<u>An Investigation Testing the Null Hypothesis "The Heather *(Calluna vulgaris)* on the British Camp Area of the Malvern Hills was Introduced."</u>

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Cover photograph; *Calluna vulgaris* in British Camp, August 2003.

Abstract.

The study presented has been carried out to try to answer the null hypothesis The Heather *(('aMina vulgaris)* on the British Camp Area of the Malvern Hills was Introduced- in response to suggestions made on its origin. Systematic field work was carried out, with the extent of the surveyed area containing *Calluna vulgaris* mapped using GPS and GIS. National Vegetation Clasification (NVC) sampling procedures were carried out on the stand of acid grassland vegetation as described in *British Nam Communities* (Rodwell. 1992). The collected data was analysed using various computer programs; DECORANA (detrended correspondence analysis), TWINSPAN (two-way indicator species analysis) and MATCH goodness of fit test. DECORANA highlighted environmental gradients in the very homogenous site, influencing plant species assemblages. with colonising species through to more mesotrophic grassland species. TWINSPAN separated the samples into six groups of varying homogeneity and MATCH matched the groups to number of NVC communities, with very little between rankings and each with numerous marked discrepancies on the vegetation composition of the site. The occurrence of *Callum, vulgaris* in any of the matched communities described by Rodwell (1992). is not out of character, but never dominates or attains constancy. Site character and vegetation composition suggested the area most closely matched the NVC Ule subcommunity, also sharing affinities with U20 and U4 communities or possibly an additional subcommunity to the Ul community not described by Rodwell (1992). This study has not proved anything in terms of the origin of the C. *vulgaris* present in the British Camp area of the Malvern Hills. but has strengthened ideas and similar conclusions made by previous studies on the hills regarding the uniqueness of plant communities in the Malvern range. aiding for a more informed management of the hills.

Keywords: *C'allitiia vulgaris, Acid grasslands, 13rnisli Camp, National I egelalion (lassificalion* OTC), *analysis, DECORA* NA, ITV/ASP.4N, *AffIT(71, Grafing*.

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• 1. Introduction.

The aim of this study is to provide a possible explanation for the presence of *Callum, vulgari•* (heather) within acid grassland in the British Camp area of the Malvern I fills. This is in response to suggestions made on its origin:

"It has been suggested that the heather on this site was introduced, but there is no clear evidence to sustain this suggestion other than the general absence qfhecuhland associates on the site and hearsay evidence which suggests that it eras *planted hi' a previous ranger.*- (Alma, 2002).

The study was designed to make comparisons with plant community descriptions of the National Vegetation Classification (from hereon abbreviated NVC). completed by following the sampling procedures for Grasslands and Montane Communities (as discussed below and outlined in Rodwell, [1992]). Applying collected data to various computerized data analysis packages, and suggesting environmental interpretations to the assemblages of plant species according to their abundance and frequency in the NVC communities described.

The methods to be used in the study are based on quantitative plant ecology, a sub-discipline of ecology and biogeography and also encompassing phytosociologv. Quantitative plant ecology is the recognition, definition and mapping of different vegetation types and plant communities (Kent. 1992). The study presented is based on an examination of an apparent homogeneous semi-natural stand of acid grassland on British Camp. Malvern. and the recognition of its vegetation type according to the NVC (Rodwell. 1992).

Plant community recognition has benefited considerably from the development of the contemporary NVC. It was commissioned in 1975 by the former Nature Conservancy Council (NCC) to produce a classification of British semi-natural vegetation along phytosociological lines. and provide a comprehensive and systematic catalogue and description of the plant communities of the British Isle. Its widespread adoption permits national inventory of comparable vegetation data (Blackstock *ei al.,* 1999; Goldberg. 2003: Rodwell ci a/. 2000). Bodies, such as the successors of the NCC (namely, English Nature. Countryside Council fbr Wales and Scottish Natural Heritage) are responsible for maintaining and developing its use as a UK standard for the description of vegetation (Goldberg, 2003; Rodwell *et al.* 2000). It is also used by Non Governmental Organizations (NGO's), universities, forestry, agriculture and water agencies. major industry as well as by nature conservation and countryside organizations. It provides a common language in which the character and value of British vegetation can be interpreted and understood (Goldberg, 2003; Rodwell *et al.* 2000).

