Monitoring of EK21, OK21, HK21 and OHK21 Options: Legume- and herb-rich swards

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EXECUTIVE SUMMARY

Introduction

1. Most grassland is dominated by perennial ryegrass with low diversity of other plants and therefore is of limited value to wider biodiversity. Under Environmental Stewardship, the rotational EK21 option (and its Higher Level and organic equivalents) which was introduced in 2013, aimed to provide a more diverse sward to benefit biodiversity but also to improve soil structure, provide high-quality livestock forage and reduce nitrogen fertiliser use. The option is now available in Countryside Stewardship.
2. A range of grasses, legumes and herbs must be sown and maintained providing food resource for invertebrates and birds and a diverse structure which benefits invertebrates. Some sown species may improve soil structure through rooting characteristics. The option prescription includes requirements for sward characteristics.
3. This study considered the quality of delivery of this option and the agreement holders' attitudes after implementation over four years.

Methodology

Sample

4. Sites selected were largely those which had been surveyed in a previous study carried out in the first year of the option. Botanical data were collected on 76 option parcels on 54 holdings.
5. On a subset of holdings, counterfactual parcels, representing the agreement holder's standard short term ley, were surveyed in summer. Soil samples were taken from a subset of option parcels and a sample of arable counterfactual parcels during autumn to assess the impact of the option on soil structure.

Agreement holder attitudes/management information

6. A questionnaire was developed to collect field-specific management data and more general information on agreement holder attitudes to and experience with the option. Interviews were conducted in autumn in face-to-face meetings.

Field survey

7. Summer field surveys were completed during the 'resting period' or when swards had regrown after grazing/cutting. In each parcel, botanical data were collected in twenty 1 m^2 quadrats. Percent cover was recorded for each species present and sward height was measured in each quadrat. In addition, flower number of each forb species was recorded in twenty 0.25 m^2 quadrats.
8. During autumn surveys, the number of seedheads of all species present was recorded in twenty 0.25 m^2 quadrats. Soil samples for chemical analysis were taken on all parcels. Laboratory analysis included: soil pH; extractable P, K, Mg; total N, C and organic matter and soil texture.
9. In addition, a subset of sites, plus arable counterfactual parcels on the same holdings, were assessed for soil structural condition. Soil structural condition was assessed using the Visual Evaluation of Soil Structure (VESS) method. Aggregate stability was assessed using the soil dispersion ratio test.

Agreement holder perspectives and experience

10. Holdings in the sample were predominantly mixed or livestock. Only five of the 51 agreement holders interviewed managed mainly arable holdings. Half (51%) were organic.

11. The option was most likely to be chosen by the agreement holder because it 'fits with current farm management/rotation' (75%) or because of the wildlife benefits (77%). Improvement of soil structure and the points target (both 69%) were also important considerations. 'Fits with current farm management' was most often the highest priority for those who ranked their reasons for choosing.
12. Parcels were most likely to be selected because the option fitted with the rotation and were most frequently medium/calcareous soils. Over half of parcels were ploughed before option establishment. Sowing rates were quite variable, but most seed mixes (72%) were drilled at between 20 and 39 kg ha^{-1}. On eight of the 63 parcels where information was available, the seed mix had been combined with other seed.
13. Information on option management indicated that parcels under conventional and organic variants of the option were generally managed in a similar way. One third of parcels received a manure/slurry application. Spot treatment using herbicides was rare. Around two thirds of parcels were cut, predominantly for silage) a single cut and cutting in June/July were most common. Around 80% of parcels were grazed, reflecting the high proportion of livestock and mixed farms in the sample. Grazing rates were highly variable; some fields were grazed extensively for a large proportion of the year, while others were 'mob grazed' at high stocking densities for a short period of time.
14. Although half the agreement holders had received no advice beyond the ES manual, the most common other sources of advice were Natural England and seed companies. However, three quarters of those who responded indicated that information in the ES manual was sufficient. Most advice was delivered verbally. Half of those who expressed an opinion would like one to one advice and the same proportion favoured written advice as a reference. Advice was most commonly associated with the seed mix and establishment/management, but the latter was the element which was most likely to benefit from advice.
15. Most agreement holders recognised that the option had multiple benefits; wildlife/biodiversity and soil quality/fertility were considered the most important.
16. One third of negative comments were associated with management restrictions imposed by the prescriptions. Comments were diverse, but the more common criticisms were around: weed control, prescriptive nature, management generally, expensive seed mix and issues with chicory. However, 18% thought there were no negative aspects of the option.
17. When asked what changes they had observed in sward composition, most common responses were a decrease in herbs and legumes, an increase in grasses and simply a change in species composition. Changes were attributed to the seed mix, the length of time it takes some species to establish and management. Half had not observed anything unexpected.
18. General comments on the prescriptions were varied. Changes to seed mixes were mentioned by one third of those who commented and greater flexibility was also mentioned by several.
19. Most (84%) of agreement holders would use the option again, most commonly because of its compatibility with existing management/rotations. Only two individuals would not and others were uncertain because they considered the option was not working well. Generally the option was considered good for livestock, profitable and easy to do.

Outcomes

Outcomes against prescription requirements

20. Botanical data collected in summer were assessed against the five prescription requirements. Two thirds (64%) of option parcels met at least three of the five thresholds. Only 9% of option parcels met all five thresholds and 7% did not meet any. Only 9% of counterfactual parcels met at least three of the thresholds and 43% met none.

21. The requirement most likely to be met was the presence of at least 5 'other' (not legume) forb species (78% of option parcels) although these were not necessarily sown species. Cover of red clover (requirement ≥ 10%) was least likely to be met (37% of parcels).
22. Unsurprisingly a smaller proportion of counterfactual parcels met the prescription requirements. Five 'other' forb species were present on 43% of parcels, whereas only 9% of parcels had three legumes present.
23. Fitting a generalised (binomial) linear model indicated that all thresholds were more likely to be met on option compared to counterfactual parcels. The likelihood of meeting the cover of other forbs requirement was different for different options, however option parcels were still significantly more likely to meet this requirement than counterfactuals.

Persistence of sown species

24. Each sown species was present at the time of the summer survey in around 60% of the parcels on which it was sown. A small number of species were under-performing (observed in a lower proportion of parcels in which they had been sown compared to other species). These results were probably related to taxonomic identification issues and small sample sizes for some species.
25. The likelihood of observing a sown species in the sward was affected by the rate (number of seeds ha^{-1}) at which it had been sown. Other factors (management and soil) where they had any effect at all, tended to have an effect on species that had been sown at lower rates.
26. pH and organic carbon affected sown species survival for: proportion of quadrats in which the species was recorded, probability that a species is recorded in the parcel and percent cover in parcels where a species was recorded. Effects of these two factors were most marked at low sown seed densities, whereas at high sown seed densities, outcomes were more similar across the range of pH and organic carbon values.
27. Previous tillage appeared to have some effect on the basic seed-rate model, with persistence of sown species more consistent across different seed densities under minimum tillage compared to ploughing. At low sown densities, persistence was higher after minimum tillage, whereas at high seed densities, persistence was greatest following ploughing although fairly similar to minimum tillage at high sowing densities.
28. Observed effects of other factors were generally small and no effects were observed for previous crop or season of drilling and surprisingly for year of drilling or extractable phosphorous.

Factors affecting sward species composition

29. Ordination analysis suggested that overall sward composition (sown and unsown species) was affected by some different factors than models for sown species indicated. These differences were likely associated with unsown species present in the swards.
30. Factors which significantly affected species composition were: previous crop (grassland vs arable), typically cut (i.e. cut in all or most years while under option), pH, grazed or cut pre-survey, option/counterfactual and years since establishment.

Soil condition

31. Overall there was no difference in soil structural condition (as scored visually using the Visual Evaluation of Soil Structure methodology) between option fields and arable counterfactual fields. However, soil dispersion ratio (DR) results indicated that the "legume- and herb-rich swards" option was resulting in more stable aggregates than management under paired 'counterfactual' arable rotations. Other factors influencing SR were site, clay content and soil organic matter content.

Resource availability for wider biodiversity

32. Options provide a much greater food resource compared to counterfactuals for both pollinating insects during the summer and granivorous birds and other seed eating species during the autumn.

Organic option and counterfactual parcels had higher flower counts than their conventional equivalents. Conventional counterfactual parcels supported very few flowers in summer. Seedhead numbers however, were similar on organic and conventional options, but much greater than organic or conventional counterfactual parcels. Autumn seedhead numbers were very low on both organic and conventional counterfactual parcels.

33. Sown species, particularly *Trifolium repens*, *Chichorium intybus*, *Trifolium pratense* and *Lotus corniculatus* were recorded in highest flower numbers on option parcels. Diversity of flowers on counterfactual parcels was very limited; flowers on counterfactuals were largely *T. repens*, plus *T. pratense* on organic parcels.

34. Similarly, seedhead numbers on option parcels were highest for sown species and *Chicorium intybus* accounted for 55% of all seedheads, probably reflecting the plant's structural characteristics.

Conclusions

35. Most agreement holders were positive about the option and found that it was compatible with management/rotations on livestock/mixed farms. Arable farms may find it more difficult to implement, but there may be benefits for weed control.

36. Although the option often did not meet the prescription requirements, it has made a positive contribution in improving soil structural stability (compared with an arable counterfactual) and to wider biodiversity. The biodiversity benefits were particularly clear in conventional systems. Greater awareness of the requirements amongst agreement holders is necessary to improve delivery.

37. Seed sowing rate is critical to species persistence in the sward. Seed mixes should be developed to improve environmental outcomes.

KEY MESSAGES

Agreement holder attitudes

The most important driver in choosing the option was that it was compatible with current management or rotation, however most agreement holders recognised the potential for improving soil structure and the biodiversity benefits.

Almost all agreement holders were positive about the option and were likely to continue the option in future agri-environment agreements.

Negative aspects of the option generally related to management restrictions, including control of noxious weeds, the cost of the seed and requirement to redrill and the difficulty of establishment.

Most options were drilled with standard 'EK21' seed mixes from companies and were anticipated to be retained for around four years. Most parcels under option were typically grazed and more than half were cut.

Agreement holders reported variable outcomes in terms of species composition, but overall there was a tendency for forbs to decrease and grasses to increase. Changes were most commonly attributed to the seed mix and one third of agreement holders thought that seed mixes should be adjusted.

There was some concern that the prescriptions were too restrictive, particularly in terms of grazing periods.

Natural England and the seed companies were the most important sources of advice, which had been delivered by traditional methods of one to one input, written text and farm visits. Agreement holders indicated that they would like to see similar types of advice/communication in future.

Outcomes

Two thirds of option parcels met at least three of the five thresholds, although only 9% met all five. Although all prescription requirements were rarely met, the option parcels were much more likely to meet requirements than standard short term leys.

Presence of five other forbs was most likely to be met (78%) but probably due to the presence of 'weed' species. Cover of *Trifolium pratense* only met the 10% requirement on one third (37%) of parcels.

The options were therefore environmentally positive, but not fully delivering the anticipated benefits.

Persistence of sown species was strongly influenced by the number of seeds ha^{-1} sown. Other effects on persistence were generally most marked at low sown seed densities. Low soil organic carbon content and pH both resulted in a greater difference in species persistence between low and high seed densities compared to high organic carbon and pH levels because they led to stronger reduction in presence at lower seed rates.

Year of drilling, season of drilling, previous cropping and available phosphorous were factors analysed which had no effect on persistence of sown species.

Outcomes were variable, but changes to seed mixes would probably deliver more positive outcomes.

There was an indication that the "legume- and herb-rich swards" option increased soil aggregate stability compared with soil in paired counterfactual fields in an arable rotation.

Option parcels provided more resource to wider biodiversity (summer pollen and nectar for pollinator species and autumn seeds for granivorous birds etc.) than standard short term leys.

1 INTRODUCTION

1.1 Background

Grassland (excluding rough grazing) covers 3.02 million hectares in England[1], most of which is improved and 627 thousand ha (ca. 20%) is temporary grassland[2] (sown within the past five years). Most grassland in England is dominated by perennial ryegrass with a low contribution from legumes and a few other plant species. Improved grassland provides little pollen and nectar and supports a very limited number of species of invertebrates, birds or other animals (Potts *et al*., 2009). It is thought that it may represent a barrier to movement of many species which will hamper their adaptation to climate change. To meet the objectives of the England Biodiversity Strategy (Biodiversity 2020) a coherent ecological network needs to be created, connecting semi-natural habitats and making farmland, including grassland, more permeable to wildlife. This has to be reconciled with the need to strengthen food security and enable sustainable intensification, improve soil condition and protect the quality of water and air. In recent years more emphasis has been placed on providing multi-functional benefits from agri-environment interventions (e.g. Storkey *et al*., 2015). The Legume LINK project (Döring *et al*., 2013) demonstrated the value of diverse legume-based leys, combining agricultural productivity with a range of ecosystem services.

Environmental Stewardship option EK21, its organic equivalent OK21, and the Higher Level variants (HK21 and OHK21) were introduced in January 2013 to help meet multiple requirements. The rationale is that swards sown with a much wider range of grasses, legumes and robust herbs than would normally be sown in commercial practice can be established on land of moderate or high fertility to support commercially attractive levels of livestock production without manufactured nitrogen (N) fertiliser, whilst also delivering a greatly increased abundance and diversity of pollinators, other invertebrates and improvements to soil structure.

1.2 Legume- and Herb-Rich Sward Option

Options EK21, OK21, HK21 and OHK21 (hereafter referred to as EK21) are rotational, applicable to arable land or temporary grassland. A range of grasses, legumes and herbs must be sown and maintained in the sward to specified levels. Sown mixes are tailored to species and varieties which are favoured by highly fertile conditions. The option is now available in the Mid-Tier of the new Countryside Stewardship (CS) as option GS4 which is present in 4.3% of MT/HT agreements (2016/17 start dates) (Jones *et al*., 2018). The options aim to diversify temporary grass swards to benefit invertebrate and bird populations without compromising agricultural production. A diverse sward structure benefits invertebrates and the inclusion of herbs benefits pollinators and granivorous birds where seed is allowed to set. In addition, the sown species (e.g. chicory, red clover) can potentially improve soil structure, through long tap roots (Fychan *et al*., 2013). Manufactured N fertiliser is excluded, thus this option can contribute to climate change mitigation. For OK21, seed must be certified organic.

A previous study (Woodcock *et al*., 2015) assessed establishment of EK21 in the first year of inclusion in ES. The report details initial establishment success and agreement holders' (AH) early experiences with the option.

The work reported here is complementary to the earlier study and was based on the same sample of agreements, although a small number of agreements were 'lost' from the sample and replaced by different agreements. This study aims to develop the understanding of the environmental quality of delivery and

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[1] *publications.naturalengland.org.uk/file/60043*

[2] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/636552/structure_june_eng_county_09aug17

agreement holders' implementation of the option beyond the first year. Botanical, soil and management information were collected to understand which factors influence the sward characteristics over time in order to refine the option requirements for the future and develop effective guidance on establishment and management. In addition, assessments of soil quality investigated the contribution that the option is making to soil structural condition.

1.2.1 EK21 Prescription

EK21 Legume- and herb-rich swards (reproduced from the ELS handbook[3])
200 points per ha

This option will provide habitat and food for invertebrates including crop pollinators, benefit soil structure, mitigate climate change by reducing nitrogen fertiliser use and provide high-quality forage for livestock.

This option is only available on temporary grassland (sown to grass or other herbaceous forage for less than five years) or grassland that has been cultivated and re-sown in the last five years. It can be applied on whole- or part-fields.

This is a 'rotational option'. This means that it can move around the farm within the normal farm rotation, but the same total hectarage must be maintained each year.

For this option, you must comply with the following:

- In the first 12 months of the agreement, establish a mixed sward of grasses, legumes and herbs/wildflowers (e.g. chicory, yarrow, ribwort, plantain, forage burnet, black knapweed, common sorrel). This is usually most reliably achieved by sowing into a clean seedbed but could be done by oversowing existing grassland following creation of 50 per cent bare ground.
- For the remainder of the agreement the sward must contain a minimum cover of 10 per cent red clover and an additional 10 per cent other legumes plus herbs, plus wildflowers (cover does not include white clover, creeping buttercup or injurious weeds). The sward must include at least 5 species of grass, 3 species of legume (including bird's-foot trefoil), and 5 species of herb/wildflower.
- Re-establish if necessary, on the same or a different field, to maintain these minima.
- Manage by cutting or grazing but allow to flower by resting for a 3-5 week period between 1 May and 31 July[4]. You must delay cutting until the majority of red clover plants have started to flower.
- Do not apply pesticides except herbicides to spot-treat or weed-wipe for control of injurious weeds (i.e. creeping and spear thistles, curled- and broad-leaved docks or common ragwort); invasive non-native species (e.g. Himalayan balsam, rhododendron or Japanese knotweed); or bracken.
- You may apply lime and organic manures.
- You may apply inorganic fertilisers provided they do not contain nitrogen.

1.3 Objectives of this report

The objectives of this study were to:

i. Understand how agreement holders have implemented the options and any implications for the wider farming system
ii. Assess the quality of establishment against option objectives
iii. Investigate the role of the seed merchants in terms of mixes and advice
iv. Establish which factors contribute to sward quality
v. Assess the contribution of the option to soil condition.

[3] *publications.naturalengland.org.uk/file/2786804*

[4] Under current CS guidance the resting period is now 'at least five weeks'.

2 METHODS

Where possible, methods replicated those used in the previous study to allow comparisons to be drawn between initial establishment and success of more mature options.

2.1 Site selection

Sites selected were largely those included in the previous work. However, some agreements had terminated or AHs were unwilling to be involved in a second survey project. A small number of 'new' AHs were approached to give a sample size similar to the original study.

A sample of ten counterfactual fields was selected from both organic and conventional farms to compare the AH's standard short term ley with the option. These were identified on agreements in the option sample to reduce the variability of other factors and to maximise efficiency of resource use. Counterfactual fields/areas were selected on the basis of management similar to the option (sowing year, time and grazing/cutting).

An additional counterfactual sample was identified to compare the effect of the option on soil quality characteristics with the arable rotation. A further ten conventional and organic fields were selected during the autumn visit on holdings in the main sample. Arable counterfactuals were paired with the subset of 20 agreement sites such that each pair was on the same NATMAP "simple description" soil type.

2.2 Collection of management information and agreement holder experience

A questionnaire was developed to collect management information specific to the field parcels surveyed and to capture the AHs' views and experience with the option. Interviews were carried out face-to-face to maximise the quality of responses. The discussion with the agreement holder collected contextual and management information including (see Appendix 1 for full details):

- Farm context and reasons for choosing the option; comparisons with normal practice.
- Seed mixture and establishment methods; period before and location of re-establishment.
- Inputs and sward management.
- Issues encountered and any changes in management of the option.
- Advice and guidance obtained from third party sources (importance, usefulness etc.).
- Any other management issues and attitude towards the option.

The questionnaire was a combination of 'tick box' and free-text responses and responses are reported either as a number of responses or as a proportion of the number of agreement holders who responded to each question (although questionnaires were largely complete, some agreement holders did not answer all questions). It was sometimes possible to record multiple responses and these were reported as a proportion of agreement holders who answered the question, therefore the number of responses can exceed 100% of respondents. Free-text responses were categorised by type of response(s) and summarised against these groupings.

Due to the delayed start of the project, interviews were completed at the autumn visit. Unfortunately, this resulted in a small number of parcels under option, surveyed during the summer which were no longer under option for the second field survey in autumn.

2.3 Field Survey

The field schedule aimed to maximise the number of options visited in the 'resting' period. ES guidance stipulated a 3-5 week resting period between 1 May and 31 July[5]. However, the project commenced later

[5] *publications.naturalengland.org.uk/file/2786804*

than expected and, although agreement holders were contacted as early as possible, many had already completed this compulsory resting period. Field surveys of options in the resting period were completed where possible but many surveys could not be scheduled during this window, therefore the visits were planned in discussion with the AH, to assess sward regrowth later in the season.

2.3.1 Summer assessments

The summer botanical field survey was designed to assess sward composition and its value for pollinators. In each parcel (option and grassland counterfactual) 20 quadrats were assessed. Quadrats were placed at evenly spaced intervals in a stratified random pattern by walking a 'W' pattern across the parcel, adapted to the shape of the field. Obviously atypical areas and edge effects were avoided. Percent cover of all higher plant species (sown and unsown) was recorded in 1 m^2 quadrats. Values represent the horizontal projection at any layer in the sward, therefore total cover could sum to more than 100%. A measure of sward height was taken from the centre of each quadrat. A 1.5 cm diameter pole was placed upright in the sward and the highest point at which a leaf touched the pole was recorded.

A 0.25 m^2 quadrat was placed in the 'bottom left' corner of the larger quadrat. Flower density was recorded as blossom units for all forbs to indicate the value of the sward for pollinating insects (Pywell *et al*., 2006). A blossom unit is a floral unit that a medium-sized bee has to fly, rather than walk, between. Changes in flower abundance can be significant over a short period of time in peak growing season and surveys were completed over a number of weeks. Records therefore included flower buds and seed heads as well as flowers to give a more complete estimate of resources

At the end of the quadrat survey, a timed search of 10 minutes recorded species observed in the sward, but not present in quadrats.

2.3.2 Autumn assessments

The number of seedheads (autumn/winter food resource for e.g. birds) was recorded in 20 quadrats 0.25 m^2 based on the same floral units outlined above. Records included any visible seed structures, even if dehisced to minimise the impact of time of visit on the results. Twenty assessments of sward height were recorded using the method described above.

Soil samples for chemical analysis were taken from 60 option sites following Natural England's Technical Note 035 and submitted to Natural England for analysis. In addition, soils were sampled and analysed from 20 counterfactual grassland sites (10 conventional and 10 organic) and 20 counterfactual sites in continuous or multi-year arable cropping (10 conventional and 10 organic). Cores were collected from the whole parcel/plot distributed on a stratified random pattern. Cores were bulked and kept cool (<4°C) before transport for analysis. Samples were analysed for:

- soil pH
- extractable phosphorus
- extractable potassium
- extractable magnesium
- total nitrogen (Dumas method)
- total carbon (Dumas method
- total organic matter content (Loss On Ignition)
- percentage sand, silt and clay content.

A subset of 20 option sites covering a range of sward ages, were assessed for soil structural condition and sampled for aggregate stability testing. The 20 arable sites were also assessed for soil structural condition and aggregate stability. Soil was sampled at three locations randomly selected within each sampling area (option or counterfactual site). Soil structural condition was assessed using the Visual Evaluation of Soil Structure (VESS) method (Guimaraes *et al*., 2011). Soil samples were taken in the autumn as this method should be done when soil conditions are moist. The VESS scoring system provides an estimate of visual porosity and the uniformity of its distribution. The following information was recorded:

- GPS location of VESS assessments (3 VESS assessments on each site/option)
- Individual and mean VESS score for the topsoil
- Individual and mean VESS score for the poorest layer in the topsoil
- Depth and thickness of the poorest layer in the topsoil at each assessment location

Aggregate stability was assessed using the soil dispersion ratio test on soil collected from the three points where VESS assessments were made. At each point, a sample of 500 g of soil was collected from the top 5-10 cm, placed in a plastic container and transported for analysis with the minimum of disturbance. The dispersion ratio test compares the proportion, by weight, of silt and clay suspended by mild slaking forces to the total amount present in the sample. The ratio has been found to be a valuable criterion for distinguishing between soils with different degrees of structural stability, and has been widely used in Defra funded R&D and monitoring projects through using the method detailed in ADAS SOP SOILS/052 (Determination of Soil Stability by the Dispersion Ratio).

2.4 Analysis

Broadly four types of analysis were undertaken:

Top level analyses: these models examined how top level requirement outcomes were affected by implementing EK21 options

Seed persistence models: these models examined how the quantity of plants observed (coverage, number of quadrats) was effected by sowing rates, management practices and soil quality

Factors affecting sward community composition: ordination of species composition and soil/management factors to assess which factors are important in overall community composition.

Analysis of soil characteristics

2.4.1 Top level analyses

Analyses were undertaken to examine performance against five requirements:

Minimum cover (mean of quadrat data):

- 10% *Trifolium pratense*
- 10% cover other forbs excluding *Trifolium repens*, *Ranunculus repens* and injurious weeds

Sward level (presence across all quadrats):

- 5 grass species
- 3 legume species
- 5 other forb species

For each of the five requirements a generalised (binomial) linear model was fitted to the proportion of parcels passing each requirement with option and whether the farm was a counterfactual. Only significant effects were estimated. This means, for example, that if being included in an option caused the proportion of parcels meeting a requirement to increase, but *which* option had no significant effect on the proportion of parcels passing, then a single value was estimated to represent all options. The estimates provide an estimate of the mean effect of each option on the probability of meeting each requirement in the population of farms to which it has been applied.

A second set of models were fitted which examined the relation between size of the quantities for requirements had been set and actions taken under each option. The effect on the number of species (grass, legumes, forbs) was estimated by fitting a generalised (Poisson) linear mixed model to the number of species with option and whether the farm was a counterfactual, with agreement as a random effect.

Models for proportion cover (*Trifolium pratense*, other forbs) had two parts: one part fitted the probability that cover was greater than zero via a generalised (binomial) linear mixed model fitted to the presence of the species with option and whether the farm was a counterfactual with agreement as a random effect; the second part fitted amount of cover (logit transformed) to with option and whether the farm was a counterfactual with agreement as a random effect via a linear mixed model.

2.4.2 Seed persistence models

Two measures of the persistence of grown species were examined: 1) the proportion of quadrats in which the sown species was found; 2) the coverage of the sown species. Coverage was described by two quantities: the probability that the species is present and the proportion coverage in those parcels where it is present.

For all three quantities the basic model was that each measure was related to the number of seeds sown per hectare; then the effect of a number of different factors on the basic model was examined. Therefore, analysis excluded any parcels where sowing rates for individual species were not available. The other factors examined were:

Land management:

Was the previous crop grass or arable
Year in which seeds were drilled
Plough, minimum tillage, other
Field cut prior to survey
Grazed after February prior to survey
Drill season
Typically cut in previous years
Typically grazed in previous years

Soil:

pH
Available phosphorous
Organic carbon (Dumas)
Clay w/w

The general form of fitted models was:

response ~ seeds sown * other factor + parcel (random effect)

A separate model was fitted for each of the 11 “other factors”. The available observations were too sparse to examine the combined effects of “other factors”.

Responses, “the proportion of quadrats” and presence of a species were fitted via binomial generalised linear mixed model. The logit transformed response “coverage (where present)” was fitted via a linear mixed model.

2.4.3 Factors affecting sward community composition

Data for all species recorded in summer botanical assessments (mean % cover) were analysed using Canonical Correspondence Analysis (CCA) to understand which management and soil factors (those used in seed persistence models) were associated with different community composition. A total of 63 parcels were analysed. Parcels with incomplete management/soil data were excluded.

2.4.4 Soil characteristics

Summary statistics were generated to describe soil characteristics of each site including soil type, organic matter content, soil pH, nutrient status, structural condition, aggregate stability. Differences in these variables between agreement and non-agreement sites and between organic and conventional samples was determined using Analysis of Variance models.

3 RESULTS

3.1 Sample

Botanical data were collected from a total of 99 parcels (Table 1) under option or counterfactual short term leys on 54 holdings. A small number of parcels were destroyed between the summer survey and the autumn revisit. 52 agreement holders were interviewed during the autumn visit. Detailed soil assessments were completed on a subset of 19 option parcels and an additional 19 arable counterfactual fields.

Table 1: Distribution of parcels surveyed across options and counterfactuals (Cf)

	Number of parcels	
Option	**In Option**	**Cf**
EK21	9	5
OK21	11	5
HK21	29	6
OHK21	27	7

3.2 Agreement Holder Perspectives

Agreement holders' responses are presented here under the following headings:

- General holding information and reasons for option choice
- Parcel level information
- Advice provision
- Experience with the option and future plans

Not all respondents answered every question, therefore the number of respondents is stated against each question.

3.2.1 Overview

A total of 51 agreement holders were interviewed, of which a slightly higher number were organic compared to conventional (Table 2). Holdings were most commonly mixed or livestock with only five mainly arable. A slightly higher proportion of agreement holders with conventional farms (32%) compared to organic farms (23%) stated that the implementation of the option had resulted in a change in farm practice. Change was not apparently related to farm enterprises; between 20% (arable) and 29% (mixed) of holdings had changed their practice although the sample size for arable was small.

Those that reported a change in farm practice indicated a wide range of specific changes but responses focussed on change in the rotation and reduction in inputs.

Table 2: Holding characteristics and impact of option

Farm type	Livestock only	Mainly arable	Mixed	Total	% change in practice
Conventional	7	4	11	22	32
Organic	8	1	17	26	23
Mixed			2	2	50
No information			1	1	

Agreement holders were asked why they chose the option from a list of predetermined answers. They could include as many responses as possible and were asked to rank them (1 = most important reason) or indicate 'yes' if they were unable to state a rank score. Table 3 outlines the responses including total number of positive responses (yes plus scores), mean score of those who did provide a score, and frequency that each reason was the highest score.

The most common reasons (ca. 75%) for choosing the option were 'fits with current management/rotation' and 'wildlife benefits' although compatibility with farm management was more likely to be the most important driver (mean score 2.1 compared to 3.1 for wildlife benefits). Other important factors (60-70% of agreement holders) were: improving soil structure, value of ES points and compatibility with grassland management. From the list of reasons presented to the agreement holders, the option was least likely to have been chosen as part of a weed control strategy or because a grass break crop was required. However, only five holdings in the sample were mainly arable (Table 2). Around half the agreement holders had been influenced by advisers, although this was the least important reason when scored.

Table 3: Reasons for option choice (n=51)

Reason	Total	% of respondents	Mean score	Frequency top score	No. of scores
Fits with current farm management/rotation	38	74.5	2.1	9	17
Similar to current grassland management	31	60.8	3.4	3	14
Part of a rotation to control weeds	17	33.3	4.3	0	9
Needed a grass break crop	20	39.2	3.6	2	12
To improve soil structure	35	68.6	2.6	4	19
Wildlife benefits	39	76.5	3.1	4	20
Needed the points (ELS) /value (HLS)	35	68.6	3.9	5	15
Recommended by adviser	24	47.1	4.7	2	11
Other	12	23.5	4.8	0	4
Other 2	1	2.0	-	0	0

Of the AH who had EK21 recommended to them by an adviser, 48% were advised by NE, 24% by FWAG and 29% by land agents. Two were advised by independent consultants and the 'other' category included a local agricultural college and the Game and Wildlife Conservation Trust (GWCT) (Table 4).

Table 4: If the option was recommended by an advisor, give details of the organisation (n=21)

Organisations	Number of AH	%
Natural England	10	48
FWAG	5	24
Land agent	6	29
Independent consultant	2	10
Other	2	10

There were some differences between organic and conventional agreement holders (Figure 1). A greater proportion of organic farmers chose the option to help control weeds and because it fitted with current management/rotation. Conventional farmers were slightly more likely to choose the option because they needed a grass break crop or needed the points. Interestingly, a much higher proportion of conventional farmers had been influenced by recommendations from an adviser.

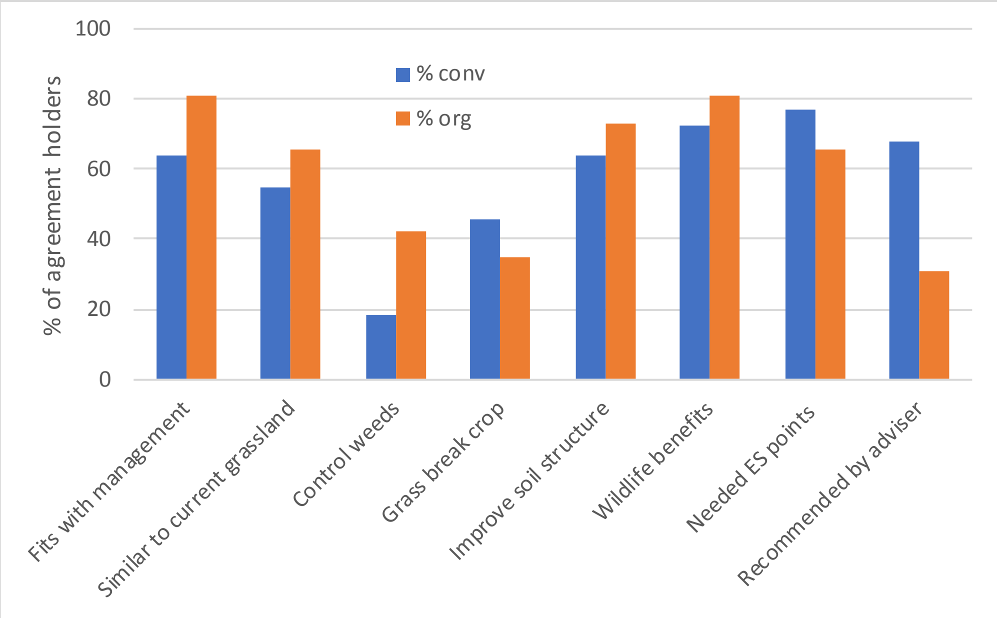

Figure 1: Reasons for choosing the option by farm type

3.2.2 Parcel Level Characteristics

3.2.2.1 Parcel Selection

The most common reason for selecting a parcel for EK21 was that it fitted with the rotation (40%) (Figure 2). Eleven parcels were chosen because they needed re-seeding or had poor soil and a further 11 were chosen based on the size requirements and/or position. The option was implemented on six parcels for availability/absence of another use. Only three parcels were selected to maximise wildlife and resource protection benefits.

