable plant communities is important both for cultural and ecological reasons and that their population trends are closely associated with human activity, to understand trends we need to both quantify changes in species' abundance and diversity and collect information on shifts in agricultural practice. The ideal approach, therefore, is a repeated, systematic vegetation survey focussed on arable fields at a national level coupled with the collection of farm management data. Where there are examples of these studies (in France (Chap. 3), Finland and Denmark (Chap. 4), and Germany (Chap. 5), the data are particularly valuable because population trends can be directly related to changes in management practice. Ideally, these surveys return to the same sample points at intervals over decadal timescales; a challenge made more tractable by the introduction of Global Positioning Systems (GPS). All of the authors in this collection of chapters are strong proponents of such surveys.

Data from a wide scale national botanical survey of this type specifically targeted at arable plants does not exist in the UK; a deficiency also highlighted for other areas of Europe discussed in this section (Chaps. 6 and 7). Rather, to identify trends in arable plant distribution and abundance at a national scale in the UK, we rely on databases from broader vegetation surveys done across all habitats. While lacking the resolution of surveys specifically focussed on weeds and the associated field level management information, these data are still indicative of broad trends in arable floras. The main source of these data in the UK are the records of the Botanical Society of Britain and Ireland (BSBI) reported in the New Atlas of British and Irish Flora (Preston et al. 2002). The Atlas includes a measure of the population change of each species between the 1930s and 1990s. The detail of the calculation of this metric is explained in Telfer et al. (2002); in summary, the proportion of 10 by 10 km squares in which species were recorded in a national botanical survey between 1987 and 1999 were plotted against the proportion of squares in which species were recorded over an earlier period, 1930–1969. The population change index is the residual for an individual species measured against a linear regression model fitted to data for all species from the two time periods. Thus, it is a relative measure of how the distribution of a species has changed between the two surveys in comparison to the rest of the U.K. flora with a negative value indicating relative declines. One of the main conclusions of this analysis was that the group of plants that had suffered the most dramatic declines in their distribution over this period were associated with arable habitats. Examples of species with the most negative population change indices are *Bupleurum rotundifolium*, *Galium tricornutum* and *Scandix pecten-veneris*. The fact that arable plants are a particularly threatened component of the UK flora is also reflected in the Vascular Plant Red Data List for Great Britain that lists five arable plants as recently extinct, seven as Critically Endangered and 14 as Endangered (Storkey et al. 2012), Table 2.1.

Two, more localised, studies in England have been published that report the change in the floras of arable landscapes between the 1950s and 2000's. At this more local scale, the trends in arable plant populations are less dramatic and more subtle. While Potts et al. (2009) documented a marked reduction in arable weed diversity in Sussex after the introduction of herbicides in the 1960s (with an initial 52% fall in species frequency), since the 1970s the abundance and occurrence of annual weeds has remained relatively stable or, for common species increased. Sutcliffe and Kay (2000) also observed many of the rarer arable plant species recorded in a 1960's

Table 2.1 Species on the Vascular Red Data List for Great Britain identified as 'arable plants' (Kate Still pers. com.) as part of a European wide survey (Storkey et al. 2012)

Recently extinct	Critically endangered	Endangered
Arnoseris minima	*Filago gallica*	*Adonis annua*
Bromus interruptus	*Chenopodium urbicum*	*Ajuga chamaepitys*
Bupleurum rotundifolium	*Galeopsis angustifolia*	*Anthemis arvensis*
Caucalis platycarpos	*Galium tricornutum*	*Filago lutescens*
Galeopsis segetum	*Lolium temulentum*	*Filago pyramidata*
	Ranunculus arvensis	*Lithospermum arvense*
	Scandix pecten-veneris	*Lythrum hyssopifolium*
		Scleranthus annuus
		Silene gallica
		Torilis arvensis
		Valerianella dentata
		Valerianella rimosa
		Veronica triphyllos
		Veronica verna

arable field survey in Oxfordshire and Berkshire were still present in a follow-up survey done in 1997. Both studies concluded that although the intensification of agriculture had an impact on arable plant communities, the diversity in the soil seedbank was still sufficient to maintain diversity at this local scale (although it is likely species have been lost from local seed banks since these studies were published). Other countries have also observed positive trends in the frequency and abundance of common species in the last two decades in response to policy measures to support farmland biodiversity (Chap. 4).