The emphasis of the NVC is on semi-natural vegetation; *"where plant communities arc largely indigenous, but es.ceniially changed by human activity and presenting a different structure and appearance to the expected natural vegetation:·* (Westhoff. 1971). It is traditional to describe woodland as the natural vegetation cover of the UK. and grassland the commonest alternative vegetation type in places too dry or high in altitude for tree growth and/or grazed heavily by herbivores. However, it has been suggested that a continuous woodland cover did not occur in the UK. and that woodland was more open and wood-pasture-like, with mosaics of grasslands, thickets with trees. solitary trees and high forest (Vera, 2000). Prehistoric plant remains such as pollen records, have been interpreted to suggest that grassland was rare before civilisation. Towards the end of the last glaciation (approximately 12.00013C) much of the country had been covered with semi-arctic grassland (tundra). and as trees moved in (10.000 to 4.00013C) grassland became less common. Pollen records also show that there Was a sudden reappearance of grassland herbs and grasses around 4.00013C. associated with Neolithic man. lherelbre grassland is a product of landscape transformation which began around

4,000BC and the only wholly natural grassland is confined to small areas on cliffs and high mountain ledges. All sites of old grassland almost without exception, were once woodland and would probably revert to woodland in a fèw decades if not managed. Almost any land which is managed as a grassland will become a grassland (Rackham. 1986: Price. 2003).

Conservationist are concerned that small patch size. fragmentation and remoteness of remnant grasslands pose particular threats to the survival of specialist grassland taxa. The extent of semi-natural grassland during the second half of the twentieth century has diminished considerably throughout the UK. Rare and declining grassland species. including for example. grassland butterflies are closely linked to particular management practices. which if altered may lead to extinction (Blackstock ci *al.* 1999). Grazing is probably the most commonly employed management technique on conservation grasslands, as herbivores have a major influence on the function and dynamics of most terrestrial biomes. Through their grazing. trampling, defecation and urination they effect nutrient flows, vegetation community dynamics and the responses of associated fauna (Britton. Marrs. Carey & Pakeman, 2000: Hester, Miles & Gimingham, 1991).

Grasslands comprising of swards with a prevailing calcifuge flora are known as acid grasslands. from the fine leafed grasslands of the uplands in the north and west and the generally similar grazed calcifugous swards and grass-heaths of the south and east, with twenty one such communities recognized within the NVC (Rodwell, 1992). An attempt has been made at assigning the acid grassland in this study to communities described by Rodwell (1992). and so help with any conclusions to he drawn on the species composition of the community. and whether the occurrence of C. vu/gari,s' suggests anything regarding its origin. This will provide new information which can he linked to existing reports on the plant communities of the Malvern 111115, thus aiding a more inf6rmed management of the area and suggestinu further research on the subject.

Vegetation surveys provide a source of spatial data for identifying communities. Systematic field survey is a prerequisite for developing effective conservation programs. Information on vegetation may be required to help solve an ecological problem. such as lbr biological, conservation and management purposes, as an input to environmental impact statements, to monitor management practices or to provide a basis of prediction of possible future changes (Kent. 1992: Blackstock *et al.,* 1999). Wide-ranging vegetation surveys covering England and Wales undertaken to provide a continuous description of land cover types, included the *Laud Utilisation Survey of Britain* (outlined in Stamp, 1955. 1962), the grassland surveys directed by Sir R. J. Stapledon in the 1930's, with updates for England in the 1940's and 1950's and an extensive sampling program in the early 1970's (Blackstock *et al..* 1999). The NVC relies on floristic features and to a lesser extent physiognomic features of the vegetation and relies upon a knowledge of the British vascular flora (including some bryophyte and lichens), without making primary use of habitat features (although providing a valuable confirmation of a diagnosis I Rodwell, 1992]). The British Camp area of the Malvern llills makes an ideal place to carry out such studies, as part of a SSSI containing plant assemblages which are poorly understood and have had relatively little attention (Alma. 2002). This would provide valuable insights and inform any future research and management of the area.

- 2. Site description.

- 2.1. The Malvern Hills.