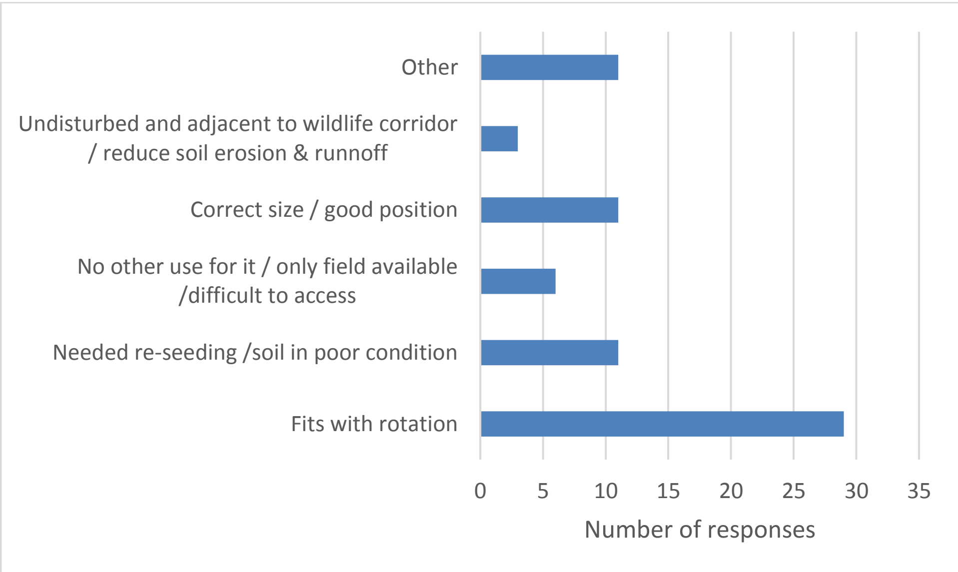

Figure 2: Why did you choose this area for your EK21? (n=72 parcels)

3.2.2.2 Parcel Characteristics

The majority (61%) of parcels under option had medium/calcareous soils. Only 15% had sandy or light silty soil (Table 5). Of the 74 parcels, two thirds (50) had been in an arable crop prior to the option and 24 were previously grass. For half of the parcels where information was available (16 parcels), grass had been in place for more than 5 years. Previous arable crops were almost exclusively cereals.

Table 5: What is the main soil type of the field (n=72)

Option code	Heavy	Medium/calcareous	Sandy/light silty
EK21	3	5	1
HK21	9	12	4
OK21	1	9	1
OHK21	4	18	5
Total	17	44	11

3.2.2.3 Establishment of the option

Just over half (57%) of the parcels were ploughed prior to establishing the EK21 mix. 15% of parcels (all arable previously) were described as 'min-till' and 11% were disced/tined. The mix was undersown on five parcels.

Most seed was reported as either drilled (44%) or broadcast (34%). A further six parcels were specified as a drill/harrow combination and four as 'air' drilled. Drilling was usually done during the spring (46% in April/May) although one third of parcels were drilled in September (Figure 3).

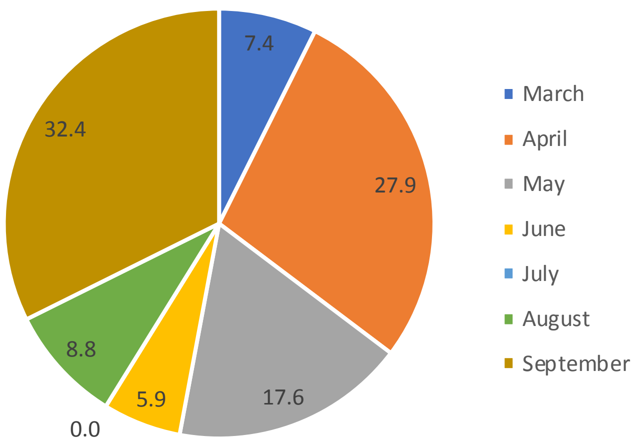

Figure 3: Percentage of parcels drilled in each month (n=68)

Parcels were most commonly drilled at 20-30 kg/ha (41%) (Table 6). Seed mixes were drilled at similar rates in conventional and organically managed parcels, although two conventional parcels were drilled at low rates (<10 kg/ha) and two organic parcels on the same agreement were drilled at particularly high rates (>40 kg/ha).

Table 6: Seed rate at which the field was drilled

Total seed rate drilled at (kg/ha)	Conventional	Organic	Total
<10	2	0	2
10-19	5	7	12
20-29	9	15	24
30-39	6	12	18
40+	0	2	2

50 agreement holders could give details of where they sourced the seed for the option. The most common source of the seed mix was Cotswold (29 parcels on 19 agreements). Oliver (6 parcels, 5 agreements) and Hurrells (5 parcels, 4 agreements) were the only other companies used on more than one agreement. A total of 26 agreement holders quoted other seed sources which were varied and often referred to seed merchants rather than a seed company. One agreement holder mixed their own seed.

Of the 59 parcels for which the agreement holder specified a likely number of years before re-establishment, the mean time was 4.3 years. This may have been influenced by the fact that grassland is considered permanent and should not be ploughed up after it has been in place and uncultivated for five years. Those parcels drilled with a mix from Cotswold anticipated 4.2 years; Hurrells, 4 years and Oliver, 6 years, although as noted above, mixes from the latter two companies were sown on only a small number of parcels.

Agreement holders made comments on flowering of the swards against 32 parcels. Those with seed mixes from Cotswold mentioned white and red clover, chicory and vetches. One agreement holder commented that annual topping limited the flowering and encouraged the grass. Those with seed mixes from Oliver mentioned clover generally and red clover specifically, buttercups/cowslips and grasses. One indicated that there weren't many flowers left, but it was unclear whether that was at the time of cutting or in relation to the number of years the land and been under option. Those with mixes from Hurrells mentioned flowering was from late May to June and that there was abundant red clover, vetches and bird's-foot trefoil.

Of the 63 parcels with data, on eight parcels the seed mix had been combined with other seed. Only two of these agreement holders could give specifics about the additional seed. One referred to undersowing, the other had added chicory.

3.2.2.4 Management of the option

On a total of 48 parcels, no fertiliser or manure were applied after establishment. There was no apparent difference between the responses of the organic and conventional farmers. In total, fertiliser, usually farmyard manure/slurry, had been applied to 24 parcels (11 organic; 13 conventional) (Figure 2). Herbicide had been applied on only six parcels, always as a spot treatment, most commonly in the first year or two post drilling.

Cutting and grazing

43 of the 73 parcels (59%) for which information was available had, or intended to cut in the year of survey, whereas 49 of 67 parcels (73%) had typically been cut in previous years under EK21. In both the year of survey and previous years around 80% of parcels had been grazed. This high percentage may reflect the small number of mainly arable holdings in the sample.

Of the 73 parcels for which info was available for cutting and grazing, 30 were both cut and grazed and only 3 were neither cut nor grazed.

Of the 43 parcels that were cut in the year of survey, 26 were cut once, 12 were cut twice and five were cut three times (Figure 4). A single cut was usually done in either June or July. The parcels cut twice were commonly cut in June and August or July and October. Of the five parcels cut three times, timings were unspecified.

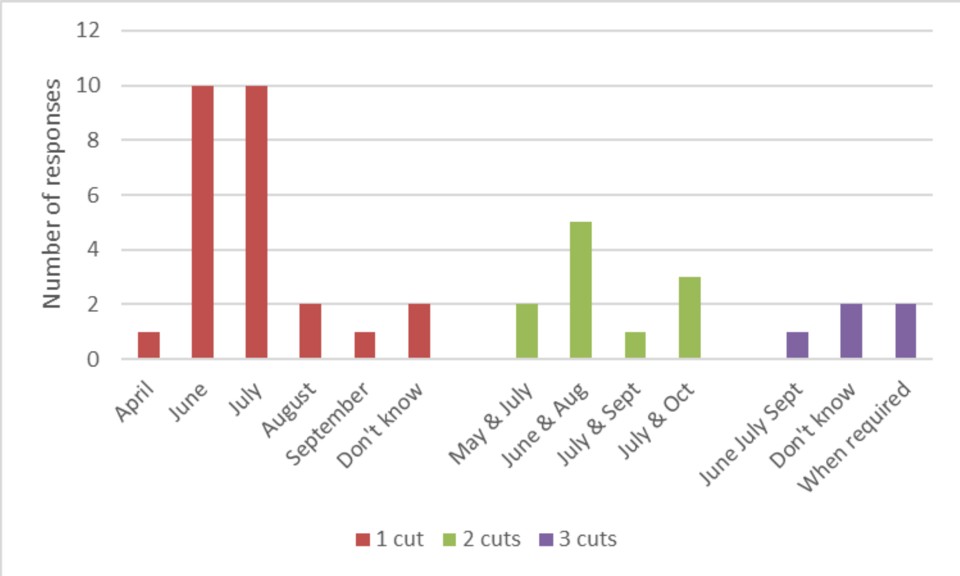

Figure 4: Cutting dates in the year of survey

The cut fields were most commonly cut for silage (27) with only four cutting for hay. Seven stated that they cut for haylage and for two parcels it depended on the weather. Of those parcels that were grazed, 20 had mixed livestock, 19 grazed cattle only and 17 grazed sheep only (Figure 5).

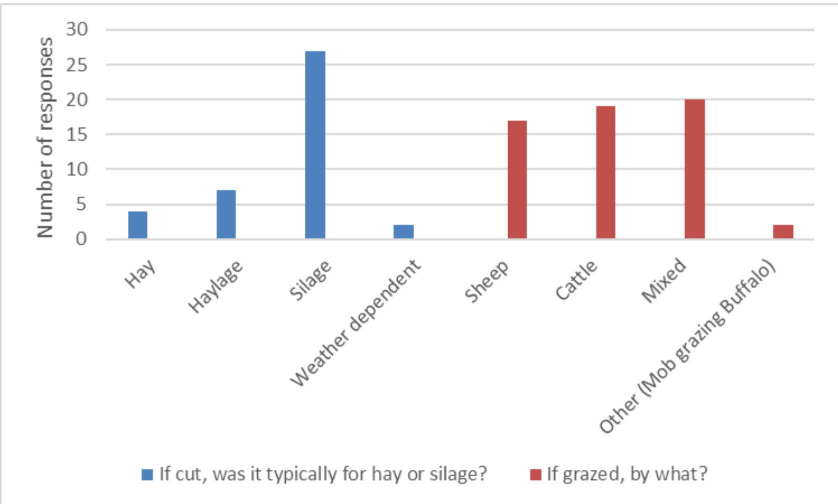

Figure 5: Cutting outputs and grazing animals

Of those parcels that were grazed, more than half grazed for between five and 20 weeks annually (Figure 6). Responses suggested that three parcels were grazed for more than 30 weeks of the year. Stocking rate was highly variable; around half of the parcels were grazed between 1 to 3 livestock units (LUs) and nearly half were grazed at high rates for short periods. A few agreement holders could not specify because they allowed flocks to roam through several fields. When asked at what growth stage grazing was started, around 30% of parcels were grazed pre-flowering, although this could have related to parcels that had already been cut earlier in the season. A similar number of parcels were grazed at a particular sward height or when the sward was tall and when the sward was in full flower.

Almost all parcels had flowered in the survey year although the agreement holders for two parcels indicated that they did not know if the sward had flowered. Comments on the flowering most commonly mentioned leguminous species. One agreement holder noted that the red clover did not flower, however five others specifically mentioned red clover in flower. Apart from legumes, chicory was the forb mentioned most frequently (6 agreement holders). Buttercups, cowslips and burnet were also mentioned. One agreement holder responded that annual topping limited the flowering species and encouraged the grass. Another reported that everything had flowered at some point over the last four years, but not all at the same time and noted that lucerne flowered in autumn.

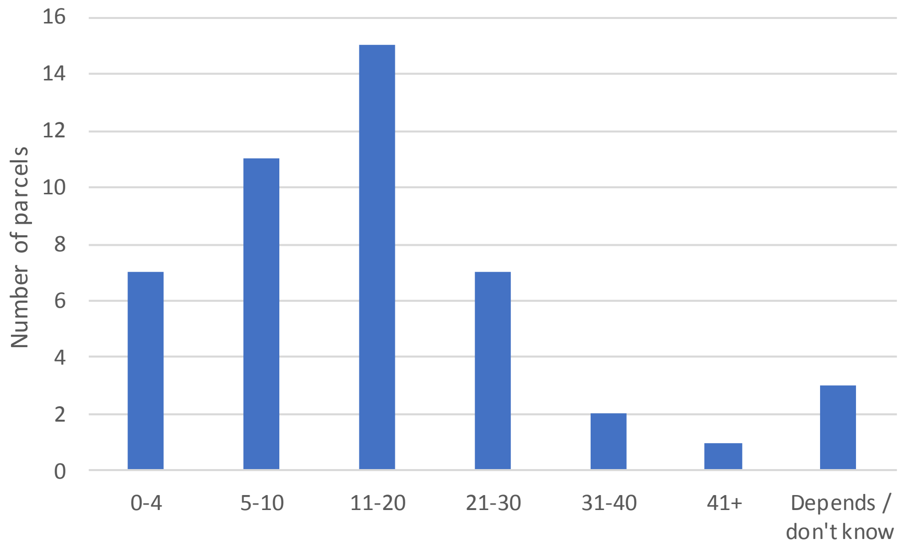

Figure 6: Annual length of grazing (weeks)

Most commonly (27%) agreement holders estimated that parcels would be retained in option for 5 years before needing to be re-established and few thought that the sward would last more than five years (Figure 7). Unfortunately, some agreement holders must have interpreted the question as how many years from survey year, since responses of 0 and 1 years were given.

For most parcels (68%) the option would be moved to a different area on re-establishment. Agreement holders expected to re-establish the option on the same parcel for only 19% of parcels, although 12% were unsure.

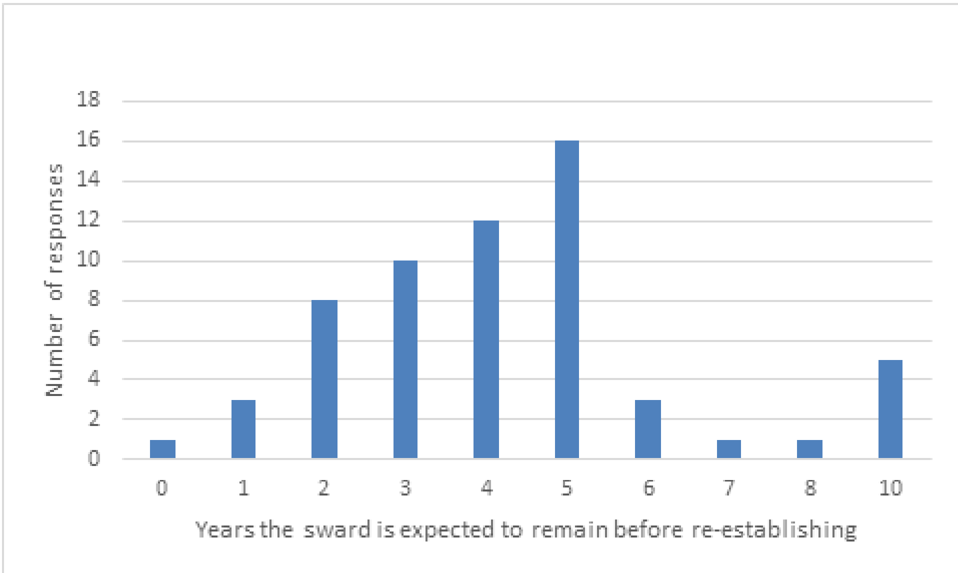

Figure 7: Number of years (from establishment) the sward will be retained before re-establishing

Agreement holders were asked if they had any other comments at the parcel level. Notable responses from individual agreement holders are summarised below.

- Late summer topping leaves lumps of biomass which allowed thistles to establish once the cut vegetation rotted away.
- Partial topping of thistles/ragwort pre-seeding produced varied sward height and flowering times which benefit wildlife.
- Payments don't quite cover loss.
- Five year permanent pasture regulations puts farmers off leaving the option longer than five years.
- Not possible to manage the option to benefit environment and production under the current prescriptions.
- More flexibility and less bureaucracy. Restrictions and potential for punishments means that farmers can't adapt or try new things to get the best for biodiversity.

3.2.3 Advice

Agreement holders were asked about the type and quality of advice they had received and about what advice they thought would be helpful in the future. Of the 52 agreement holders interviewed, half received no advice beyond the ES manual and most of these (77%) felt that the information in the manual was sufficient to meet their needs, whereas four agreement holders disagreed.

Of those that did receive advice in addition to the manual, most received advice from Natural England or the seed company (Figure 8). Other sources of advice included wildlife trusts, private advisers and a local agricultural college. All agreement holders had one-to-one advice and two of them had also received advice as part of a group.

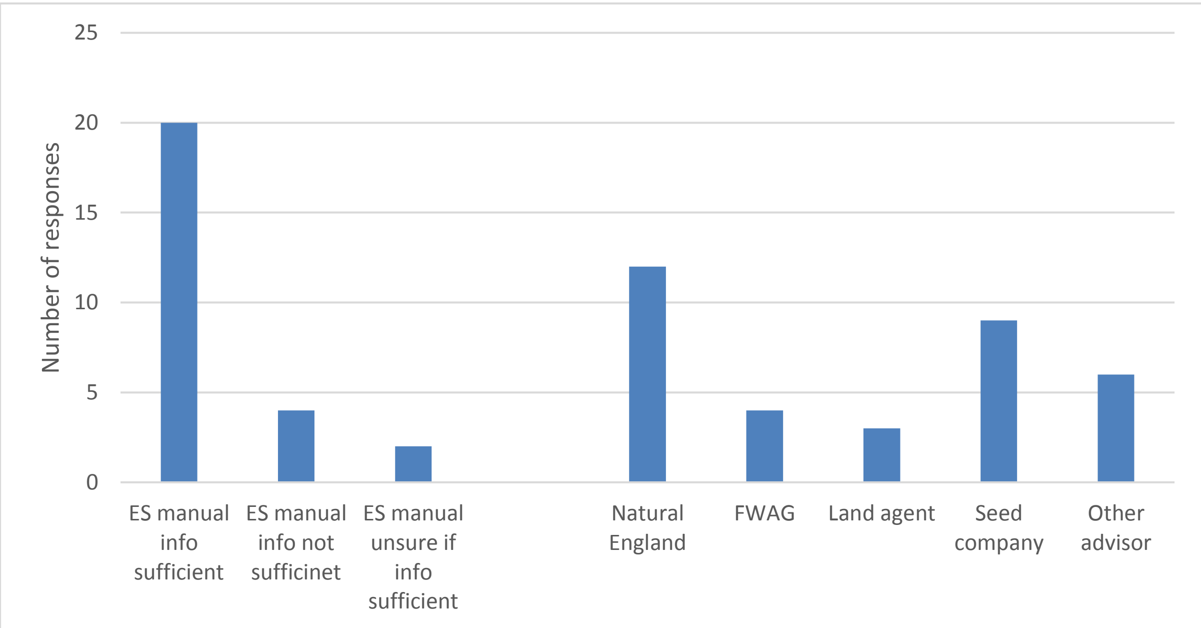

Figure 8: From whom was advice received?

When asked whom they would have liked to have received advice from, 12 AHs said they were happy with the advice they received. 12 would have liked advice from NE advisors and seven would have liked advice from the seed companies. Two answered that they would have liked advice from other farmers and one would have liked advice from ecologists / scientists. Seven thought any, or a combination of all (Figure 9).

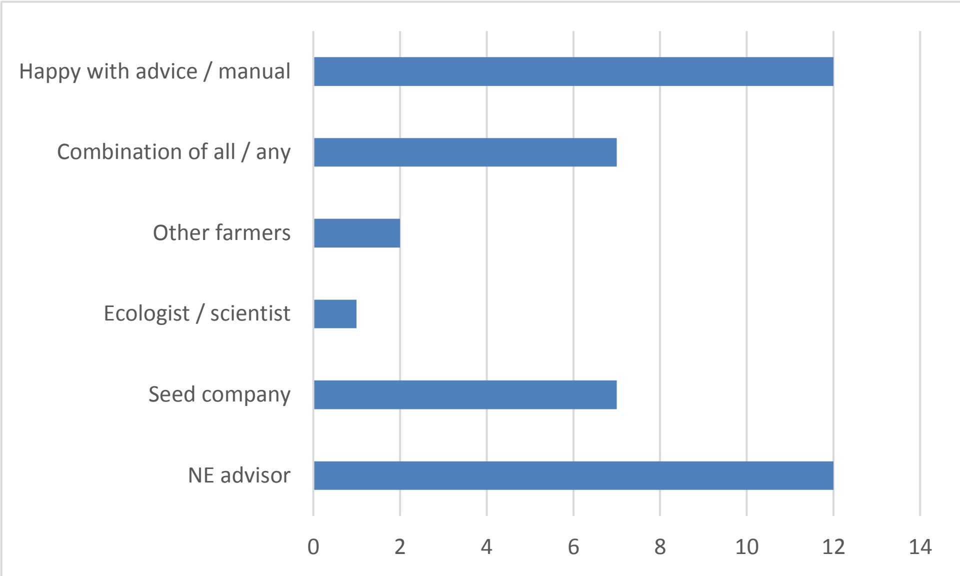

Figure 9: With hindsight, whom would you have liked to receive advice from?

Those agreement holders who received advice from sources other than the ES manual were asked in what form the advice was given. Several agreement holders received advice in more than one format. Most (81%) received advice in verbal communication and nine (35%) received written advice (Figure 10). Four had attended farm visits/walks from which they received advice and one took advice from the video on the Cotswold seed website. Another mentioned that he got advice from visiting the trial plots at the Hutchinsons seed company.

With hindsight 52% of those who responded (n=29) would have liked one to one advice, 24% would have valued a workshop/presentation and the same number wanted the written guidance. Four agreement holders thought that a farm walk/field demonstration would have been valuable. The format most valued was written (54% of 28 respondents) in part so that the agreement holder could refer back to advice. Verbal communication (11 AH) and farm walks (8 AH) were valued and videos (4) and photos/diagrams (3) were also mentioned.

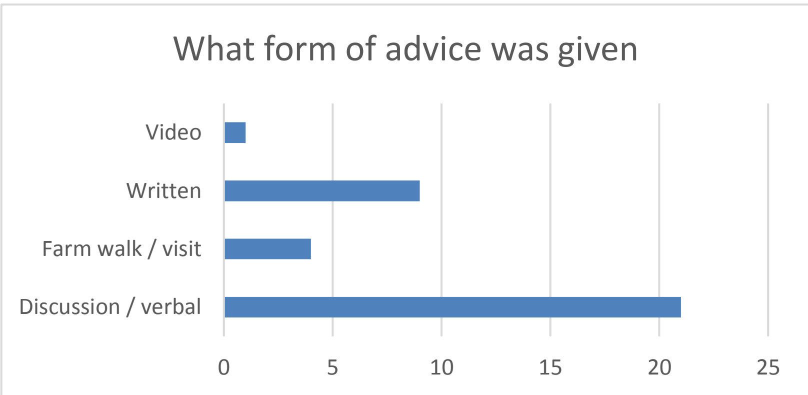

Figure 10: Form of advice received

Agreement holders were asked both what aspects of the option they had received advice about and what advice they considered would most benefit from advice. Agreement holders had most commonly received advice on seed mix and establishment/management of the option (Figure 11). Interestingly, 40% of all AHs interviewed thought that management would most benefit from advice in the future, whereas only four individuals thought that seed mix needed advice. Only two had received advice on field choice, but seven of the total population thought this aspect would benefit from advice.

When asked how useful the agreement holders found the advice, 18 said they found the advice given very useful, seven fairly useful and five only found the advice 'a little' useful.

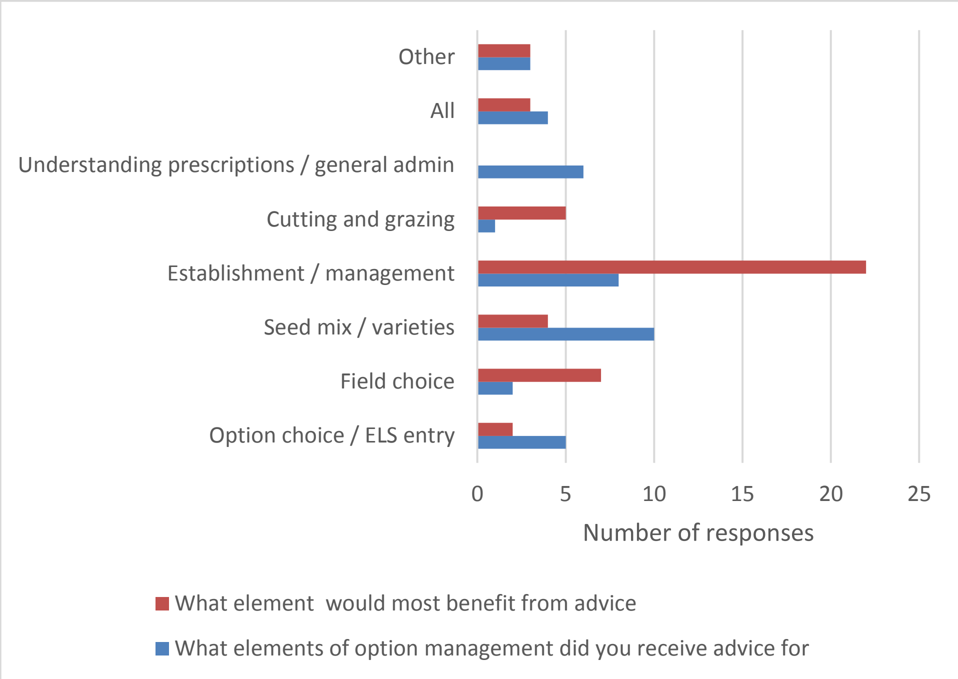

Figure 11: Elements of option management for which AHs had received advice (n=26) and would most benefit from advice (n=52).

General comments made about the value of the advice received included that advice from other farmers was more useful than from more formal sources, one AH said that because the option was new, the adviser was unfamiliar with the option and the advice was of limited value. Two AHs mentioned that the manual was clear with no ambiguity whereas one said that the manual was of little use, lacking in detail and that the information in there was obvious. Several mentioned that the advice from the seed merchants was particularly useful. In general, the majority of AH interviewed appeared to be happy with the advice they received.

3.2.4 Overall attitudes and future management

3.2.4.1 Benefits

Most agreement holders thought the option had multiple benefits. More than half of those who responded thought the option was beneficial for wildlife and for soil (Table 7). Forty three percent of respondents quoted grazing quality or livestock health and a quarter considered the fact that it fitted with current farm practice as a benefit. Costs were mentioned as a benefit by only four agreement holders and only three thought the option was a benefit for weed suppression, but few holdings in the sample were 'mainly arable'. 'Other' responses included one agreement holder who quoted climate resilience. Only one respondent thought there were no benefits to the option, saying that they cannot meet requirements, found it expensive to establish and that they had not seen any benefits.

There were no particular differences between the answers of conventional farmers to those of organic farmers, except that the option was more likely to fit with the current farm management and rotation on organic farms.

Table 7: What do you consider are the benefits of the option? n=51

Response categories	Number of responses	% of respondents
Good for wildlife / increased biodiversity	29	57
Improved soil / increased fertility	29	57
Better grazing quality / longer grazing / better livestock health	22	43
Fits well with current farm management / rotation	12	24
Financial benefits / low cost	4	8
Aesthetically pleasing	3	6
Increased productivity	3	6
Weed suppression	3	6
Other	5	10
Total	110	

3.2.4.2 Negative aspects

Of the 73 responses from 49 agreement holders detailing negative aspects of the option, one third focused on the restrictions on management imposed by the prescription (Table 8). Aspects of the prescription that were most commonly criticised were control of noxious weeds and the prescriptive requirements generally. Cutting prescriptions were mentioned in general terms, but one agreement holder noted the conflict between agricultural production (cut early) and biodiversity (cut late). A further 16% of respondents reported that they found it difficult to establish or manage, with comments often relating to competition from grasses and difficulty in establishing or maintaining legume and herb species (see section 3.3 for information on sward composition outcomes).

Chicory/woody species dominance was mentioned by seven agreement holders. Concerns were that it became too woody and was avoided by grazing animals and was not a suitable component in silage/hay plus it led to damage of bale wrapping. One agreement holder reported that the mix became so tall that deer hide in it and can get injured by the topper.

Other concerns were the cost of the seed mix (16%), risk of bloat from clover-rich mixes (10%) and general bureaucracy (6%). Two agreement holders felt that they would have liked to have incorporated more of the option into their farm but reported that they were restricted by how much was allowed in HLS.

Organic farmers were more likely to report that cutting and grazing dates were a problem and unsurprisingly more conventional farmers found restrictions on weed control to be problematic. More of the conventional farmers mentioned difficulties with establishing and re-establishing whereas organic farmers were more likely to have concerns with chicory and woody species dominance, however numbers of these responses were small.

Table 8: What do you think are the negative aspects of the option? n = 49

Response categories	Number of responses	% of respondents
Management restrictions: cutting dates	5	10
Management restrictions: weed control	8	16
Management restrictions: grazing	2	4
Management restrictions: generally, too prescriptive	8	16
Expensive seed mix	8	16
Difficult to manage / establish / needs to be re-established	8	16
Too much admin	3	6
Bloat in livestock	5	10
Too many species in seed mix	2	4
Chicory dominance / too woody	7	14
None	9	18
Other	8	16
Total	73	

3.2.4.3 Changes in sward composition

Agreement holders were asked to summarise any changes they had observed in sward composition after the first year (Table 9). More agreement holders observed a decrease in the abundance of herbs and legumes (28%) than those seeing an increase (13%). There were several comments on the difficulty in establishing the mix, one agreement holder commented that the species mix didn't winter well and 11 (24%) commented that the sward composition differed from year to year. There were very varied accounts of sward composition with five comments of increased chicory and three comments of decreased chicory, three comments on increased bird's-foot trefoil along with a decrease in other herbs, and three comments on an increase in cocksfoot dominance. Only two agreement holders saw no change in sward composition. Overall the responses suggest significant site to site variability in sward composition and change over time.

There were no particular differences in response between organic and conventional farmers, although organic agreement holders commented on observing a decrease in herbs and an increase in grasses more frequently than conventional farmers.

Table 9: If the swards have been in place for more than 2 years, what changes have you observed in the sward composition? n = 46

Response categories	Number of responses	% of respondents
Herbs increased (excluding legumes)	6	13
Herbs decreased (excluding legumes)	13	28
Grasses increased	8	17
Grasses decreased	1	2
Weeds increased	5	11
Legumes increased	4	9
Legumes decreased	12	26
Different species composition in different years	11	24
Takes 2 – 3 years to establish	4	9
None	2	4
Other	2	4
Total	68	

When asked what they thought were the reasons for observed changes, the most common response (38%) was the seed mix (Table 10). 24% mentioned establishment of the mixes, commenting on the length of time required:

"[The] mixture takes time to establish and requires patience. Don't give up after initial establishment if it's not looking that great"

21% attributed the changes to the management of the option including comments on timing/intensity of grazing and weed seeds contained in the seed bank or manure.

There were no apparent differences in responses between organic and conventional farmers.