3 What Are the Defining Characteristics of an Arable Habitat?

In 1974, the English plant ecologist, Philip Grime, introduced the idea that plants could be thought of having contrasting Plant Ecological Strategies that have evolved in environments with different levels of competition, abiotic stress and disturbance (Grime 1974). Any plant species could be assigned a strategy based on the combination of their functional traits that determined their fitness in different habitats. The functional composition of communities, in terms of the dominance of different strategies was found to shift along gradients of soil fertility and disturbance – the main characteristics of a habitat that determine pant community assembly. 'Competitors' (C) are adapted to undisturbed environments with high soil fertility, 'Stress tolerators' (S) to undisturbed, infertile habitats and 'Ruderals' (R) to highly disturbed, fertile habitats. These three strategies can be visualised as the corners of a 'C-S-R triangle' (Fig. 2.1) and any plant species positioned within that triangle on the

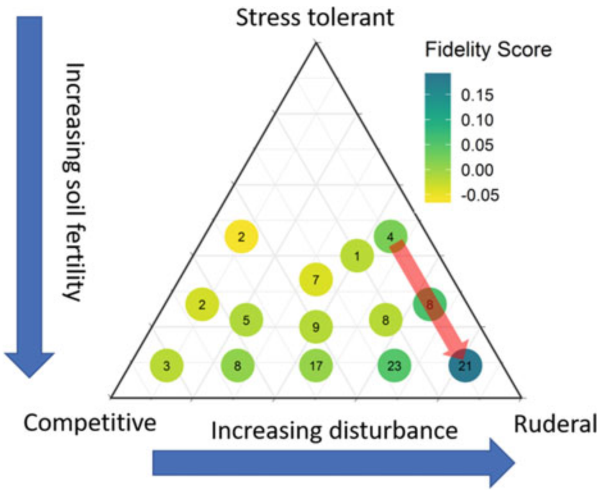

Fig. 2.1 Median fidelity score for common arable plant species showing different ecological strategies according to Grime et al. (2014). Fidelity is a measure of how frequently a species was recorded in arable fields compared to all other habitats; scores range from −1 to +1 with positive (negative) values indicating that the species and the habitat of interest occur more (less) frequently than would be expected by chance. The relative position of the circle indicates the ecological strategy, the colour of the circle represents the median fidelity score for the ecological strategy and the number within the circle is the number of species represented by the ecological strategy. The red arrow indicates the direction of selection pressure as a consequence of increased fertiliser use. (Adapted from Metcalfe et al. 2019)

basis of the traits that determine how well it is adapted to different habitats (Grime et al. 1997). This is a useful framework for defining the important characteristics of arable habitats and understanding the assembly of arable plant communities in response to changes in management. So, how should an arable habitat be defined in this context?

Arable cropping systems are dominated by annual crops meaning soils are generally disturbed at least once a year when crops are established and areas of very low fertility or high abiotic stress (such as arid regions or low pH soils) tend to be avoided as they do not support crop production. Arable habitats are, therefore characterised by frequent disturbance and relatively fertile soils favouring a ruderal plant ecological strategy. Ruderal plants are characterised by traits that enable them to acquire resources quickly (high relative growth rate) and complete their life cycle in between disturbance events (they are generally annuals or 'therophytes' that reproduce exclusively with seed). An analysis of a pool of 118 UK weed species with an ecological strategy listed by Grime confirmed that the majority were concentrated in the 'R' corner of the triangle and that species with this strategy had a higher fidelity to arable fields (more likely to be found in cultivated land than in other habitats), Fig. 2.1. A second study comparing the plant traits of a species pool recorded in French arable fields with a list of species from other open habitats also found that arable plants were more likely to be therophytes (over wintering as seed)