A number of hills, stretching approximately 12km north to south, rise dramatically from the landscape and cast a distinctive silhouette. The Malvern Hills (see Figure 1. page 11). The Worcester Beacon is the highest of the hills rising to 425m (Alma, 2002: DreL2,horn). The upper slopes are predominantly open on a steep weathered ridge supportine, a mosaic of acid grassland extending down slope into encroaching scrub vegetation. They are mainly covered with acid grassland. scrub and bracken with encroaching broadleaf woodland softening the transition to the more densely wooded slopes to the urban fringes of Malvern. Former disused quarries found throughout its range, add to the dramatic northerly aspect of the hills. To the west of the hills is a

wooded limestone ridge (including Park Wood and Colwall Coppice) rising out of estate and arable land. The hills to the south-southwest are lower in altitude and more wooded than the hills to the north. Pasture and common land, along with the Victorian urban areas, housing estates, enclosed farmland, a uolf course and the Three Counties Showground also make up part of the Malvern Hills (Alma, 2002). Further information on the landscape of the Malvern Hills can be found in the Countryside Commission's *The Malvern Hills Landscape (1993)* and in the Malvern Ilills Joint Advisory Committee's *The Malvern Hills Area of Outstanding Natural Beauty Management Plan (1996).*

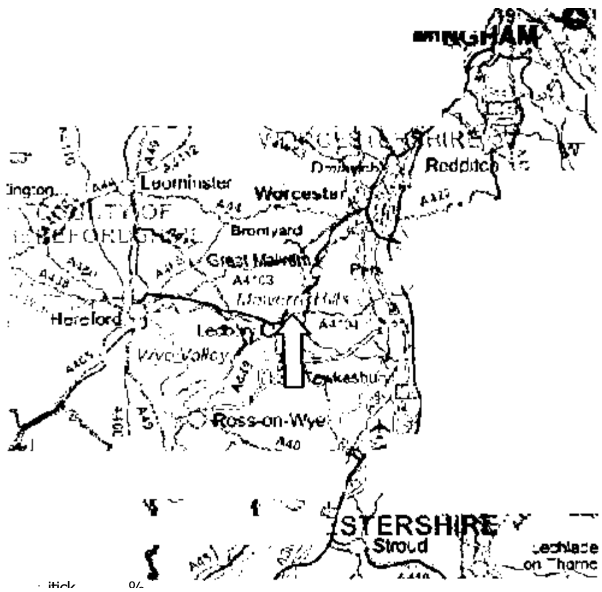


Figure 1, Map showing location of the Malvern Hills (http://www.multimap.com).

- 2.2. British Camp and reasons for site selection.

The British Camp, also called Herefordshire Beacon (SSSI, AONB, SAM0003 [Scheduled Ancient Monuments Number WSM009321) area of the Malvern Hills including the southern spur, Millennium Hill (S0760399), was selected as the site for this study (see Figure 2, page 12) primarily due to the floral communities it supports, especially *Calluna vulgaris*, which forms the topic of this research. C. *vulgaris* occurs within the acid grassland mosaic, and except for small areas along the southern edge of the British Camp reservoir, Broad Down and Hangman's Hill, does not occur elsewhere within the Malvern Range (Alma & Jones, 1992; Bryant, 2003). British Camp, Broad Down and Hangman's Hill habitat consists of open water, quarries, spoil and rock, improved grassland and arable land, mixed and conifer plantations, deciduous woodlands, scrub, flush, bracken, acid grassland, semi-improved acid grassland, acid grassland with bracken and acid grassland with heather (Alma, 2002).

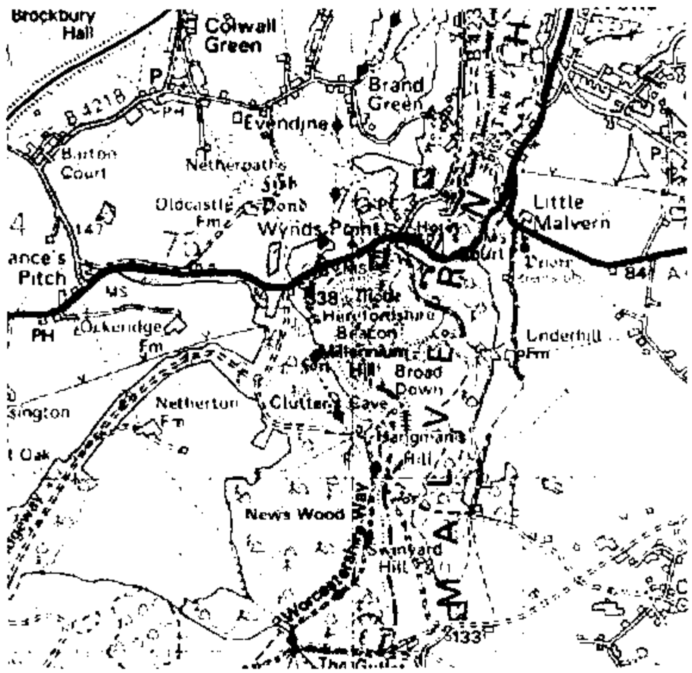


Figure 2, Map showing location of the British Camp area of the Malvern Hills (http://www.multimap.com).