Table 10: What do you think are the reasons for any changes n = 42

Response categories	Number of responses	% of respondents
Seed mix	16	38
Weather conditions	7	17
Different species take time to respond / establish in local conditions	10	24
Grazing regime / need to graze longer to control weeds / stock traffic / weed seeds in manure	6	14
Management	9	21
Soil type	3	7
Don't know	6	14
Other	7	17
Total	64	

Half of those who responded had not observed anything unexpected with the option (Table 11). Of those that did comment, the majority of responses were positive. For example:

> *"…grew faster than expected and produced a lush sward"*

Two agreement holders were surprised that the option had met/exceeded their expectations, four thought it provided good productivity and three noted an increase in wildlife:

> *"…the (high) level of use of option by invertebrates and birds, including nesting Reed Bunting"*

The response from one agreement holder suggested that his experience was in contrast to some others:

> *"Ease of establishment of herbs and how different species developed"*

Four commented on the variability in sward species composition:

> *"It's surprising how species composition changes within and between years, irrespective of management"*

Table 11: Did you encounter anything unexpected / did anything surprise you about the option and how it developed? n = 46

Response categories	Number of responses	% of respondents
Met / exceeded expectations	2	4
Variability in species composition between fields / years	4	9
Good productivity	4	9
Increase in wildlife	3	7
No	23	50
Other	9	20
Total	47	

3.2.4.4 Comments on prescriptions

Agreement holders were asked to summarise what aspects of the prescription they thought should be changed (Table 12). 34% felt that improvements could be made with a seed mix more tailored to local conditions. 16% thought flexibility in the prescriptions, particularly with regards to the grazing window, would improve the option. One respondent suggested that fertiliser could be allowed in year one to help establishment. Another agreement holder felt that prescriptions should be tightened up for wildlife benefits and that there should be greater differentiation between prescriptions for silage/hay and grazing. Two agreement holders would like to have been able to put more of their land into the scheme but were restricted by how much could be included in HLS and felt improvements could be made with less such restrictions. Two felt that the initial advice received could be improved upon and suggested that a revisit after the first year to see which crops have established would be useful and a questionnaire after two years at a point where there is still time to make changes would be good. One third of agreement holders thought nothing should be changed as it had worked well for them.

More organic farmers wanted more flexible prescriptions and more tailored advice. Conventional farmers had more answers concerning the restrictions on the amount of EK21 allowed to be applied to the holding in HLS. Both organic and conventional farmers wanted more bespoke seed mixes and the same proportion of organic and conventional farmers thought the prescriptions were OK as they are and that no changes were necessary.

Table 12: Summarise what aspects of the prescription you think should be changed and why. n = 44

Response categories	Number of responses	% of respondents
Bespoke seed mixes / changes to seed mix / separately sold seed species	15	34
Flexibility in prescriptions for grazing / weed control / response for local conditions	7	16
Increased payment	4	9
Less restrictions in how much of option can be included in HLS agreement	2	5
More tailored initial advice / visits	2	5
None	14	32
Other	3	5
Total	47	

Agreement holders were invited to make any further comments and 28 responded, however nearly all reiterated points raised elsewhere. Positive comments were usually general but included wildlife benefits and the fact that the option fitted well with the system. Negative comments included issues of bloat, bureaucracy, seed mixes and cutting restrictions. One noted:

> *"sometimes difficult getting seed merchants to include more legumes and less grass in mix - tend to push standard mixes"*

Another suggested that revisits from Natural England to observe outcomes would help improve recommendations. Another commented that the benefits of the option (soil structure / high quality feed for livestock) should be promoted much more and another thought there was scope for research into appropriate herbicides.

3.2.4.5 Future use of the option

When asked 'would you use this option again?', most (84%; n=52) said they would (Figure 12) six were undecided and only two would definitely not use the option in future. However, evidence from the field survey indicated that, although agreement holders were positive about the option, sward composition requirements were often not met (see section 3.3.1).

Those that were intending to continue with the option felt it was a good mix for livestock, getting good results, profitable and easy to do. Several were enjoying the wildlife and environmental benefits and the benefits to the soil. Twenty AHs said they would use the option again because it fits well into the management and/or rotation.

Of the two who would not use the option in future, one would use the land for other purposes, the other responded:

> *"cannot meet targets. Expensive to establish and have not seen any benefits"*

Those who were undecided expressed varied concerns about: restrictions, meeting the requirements, seed mixes and would like to see evidence of soil improvement.

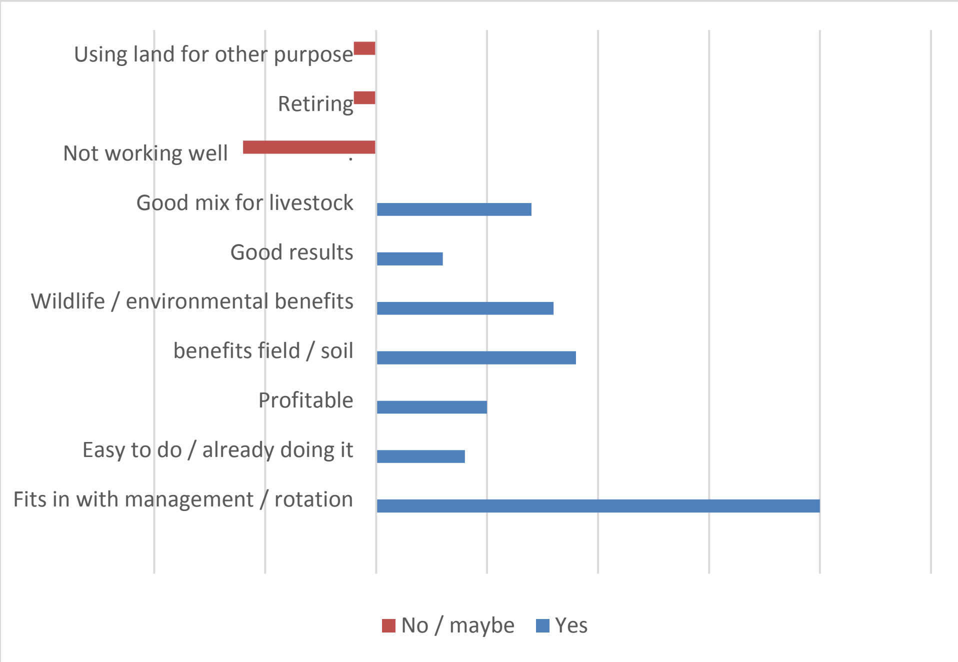

Figure 12: Would you use this option again? Why?

3.3 Option Outcomes

3.3.1 Outcomes Against Requirements

For each option and grassland counterfactual area, the summer botanical data was analysed to provide a global overview of the effect of interventions (EK21, HK21, OK21, OHK21) on the five requirement outcomes:

1. At least 10% cover of *Trifolium pratense*
2. At least 10% cover of other forbs excluding *Trifolium repens*, *Ranunculus repens* and injurious weeds
3. The presence of at least 5 grass species
4. The presence of at least 3 legume species
5. The presence of at least 5 other forb species

Observations were taken in 99 land parcels on 54 agreements as shown in Table 13. Throughout this report section we use ‘parcel’ to define an option (action) or counterfactual (c.f.) area. However, many options were applied to part parcels and some counterfactuals were located in the same parcel as the option area.

Table 13: Study size[1]

Option code	Agreements	Land parcels under option	Counterfactual land parcels
EK21	8	9	5
HK21	21	29	6
OHK21	18	27	7
OK21	7	11	5

[1] A small number of fields were surveyed in summer, but were destroyed before the autumn visit and were not included in the interview survey therefore option numbers are slightly different to those reported in section 3.2.

3.3.1.1 Number of parcels in which requirements are met

The number and proportion of parcels meeting each of the requirements are presented in Table 14, Table 15 and Figure 13. Data for both option (action) and counterfactual (c.f.) parcels are presented for comparison. Information for all species present in the sward has been used to assess the thresholds, not just the sown species. Overall, option areas were more likely to meet each of the individual requirements than counterfactual parcels. On both option and counterfactual parcels, swards were most likely to meet the requirement for the presence of five other forbs (78% and 43% respectively). The 10% *Trifolium pratense* cover was the threshold least likely to be met on option parcels (37%). Only 9% of counterfactual parcels had at least three legume species. Interestingly, no organic counterfactual, but two conventional counterfactual parcels met the legume species requirement (Table 14, Figure 13).

Table 14: Observed number of parcels in which requirements were met

Option	In option?	Total number of parcels	Trifolium pratense cover	Other forb cover	Grass species	Legume species	Forb species
EK21	action	9	3	7	7	3	6
	c.f.	5	0	2	1	1	3
HK21	action	29	10	17	18	11	21
	c.f.	6	0	0	0	1	1
OHK21	action	27	12	22	17	17	25
	c.f.	7	3	1	2	0	3
OK21	action	11	3	3	5	3	7
	c.f.	5	0	2	2	0	3
Total	Action	76	28	49	47	34	59
	c.f.	23	3	5	5	2	10

Table 15: Observed proportion of parcels (%) in which requirements were met

Option	In option?	Total number of parcels	Trifolium pratense cover	Other forb cover	Grass species	Legume species	Forb species
EK21	action	9	33	78	78	33	67
	c.f.	5	0	40	20	20	60
HK21	action	29	34	59	62	38	72
	c.f.	6	0	0	0	17	17
OHK21	action	27	44	81	63	63	93
	c.f.	7	43	14	29	0	43
OK21	action	11	27	27	45	27	64
	c.f.	5	0	40	40	0	60
Total	action	76	37	64	62	45	78
	c.f.	23	13	22	22	9	43

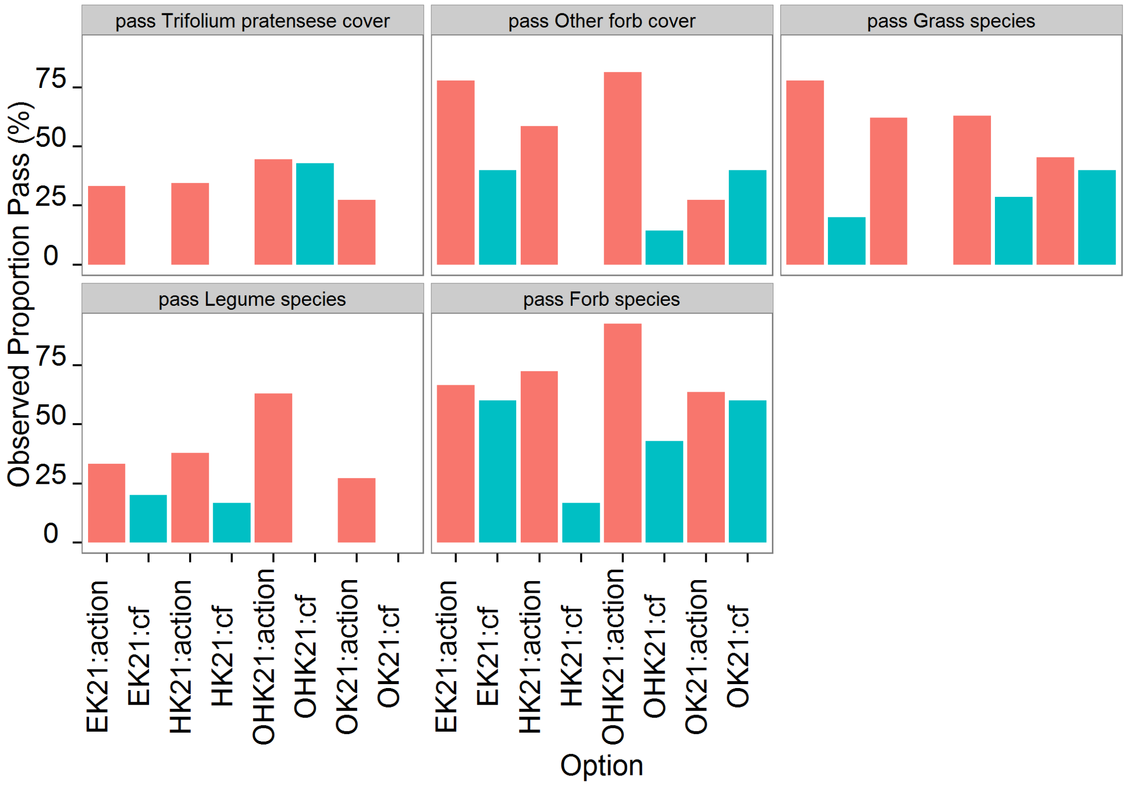

Figure 13: Observed proportion of parcels in which requirements were met

Parcels were assessed against how many (Table 16) or what proportion (Table 17, Figure 14) of the five thresholds they met. Most option parcels (64%) met at least three of the five requirements, although only 7 parcels (9%) met all five and 5 parcels (7%) did not meet any of the thresholds. Unsurprisingly, counterfactual parcels were much less likely to meet the requirements. 43% of parcels did not meet any requirements and only 2 parcels (9%) met at least three of the thresholds.

Table 16: Observed number of parcels in which multiple requirements were met

Option	In option?	Total number of parcels	none	one or more	two or more	three or more	four or more	five
EK21	action	9	0	9	7	6	3	1
	c.f.	5	2	3	2	1	1	0
HK21	action	29	2	27	19	16	12	3
	c.f.	6	5	1	1	0	0	0
OHK21	action	27	1	26	25	23	16	3
	c.f.	7	1	6	3	0	0	0
OK21	action	11	2	9	6	4	2	0
	c.f.	5	2	3	3	1	0	0
Total	action	76	5	71	57	49	33	7
	c.f.	23	10	13	9	2	1	0

Table 17: Observed proportion (%) of parcels in which multiple requirements were met

Option	In option?	Total number of parcels	none	one or more	two or more	three or more	four or more	five
EK21	action	9	0	100	78	67	33	11
	c.f.	5	40	60	40	20	20	0
HK21	action	29	7	93	66	55	41	10
	c.f.	6	83	17	17	0	0	0
OHK21	action	27	4	96	93	85	59	11
	c.f.	7	14	86	43	0	0	0
OK21	action	11	18	82	55	36	18	0
	c.f.	5	40	60	60	20	0	0
Total	action	76	7	93	75	64	43	9
	c.f.	23	43	57	39	9	4	0

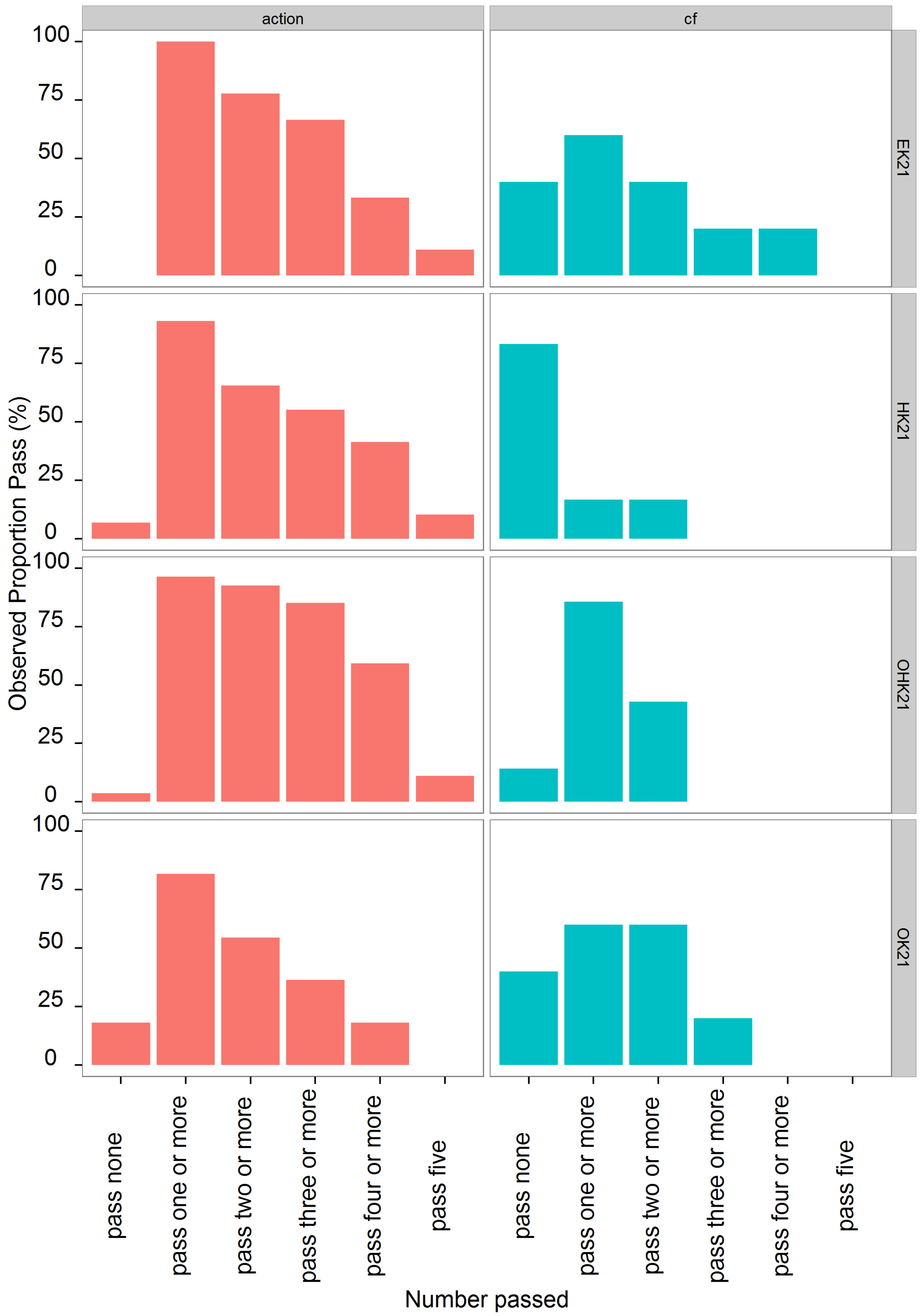

Figure 14: Observed proportion of parcels in which multiple requirements were met

3.3.1.2 *Effect of options on the proportion of parcels meeting requirements*

The likelihood of meeting individual requirements was estimated for each option variant and counterfactuals by fitting a generalised (binomial) linear model to the proportion of parcels passing each requirement. Only significant effects were estimated. This means, for example, that if being in option caused the proportion of parcels meeting a requirement to increase, but *which variant of the option* had no significant effect on the proportion of parcels passing, then a single value was estimated to represent all option variants. The estimates provide an estimate of the mean effect of each option on the population of farms to which it has been applied. An overview of estimates is given in Table 18. Effects are shown in Figure 15 to Figure 19. All thresholds were more likely to be met on option than on counterfactual parcels. The likelihood of meeting the cover of other forbs requirement was different for different options, however option parcels were still significantly more likely to meet this requirement than counterfactuals (Figure 16).

Table 18: Estimates of the proportion of land parcels in which requirements were met in the population of farms

Requirement	Option	In Option?	Proportion parcels pass (%)		
			Estimate	95% C.I.	
***Trifolium pratense* cover**	All	cf	13.0	4.3	33.5
		action	36.8	26.8	48.2
Other forb cover	EK21	cf	34.3	11.4	67.9
		action	81.0	52.5	94.2
	HK21	cf	13.4	4.1	36.1
		action	55.8	38.4	72.0
	OHK21	cf	29.7	11.2	58.5
		action	77.5	59.8	88.8
	OK21	cf	8.1	1.9	29.0
		action	41.8	18.8	69.0
Grass species	All	cf	21.7	9.3	42.8
		action	61.8	50.5	72.0
Legume species	All	cf	8.7	2.2	28.9
		action	44.7	34.0	56.0
Other forb species	All	cf	43.5	25.2	63.7
		action	77.6	66.9	85.6

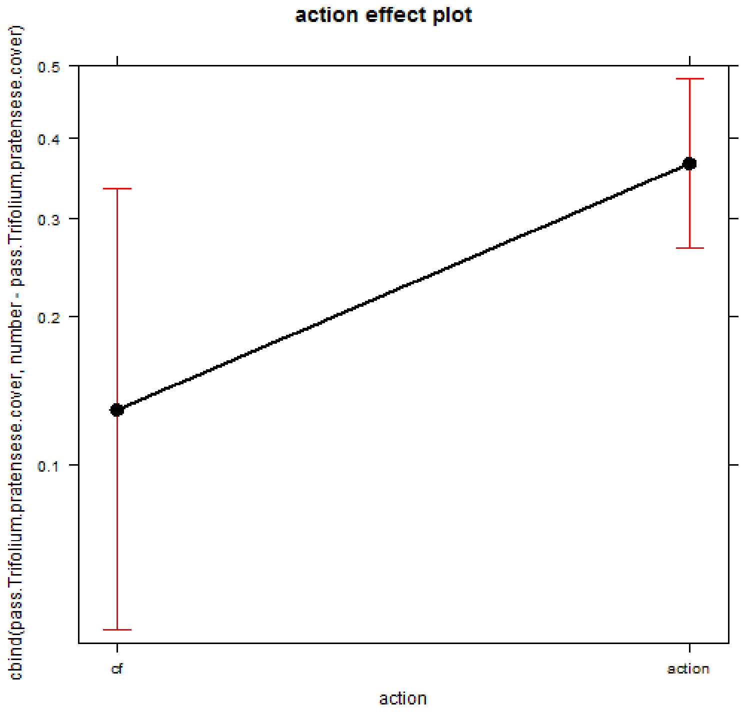

Figure 15: Estimated effect of being in option on proportion of parcels with at least 10% cover of *Trifolium pratense*

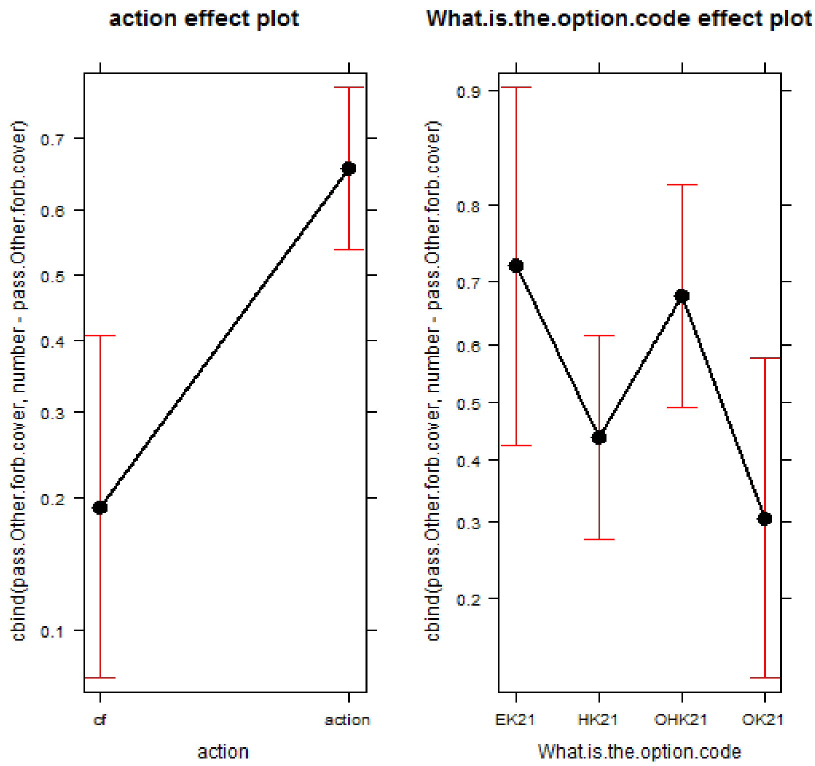

Figure 16: Estimated effect of being in option on proportion of parcels with at least 10% cover of other forbs

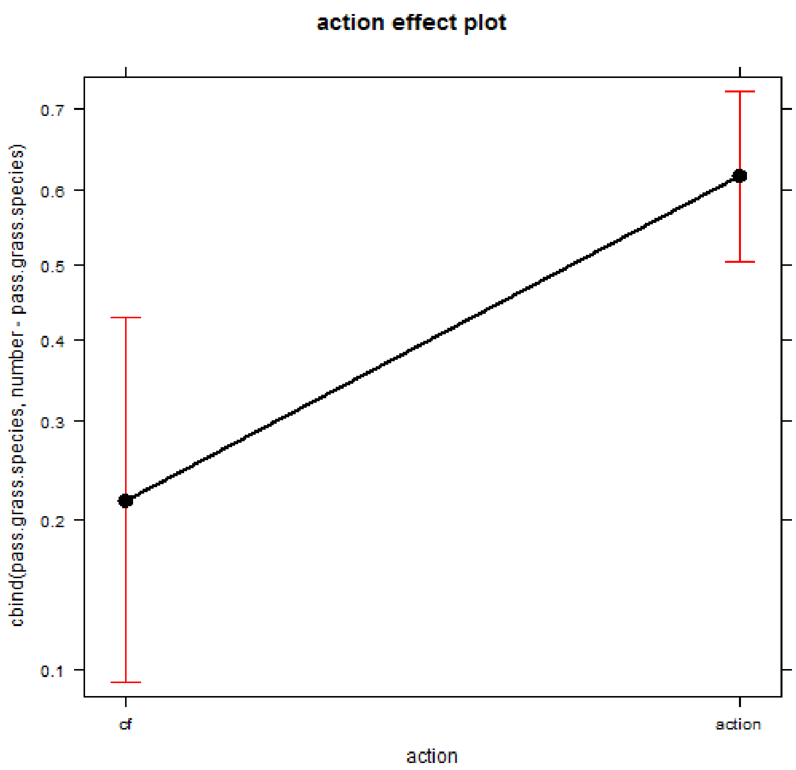

Figure 17: Estimated effect of being in option on proportion of parcels with at least 5 grass species

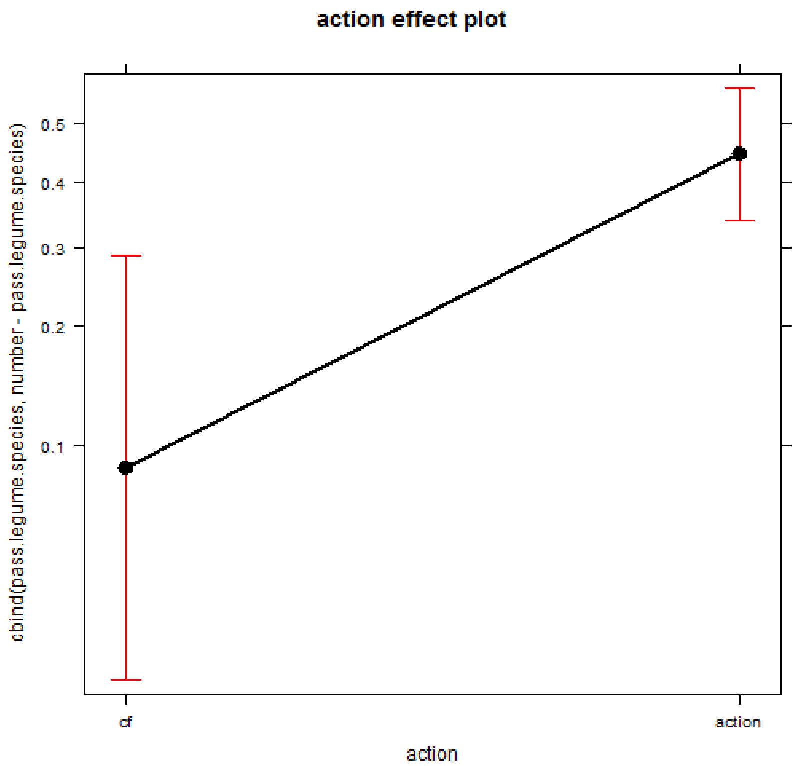

Figure 18: Estimated effect of being in option on proportion of parcels with at least 3 legume species

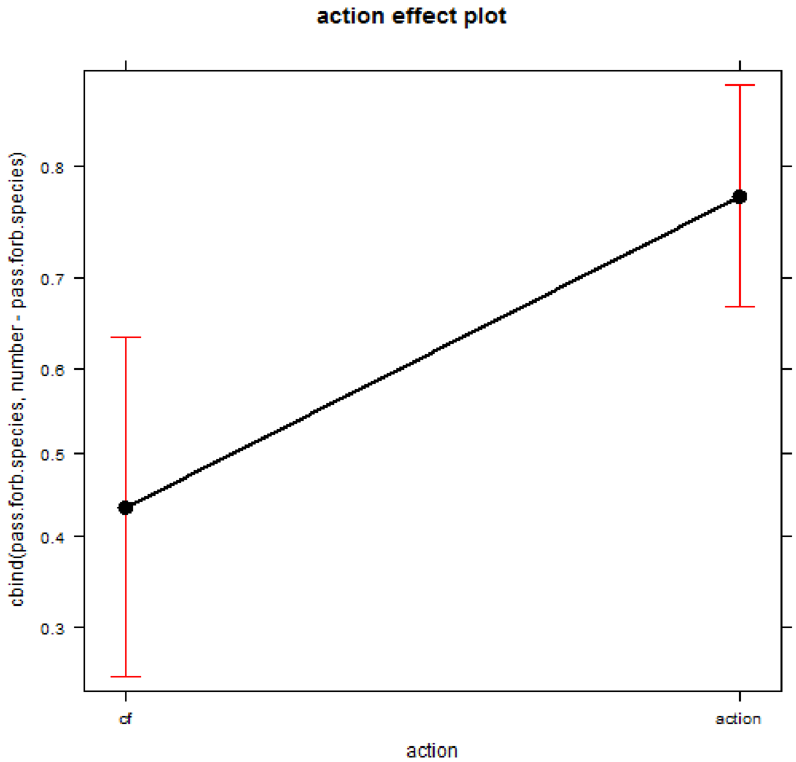

Figure 19: Estimated effect of being in option on proportion of parcels with at least 5 other forb species

3.3.1.3 Effect of options on requirement mean quantities in parcels

The effect of the option(s) on the % cover of forbs and of *Trifolium pratense* and number of species (grass, legumes, forbs) was estimated (see section 2.4). As for the proportion of holdings that passed criteria, only significant effects were estimated. The estimates provide an estimate of the mean effect of each option on the population of farms to which it has been applied (Figure 24 to Figure 26). An overview of estimates is given in Table 19.

Other forb species were more likely to be present on option parcels compared to counterfactuals (Figure 20). Where they were present, they occurred at a significantly higher percent cover on option areas (Figure 21).

Similarly, *T. pratense* was more likely to be present on option parcels (Figure 22), however parcels under OHK21 were more likely to have *T. pratense* in the sward compared to parcels under HK21. In contrast to the results for other forbs, where *T. pratense* was present in the sward, there was no difference in percent cover between option and counterfactual parcels (Figure 23).

The number of grass species recorded in the sward was greater on option parcels compared to counterfactuals (Figure 24) however, very few grass species were recorded in HK21 parcels compared to the other option variants. A greater number of both legume species and other forb species were present in option compared to counterfactual parcels (Figure 25 and Figure 26).