- 2.3. Acid grassland with heather *(Calluna vulgaris).*

An open area of acid grassland with heather of approximately 6.38ha, south of British Camp, predominantly along the summit and east facing slopes of Millennium Hill, with an approximate altitude range of 245-315m. The northern parts are sandwiched between dense bracken *(Pteridium aquilinum)* cover below and areas of western gorse *(Ulex gallii)* cover and open acid grassland above. It has an east to southerly aspect and crosses one of the steep ramparts that encompass much of the British Camp. The majority of *C. vulgaris* growth occurs along the length of the east facing slopes of the southern spur (Millennium Hill), in which there are isolated occurrences of hawthorns *(Crateagus monogyna)* and bramble *(Rubus fruticosus)* patches. The lower southeastern limits are met with encroaching woodland, fringed in areas with dense scrub growth including rosebay willow herb *(Chamaenerion angustifolium),* brambles *(Rubus fruticosus)* and bracken *(P. aquilinum).* A large majority of the plateaux of Millennium Hill is included, with mosaics of dense C. *vulgaris* cover (see Figure 3, page 13).

Figure 3, Photograph of British Camp (taken August, 2003, North facing), with *C. vulgaris* in foreground, displaying approximate boundaries of vegetation types: A, acid grassland. B, acid grassland with heather *(C. vulgaris).* C, bracken, scrub and encroaching broadleaf woodland.

A footpath that crosses the summit is frequently used by visitors and shows signs of heavy trampling and disturbance with areas of exposed soil and bedrock and very short grasses. This trampled area is up to 3m wide in places and is entirely without the occurrence of C. *vulgaris.* There is a small area of acid grassland to the west of the trampled footpath with C. *vulgaris* growing on a westerly aspect with neighbouring fringes of dense gorse *(Ulex gallii)* and scrub at lower altitudes. At the southern end of the extent of *C. vulgaris* growth is a steep south-facing slope of acid grassland with C *vidgaris.* Rabbit warrens are most extensive in this area and this is reflected in the grazing it receives, with very short grass swards and short cropped. young *C. vulgaris* growth. Expelled bedrock debris from the warren litters the area and there is a high occurrence of lichen species (particularly *('ladonia* App.). The area is partly encompassed with scrub, in particular brambles and gorse. above and to the west, and encroaching broadleaf woodland below.

At the lowest point of the area surveyed (approximately 245m altitude) there is an area that extends below the bridleway to the east on a predominantly east facing slope. This area extends into dense bracken and scrub cover to the north and east, with encroaching broadleaf woodland to the south and east. Small discrete footpaths made and maintained by grazing sheep and visitors criss-cross the entire area of C. *vulgari.s'* growth. Many anthills. some very large. are found throughout the area and the ancient earthworks span much of the area.

- 2.4. Geology, ecology, past and present management.

The geology of the area is composed mostly of Pre-Cambrian rocks that start at the Col between the I lerefordshire Beacon and Broad Down. These rocks are some of the oldest on the planet - 600-2.000 million years old. They are hard igneous, crystalline volcanic rocks. fractured during, the last million years. Glaciations from the last but one ice age has fbrmed a sub-soil that is best seen at the southern end of the surveyed area. expelled from the numerous rabbit warrens (Bullard. 1989: Dreghorn: Hardie, 1970). The lfriconian Pre-Cambrian rocks, which include possibly only a very small part of the surveyed area along the Col of the I lerefordshire Beacon and Broad Down, are slightly Younger than the Pre-Cambrian rocks of the Beacon and are much altered crystalline rocks. The overlying soil is an acidic. shallow sandy-loam. mostly 5-10cm deep. but up to 20cm deep in places. This is particularly so in small hollows. between some anthills and Warrens where. over time dead organic matter has accumulated. 'there are also areas of exposed bedrock found mainly on the steep earthworks and expelled sub-soil (Bullard. 1989; Dreghorn; Hardie. 1970).

The diverse nature of the hills provides an array of habitat types. Within the Malvern I fills the diversity of habitats providing support for rare species of flora and fauna supports the justification of its SSSI status, designated in the mid 1950's (Alma, 2002). The number of bird species found establishes the significance of bird assemblages, and other animals of significance include nationally rare and scarce butterflies and nationally rare and protected mammals (Gibbons *el al.*, 1996 in Alma, 2002).

The nature of the vegetation on the hills has been created in response to climate and geology and maintained by hundreds of years of human activity. Woodland clearance in the hills started in the Bronze Age (2.400-75013C) and thereafter accelerated for grazing, arable farming, orchards and the development of hill torts (British Camp and Midsummer Iron Age Hill Forts [Alma. 2002; Rackham, 1986]). Sheep and some cattle maintained a close grass sward, gorse and bracken were harvested; gorse widely used as a fuel, bracken as a fuel but mainly for livestock bedding and thatch for roofing up until the 19th century when its uses declined (Alma. 2002; Rackham, 1986). Fire was also probably a significant factor in preventing the succession of trees and shrubs. There are numerous accounts of fires on the hills with an almost annular occurrence. There is no detailed record of the vegetation on the Malvern Hills prior to the 1800's but a close grassland sward existed in the 1840's and evidence from postcards in the early 1900's suggest an open aspect to the hills free from woodland and scrub (Alma. 2002; Lees, 1868),

Rabbit populations declined rapidly in the mid 1950's due to the introduction of the South American Myxomatosis virus as a means of biological control. This killed 99% of Britain's rabbit population with consequences for both the heathlands and grasslands they maintained (Rackham. 1986). By the mid 1970's onwards there was an increase in scrub and woodland encroachment on the Malvern Ilills. due to a lack of grating by sheep. cattle and rabbits (Alma. 2002). The management procedures implemented on the hills today are designed to maintain the limits of the closed canopy that existed in 1990 and to provide habitat diversity for floral and faunal species. Due to the ecological and archaeological interests of the site, consultations on management procedures are frequently undertaken with English Nature and English I leritage (Alma. 2002).

- 3. Method.

- 3.1. Global Positioning Satellite (GPS) and map production.

A GPS Navigational System developed by the American Defence Department using 24 orbiting satellites (NAVSTAR) was used to accurately map out the boundary of the area of acid grassland with *C. vulgaris* occurring on British Camp (Clarke. 2001: llaines-Youn, 1993). A Trimble ProXR Receiver and Datalogger, and Community Base-Station located at UCW in a pre-surveyed position, was used to differentiate information up to l cm accuracy with altitude. Parameters were set in order to increase the accuracy of readings prior to its use on site, the angle of incidence was set at 15^0. This was the angle a minimum of three satellites made from the horizon for the data-logger to record. the consolation of satellites (=6). beinv, the relative spacing between satellites. Once set to these parameters the Data-Logger ignored any combination of signals (P-Dop) greater than 6 and/or any angle less than 15^0 (Clarke. 2001: flaines-Young. 1993). Once the parameters were set, a data-dictionary was created. This included any features and attributes that needed to he recorded, for example, the boundary of C. *vulgari.s* growth, footpaths. and other vegetation.

The site was visited frequently and the boundary around the *vidgaris* growth Was walked several times in order to familiarise myself with the area. Data collection took place during the months of June and August 2003. Prior to leaving for British ('amp. the base station at I. was turned on. The receiver (backpack set and antennae) was used to record the boundary. Startimi, at a bench situated on the bridlewaN along the boundary as a reference point. coloured markers were tied to Ve:Letation encompassing the area of (*vulgar/s* Llrowth and gave a reasonably accurate representation of the limits of its growth. The receiver was then fitted and the data-logger turned on selecting the *C. vulgaris* limit feature in the area class. The boundary was recorded by slowly walkino, along the boundary of coloured markers removing each marker as it was passed. At the bench reference point the recording was stopped. The bridleway was also recorded using the Receiver and Data-Logger. At the time of this study, the ridgeline path (not the bridleway) was heavily trampled with areas of very short grasses and exposed soil and bedrock. in places up to 3m wide, and entirely without C. *vulgari.s*• growth. It was therefore decided to record the extent of the ridgeline path so future quadrats to he taken did not fall into this area. Such features as homogeneous stands of vegetation, for example, bracken, broadleaf trees, gorse and brambles that occurred within the area of *C. vulgaris* growth, were also recorded using the Receiver and Data-Logger.