Table 19: Effect of options on cover and numbers of target species (cf = counterfactual; action = option)

Measure	Option	In option?	Between-agreement RSD	Quantity		
				Estimate	95% C.I.	
Forb cover >0 (+/-)	All	cf	0	0.78	0.57	0.91
		action		0.96	0.88	0.98
Forb cover where >0	All	cf	3.6 (logit scale)	0.015	0.005	0.043
		action		0.13	0.071	0.23
Trifolium pratense cover >0 (+/-)	EK21	cf	1.5 (logit scale)	0.21	0.035	0.66
		action		0.83	0.40	0.97
	HK21	cf		0.11	0.017	0.46
		action		0.70	0.42	0.88
	OHK21	cf		0.58	0.20	0.89
		action		0.96	0.72	1.00
	OK21	cf		0.16	0.022	0.62
		action		0.78	0.33	0.96
Trifolium pratense cover where >0	All	cf	2.1 (logit scale)	0.086	0.021	0.29
		action		0.084	0.043	0.16
Grass species	EK21	cf	0.26 (log scale)	4.0	2.5	6.6
		action		5.9	4.3	8.2
	HK21	cf		1.6	0.8	3.0
		action		6.0	4.9	7.2
	OHK21	cf		4.0	2.7	6.0
		action		5.3	4.3	6.5
	OK21	cf		3.9	2.4	6.2
		action		4.6	3.3	6.5
Legume species	all	cf	0.41 (log scale)	0.7	0.4	1.2
		action		2.2	1.8	2.7
Other forb species	all	cf	0.51 (log scale)	4.5	3.5	5.7
		action		8.0	6.9	9.4

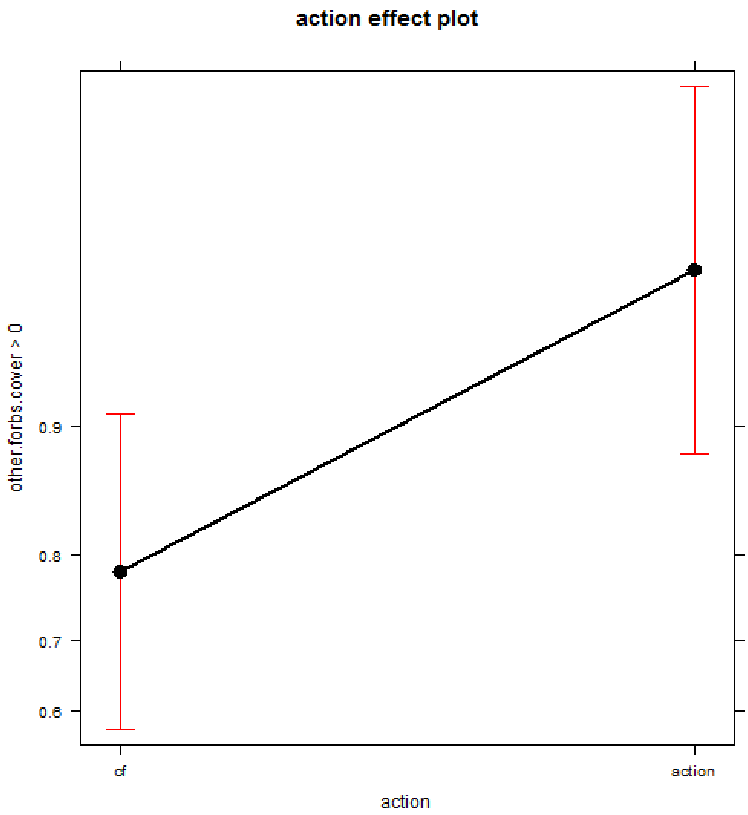

Figure 20: Effect of options on the coverage by forbs (probability that forbs are present)

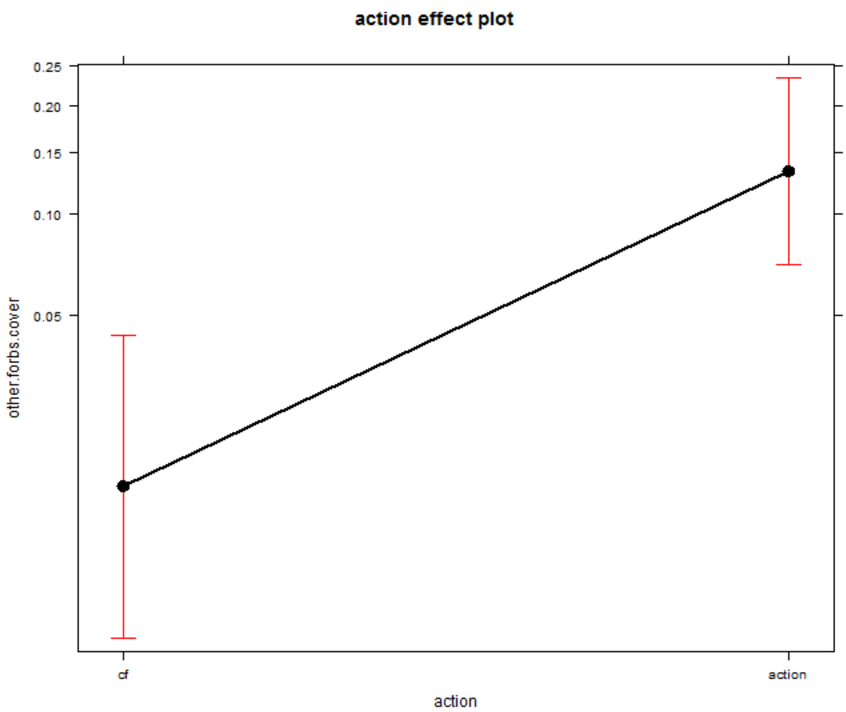

Figure 21: Effect of options on the coverage by forbs (proportion coverage where they are present)

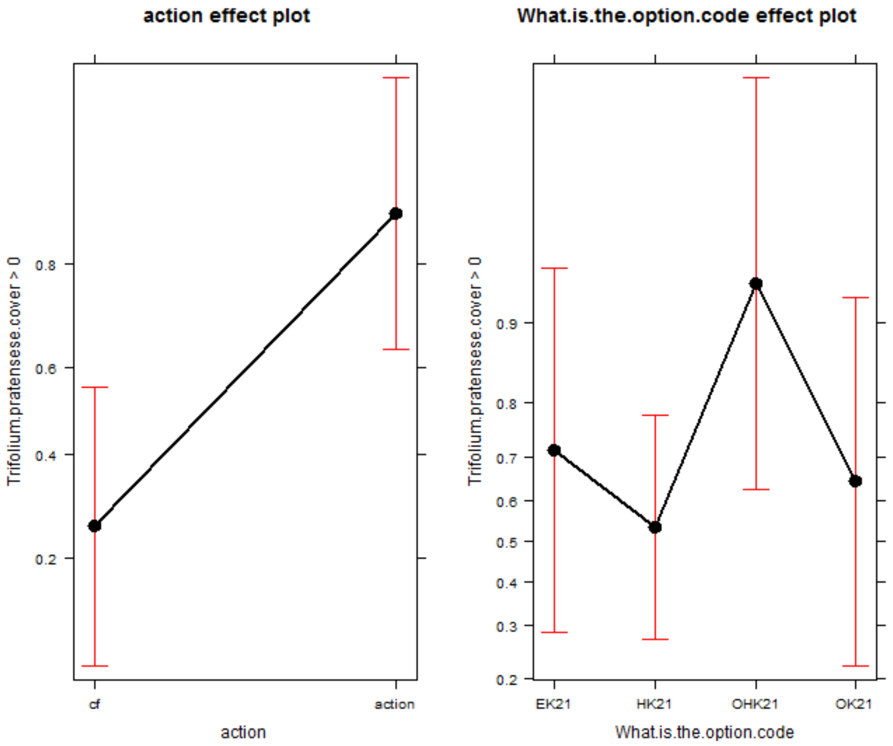

Figure 22: Effect of options on the coverage by *Trifolium pratense* (probability that it is present)

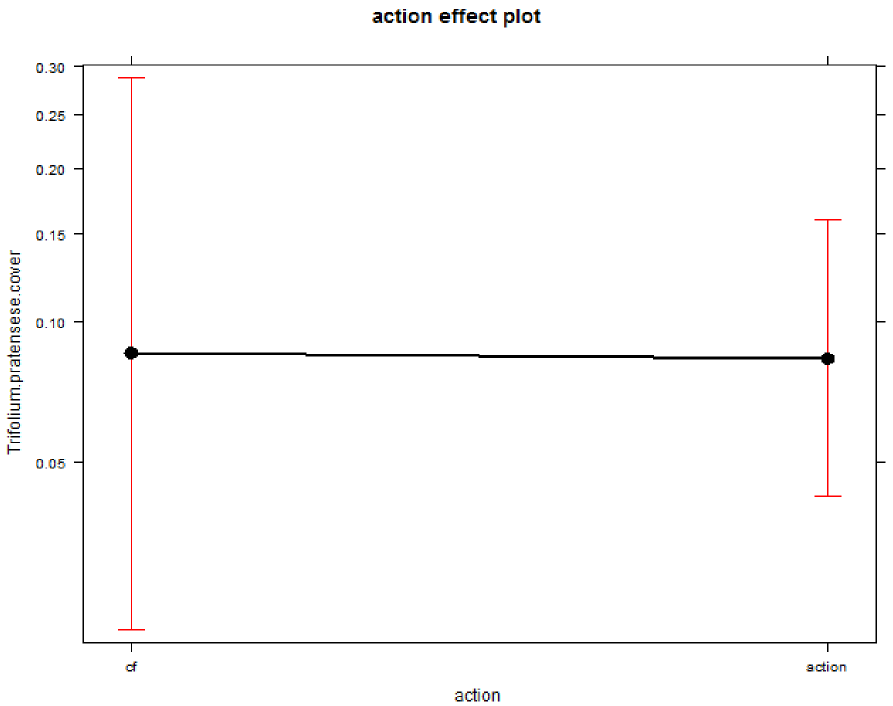

Figure 23: Effect of options on the coverage by *Trifolium pratense* (proportion coverage where it is present)

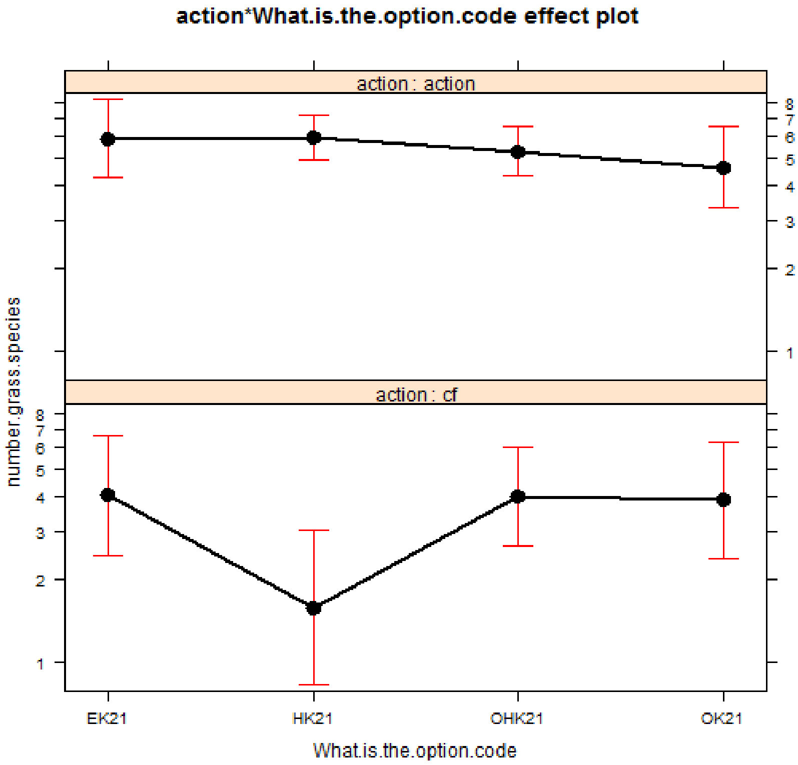

Figure 24: Effect of options on the number of grass species

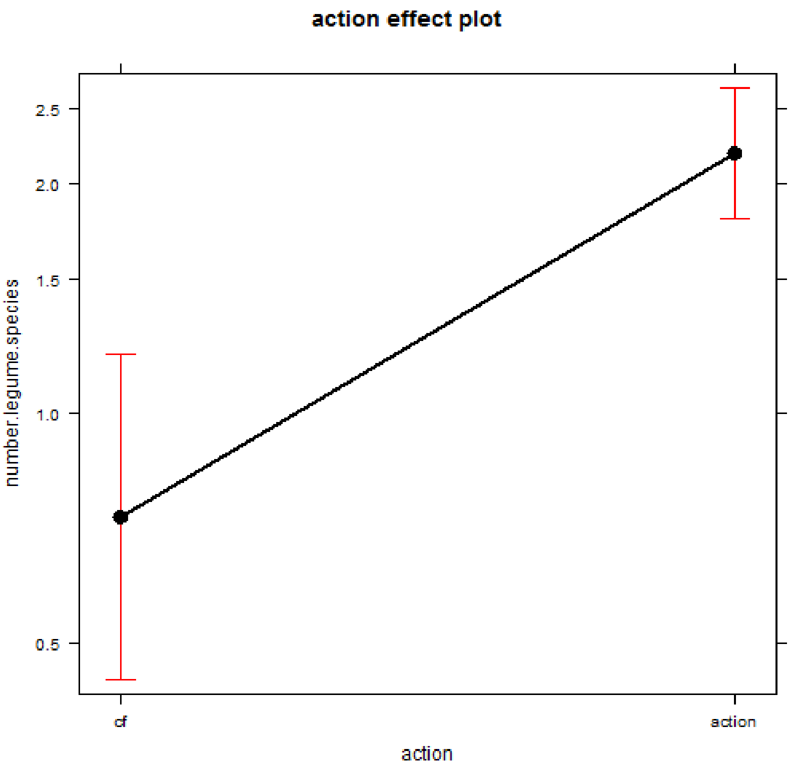

Figure 25: Effect of options on the number of legume species

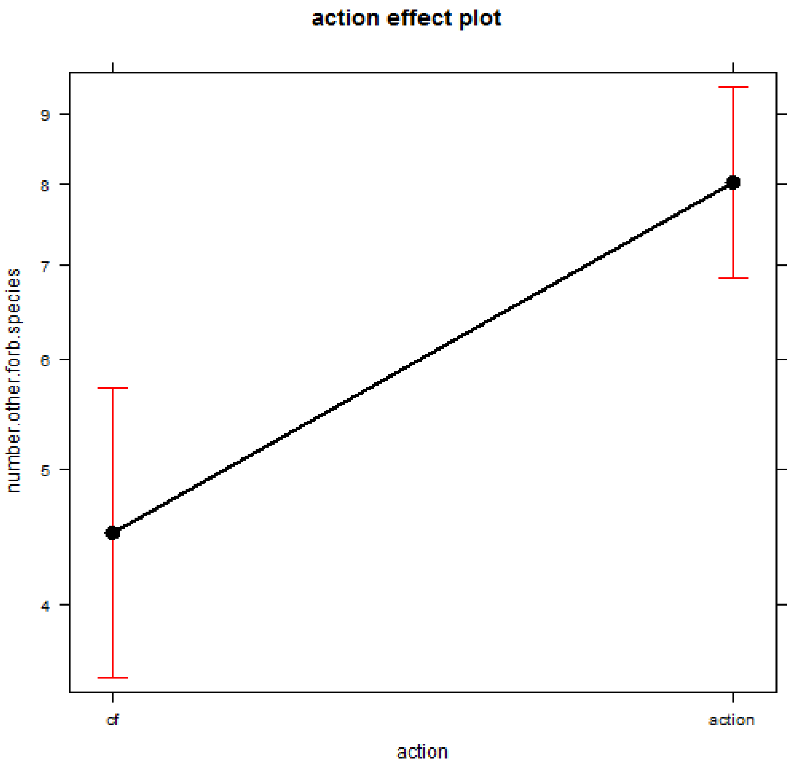

Figure 26: Effect of options on the number of other forb species

3.3.2 Persistence of Sown Species

Sward data was compared with information, derived from interviews, on the composition of the option sown mixes. Not all agreement holders could supply this information, therefore the analysis is based on a subset of option areas.

Figure 27 presents the relationship between sown species and their presence in the sward during the summer survey. Each point is the number of parcels in which a species was found (presence/absence) against the number of parcels in which it was sown. The size of the point is the number of species with those coordinates. On average across species, a species is present in around 60% of the parcels on which it was sown.

A few species may be under-performing; they are observed in a significantly lower proportion of parcels in which they have been sown: *Festuca pratensis, Petroselinum crispum, Festuca arundinacea, Melilotus officinalis, Rumex acetosa, Rumex acetosella, Festuca ovina, Medicago sativa, Poa pratensis* and *Lolium multiflorum*. These results could be due to a range of factors other than poor persistence by these species. In-field identification of grasses can be difficult and the grasses listed above, may have been confused with closely related species (sown species lists were not available to surveyors before completion of botanical surveys). *R. acetosella*, *F. ovina*, *M. sativa* and *L. multiflorum* were all sown in fewer than 10 parcels. However, these results suggest that *P. crispum*, *M. officinalis* and *R. acetosa* persisted on a smaller proportion of parcels than other sown species.

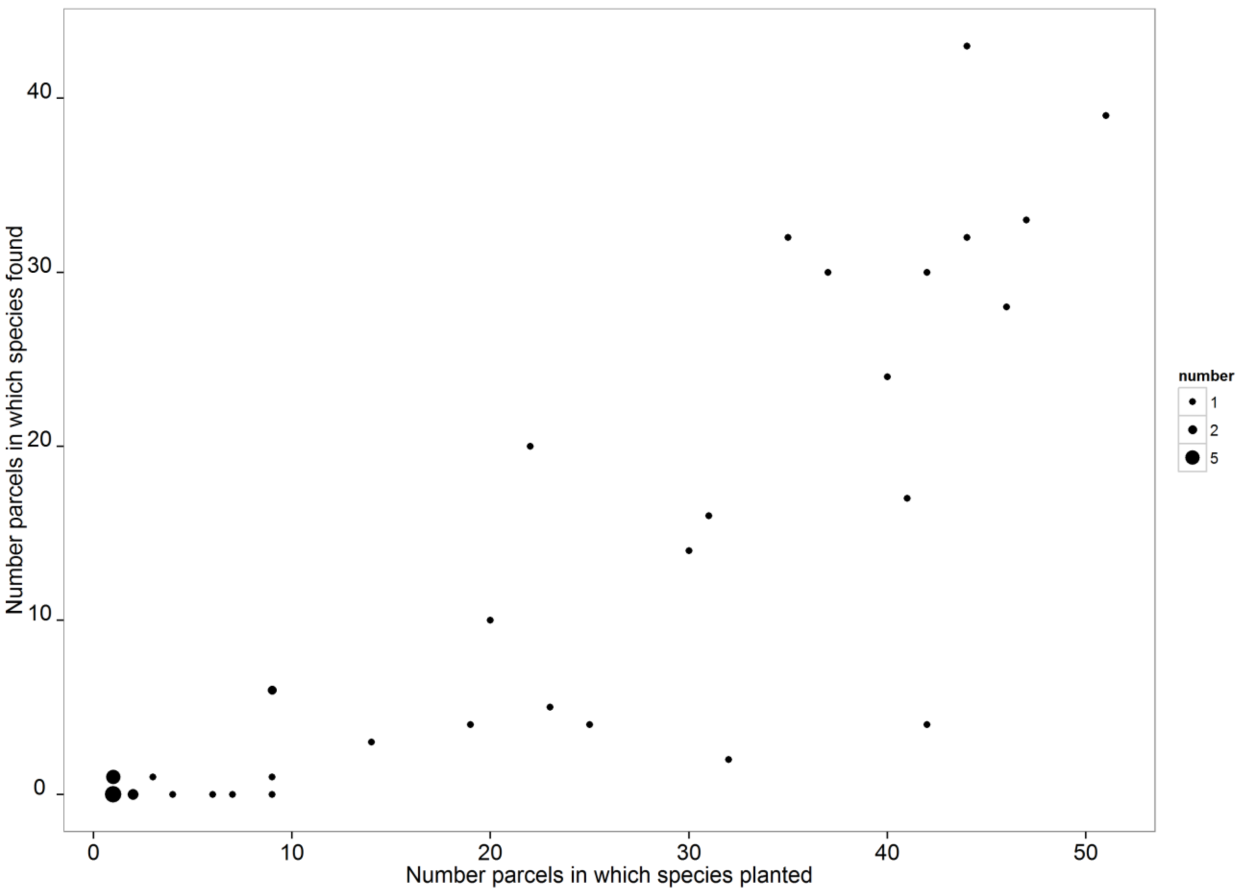

Figure 27: Comparison of species sown and their presence in the swards. Based on presence/absence only.

Two measures of the persistence of grown species were examined: 1) the proportion of quadrats in which the sown species was found; 2) the coverage of the sown species. Coverage was described by two quantities: the probability that the species is present and the proportion coverage in those parcels where it is present.

For all three quantities the basic model was that each measure was related to the number of seeds sown per hectare; then the effect of a number of different factors on the basic model was examined. Therefore, analysis excluded any parcels where sowing rates for individual species were not available. The other factors examined were:

Land management:

Was the previous crop grass or arable
Year in which seeds were drilled
Plough, minimum tillage, other
Field cut prior to survey
Grazed after February prior to survey
Drill season
Typically cut in previous years
Typically grazed in previous years

Soil:

pH
Extractable phosphorous
Organic carbon (Dumas)
Clay w/w

Effects of individual factors were generally similar for each of the three metrics analysed, although the proportion of quadrats was the most sensitive to the effects of the different factors. Full outputs are therefore presented for the proportion of quadrats in which a species was observed. For presence/absence and percent cover in parcels in which a species was recorded, results are summarised for high and low seed sowing numbers (Table 21 and Table 22) and the basic model is presented (Figure 41 and Figure 42). Full model outputs are given in Appendix 4 (Figure 49 to Figure 72).

Effects were often different at different sowing densities but generally differences were greatest where seed sowing densities were low. Table 20 presents a summary of model outputs for low and high sown seed numbers. Figure 28 presents the basic model of the number of seeds sown. Figure 29 to Figure 40 detail model outputs for the effect of individual factors on the basic model.

Organic carbon content, pH and tillage prior to establishment had a significant effect on the basic model (Table 20). The pH of samples ranged from 5.65 to 8.43, therefore 6 was considered low and 8 high for the purposes of this analysis. At a low pH (6) there was a significant difference in the estimated proportion of quadrats in which a species would be found when sown at low compared to high densities (Figure 37). With increasing pH, the difference between low and high sowing densities decreases. Model outputs for the effect of organic C were similar to those for pH (Figure 39).

Estimates of the proportion of quadrats indicated that sown species were more frequent under minimum tillage compared to other types of cultivation at low sown densities (Figure 31). However, at higher sown densities the fitted proportion of quadrats in which a species was observed was greatest after ploughing, although frequency was similar after minimum tillage.

Fitted estimates of the proportion of quadrats where a sown species was observed suggested an effect for: typically cut, typically grazed, cut or grazed prior to monitoring in the year of survey and clay content. However these differences were small.

The proportion of quadrats in which a species was recorded was not affected by: previous crop, year of drilling, season of drilling or extractable phosphorous.

Table 20: Effect of sowing, management and soil on persistence of sown seeds expressed as proportion of quadrats in which sown plants were observed

Model	Low seeds sown (2,500 / Ha)			High seeds sown (7,400,000/Ha)			Between parcel s.d.
	Estimate	95% CI		Estimate	95% CI		
Seeds sown	**0.075**	**0.053**	**0.10**	**0.47**	**0.39**	**0.56**	**1.1 (logit)**
+Previous crop	No Effect p=0.16						
+Year of drilling	No effect p=0.99						
+Plough/tillage (min.till)	0.24	0.11	0.45	0.40	0.21	0.62	0.98 (logit)
+Plough/tillage (Other)	0.044	0.021	0.092	0.30	0.18	0.46	
+Plough/tillage (Plough)	0.071	0.047	0.105	0.57	0.47	0.66	
+cut prior (no)	0.10	0.064	0.15	0.46	0.36	0.57	1.1 (logit)
+cut prior (yes)	0.052	0.029	0.091	0.50	0.37	0.63	
+grazed prior (no)	0.061	0.037	0.10	0.50	0.39	0.62	1.1(logit)
+grazed prior (yes)	0.099	0.061	0.16	0.43	0.32	0.55	
+Drill season	No Effect p=0.67						
+typically cut (no)	0.071	0.035	0.14	0.30	0.17	0.46	1.1 (logit
+typically cut (yes)	0.096	0.063	0.14	0.50	0.40	0.60	
+typically grazed (no)	0.050	0.019	0.12	0.55	0.33	0.74	1.1(logit)
+typically grazed (yes)	0.093	0.063	0.14	0.43	0.34	0.52	
+pH (low=6)	0.0053	0.0027	0.010	0.48	0.35	0.62	0.96 (logit)
+pH (high=8)	0.22	0.15	0.31	0.50	0.39	0.61	
+Available Phosphorus	No Effect p=0.37						
+Organic carbon (low=1.3)	0.025	0.013	0.047	0.35	0.17	0.58	1.0 (logit)
+Organic carbon (high=5)	0.35	0.32	0.60	0.52	0.32	0.71	
+Clay w/w (low=4)	0.050	0.017	0.14	0.63	0.40	0.83	1.0 (logit)
+Clay w/w (high=50)	0.11	0.040	0.27	0.32	0.15	0.56	

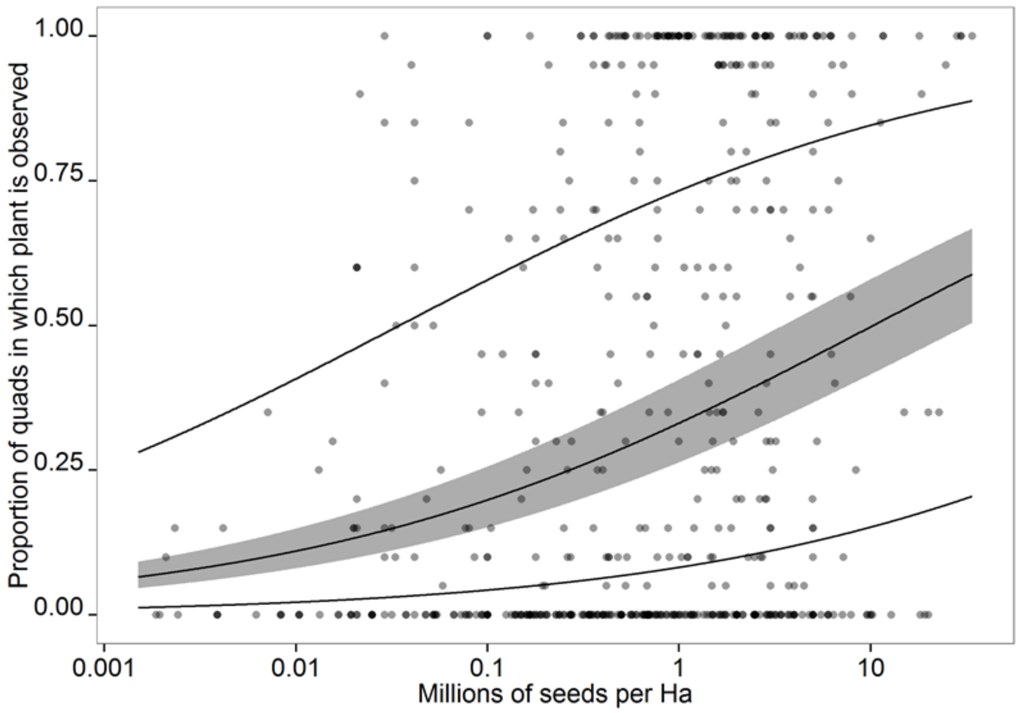

Figure 28: Basic model for proportion of quadrats in which plants were found – proportion of quadrats was related to the quantity of seeds sown

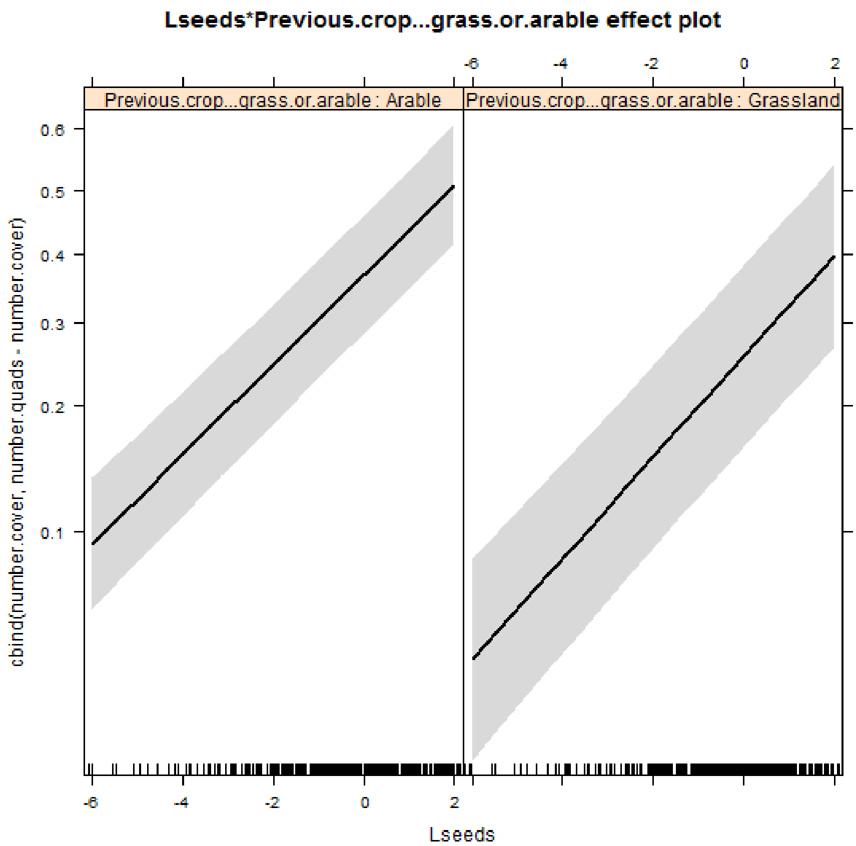

Figure 29: Effect of previous crop on basic model for proportion of quads in which plant was seen

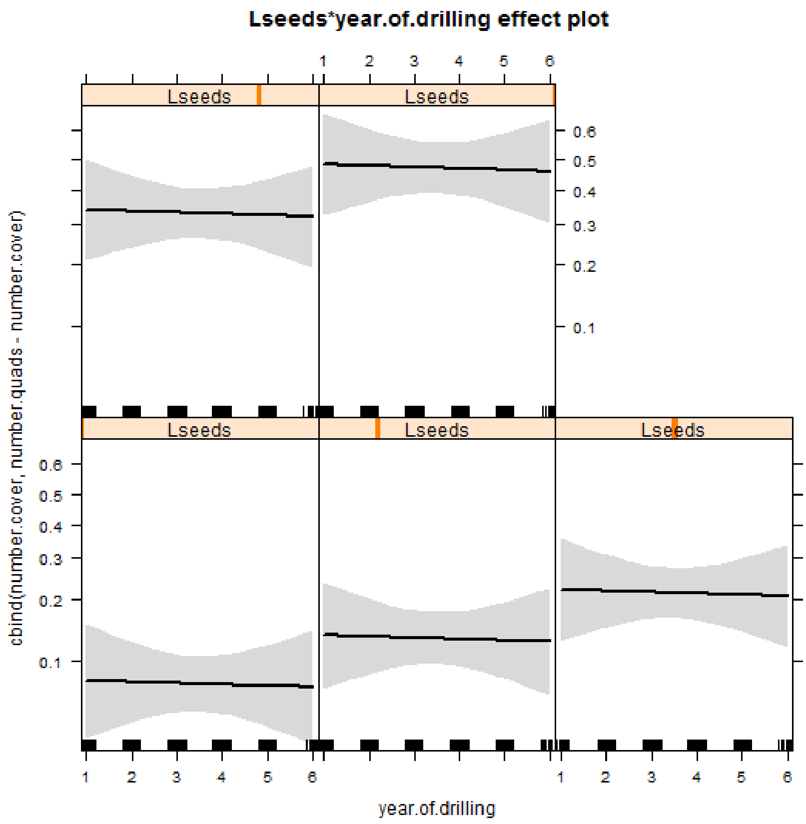

Figure 30: Effect of year of drilling on basic model for proportion of quads in which plant was seen (years since drilling)

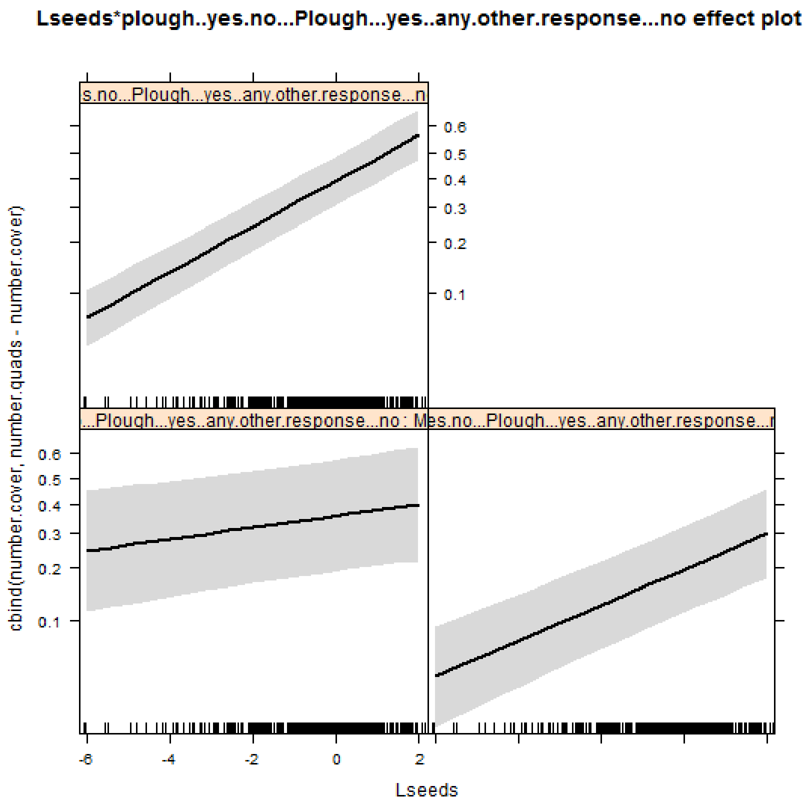

Figure 31: Effect of tillage method on basic model for proportion of quads in which plant was seen (minimum tillage bottom left, 'other' bottom right, plough top.