At UCW the recordings made on site using the Trimble ProXR Receiver & Data-Logger (GPS data), was differentiated with the Community Base-Station data in order to gain readings of altitude and to filter out any atmospheric anomalies to an accuracy of a few centimetres. The GPS data was downloaded to a computer using Geographic Information Systems (GIS) (pathfinder office) and a number of maps with eastings and westings were printed to a 1:5.000 scale. These showed the area of *C. vulgaris* growth, bridleway, ridgeline footpath and other homogeneous stands of vegetation recorded in the field. A second set of 1:5,000 scale maps with castings and westings of British Camp showing major land features including earthworks (ramparts) and footpaths was acquired by permission and courtesy of Worcester County Council Archaeological Services Information and Records Section. A tracing of the maps created by the GIS was transferred to the maps from the Archaeological Services. using the castings and westings and the bridleway recorded. as templates to ensure an accurate transfer (see Figure 4. paLe. 23).

• <u>3.2. Sampling procedures of the NVC.</u>

30 2x2m quadrats were taken in total within the area of recorded C. *vulgaris* growth. 15 with the occurrence of C. *vie/gar/A'* and 15 without. The positions of the quadrats were selected randomly using a random numbers table, and using the bridleway as a base-line. A randomly selected number of paces were made along the bridleway, north to south. followed by another randomly selected number of paces up-slope, westwards and each 2x2m quadrat was consistently positioned on its south-western corner: any quadrats !Idling on or close-beside any footpaths were moved directly 2m away. A small area of acid grassland with *C. vulgari.e* occurring below the bridleway was included, and one quadrat was positioned randomly in this area using the same technique (only pacing downhill, eastwards). An NVC record sheet was completed on site for each quadrat, completing the location and region (British Camp, Malvern Hills, Worcestershire, West-Midlands). author name (initials), date and sample number, the sample area (2x2m) and the stand area (6.38ha). A GPS handset was then used to complete a full number grid reference and altitude for the quadrat sample. A compass and clinometer were used to measure the slope and aspect to the nearest degree, and a probe was used to measure the soil depth by inserting it into the soil as far as the bedrock. This was done several times in order to gain an average reading. The soil profile box was left empty on each of the NVC record sheets, as it would be impractical in an AONB and SSSI to dig a number of small holes: the area has had much attention from a number of various studies and a good representation of a soil profile for the area could be obtained at a later date. Geological records indicated that. for the area sampled. the geology would be the same for all samples: therefore. the geology box was also left empty.

A site and vegetation description was recorded on the NVC sheet fbr each of the quadrats. giving a brief description of the site topography. vegetation structure. biotic factors and other notes and sketches Where relevant. All plant species present were identified. using (Stace. 1997: Rose. 1981. 1989: I lubbard. 1984: Watson. 1981: Dobson. 1992). and with the aid of a species list of plants recorded on the North I I ills (Alma & Jones. 1992). Any species of flora that proved difficult to identify had a small sample removed to be identified at a later date with the aid of professional help (see Acknowledgements). Each species of plant was allocated a Domin score derived from their relative percentage of cover within the 2x2m quadrat (see Table 1, page 19. [Rodwell. 1992D.

Table 1: Domin score correspondinu to percentage-cover of plant species (Rodwell, 1992).

Domin Scale	
cover	Domin score
91-100	10
76-90	9
51-75	8
34-50	7
26-33	6
11-25	5
4-10	4
many individuals	3
several individuals	2
kw individuals	1

• 3.3. Multivariate analysis.

Various computer software programs have been used to analyse the data. in particular DECORANA (I Lill, 1979a), TWINSPAN (Hill. 1979b) and MATCH (Malloch, 1990). When one is trying to describe a plant community from samples by the presence and/or quantity of a number of species, the data is multivariate (Gauch, Whittaker & Singer, 1981). Multivariate analysis examines numerous variables simultaneously and treats the multivariate data as a whole. summarising and revealing their structure, with aims of displaying the data from highly dimensional (many samples and species) in few dimensions. which allows subsequent environmental interpretations to be made using additional information from that used in the multivariate analysis (obtained from the NVC sheets completed on site [Gauch. 1982: Gauch, Whittaker & Singer, 19811).

The need fur multivariate analysis arises whenever more than one characteristic is *measured on a number of individuals, and relationships make it necessary fur them to he studied simultaneously.*- (Krzanowski, 1972 in Gauch. 1982).

The data were analysed using the computer programmes of the software suite VESPAN (Malloch 1997). VESPAN was used to analyse the sample data by Two Way Indicator Species Analysis (TWINSPAN) and Detrended Correspondence Analysis (DEVORANA) (I fill 1979a. b). Data entered was a species list and their allocated Domin scores for each sample, obtained from the NVC sheets completed on site (see results. section 4).

• 3.3.1. DECORANA (Detrended Correspondence Analysis.

DI ',CORANA (11ill. I 979a). a software programme used for detrended correspondence analysis. a robust and effective ordination technique based on reciprocal averaging (Gauch. 1982). The ordination of species and/or samples may he presented in two dimensional graph. the program ordinates the species/samples in such a WaV to represent relationships in a low dimensional space in which species and/or samples which are similar are near to each other, and those dissimilar, far apart. in a way to represent the data as faithfully as possible (Gauch. 1982; Gauch, Whittaker & Singer, 1981). The DECORANA ordination program is designed to show relationships between plant species and samples in terms of their botanical composition with no additional environmental data. The ordination can however be interpreted in terms of environmental gradients, and by combining the DECORANA ordination analysis with a multivariate classification technique to the same data set. especially useful results can he obtained (Gauch, 1982; DEF RA. 1999). The advantages of using the DECORANA program include its effectiveness in summarising community variation realistically in terms of the structure of the community data. and the communicability of the displayed results (Gauch. 1982). The ordination technique is robust and can handle a wide range of data sets. and is practical in terms of labour cost. The DECORANA program needs exceptionally little computer time and storage (Gauch. 1982; Gauch. Whittaker & Singer, 1981 [for a more detailed account including technical details on detrended correspondence analysis please refer to Hill, 1979a]).

• 3.3.2. TWINSPAN (two-way indicator species analysis).

TWINSPAN (two-way indicator species analysis) is a polythetic divisive classification technique developed by Hill (1979b). The technique is polythetic as it incorporates information in its calculations from all of the species in the data and defines groups on the basis of many characteristics, and is divisive as it divides samples into groups of samples of similar species composition (Gauch, 1982; IPMRC, 2003). The program examines the overall gradients in the data and ordinates the samples in a single dimension using reciprocal averaging. and all information is used in the first most critical division based on significant differences in community composition in relation to differences in environment and history (Gaud). 1982). The data is divided into two clusters. and those two clusters are further divided producing four clusters and so on with levels of divisions producing progressively finer groups of samples in to increasingly homogeneous groups. until a group has no more than a chosen minimum number of members and/or until a chosen maximum number of divisions has been achieved. A corresponding species classification is produced and displayed together with the sample classification producing an arranged data matrix (Gauch. 1982).

- 3.3.3. MATCH

MATCH (Malloch. 1990), is a computer program. a goodness-of-lit test which aids the assignment of vegetation data to the communities and subcommunities of the NVC (Malloch, 1997; Blackstock *el al.,* 1999). It compares, by calculating similarity coefficients test data with the NVC diagnosis as described by Rodwell (1991a. 1991b, 1992) presenting the ten best ranked matches to the NVC and drawing attention to the main discrepancies (Alma & Jones, 1992; Malloch, 1997). It has been widely used to aid sample placement and is the computer key to the NVC providing a consistent way of classifying data (Blackstock cal *cd.,* 1999; Malloch. 1997: Goldberg, 2001). The top ranked NVC matched data. may not however, be the "correct answer- the presence or absence of one or two anomalous or key species, may lead to a best overall lit being the second or third ranked community (and/or subcommunity) on the list, requiring some degree of ecological interpretation with use of the keys and descriptions in Rodwell (1992 (Goldberg, 2001. Alma *&* Jones. 19921).

• 4. Results.