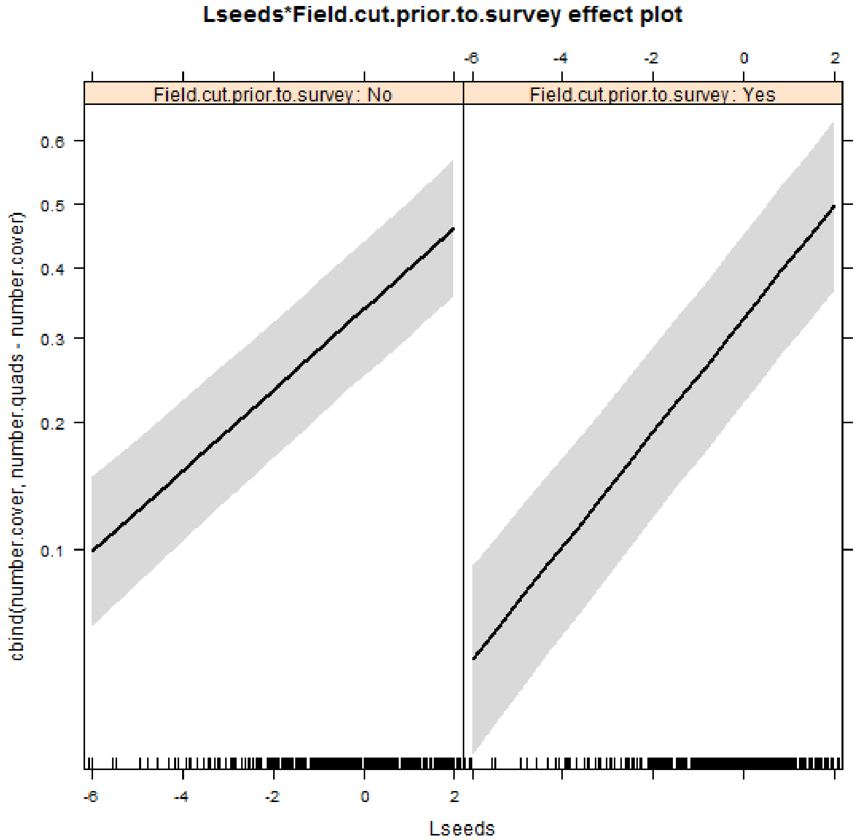

Figure 32: Effect of cutting prior to survey on basic model for proportion of quads in which plant was seen

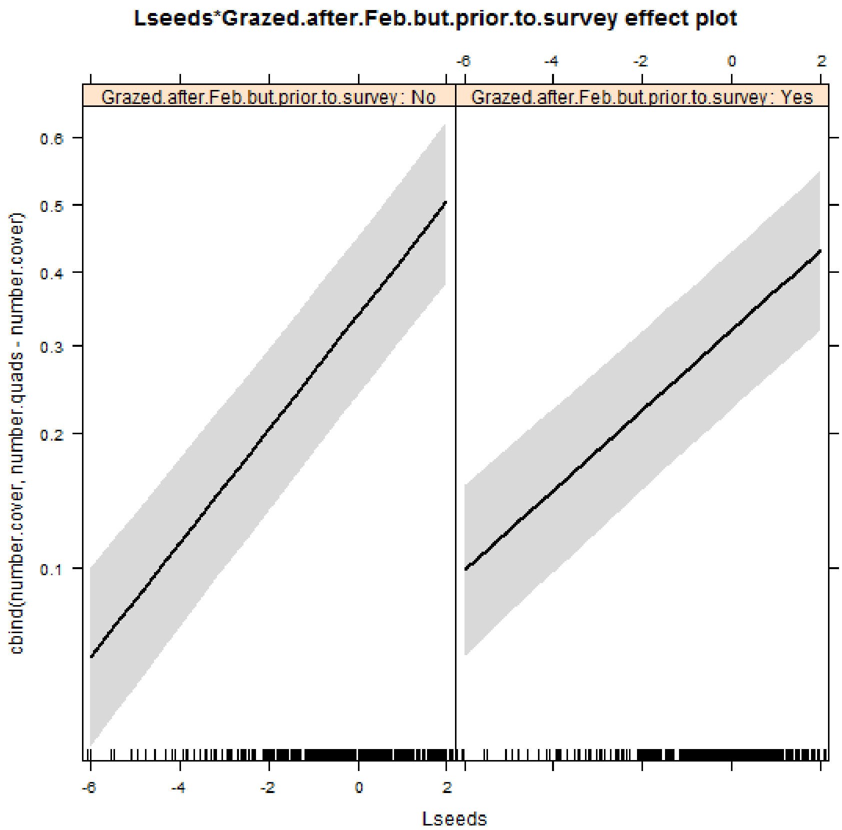

Figure 33: Effect of grazing prior to survey on basic model for proportion of quads in which plant was seen

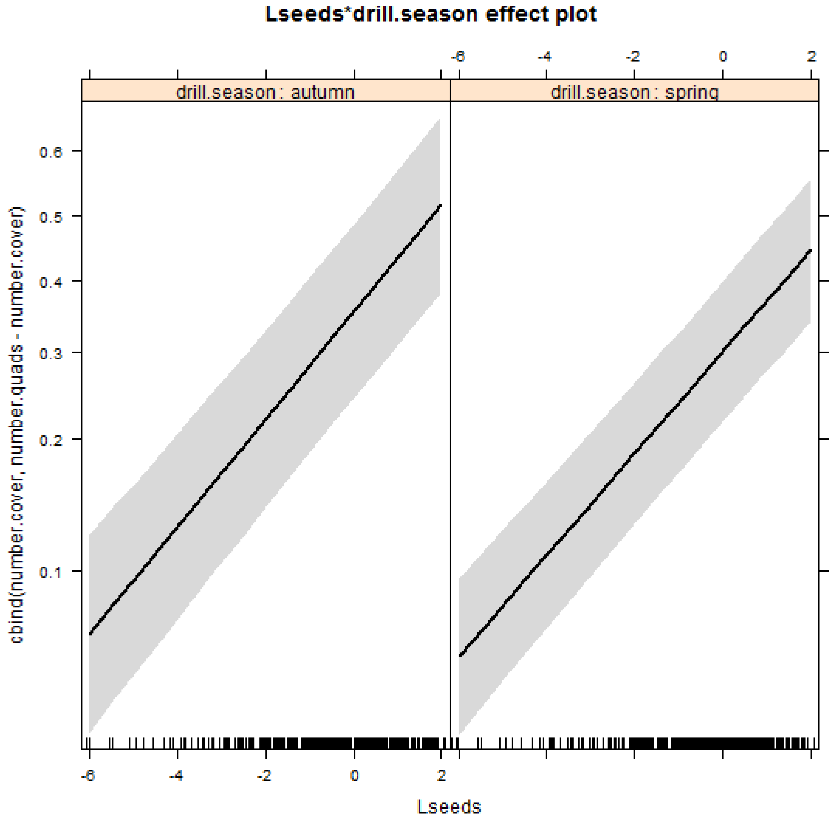

Figure 34: Effect of drill season to survey on basic model for proportion of quads in which plant was seen

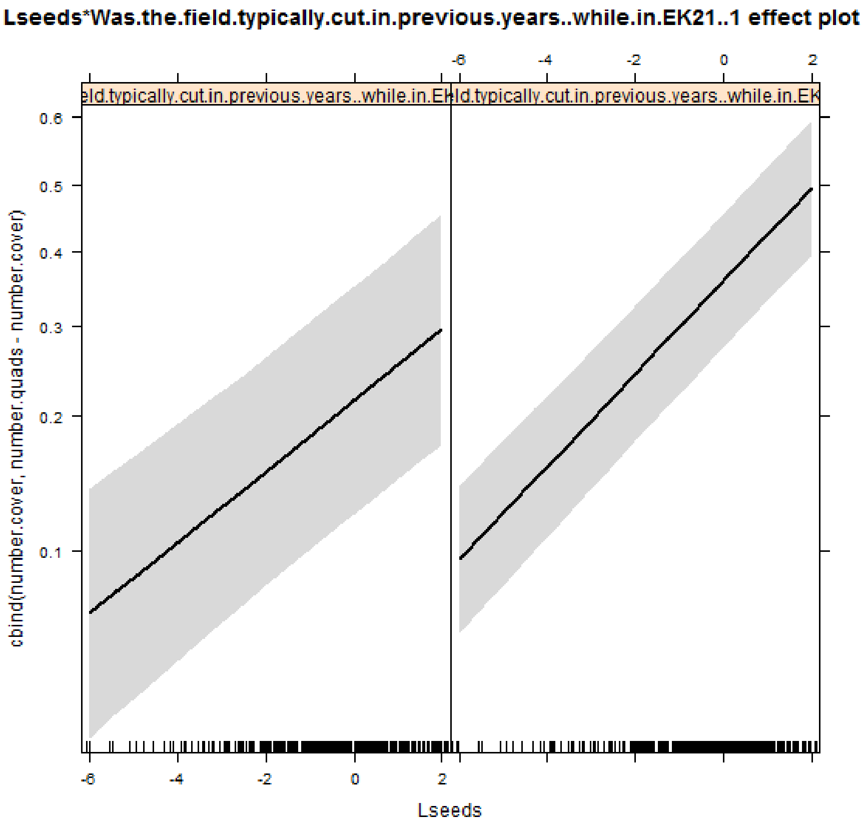

Figure 35: Effect of previous years' cutting on basic model for proportion of quads in which plant was seen. Left = no; right = yes.

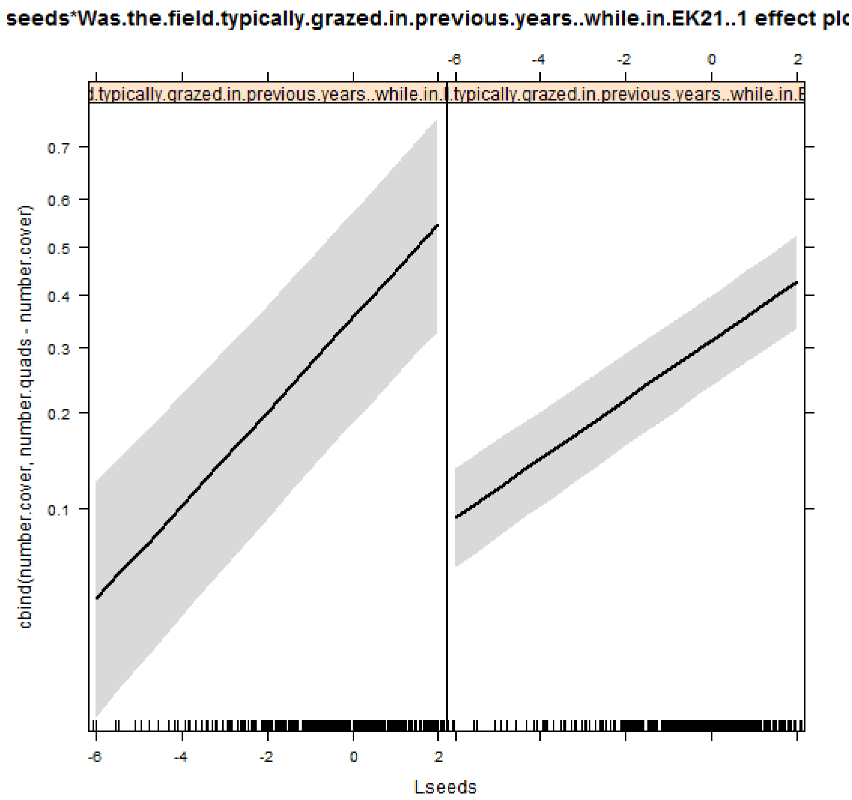

Figure 36: Effect of previous years' grazing on basic model for proportion of quads in which plant was seen. Left = no; right = yes.

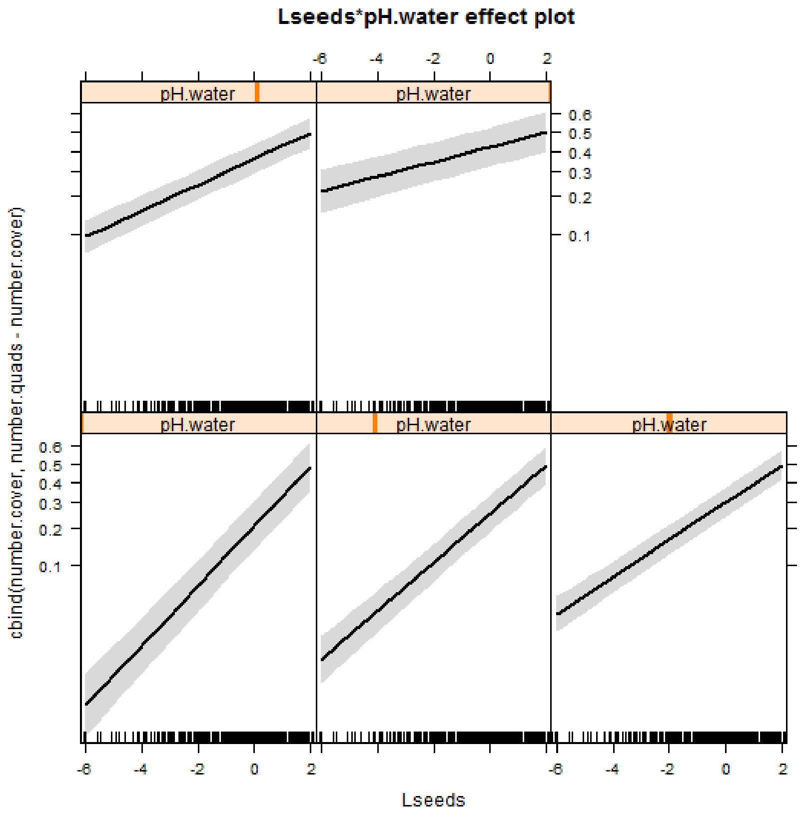

Figure 37: Effect of soil pH on basic model for proportion of quads in which plant was seen. pH increases from bottom left to top centre plot.

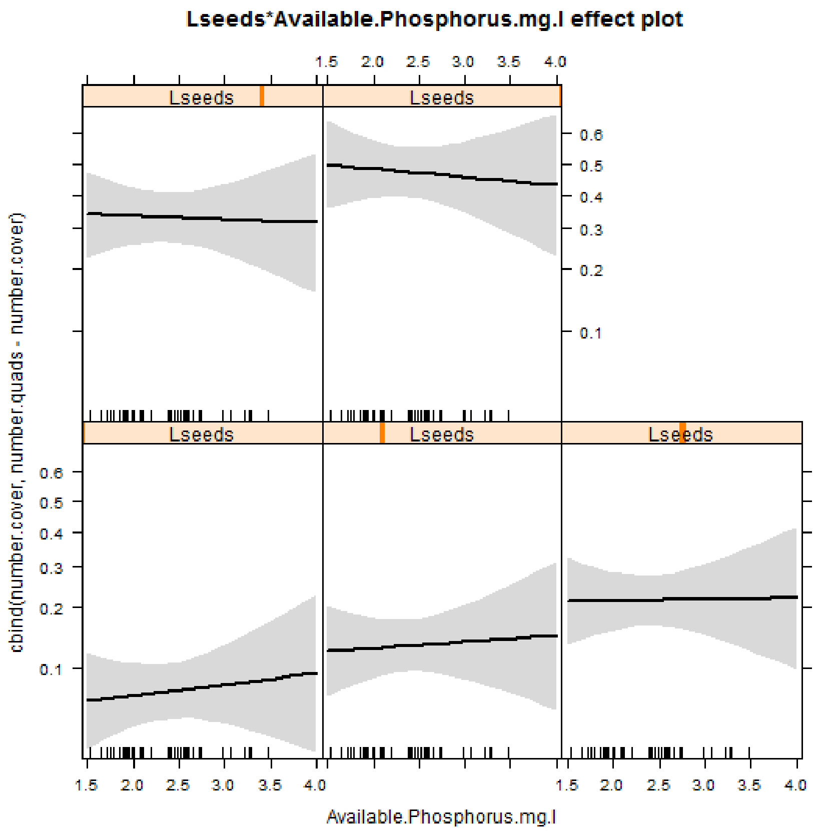

Figure 38: Effect of extractable phosphorous on basic model for proportion of quads in which plant was seen. Extractable P increases from bottom left to top centre.

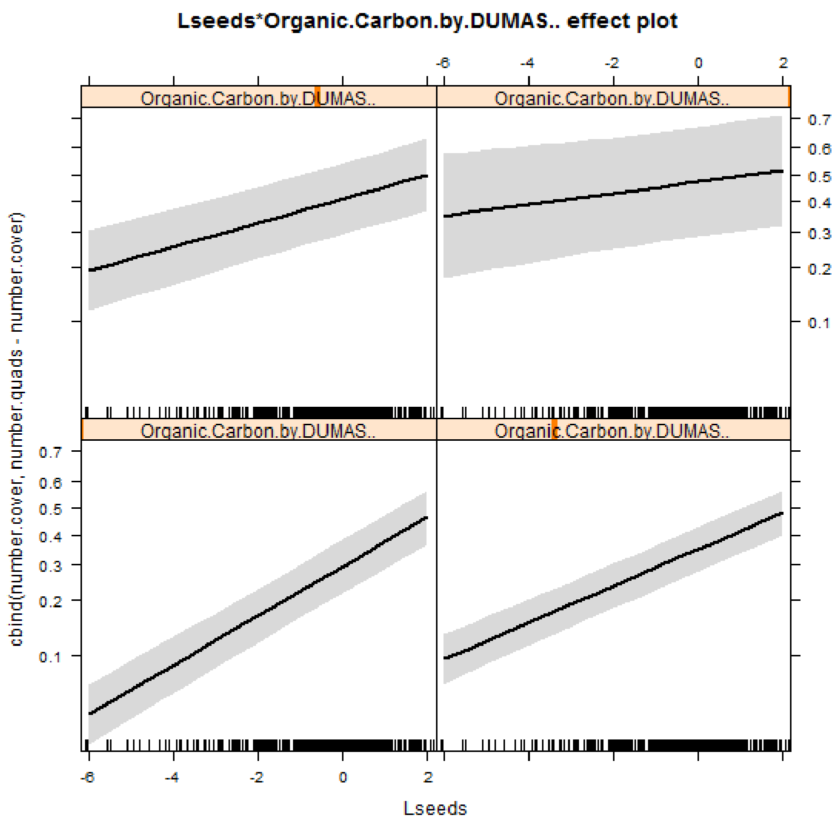

Figure 39: Effect of organic carbon content on basic model for proportion of quads in which plant was seen. Organic C increases from bottom left to top right plot.

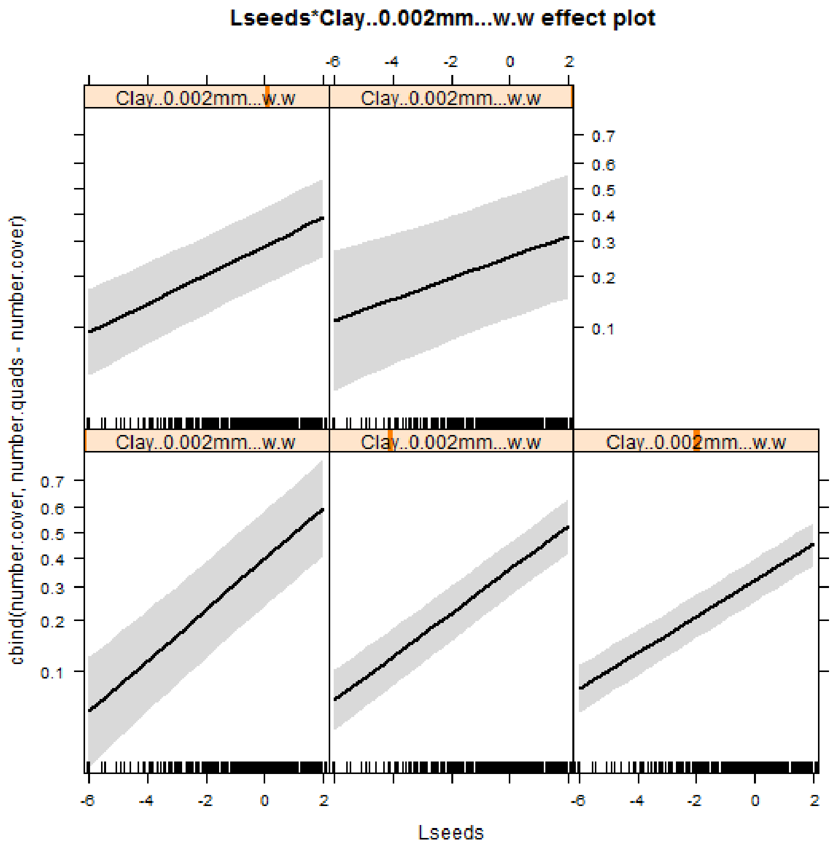

Figure 40: Effect of clay content on basic model for proportion of quads in which plant was seen. % clay content increases from bottom left to top centre plot.

When the probability of observing a species (presence/absence) was considered, the effects of factors on the basic model were only significant for pH and type of tillage (Table 21). At low sown seed densities, high pH resulted in a greater probability of recording the species compared to low pH. Species were more likely to be present in the sward at low sown seed density under minimum tillage compared to other types of cultivation, but at high seed densities the reverse was true.

Table 21: Effect of sowing, management and soil on persistence of sown seeds expressed as probability that plant was observed

Model	Low seeds sown (2,500 / Ha)			High seeds sown (7,400,000/Ha)			Between parcel s.d.
	Estimate	95% CI		Estimate	95% CI		
Seeds sown	**0.29**	**0.17**	**0.43**	**0.67**	**0.58**	**0.76**	**0.80 (logit)**
+Previous crop	No effect p=0.49						
+Year of drilling	No effect p=0.59						
+Plough/tillage (min.till)	0.62	0.23	0.90	0.36	0.15	0.64	0.67 (logit)
+Plough/tillage (Other)	0.22	0.058	0.55	0.62	0.41	0.80	
+Plough/tillage (Plough)	0.27	0.14	0.46	0.76	0.66	0.84	
+cut prior	No effect p=0.41						
+grazed prior	No effect p=0.83						
+Drill season	No effect p=0.45						
+typically cut	No effect p=0.21						
+typically grazed	No effect p=0.51						
+pH (low=6)	0.023	0.0052	0.096	0.74	0.57	0.86	0.75 (logit)
+pH (high=8)	0.66	0.43	0.83	0.65	0.52	0.76	
+Available Phosphorus	No Effect p=0.082						
+ Organic carbon	No Effect p=0.38						
+ Clay w/w	No Effect p=0.22						

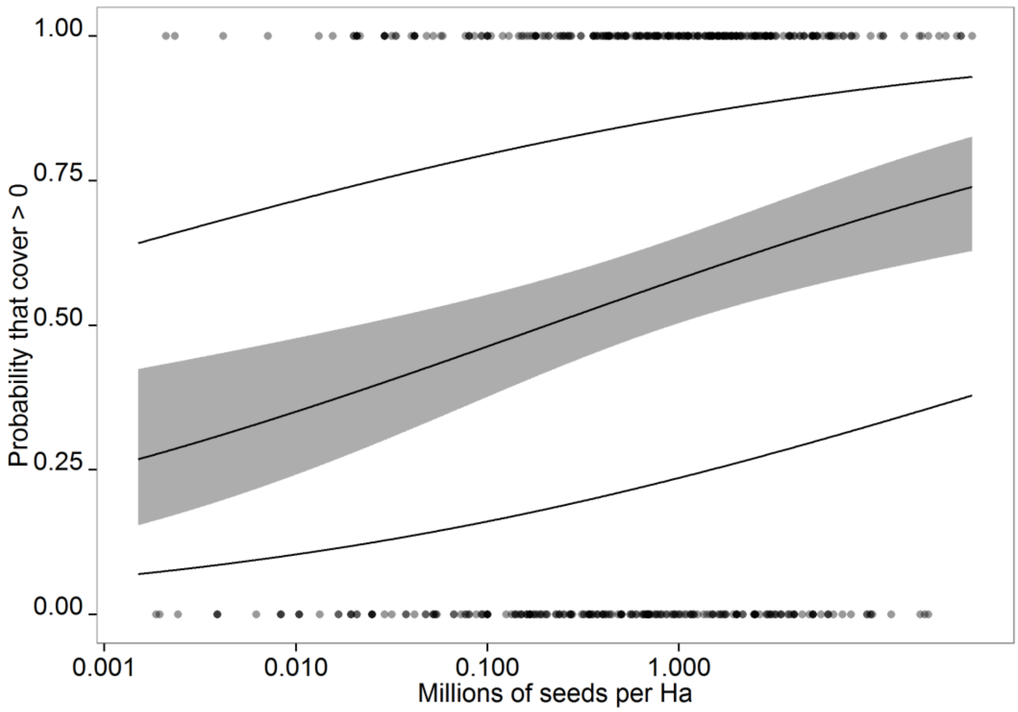

Figure 41: Basic model for probability that the plants were found – probability is related to the quantity of seeds sown

Similar to results for the probability of a species being recorded in the sward, at low sown seed densities, cover of sown species (where present) was higher after minimum tillage compared to other methods of cultivation (Table 22). In contrast to the probability or recording a species, at high sown densities, percent cover was higher after minimum tillage. The effect of pH was also significant on percent cover, but the effects were smaller than for the probability of recording a species.

Table 22: Effect of sowing, management and soil on persistence of sown seeds expressed as proportion coverage by plants in parcels where they were observed

Model	Low seeds sown (2,500 / Ha)			High seeds sown (7,400,000/Ha)			Between parcel s.d.
	Estimate	95% CI		Estimate	95% CI		
Seeds sown	**0.0072**	**0.0033**	**0.016**	**0.075**	**0.052**	**0.11**	**0.60 (logit)**
+Previous crop	No Effect p=0.56						
+Year of drilling	No effect p=0.84						
+Plough/tillage (min.till)	0.020	0.0030	0.12	0.24	0.074	0.56	0.44 (logit)
+Plough/tillage (Other)	0.0052	0.0009	0.031	0.039	0.017	0.087	
+Plough/tillage (Plough)	0.0056	0.0022	0.014	0.076	0.051	0.11	
+cut prior	No Effect p=0.75						
+grazed prior	No Effect p=0.32						
+Drill season	No Effect p=0.87						
+typically cut	No effect p=0.75						
+typically grazed	No effect p=0.48						
+pH (low=6)	0.0012	0.0002	0.0088	0.071	0.034	0.14	0.53 (logit)
+pH (high=8)	0.013	0.0051	0.032	0.083	0.052	0.13	
+Available Phosphorus	No Effect p=0.62						
+Organic carbon	No Effect p=0.25						
Clay w/w	No Effect p=0.99						

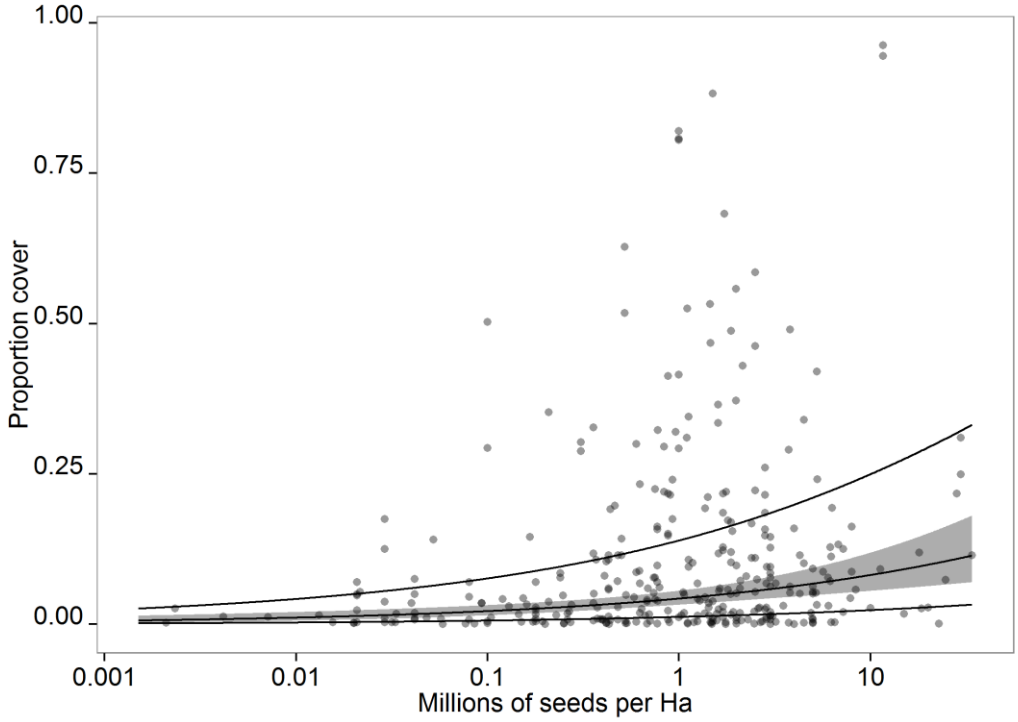

Figure 42: Basic model for coverage in parcels in which plants were found – coverage is related to the number of seeds sown

3.3.3 Impact of Environmental and Management Factors on Sward Development

Analysis of vegetation communities (sown and unsown species) using ordination techniques combined species composition (% cover) with the same management and soil factors used in the models of sown species persistence. Counterfactual parcels were included in the analysis where soil/management factor data was complete. Significant factors are presented in

Table 23. Species, site and factor triplots are presented in Figure 43 (all factors presented) and Figure 44 (only significant factors included). The length of the blue arrows denotes the importance of each factor associated with the community composition.

The most important factor in determining vegetation community composition was the previous crop (grassland or arable). This result probably relates to the community of 'weed' species present in the parcels, particularly since the persistence of sown species was not affected by this factor. Grazing and cutting prior to survey both had a significant but different effect on community composition. Both these factors apparently affected sown species persistence, but differences were small.
Other factors which affected community composition were: option/counterfactual, years since drilled and typically cut. The only soil factor which was significant was pH. This reflects sown species models for percent cover (Table 22).

Table 23: Significance of individual factors*

Factor code	Factor	Df	Pr(>F)
YsDrill	Years since drilled	1	0.0260
DrilSeas	Season of drilling	1	0.6292
PrevCrop	Previous crop (arable/grassland)	1	0.0005
X1.	***Tillage (plough vs other)***	***1***	***0.0845***
CutPreSu	*Cut pre-survey*	*1*	*0.0290*
GraPreSur	*Grazed pre-survey*	*1*	*0.0115*
CutTypic	*Typically cut*	*1*	*0.0050*
GraTypic	*Typically grazed*	*1*	*0.1374*
pH	***pH***	***1***	***0.0075***
ExtractP	Extractable P	1	0.5767
OrgCDuma	***Organic C (Dumas)***	***1***	***0.1509***
OptCf	Option vs Counterfactual	1	0.0200
clay.	*% Clay content*	*1*	*0.5787*

*Bold italics denote factors which were significant in sown species persistence models. Italics denote factors, where effects were small in those models.

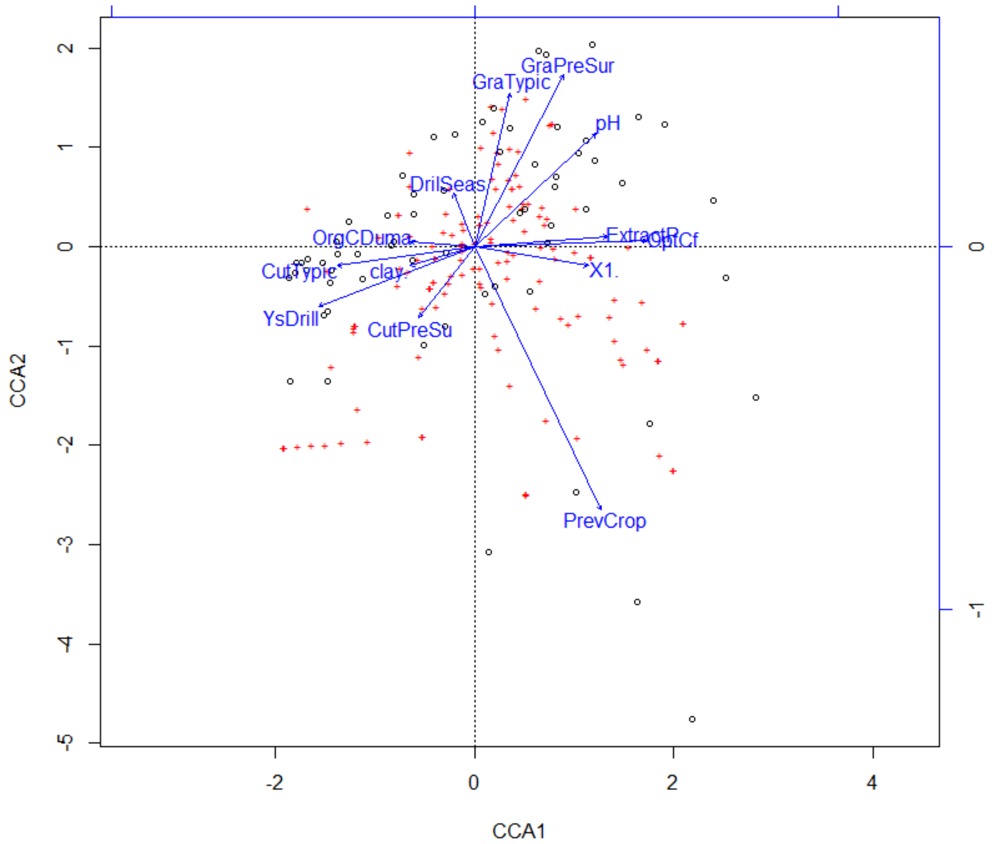

Figure 43: CCA plot including all soil and management factors. Red crosses = species; circles = parcels.

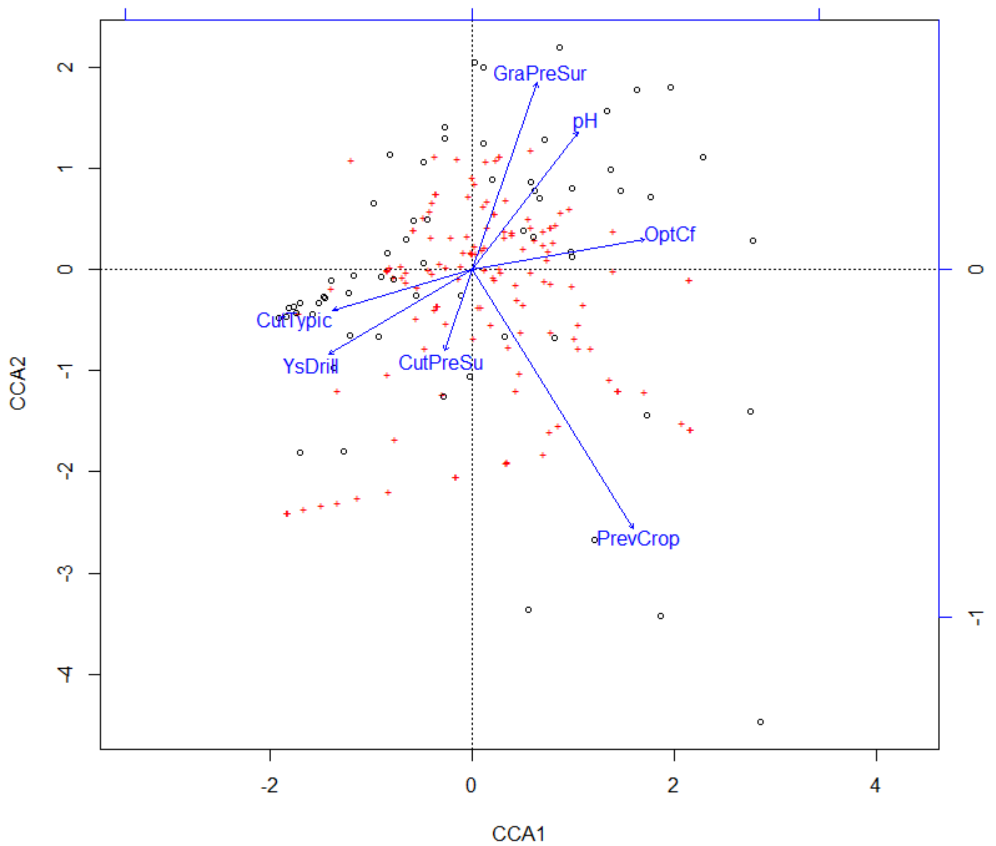

Figure 44: CCA plot including only significant soil/management factors Red crosses = species; circles = parcels.

3.3.4 Soil Characteristics

A summary of soil chemical characteristics is provided in Appendix 2. The raw soil chemical analysis data is provided in the project database. There was some indication that soil total nitrogen values were higher in organic arable than in conventional arable fields (mean = 3.4 for organic arable cf. 0.21 for conventional arable; standard deviation = 0.06; P=0.05). However, there were no significant differences between land management types for any of the other soil chemical properties measured.

3.3.4.1 Visual Evaluation of Soil Structure (VESS) results

There were 19 sites at which it was possible to compare VESS (poorest layer) soil structure score between a field in the "legume and herb-rich swards" option (EK21, OK21, HK21 and OHK21) and an arable counterfactual field (

Table 24).

Table 24: VESS table of means (of three samples) for option and arable counterfactual fields at 19 sites.

Site	EK21 option	Arable counterfactual
EK21-02-01	1.17	2.33
EK21-02-02	1.00	1.00
EK21-02-04	3.00	2.83
EK21-02-08	3.00	2.00
EK21-03-01	3.67	1.17
EK21-03-03	3.00	3.17
EK21-03-04	3.33	2.67
EK21-03-06	2.50	3.00
EK21-03-10	3.17	3.17
EK21-03-13	2.83	2.33
EK21-03-16	1.00	1.17
EK21-03-20	2.53	2.27
EK21-03-22	1.83	2.33
EK21-04-02	3.33	2.50
EK21-04-07	2.00	2.67
EK21-04-09	3.17	3.00
EK21-04-12	1.33	1.50
EK21-04-13	3.50	3.33
EK21-04-18	1.67	1.67

Mean VESS scores for the poorest layer ranged from 1.2 to 3.7, placing them in the ''friable' to 'firm' structural quality classes (

Table 25). Notably, none of the field sites had topsoil layers that were scored as 'compact' or 'very compact'.

Table 25: VESS soil Structure quality scores (Guimaraes *et al*., 2011).

Class	VESS score	Interpretation
1	<2	Friable
2	2-3	Intact
3	3-4	Firm
4	4-5	Compact
5	5	Very compact

Analysis of variance (ANOVA) was used to investigate site by land use interactions and differences in VESS score between option fields and arable counterfactual fields; and between sites (

Table 26).

The overall VESS mean for option fields was 2.3 and for arable counterfactual fields 2.5. There was a significant difference in VESS score between sites (P<0.001), and a significant site/land use interaction, indicating that differences between option and counterfactual fields were not consistent across sites (P<0.001;

Table 26). There was no significant difference between land management 'treatments' (option/counterfactual; P=0.115).

At 9 out of 19 sites, the option field had a higher VESS score than the arable counterfactual field. The arable field was higher at 7 sites and at 2 sites both fields had the same score, indicating overall that that there was no difference in VESS soil structural quality between option fields and arable counterfactual fields.

Table 26: Results of ANOVA for interaction between site land use and the effect of site and land use on VESS score

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Site	17	56.0463	3.2968	12.38	<.001
Option/counterfactual	1	0.6793	0.6793	2.55	0.115
Site/land use interaction	17	16.0940	0.9467	3.56	<.001
Residual	72	19.1667	0.2662		
Total	107	91.8796			

3.3.4.2 Dispersion ratio results

There were 18 sites at which it was possible to compare a field in the "legume and herb-rich swards" option (EK21, OK21, HK21 and OHK21) with an arable counterfactual field (Table 27).

Table 27: Soil dispersion ratio table of means (of three samples) for option and arable counterfactual fields at 18 sites

Site	EK21 option	OPTION AGE (MONTHS)	Arable counterfactual
EK21-02-01	1.55	65	4.15
EK21-02-04	3.19	19	5.36
EK21-02-08	4.22	20	3.76
EK21-03-01	3.11	nd	4.03
EK21-03-03	3.31	6	3.57
EK21-03-04	2.59	50	4.90
EK21-03-06	4.80	49	3.87
EK21-03-10	5.59	13	5.73
EK21-03-13	3.51	39	3.77
EK21-03-16	9.85	111	10.35
EK21-03-20	5.30	25	7.74
EK21-03-22	3.45	50	2.25
EK21-04-02	2.51	39	3.05
EK21-04-07	6.38	49	3.70
EK21-04-09	1.52	55	2.87
EK21-04-12	2.96	13	3.21
EK21-04-13	2.36	41	2.41
EK21-04-18	5.36	32	4.31

Mean dispersion ratio (DR – a measure of soil aggregate stability) values ranged from 1.5 to 10.4, placing them in the 'very stable' to 'fairly stable' stability classes (Table 28). Notably, there were no soil samples that were 'unstable' or 'very unstable'.

Table 28: Stability classes based on dispersion ratio determinations (ADAS, 1995)

Class	Dispersion ratio	Interpretation
1	<5	Very stable
2	5-10	Stable
3	10-15	Fairly stable
4	15-25	Slightly stable
5	25-30	Unstable
6	>30	Very unstable

Analysis of variance (ANOVA) was used to investigate site by land use interactions and differences in dispersion ratio (DR – a measure of soil aggregate stability) between option fields and arable counterfactual fields; and between sites (Table 29).

The overall DR mean for option fields was 4.39 and for arable counterfactual fields 3.98. There was a significant difference in DR between sites (P<0.001), between land management 'treatments' (option/counterfactual; P<0.05) and there was also a significant site/land use interaction (P=0.001; Table 29).

At 13 out of 18 sites, the option field had a lower DR than the arable counterfactual field, indicating that the option was resulting in more stable aggregates than management under an arable rotation.

Table 29: Results of ANOVA for interaction between site land use and the effect of site and land use on DR

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Site	17	355.33	20.902	19.87	<.001
Option/counterfactual	1	4.66	4.662	4.43	0.039
Site/land use interaction	17	50.89	2.994	2.85	0.001
Residual	72	75.73	1.052		
Total	107	486.62			

Although of low predictive value there was a significant negative relationship between DR and soil organic carbon content (P=0.02; Figure 45). There was also a significant relationship between DR and clay content (P=0.03; Figure 46) indicating that soil type was an important factor influencing soil aggregate stability.

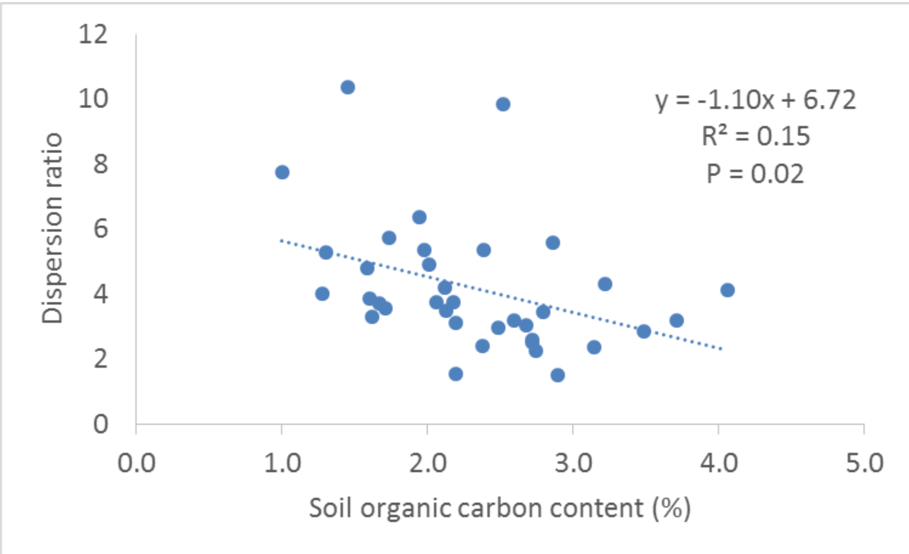

Figure 45: Relationship between dispersion ratio and soil organic carbon content (%)

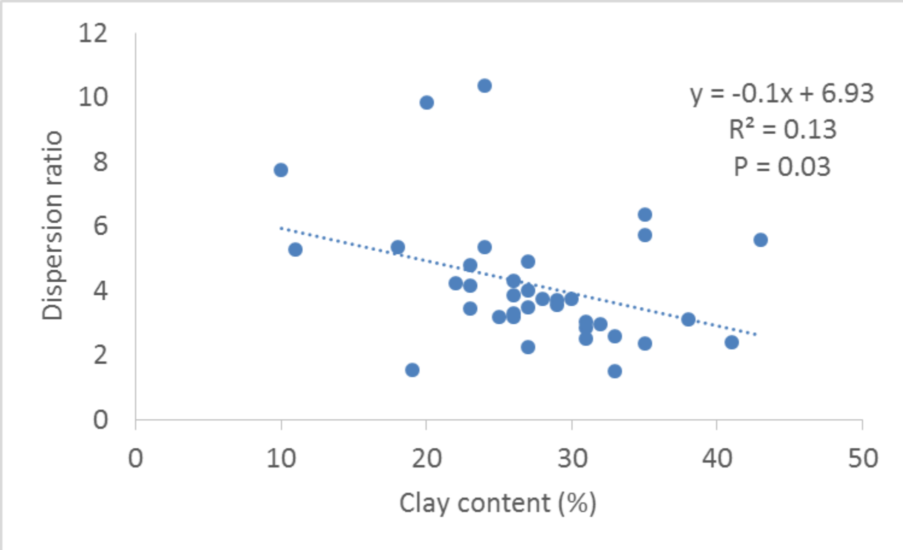

Figure 46: Relationship between dispersion ratio and soil clay content (%)

3.3.5 Value of Swards to Wider Biodiversity

Analysis of summer flower counts and autumn seedheads indicate that the options provide a much greater potential food resource for pollinating insects (summer) and seed provision for birds and other groups through the autumn and winter than the counterfactual (Figure 47 and Figure 48). Because the data were collected over a period of weeks and at different growth/regrowth stages, both flowers and fruiting structures were recorded and have been combined in the data presented. However, summer records were largely flowers and autumn records predominantly seedheads.

Summer flower numbers were higher in organic (179 blossom units m^{-2}) compared to conventionally managed options (97 blossom units m^{-2}) (Figure 47) and were greater in option compared to the counterfactual. Data presented include all forb species (sown and unsown) and numbers are based on 'blossom units'. Species with high flower numbers were most likely to be sown; the most common flowers were: *Trifolium repens*, *Chichorium intybus*, *Trifolium pratense* and *Lotus corniculatus*, but only *T. repens* and *T. pratense* on organic holdings were common in counterfactual parcels (Table 30 and see Appendix 3 Table 39 for a full list of species recorded flowering in summer assessments). Flower numbers of unsown species were sometimes high on individual parcels, but individual species were rarely common across different parcels. The exception was *Ranunculus repens* which was recorded flowering in 55% of option parcels.

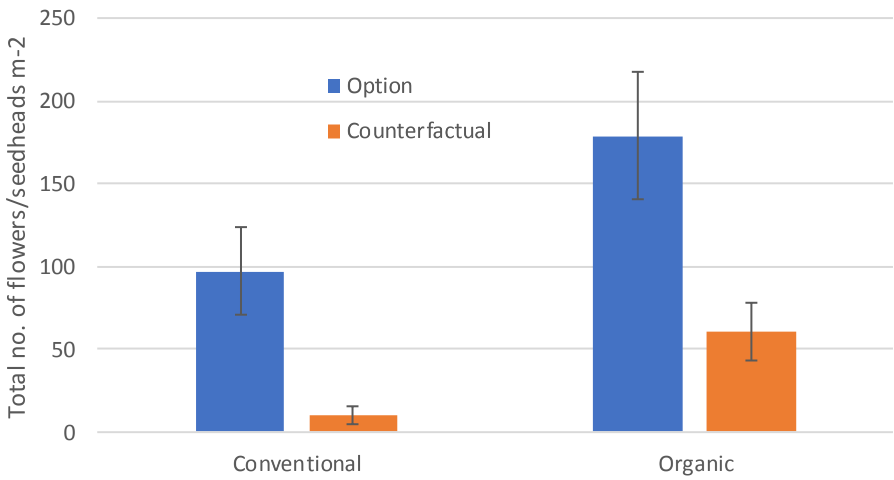

Figure 47: Total number of flowers (m^{-2}) recorded in options at summer visits (broad-leaved species). Error bars represent plus/minus 1 SE.

Seedhead numbers in autumn were lower than summer flower counts at around 40 'blossom units' m^{-2} on organic and conventional options (Figure 48). Numbers were highly variable between individual option parcels. Counts on counterfactual parcels were very low on both organic and conventional holdings.

Again, most species present at high seedhead numbers were sown species (Table 31 and see Appendix 3 Table 40 for a full list of species). *Chicorium intybus* accounted for 55% of all seedheads recorded although it was only present on 26% of all option parcels. This probably reflects the structure of the plant which is woody and will stand well into autumn if uncut/ungrazed, plus multiple seedheads are counted per flowering stem. The only other species which represented ≥5% of all seedheads recorded were *T. pratense* and *Mellilotus officinalis*, although the latter was recorded on only two (organic) parcels. Although *T. repens* was the most common species in summer flower counts, seedheads were recorded in low numbers and on only nine of the 103 parcels assessed.

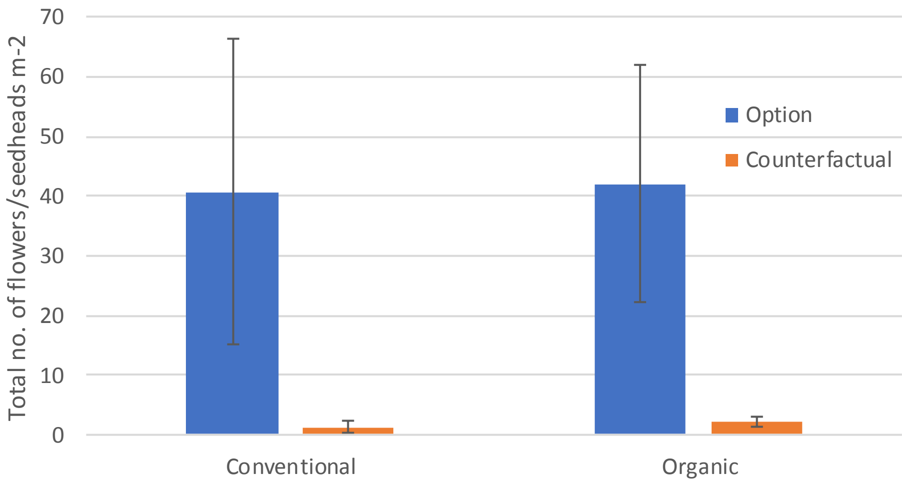

Figure 48: Total number of seedheads (m^{-2}) recorded in options at autumn visits (all species). Error bars represent plus/minus 1 SE.

Table 30: Number of flowers (m^{-2}) recorded in summer for species with potential benefits for pollinators. Individual species which represent ≥0.5% of all flowers recorded.

	ELS				OELS			
	Option (n=40)		Counterfactual (n=13)		Option (n=37)		Counterfactual (n=13)	
Species	No. flowers	No. of occurrences	No. flowers	No. of occurrences	No. flowers	No. of occurrences	No. flowers	No. of occurrences
Summer								
Trifolium repens	11.95	37	7.34	8	43.12	29	44.37	11
Cichorium intybus	27.86	17	0.00	1	68.32	30	0.45	2
Trifolium pratense	21.98	28	0.51	2	19.70	30	10.18	6
Lotus corniculatus	18.58	22	0.09	1	12.67	21	0.00	0
Medicago sativa	1.39	3	0.00	0	8.16	3	0.00	0
Medicago lupulina	0.69	3	0.03	1	6.05	9	0.00	0
Ranunculus repens	0.59	25	0.03	5	0.76	17	3.29	7
Lapsana communis	0.00	0	0.02	1	4.24	1	0.00	0
Plantago lanceolata	2.12	26	0.00	3	1.51	25	0.11	4
Melilotus officinalis	0.02	1	0.00	0	2.61	4	0.00	0
Centaurea nigra	2.05	13	0.00	0	0.39	12	0.00	0
Sonchus asper	0.07	5	0.00	0	2.46	1	0.00	1
Prunella vulgaris	0.19	3	0.00	1	0.60	7	1.46	3
Crepis capillaris	1.42	8	0.37	2	0.53	5	0.00	1

Table 31: Number of seedheads (m^{-2}) recorded in autumn for all species. Individual species which represent ≥1% of all seedheads recorded.

	ELS				OELS			
	Option (n=40)		Counterfactual (n=13)		Option (n=37)		Counterfactual (n=13)	
Species	No. seedheads	No. of occurrences	No. seedheads	No. of occurrences	No. seedheads	No. of occurrences	No. seedheads	No. of occurrences
Autumn								
Cichorium intybus	27.54	6	0.00	0	17.93	14	0.00	0
Trifolium pratense	0.45	8	0.00	0	6.23	7	0.35	2
Melilotus officinalis	0.00	0	0.00	0	4.65	2	0.00	0
Lapsana communis	0.00	0	0.00	0	3.08	2	0.00	0
Centaurea nigra	2.02	6	0.00	0	0.18	2	0.00	0
Lolium perenne	1.58	6	0.00	0	0.42	9	0.60	5
Lotus corniculatus	0.90	4	0.00	0	1.05	2	0.00	0
Plantago lanceolata	0.57	7	0.00	0	1.20	13	0.23	2
Dactylis glomerata	0.13	4	0.03	1	1.66	6	0.02	1
Agrostis capillaris	1.47	3	0.00	0	0.03	1	0.00	0
Phleum pratense	0.51	2	0.00	0	0.85	5	0.02	1
Onobrychis viciifolia	0.10	2	0.00	0	1.24	4	0.00	0
Achillea millefolium	0.78	3	0.00	0	0.03	3	0.00	0

3.4 Discussion

Farmer experience

The introduction of EK21 into the ES scheme has allowed farmers to diversify their short term leys with benefits to soil structure and wider biodiversity. Some agronomic benefits have also been observed and most agreement holders were positive about the option both in terms of the environmental benefits and the compatibility with their existing farm management/rotation.

Short term leys have been suggested as a strategy for controlling herbicide resistant weeds (e.g. black-grass) and can reduce seed bank densities to 90% in two years (Moss & Lutman, 2013). Most of the holdings in the sample were mixed or livestock only. Only a small number were mainly arable and, perhaps as a consequence, few agreement holders had chosen the option for its contribution to weed control. This reflects opinions from the same sample of agreement holders at the start of their agreements (Woodcock *et al*., 2015). In order to achieve compatibility with the previous study of the option completed in the first year the option was available (Woodcock *et al*.) this work surveyed the same agreement holders where possible (89%). Early uptake of the option may have been predominantly amongst livestock farmers because incorporation into the rotation involves little change in practice. Uptake on arable holdings may have increased after the first year of option inclusion in ES. If the option can be shown to have positive benefits and to be manageable within an arable system, farmers may be encouraged to include this option in predominantly arable areas to increase habitat diversity.

Outcomes against requirements

The option was generally not meeting its requirements in terms of diversity and forb/legume cover. However, option parcels were much more likely to meet the prescription requirements than counterfactuals and summer flower and autumn seedhead counts indicate an increase in resource availability for pollinators and granivorous species, particularly on conventional systems where standard leys were particularly species poor. Orford *et al*. (2016) reported that modest increases in conventional grassland species richness were associated with significantly enhanced pollination services.

Although not assessed directly in this study, greater diversity of flowering species should result in resource provision over a longer period of time because species with different phenologies contribute at different times. This potential is of course modified by management, however the increase in the resting period from 3-5 weeks in ES to 'at least 5 weeks' under the equivalent option in CS is a positive move to encouraging a longer period of flowering and of different species.

Seed mix

Although there were some criticisms of the seed mix (forbs and legumes disappear) few agreement holders suggested that they would like more advice about the seed mix. However, when asked which elements of the prescription should be changed, one third would like to see changes to the seed mix. The rate at which individual species were sown was shown to be important in persistence of species in the sward.

Effects of other factors were generally small except for pH and soil organic carbon. Although declining legume and forb persistence over time were noted by a number of agreement holders, analysis of the botanical survey data revealed no effect of year of drilling on sown species persistence in any of the measures used.

The absence of a relationship between either sown species survival or the complete vegetation community and extractable P was surprising since grassland plant species richness has been reported as negatively related to soil P (e.g. Ceulemans *et al*., 2014) although the effect has not been consistently observed (Oerlemans *et al*., 2007).

Results suggest that improvements in the seed mixes could result in significant improvements to the outcomes. Beneficial changes could include:

- Reduced dominance of grasses
- Better selection of species which persist
- Greater differentiation of mixes depending on soil type etc.

However, the seed mixes are already considered expensive by some agreement holders. It seems likely that seed companies include a high proportion of grass seed in mixes to maintain a competitive price. This study has shown that some species in the mixes did not persist in any swards surveyed. More work is needed to develop cost-effective mixes that will deliver the required outcomes, either in a variety of situations, or as a series of different mixes for different soil types and conditions.

Benefits to soil quality

It was notable that there was no difference in VESS (Visual Evaluation of Soil Structure) score between option and arable counterfactual sites; and that no sites were 'compact' or 'very compact' despite being in an arable rotation and in some cases being down to grass for up to nine years (although most fields had been in the option for less than five years). This contrasts with a survey of 300 permanent grassland fields in England and Wales, in which 12% of soils were in 'poor' condition ('compact' or 'very compact'; Newell Price *et al*., 2013). This difference may be due to the longer period of time in which topsoils in permanent grassland fields can be impacted by livestock poaching or compression from agricultural machinery.

Although the option generally improved aggregate stability, site had a greater influence than management, demonstrating the importance of clay content and mineralogy on aggregate stability (Tisdall and Oades, 1982). Organic matter content also has an important influence, but takes many years to change (Johnston *et al*., 2009). Nevertheless, the results overall indicate that the "legume and herb-rich swards" option can be effective in improving soil structural stability when compared with land under an arable rotation.

Future uptake and option development

Agreement holders were very positive about the option, however field survey indicated that it rarely delivered the outcomes defined by the prescription requirements. Conversely one agreement holder would not include this option in a future agreement because it was not delivering against the requirements. Others would continue, but were either not aware or were not concerned that sward characteristics were not meeting the prescription requirements. Agri-environment payments are currently based on management practice rather than outcomes (the inclusion of outcome requirements in EK21 is unusual in mid/entry level schemes) and there is currently no payment penalty if outcomes are not achieved. If, under the new Environmental Land Management scheme being developed to replace CS as a result of EU exit, payments were based on outcomes, the requirements for EK21 would have to be considered carefully in the context of what is achievable and how the requirements might affect uptake of this option.

Conclusion

Although the expectations associated with the option were greater than the outcomes, the option does represent a positive contribution to wider farmland biodiversity. Greater benefits could result from changes to seed mixes, greater advice provision and, given the apparent lack of understanding of the prescription requirements, more emphasis on the outcomes.

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APPENDIX 1 – AGREEMENT HOLDER INTERVIEW SCHEDULE

Agreement Holder Questionnaire

A. Farm details & enterprises

1. Agreement number
2. Agreement holder name
3. Farm name
4. Organic/Conventional/Mixed
5. Enterprises
    - Livestock only, if yes, details (breeding, fattening, dairy etc.)
    - Mainly arable, if yes, details of crops and rotations (length and typical crops)
    - Mixed, if yes, details as above
6. Which enterprises are applicable to the EK21 fields
7. Has the option resulted in a change in farm practice (other than the option prescription) (detail)
8. General comments

B. Choice of option

Why did you choose this option – rank in order of importance (tick all that apply if that's not possible) and give details

- Fits with current farm management/rotation
- Similar to current grassland management
- Part of a rotation to control weeds
- Needed a grass break crop
- To improve soil structure
- Wildlife benefits
- Needed the points (ELS) /value (HLS)
- Recommended by adviser (details of organisation: e.g. NE, FWAG, ADAS, land agent....)
- Other (specify)

C. Management of the fields surveyed (in option and counterfactual – complete for each field)

1. Choice

Why did you choose this area for your EK21?

2. Information
    - Soil type (group)

SOIL GROUPS	TOPSOIL TEXTURES
Sandy and light silty soils	Sand, Loamy Sand, Sandy Loam, Sandy Silt Loam, Silt Loam
Medium and calcareous soils	Sandy Clay Loam, Clay Loam, Silty Clay Loam
Heavy soils	Sandy Clay, Clay, Silty Clay
Peaty	Peat/Peaty

3. Previous crop
    - Grassland (number of years since re-established; grazed or cut)
    - Arable crop (specify)
    - Herbicides applied to previous crop (active ingredient)

4. Cultivations post-harvest/pre-drilling
   i. Method of cultivation (plough, min till, none)
   ii. Depth of cultivation (cm)
5. Drilling
   i. Seed mix:
      - List sown species with individual seed rates (may need to calculate these from % of total)
   ii. Seed rate (kg/ha)
   iii. Source of seed:
      - Boston
      - Cotswold
      - DLF
      - Farmseeds
      - Horizon
      - Hurrells
      - IG
      - Kings
      - Nickerson
      - Oliver
      - Pearce
      - Shepherd
      - Other (specify)
   iv. Date of drilling (month and year)
   v. Method of seed sowing (drill, broadcast, slot seeded etc.)
   vi. Any other management around establishment
6. Management since establishment
   i. Rolling

Was the field rolled after drilling?

If yes, how many times

ii. Fertiliser/manure

Any applied since establishment (manure, slurry, lime). Rate with units

iii. Herbicide

Any applied since establishment (active ingredient, rate, method of application, year after establishment, month of application)

iv. Cutting

Is the field cut? Yes/no: This year, previous years

How many times a year: This year, previous years

Date(s) of cutting: this ear, previous years

For hay or silage: this year, previous years

v. Grazing

Is the field grazed? If yes, give details. This year and typical previous years

- Stock (cows, sheep, other (specify)) (no.ha)
- Period of grazing (no. of weeks and which months)

- Growth stage at the start of grazing (free text, but could be: pre-flowering; ryegrass/clover in flower; red clover in flower; specific (or not) height; sufficient biomass (how defined?); aftermath grazing – early regrowth; calendar date)

vi. Did the sward flower this year?

vii. How many years do you expect to retain the sward before re-establishing?

viii. Will you rotate the option or re-establish on the same ground?

7. Any other comments

D. Advice

Advice received

1. Did you receive any advice in addition to the information in the ES manuals
2. If no, was the information in the ES manuals sufficient to meet your needs yes, no, don't know (or would you have liked further guidance)
3. If yes, who was advice received from? (NE adviser, other adviser (specify), seed company (specify))
4. Was it one to one advice or a group event (detail)
5. What form what the advice given in (written, photographic/diagrams, workshop/demonstration, video)
6. What elements of the option management did you receive advice for (field choice, establishment, management, other - specify)
7. How useful was the advice? (very, fairly, a little, not at all)
8. Comments on value of advice

Future advice for those new to EK21

9. With hindsight, who would you have liked to receive advice from
10. Which elements of the management do you think you would most benefit from advice (e.g. field choice, establishment, management)
11. What format of advice would you like to see (e.g. one to one, presentation, workshop)
12. How would you like advice to be presented (e.g. written, photographs/diagrams, video, farm walk)

E. Experience with the option

1. Would you use this option again: yes, no, maybe (outline summary details)
2. What do you consider are the benefits of the option
3. What do you think are the negative aspects of the option

Some examples for responses to 2 and 3, but not exhaustive.

- Quality of forage/silage (nutrition, bloat, ewe fertility and physical properties of the biomass)
- Species mix (species or diversity)
- **Resting period (time, timing) Would they use the option more extensively without the restrictions on cutting/grazing**
- Impact on soil structure
- Weeds
- Wildlife

4. If the swards have been in place for more than 2 years, what changes have you observed in the sward composition?

- What do you think are the reasons for any changes (e.g. initial establishment, weather conditions, seed mix….)

5. Did you encounter anything unexpected/did anything surprise you about the option and how it developed?
6. Summarise what aspects of the prescription you think should be changed and why
7. Any further comments on your experience with the option

F. Would you manage the option differently in future?

If yes, which aspects and give details?

i. Redrilling frequency
ii. Species mix
iii. Cutting/grazing regime
iv. Fields chosen
v. Other

APPENDIX 2 – SOIL CHEMICAL CHARACTERISTICS

Table 32: Summary of soil pH statistics in arable counterfactual, grass counterfactual and option fields split by organic and conventional systems (SD = standard deviation)

	Soil pH			
	Mean	**Min**	**Max**	**SD**
Arable conventional counterfactual	6.8	5.8	8.1	0.8
Arable organic counterfactual	7.7	6.5	8.2	0.6
Grass conventional counterfactual	6.7	5.7	8.4	1.0
Grass organic counterfactual	7.1	6.2	8.4	0.8
Option conventional	6.8	5.7	8.1	0.8
Option organic	7.3	5.7	8.2	0.8
All samples	7.1	5.7	8.4	0.8

Table 33: Summary of soil extractable phosphorus (P) statistics in arable counterfactual, grass counterfactual and option fields split by organic and conventional systems (SD = standard deviation)

	Extractable P (mg/l)			
	Mean	**Min**	**Max**	**SD**
Arable conventional counterfactual	15	7	32	8
Arable organic counterfactual	15	4	45	13
Grass conventional counterfactual	16	5	47	13
Grass organic counterfactual	9	5	18	4
Option conventional	14	4	27	7
Option organic	13	4	82	14
All samples	13	4	82	11

Table 34: Summary of soil extractable potassium (K) statistics in arable counterfactual, grass counterfactual and option fields split by organic and conventional systems (SD = standard deviation)

	Extractable K (mg/l)			
	Mean	**Min**	**Max**	**SD**
Arable conventional counterfactual	160	41	295	94
Arable organic counterfactual	218	92	535	138
Grass conventional counterfactual	102	24	217	67
Grass organic counterfactual	168	35	293	83
Option conventional	139	44	368	80
Option organic	148	21	313	65
All samples	150	21	535	83

Table 35: Summary of soil extractable magnesium (Mg) statistics in arable counterfactual, grass counterfactual and option fields split by organic and conventional systems (SD = standard deviation)

	Extractable Mg (mg/l)			
	Mean	**Min**	**Max**	**SD**
Arable conventional counterfactual	249	51	698	253
Arable organic counterfactual	85	56	147	33
Grass conventional counterfactual	123	58	288	81
Grass organic counterfactual	121	33	330	105
Option conventional	203	46	718	192
Option organic	123	38	1079	187
All samples	153	33	1079	177

Table 36: Summary of clay content (%) statistics in arable counterfactual, grass counterfactual and option fields split by organic and conventional systems (SD = standard deviation)

	Clay content (%)			
	Mean	**Min**	**Max**	**SD**
Arable conventional counterfactual	28	24	35	3
Arable organic counterfactual	29	23	41	6
Grass conventional counterfactual	30	23	50	8
Grass organic counterfactual	28	18	46	9
Option conventional	30	4	60	11
Option organic	27	8	50	8
All samples	28	4	60	9

Table 37: Summary of soil total nitrogen (%) statistics in arable counterfactual, grass counterfactual and option fields split by organic and conventional systems (SD = standard deviation)

	Total nitrogen by Dumas (%)			
	Mean	**Min**	**Max**	**SD**
Arable conventional counterfactual	0.21	0.14	0.35	0.06
Arable organic counterfactual	0.34	0.23	0.42	0.06
Grass conventional counterfactual	0.31	0.14	0.69	0.17
Grass organic counterfactual	0.32	0.14	0.49	0.12
Option conventional	0.32	0.14	0.59	0.13
Option organic	0.31	0.12	0.58	0.11
All samples	0.31	0.12	0.69	0.12

Table 38: Summary of total soil organic carbon (%) statistics in arable counterfactual, grass counterfactual and option fields split by organic and conventional systems (SD = standard deviation)

	Total organic carbon by Dumas (%)			
	Mean	**Min**	**Max**	**SD**
Arable conventional counterfactual	1.92	1.45	2.75	0.38
Arable organic counterfactual	3.01	2.18	4.06	0.70
Grass conventional counterfactual	2.56	1.28	4.95	1.21
Grass organic counterfactual	2.75	1.74	4.54	0.72
Option conventional	3.01	1.27	5.44	1.15
Option organic	2.66	1.11	5.93	0.84
All samples	2.72	1.11	5.93	0.95

APPENDIX 3 – FLOWER AND SEEDHEAD SPECIES LISTS

Table 39: Mean number of flowers/seedheads (m^{-2}) recorded in summer for individual species of potential benefit to pollinators

	ELS				OELS			
	Option (n=40)		Counterfactual (n=13)		Option (n=37)		Counterfactual (n=13)	
Species	No. flowers	No. of occurrences	No. flowers	No. of occurrences	No. flowers	No. of occurrences	No. flowers	No. of occurrences
Summer								
Achillea millefolium	0.68	24	0.00	0	0.46	21	0.02	4
Anagallis arvensis	0.01	4	0.00	1	0.00	3	0.00	1
Bellis perennis	0.03	4	0.00	0	0.00	1	0.00	2
Capsella bursa-pastoris	0.00	2	0.00	0	0.54	1	0.00	0
Carduus nutans	0.00	0	0.00	0	0.10	1	0.00	0
Centaurea nigra	2.05	13	0.00	0	0.39	12	0.00	0
Cerastium fontanum	0.43	19	0.00	3	0.12	11	0.94	7
Cichorium intybus	27.86	17	0.00	1	68.32	30	0.45	2
Cirsium arvense	0.29	11	0.00	1	0.02	21	0.00	7
Cirsium palustre	0.00	0	0.00	0	0.03	1	0.00	1
Cirsium vulgare	0.46	7	0.00	1	0.33	8	0.00	3
Convolvulus arvensis	0.02	4	0.75	1	0.17	6	0.00	1
Crepis capillaris	1.42	8	0.37	2	0.53	5	0.00	1
Crepis vesicaria	0.00	0	0.00	0	0.46	3	0.00	0
Geranium dissectum	0.00	2	0.00	0	0.08	1	0.00	2
Geranium molle	0.00	2	0.00	2	0.14	3	0.00	0
Gnaphalium uliginosum	0.45	1	0.00	0	0.00	0	0.00	0
Hypochaeris radicata	0.00	3	0.00	1	0.08	5	0.00	0
Lapsana communis	0.00	0	0.02	1	4.24	1	0.00	0
Leontodon autumnalis	0.19	1	0.00	0	0.09	5	0.00	0
Leucanthemum vulgare	0.59	4	0.00	1	0.00	1	0.00	0
Linum catharticum	0.06	1	0.00	0	0.00	2	0.00	0
Lotus corniculatus	18.58	22	0.09	1	12.67	21	0.00	0
Matricaria discoidea	0.14	2	0.00	0	0.00	0	0.00	0

Matricaria recutita	0.00	0	0.00	0	0.30	1	0.00	1
Medicago lupulina	0.69	3	0.03	1	6.05	9	0.00	0
Medicago sativa	1.39	3	0.00	0	8.16	3	0.00	0
Melilotus officinalis	0.02	1	0.00	0	2.61	4	0.00	0
Myosotis arvensis	0.00	1	0.00	0	0.02	1	0.00	0
Odontites vernus	0.00	0	1.37	1	0.00	0	0.00	1
Onobrychis viciifolia	0.60	6	0.00	0	1.05	13	0.00	1
Orobanche minor	0.03	2	0.00	0	0.14	3	0.00	0
Persicaria maculosa	0.75	3	0.00	0	0.00	0	0.00	0
Petroselinum crispum	0.00	0	0.00	0	0.23	2	0.00	0
Phacelia tanacetifolia	0.01	1	0.00	0	0.00	0	0.00	0
Plantago lanceolata	2.12	26	0.00	3	1.51	25	0.11	4
Plantago major	0.00	5	0.00	2	0.06	9	0.00	6
Polygonum aviculare	0.10	5	0.00	0	0.05	2	0.00	0
Prunella vulgaris	0.19	3	0.00	1	0.60	7	1.46	3
Ranunculus repens	0.59	25	0.03	5	0.76	17	3.29	7
Rumex crispus	0.01	6	0.00	0	0.00	9	0.00	2
Sanguisorba minor	0.16	15	0.00	0	0.48	22	0.00	1
Sanguisorba sp.	0.01	2	0.00	0	0.00	1	0.00	0
Senecio squalidus	0.03	2	0.00	0	0.00	0	0.00	0
Sherardia arvensis	0.00	0	0.00	0	0.03	6	0.00	0
Silaum silaus	0.01	1	0.00	0	0.02	1	0.00	0
Sinapis arvensis	0.00	1	0.00	0	0.97	2	0.00	0
Sonchus arvensis	0.00	1	0.00	0	0.09	3	0.00	0
Sonchus asper	0.07	5	0.00	0	2.46	1	0.00	1
Sonchus oleraceus	0.01	1	0.00	2	0.00	1	0.00	0
Stellaria media	0.18	5	0.00	1	0.00	1	0.00	0
Taraxacum officinale agg.	0.00	28	0.00	8	0.03	20	0.00	7
Trifolium campestre	0.04	2	0.00	1	0.00	1	0.00	0
Trifolium dubium	0.00	2	0.05	1	0.00	3	0.00	0
Trifolium hybridum	0.53	11	0.00	0	1.12	10	0.00	2
Trifolium pratense	21.98	28	0.51	2	19.70	30	10.18	6
Trifolium repens	11.95	37	7.34	8	43.12	29	44.37	11

Trifolium sp.	0.02	3	0.00	0	0.00	1	0.00	0
Tripleurospermum inodorum	0.01	2	0.00	0	0.88	4	0.00	0
Tripleurospermum sp.	0.09	3	0.00	0	0.00	0	0.00	0
Veronica chamaedrys	0.01	3	0.00	0	0.00	2	0.08	2
Veronica persica	0.00	0	0.00	1	0.10	3	0.00	1
Veronica serpyllifolia	0.00	0	0.00	0	0.01	2	0.00	2
Vicia cracca	0.03	1	0.00	1	0.00	0	0.00	0
Viola arvensis	0.03	4	0.00	0	0.00	0	0.00	1

Table 40: Mean number of seedheads (m^{-2}) recorded in autumn for individual species

	ELS				**OELS**			
	Option (n=40)		**Counterfactual (n=13)**		**Option (n=37)**		**Counterfactual (n=13)**	
Species	**No. seedheads**	**No. of occurrences**	**No. seedheads**	**No. of occurrences**	**No. seedheads**	**No. of occurrences**	**No. seedheads**	**No. of occurrences**
Autumn								
Achillea millefolium	0.78	3	0.00	0	0.03	3	0.00	0
Agrostis capillaris	1.47	3	0.00	0	0.03	1	0.00	0
Agrostis sp.	0.13	2	0.00	0	0.00	0	0.00	0
Alopecurus geniculatus	0.32	1	0.00	0	0.00	0	0.00	0
Arctium lappa	0.00	0	0.00	0	0.13	1	0.00	0
Arrhenatherum elatius	0.00	0	0.00	0	0.07	1	0.00	0
Bellis perennis	0.03	3	0.00	0	0.01	2	0.00	0
Bromus hordeaceus	0.01	1	0.00	0	0.00	0	0.00	0
Carduus nutans	0.00	0	0.00	0	0.05	1	0.00	0
Centaurea nigra	2.02	6	0.00	0	0.18	2	0.00	0
Cerastium fontanum	0.31	5	0.00	0	0.06	2	0.00	0
Chenopodium album	0.00	0	0.00	0	0.03	1	0.00	0
Cichorium intybus	27.54	6	0.00	0	17.93	14	0.00	0
Cirsium arvense	0.36	3	0.00	0	0.00	0	0.00	0

Cirsium palustre	0.00	0	0.00	0	0.00	0	0.15	1
Cirsium vulgare	0.00	0	0.00	0	0.00	0	0.08	1
Crepis capillaris	0.78	2	0.06	1	0.00	0	0.00	0
Crepis vesicaria	0.00	0	0.00	0	0.05	1	0.00	0
Cynosurus cristatus	0.24	3	0.00	0	0.09	2	0.00	0
Dactylis glomerata	0.13	4	0.03	1	1.66	6	0.02	1
Daucus carota	0.04	1	0.00	0	0.02	1	0.00	0
Deschampsia cespitosa	0.29	1	0.00	0	0.00	0	0.00	0
Elytrigia repens	0.00	0	0.00	0	0.01	1	0.00	0
Epilobium sp.	0.11	1	0.00	0	0.00	0	0.00	0
Erigeron acer	0.02	1	0.00	0	0.00	0	0.00	0
Festuca rubra	0.04	1	0.00	0	0.00	0	0.00	0
Festuca trachyphylla/brevipila	0.28	1	0.00	0	0.00	0	0.00	0
Holcus lanatus	0.14	2	0.00	0	0.00	0	0.00	0
Hypericum perforatum	0.00	0	0.62	1	0.00	0	0.00	0
Hypochaeris radicata	0.00	0	0.00	0	0.06	2	0.00	0
Juncus acutiflorus	0.00	0	0.00	0	0.00	0	0.12	1
Lapsana communis	0.00	0	0.00	0	3.08	2	0.00	0
Leontodon autumnalis	0.01	1	0.00	0	0.00	0	0.00	0
Leucanthemum vulgare	0.02	1	0.00	0	0.00	0	0.00	0
Lolium multiflorum	0.00	0	0.03	1	0.00	0	0.03	1
Lolium perenne	1.58	6	0.00	0	0.42	9	0.60	5
Lolium sp.	0.03	1	0.00	0	0.00	0	0.00	0
Lotus corniculatus	0.90	4	0.00	0	1.05	2	0.00	0
Matricaria discoidea	0.07	2	0.00	0	0.00	0	0.00	0
Medicago lupulina	0.01	1	0.00	0	0.24	2	0.02	1
Medicago sativa	0.00	0	0.00	0	0.17	1	0.00	0
Melilotus officinalis	0.00	0	0.00	0	4.65	2	0.00	0
Myosotis sp.	0.00	0	0.00	0	0.00	0	0.14	1
Odontites vernus	0.00	0	0.14	1	0.00	0	0.00	0
Onobrychis viciifolia	0.10	2	0.00	0	1.24	4	0.00	0
Origanum vulgare	0.00	0	0.05	1	0.00	0	0.00	0
Orobanche minor	0.00	0	0.00	0	0.05	1	0.00	0

Papaver rhoeas	0.00	0	0.00	0	0.04	1	0.00	0
Phleum pratense	0.51	2	0.00	0	0.85	5	0.02	1
Picris echioides	0.03	1	0.00	0	0.08	1	0.00	0
Plantago lanceolata	0.57	7	0.00	0	1.20	13	0.23	2
Plantago major	0.00	0	0.02	1	0.01	1	0.00	0
Poa annua	0.30	4	0.00	0	0.16	3	0.05	3
Poa pratensis	0.02	1	0.00	0	0.00	0	0.00	0
Poa sp.	0.03	1	0.00	0	0.00	0	0.00	0
Poa trivialis	0.03	1	0.00	0	0.00	0	0.00	0
Prunella vulgaris	0.17	1	0.00	0	0.06	2	0.00	0
Rumex crispus	0.00	0	0.00	0	0.03	3	0.00	0
Rumex obtusifolius	0.20	2	0.00	0	0.03	2	0.00	0
Sanguisorba minor	0.02	1	0.00	0	0.01	2	0.00	0
Senecio jacobaea	0.00	0	0.06	1	0.00	0	0.00	0
Senecio vulgaris	0.00	0	0.00	0	0.03	1	0.00	0
Silaum silaus	0.00	0	0.00	0	0.08	2	0.00	0
Silene latifolia	0.00	0	0.00	0	0.03	1	0.00	0
Sonchus asper	0.04	2	0.00	0	0.00	0	0.00	0
Stellaria media	0.14	3	0.00	0	0.00	0	0.00	0
Taraxacum officinale agg.	0.06	5	0.26	1	0.12	9	0.15	4
Trifolium hybridum	0.16	2	0.00	0	0.30	3	0.00	0
Trifolium incarnatum	0.01	1	0.00	0	0.00	0	0.00	0
Trifolium pratense	0.45	8	0.00	0	6.23	7	0.35	2
Trifolium repens	0.03	2	0.00	0	0.28	5	0.05	2
Tripleurospermum sp.	0.34	1	0.00	0	0.00	0	0.00	0
Triticum aestivum	0.00	0	0.00	0	0.45	1	0.00	0
Veronica arvensis	0.01	1	0.00	0	0.00	0	0.00	0
Veronica chamaedrys	0.01	1	0.00	0	0.00	0	0.00	0
Veronica persica	0.00	0	0.00	0	0.75	3	0.02	1
Vicia sp.	0.00	0	0.00	0	0.00	0	0.15	1

APPENDIX 4 – FULL MODEL OUTPUTS FOR PRESENCE/ABSENCE AND % COVER WHERE RECORDED

Probability of species being present in the sward

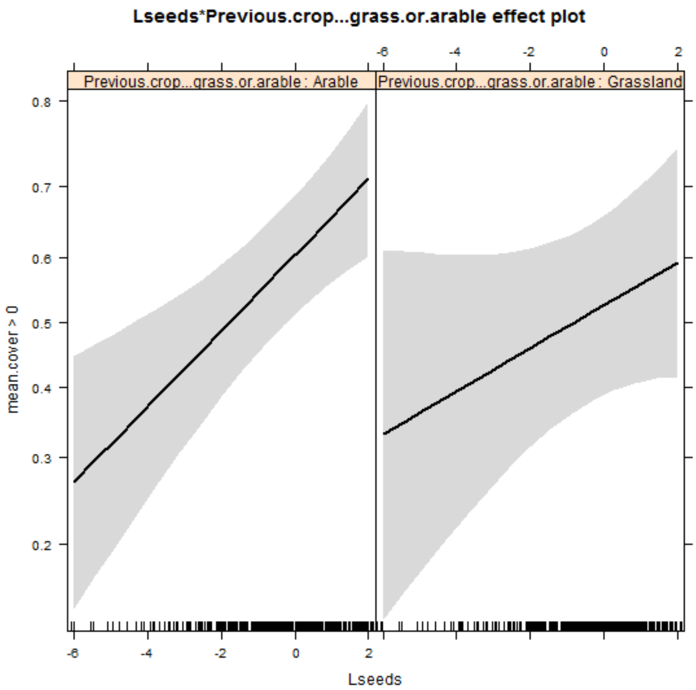

Figure 49: Effect of previous crop on basic model for probability of presence of plant

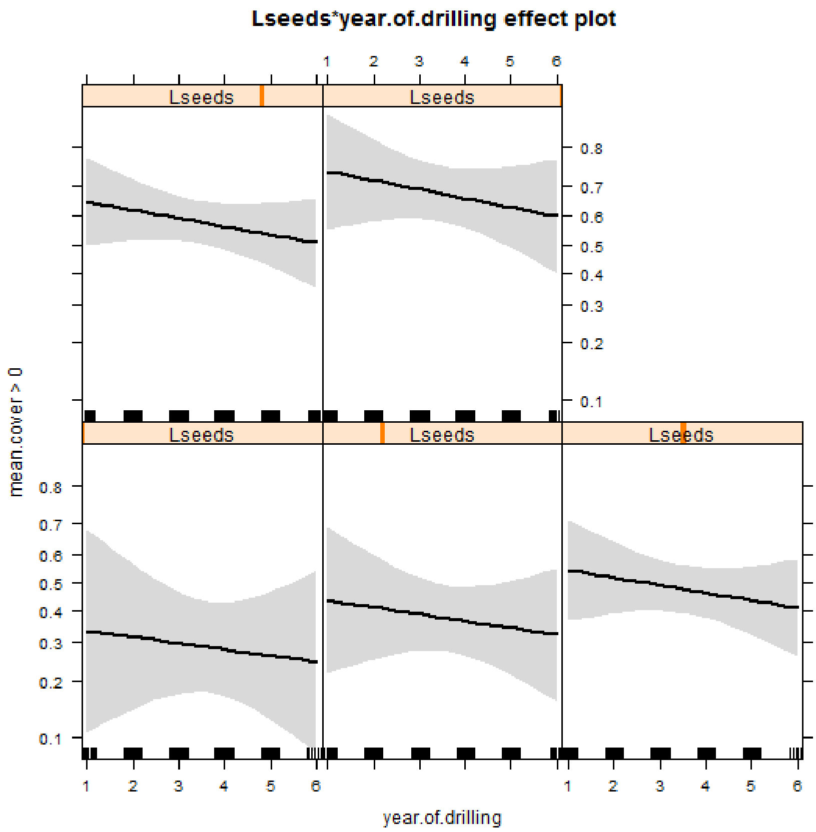

Figure 50: Effect of drilling year on basic model for probability of presence of plant (years since drilling).

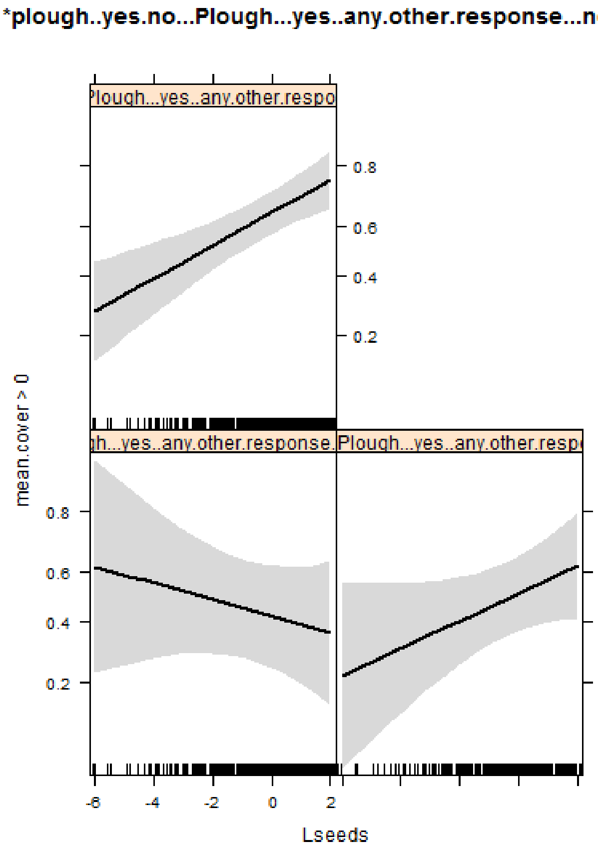

Figure 51: Effect of tillage method crop on basic model for probability of presence of plant. Minimum tillage bottom left, other bottom right, plough top.

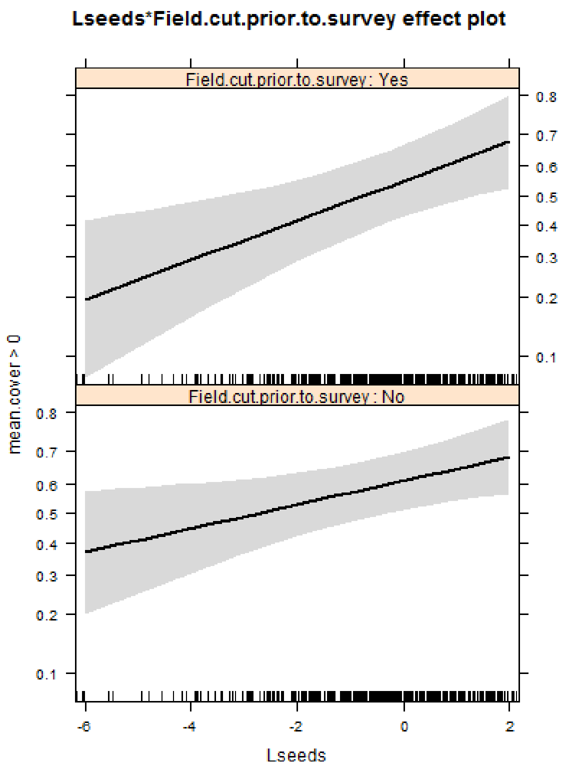

Figure 52: Effect of cutting prior to survey on basic model for probability of presence of plant

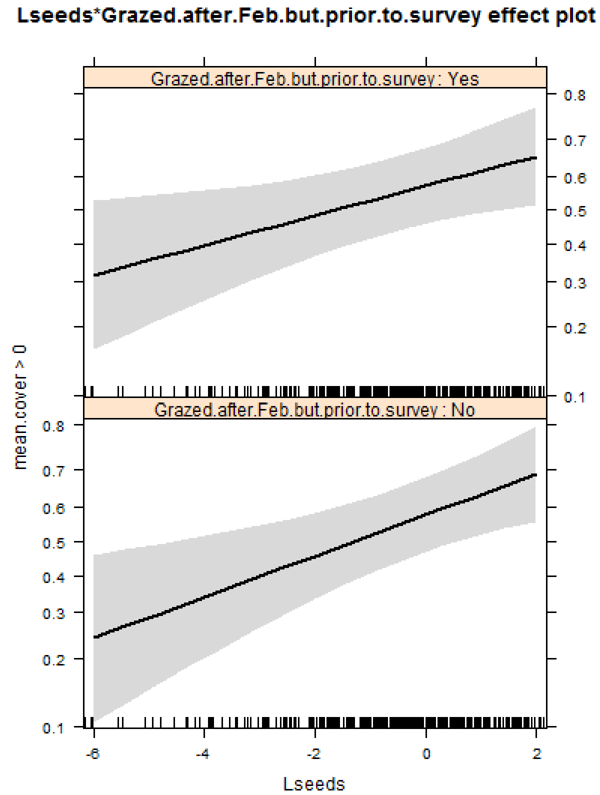

Figure 53: Effect of grazing prior to survey on basic model for probability of presence of plant

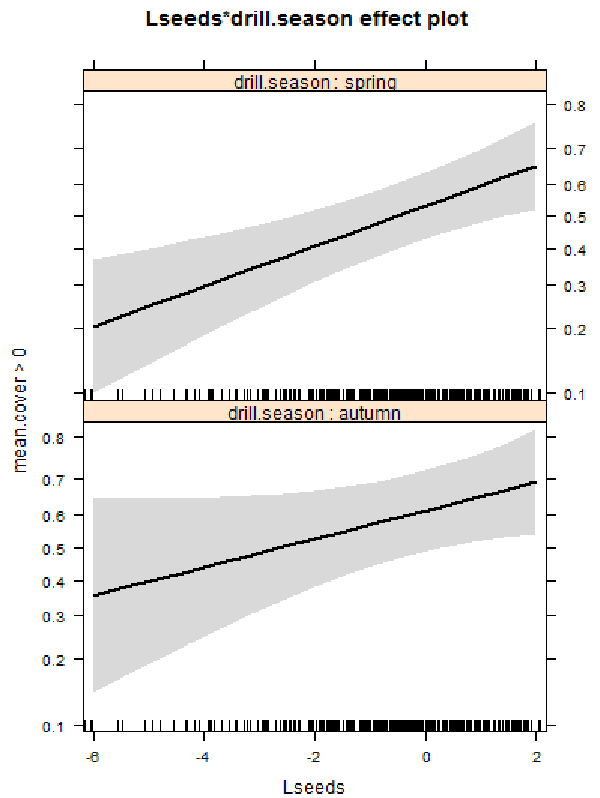

Figure 54: Effect of drill season on basic model for probability of presence of plant

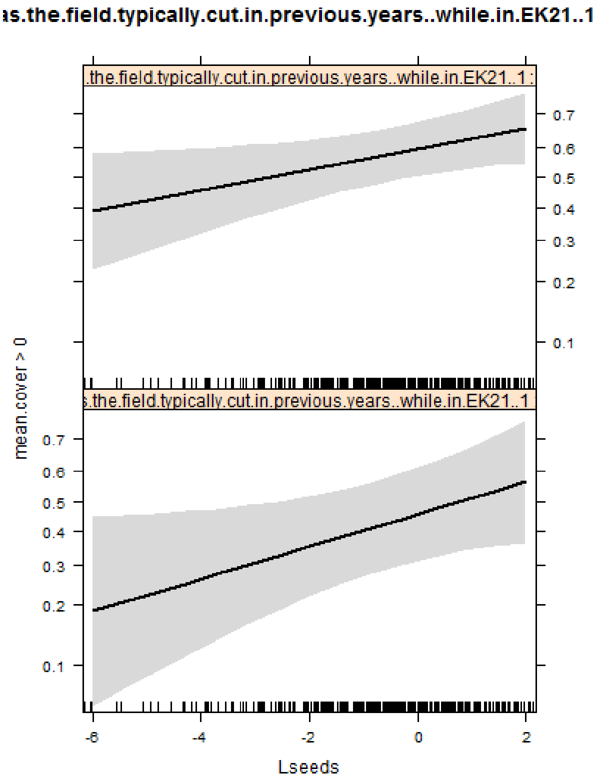

Figure 55: Effect of cutting crop in previous years on basic model for probability of presence of plant.

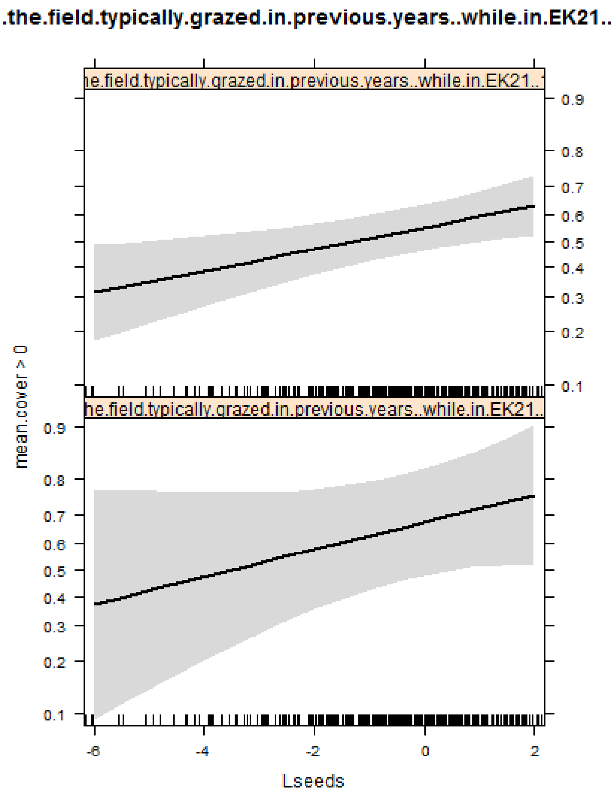

Figure 56: Effect of grazing crop in previous years on basic model for probability of presence of plant

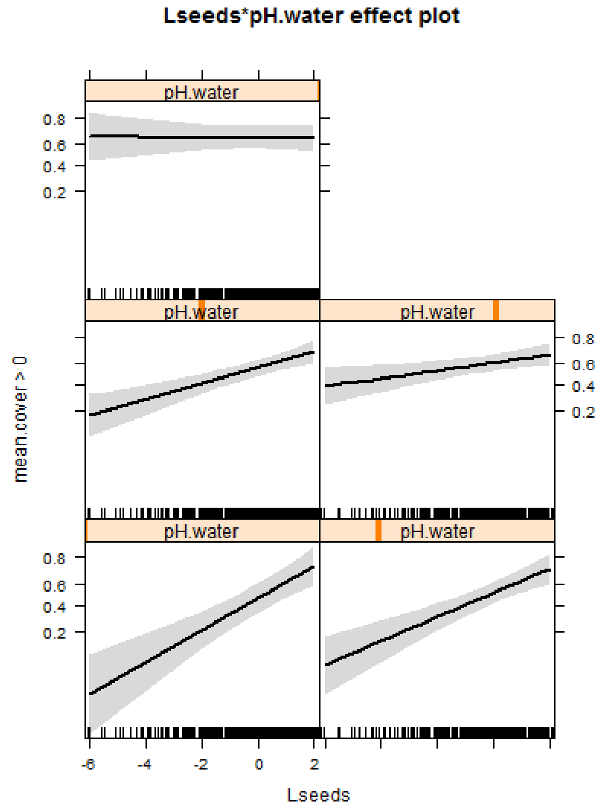

Figure 57: Effect of soil pH on basic model for probability of presence of plant. Soil pH increases from bottom left to top plot.

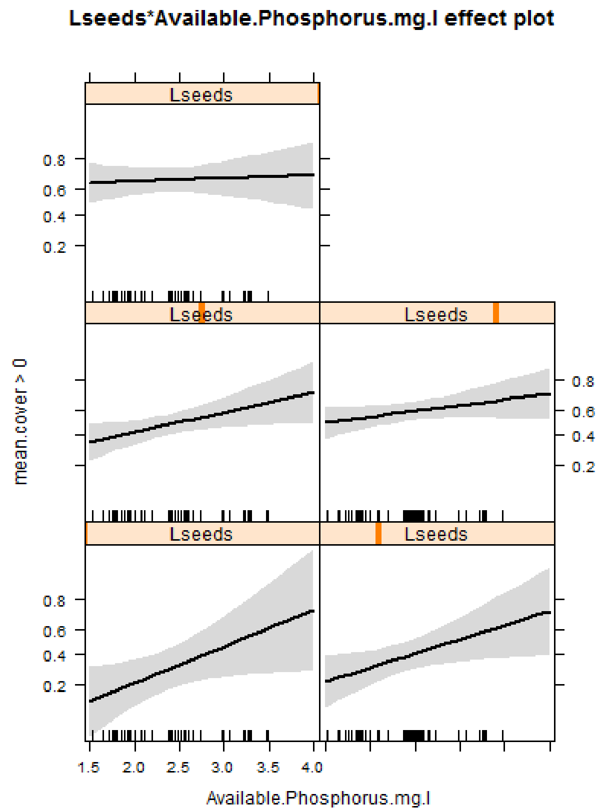

Figure 58: Effect of available phosphorous on basic model for probability of presence of plant. P content increases from bottom left to top plot.

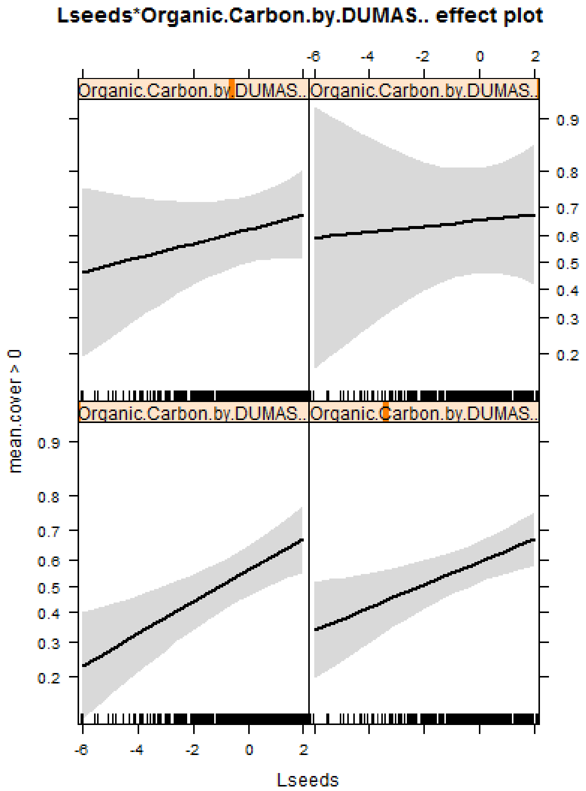

Figure 59: Effect of available phosphorous on basic model for probability of presence of plant. Organic C increases from bottom left to top right plot.

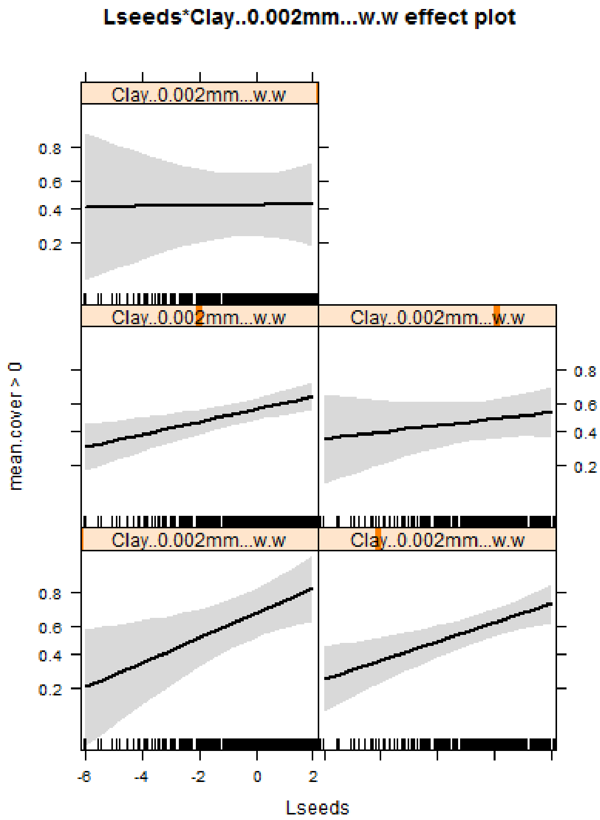

Figure 60: Effect of clay on basic model for probability of presence of plant. Clay content increases from bottom left to top plot.

Percent cover where a species was recorded

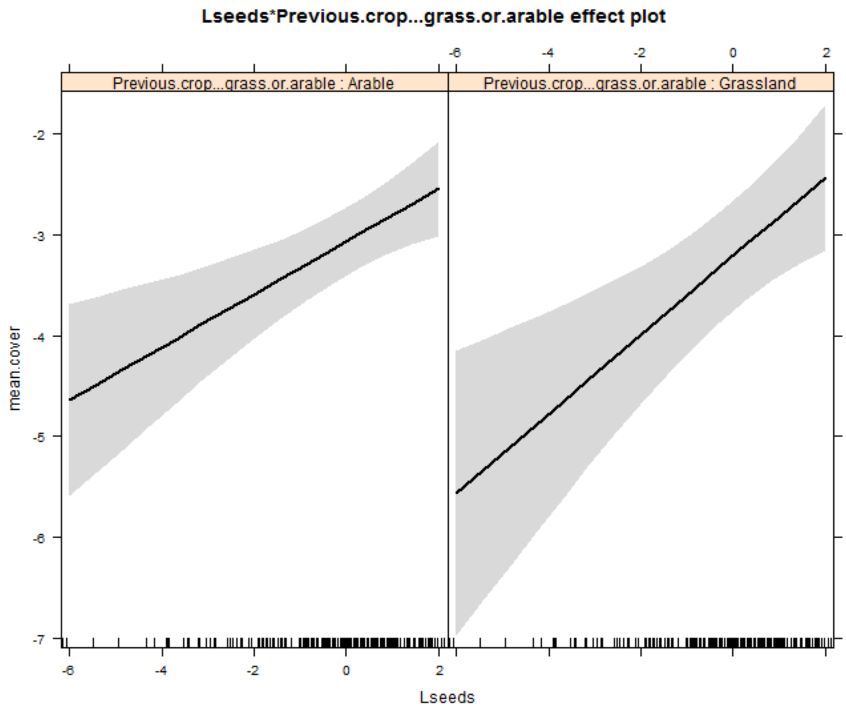

Figure 61: Effect of previous crop on basic model for coverage

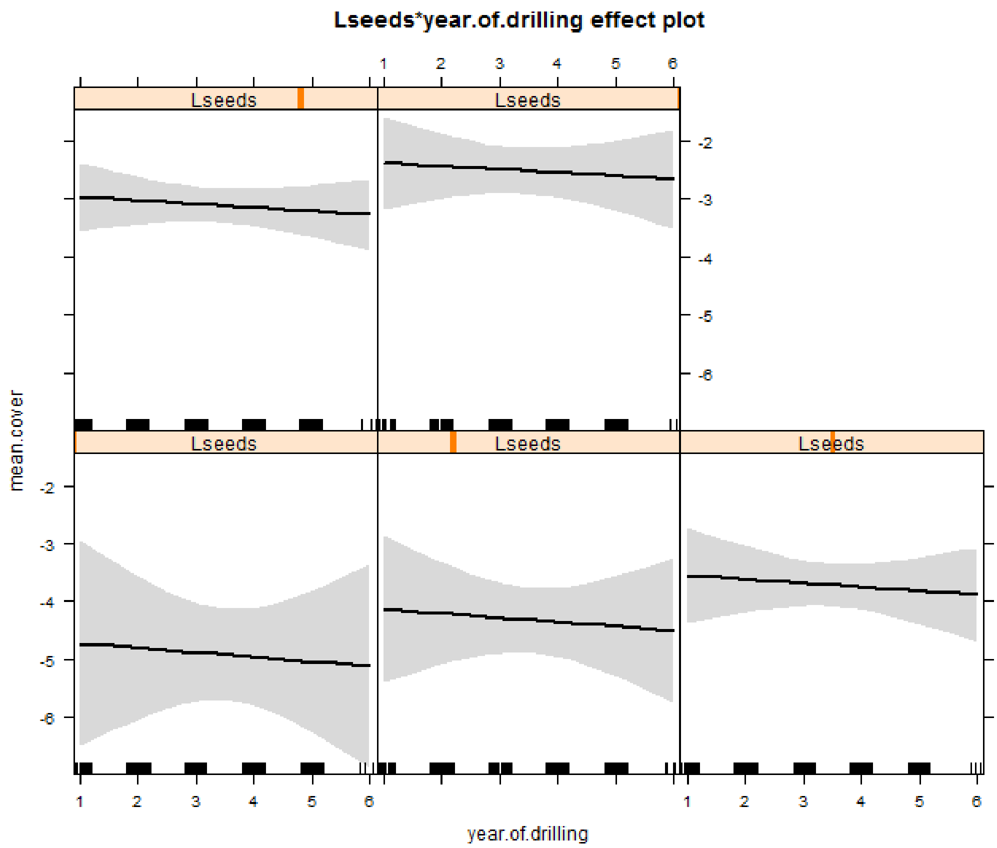

Figure 62: Effect of drilling year on basic model for coverage (years since drilling).

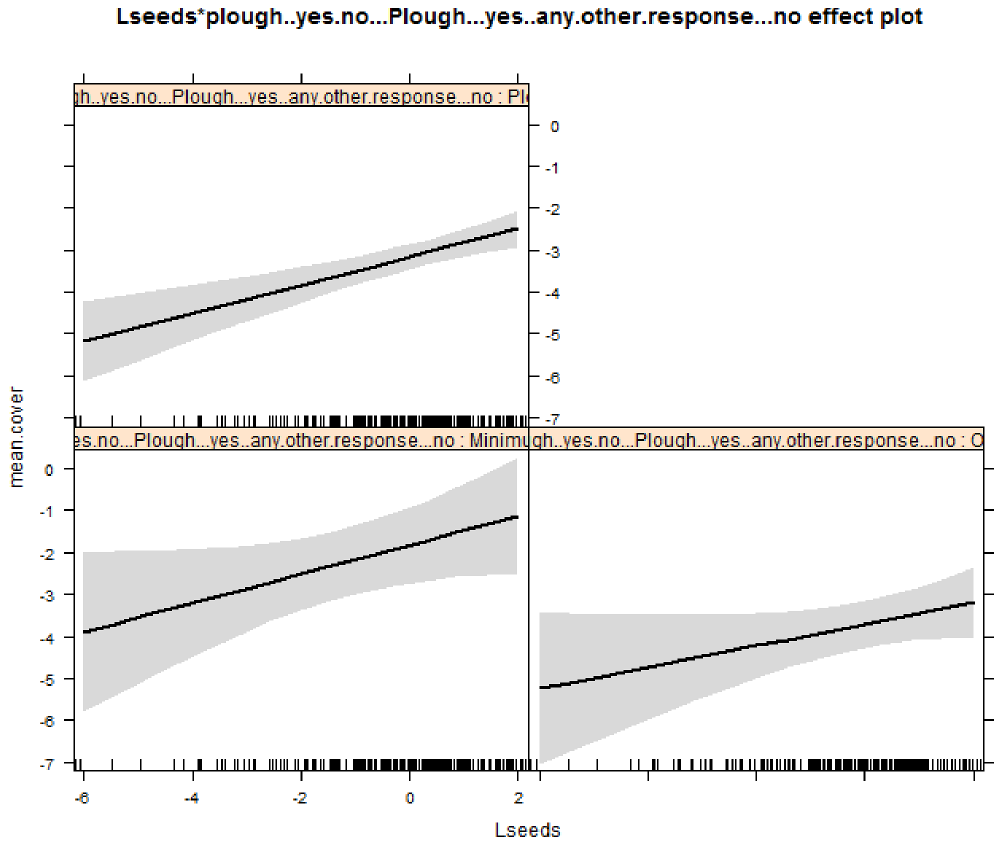

Figure 63: Effect of tillage method crop on basic model for coverage (minimum tillage bottom left, other bottom right, plough top).

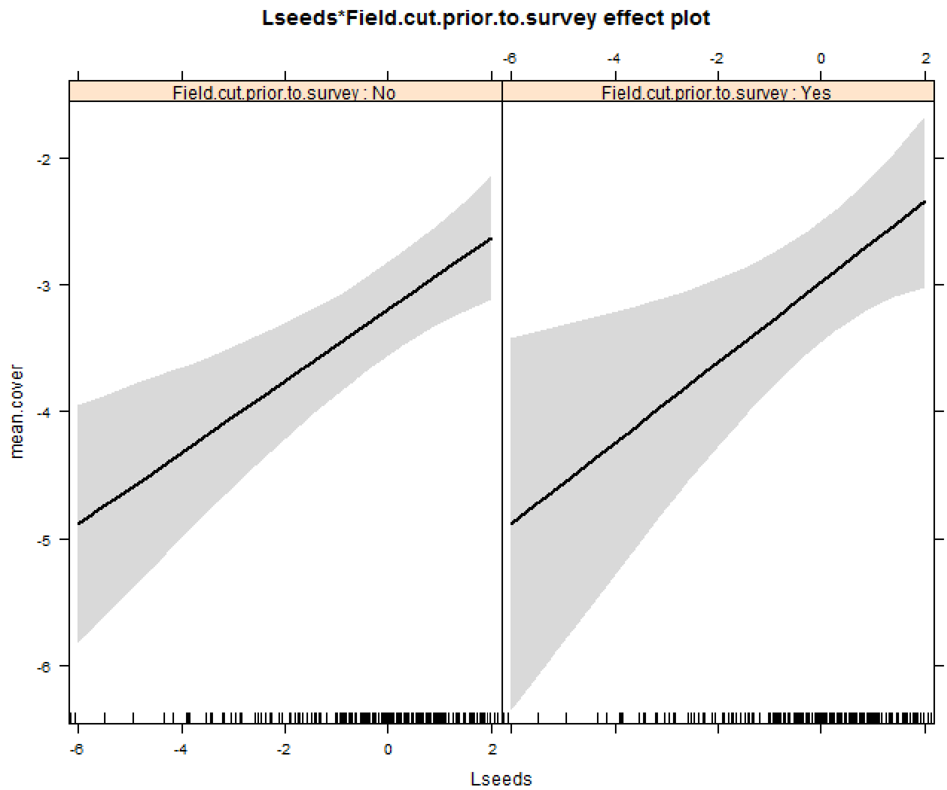

Figure 64: Effect of cutting prior to survey on basic model for coverage

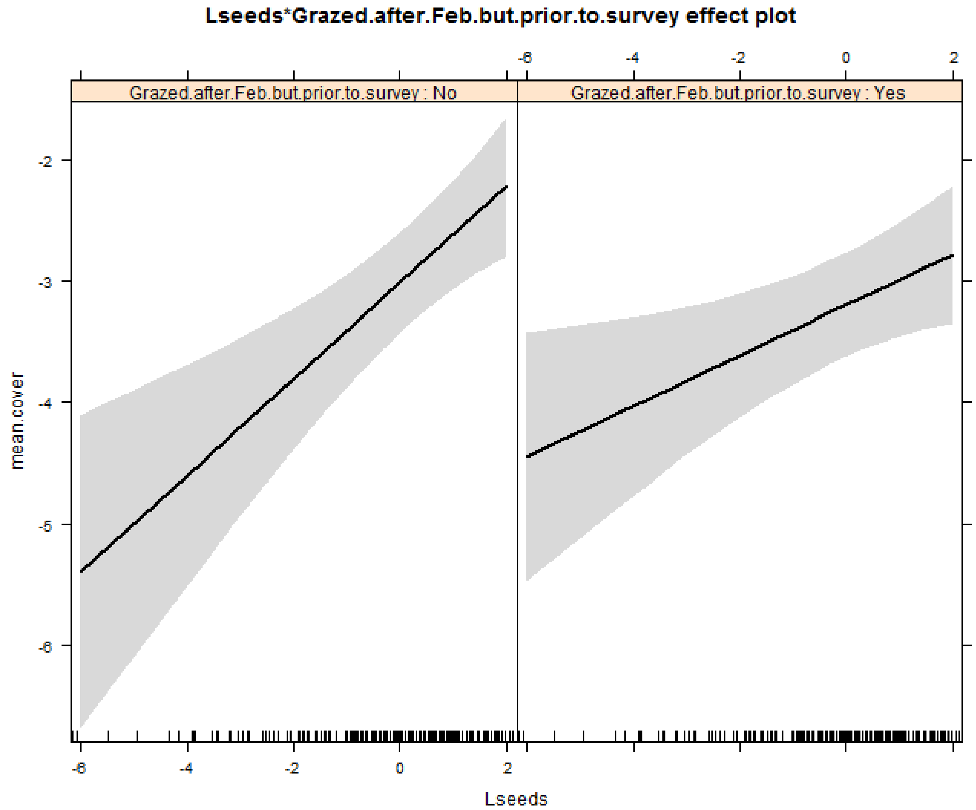

Figure 65: Effect of grazing prior to survey on basic model for coverage

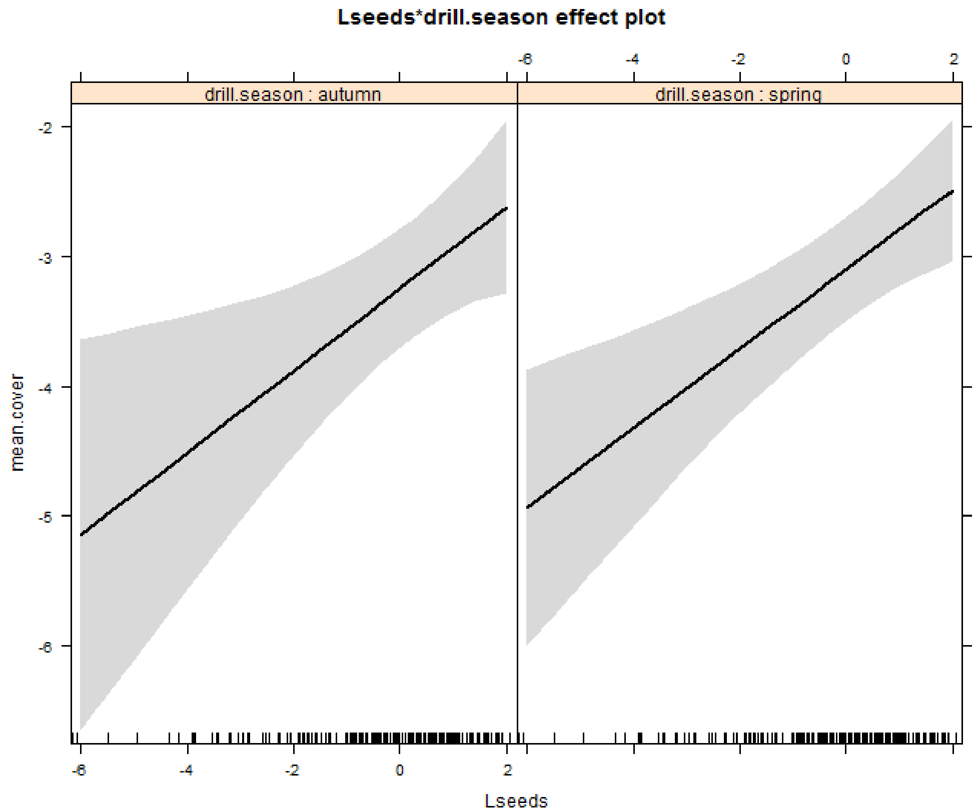

Figure 66: Effect of drill season on basic model for coverage

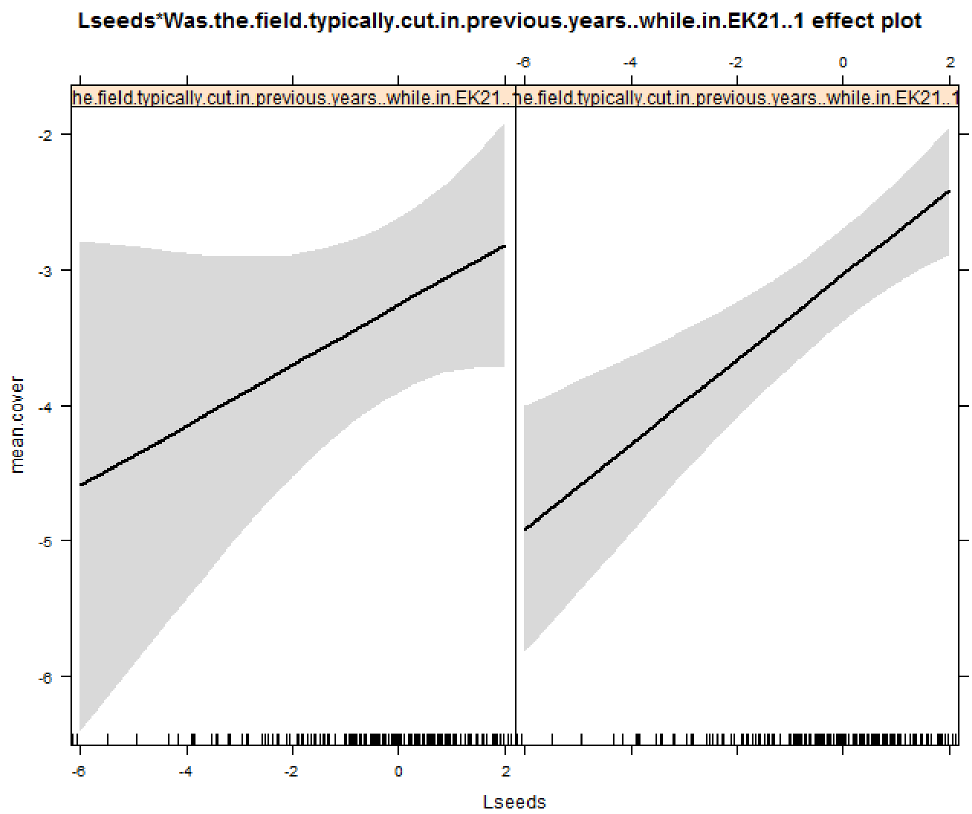

Figure 67: Effect of cutting crop in previous years on basic model for coverage. Left = no; right = yes.

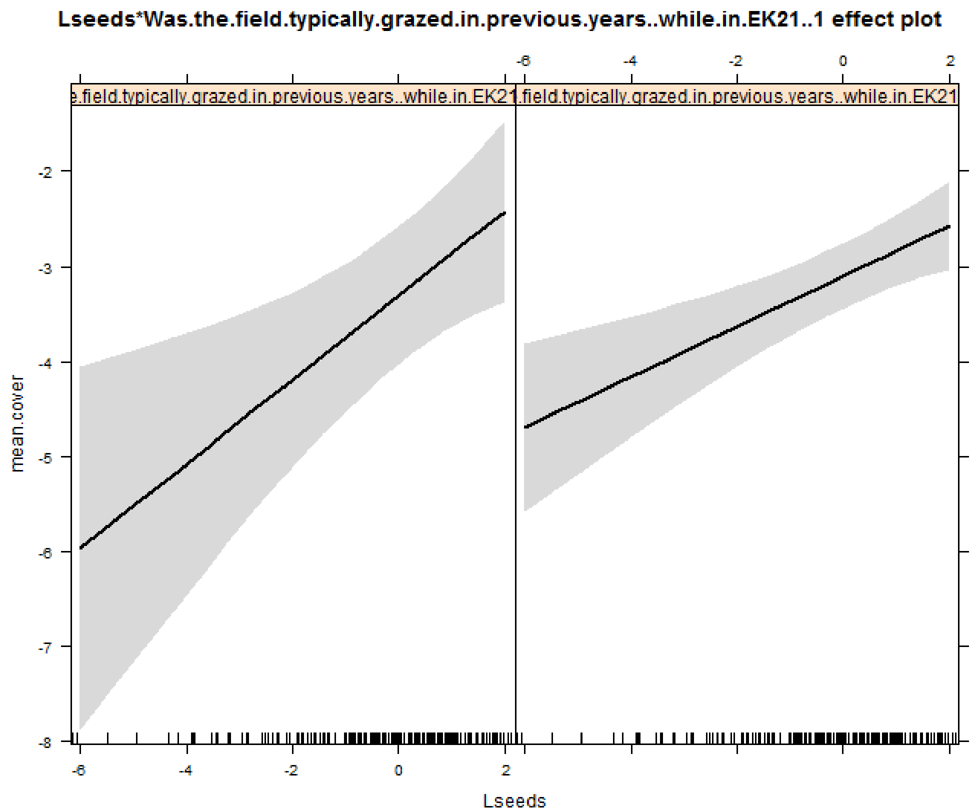

Figure 68: Effect of grazing crop in previous years on basic model for coverage. Left = no; right = yes.

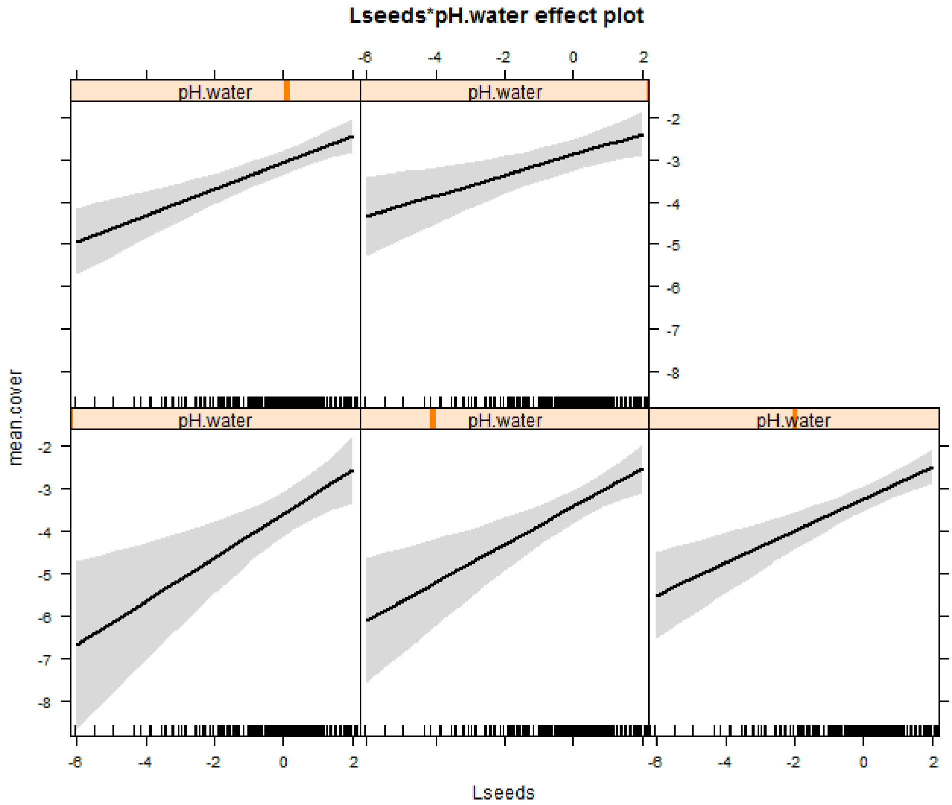

Figure 69: Effect of soil pH on basic model for coverage. pH increases from bottom left to top centre plot.

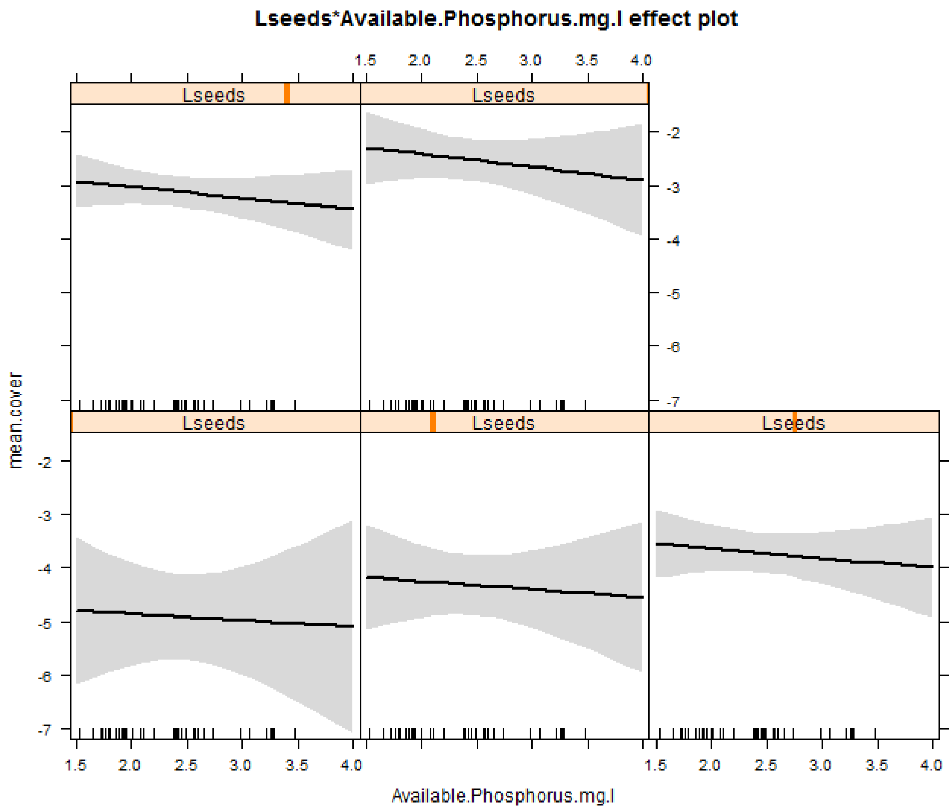

Figure 70: Effect of available phosphorous on basic model for coverage. P content increases from bottom left to centre top plot.

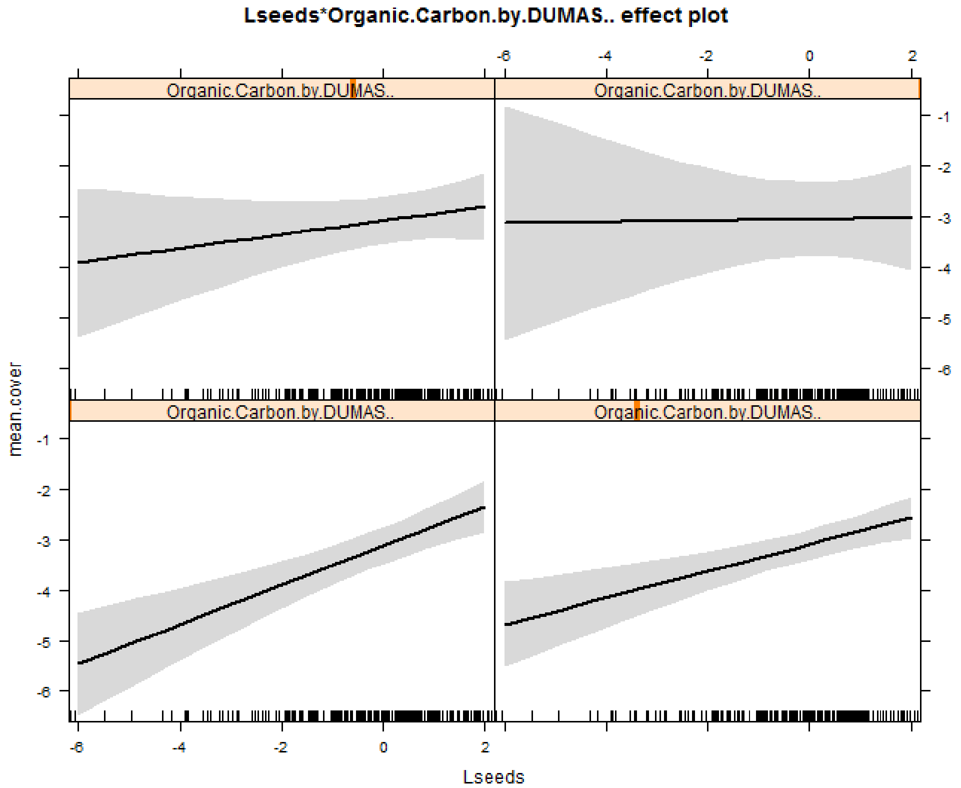

Figure 71: Effect of organic carbon on basic model for coverage. Organic C content increases from bottom left to top right plot.

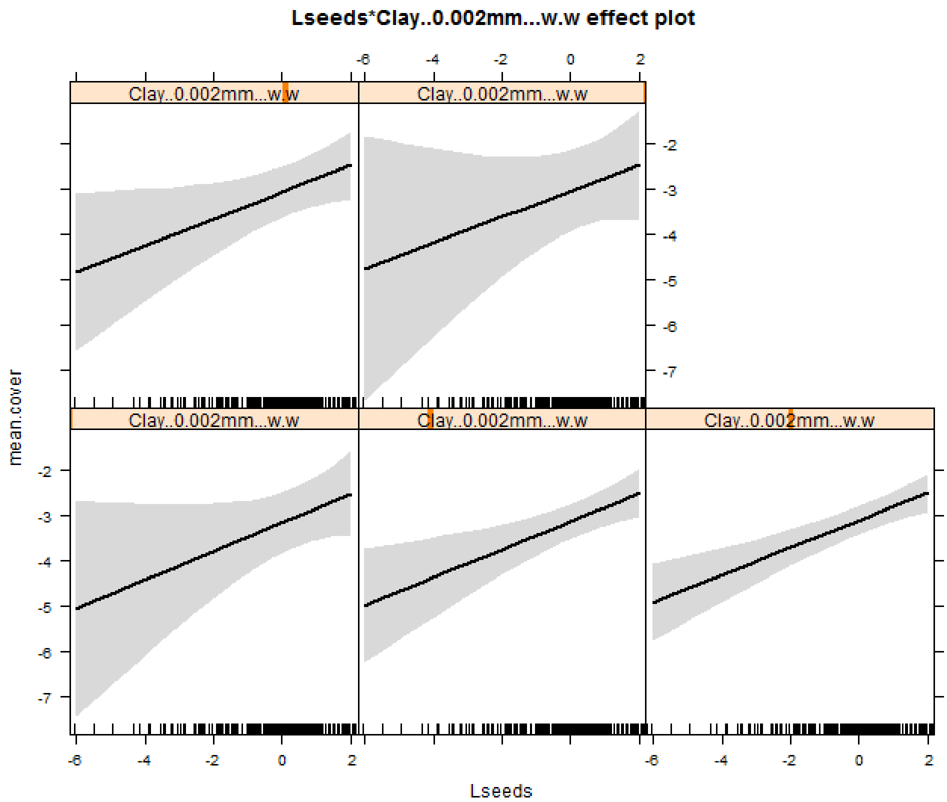

Figure 72: Effect of clay on basic model for coverage. Clay content increases from bottom left to centre top plot.