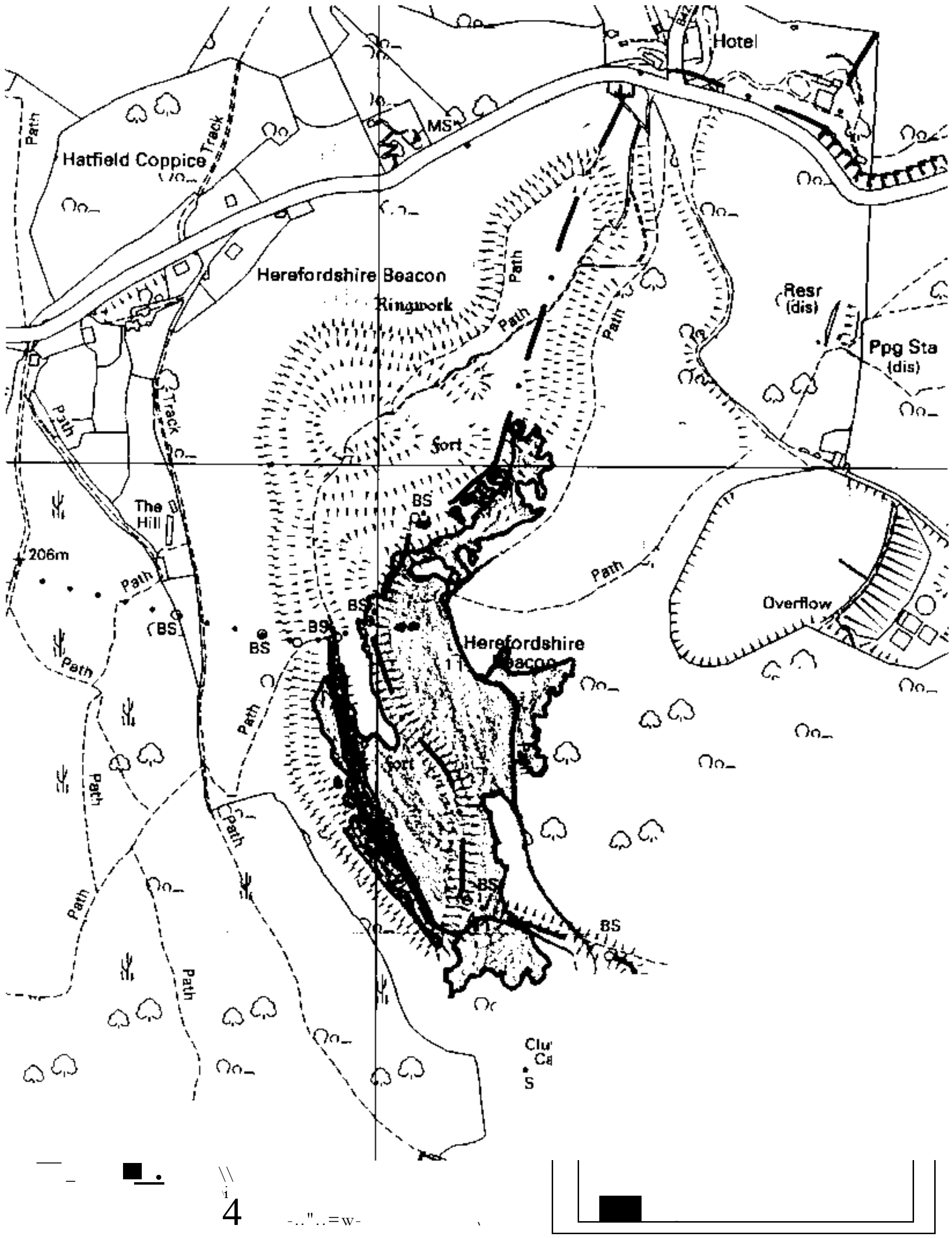


Figure 4. Map showing surveyed area of acid grassland with *C. vulgaris,* created by GIS.

28 species of calcifugous plants were found (26 identified) in the samples. the species list is given in Table 2 (page 24).

Table *1* Species list.

Species list

I *4grarlis capillaris* L. *(Agraslis* Sihth. common bent).

2Agroslis suVonifera L. (creeping bent).

3 4 *ira praecox I.*. (early hair-grass).

4 *4n/haw/wham oiloranan* L. (sweet vernal-grass).

5 *Callum! vulgaris*· L (ling, heather).

6 *C/adonia* .sp. An unidentified species of lichen, identified to its genus *C/adonia.*

7 *Deschampsia flexuosa* L. (wavy hair-grass).

8 *Dicranella heleromalla* (1-ledw.) Schp.

9 *DiCr(11111111 SCOparill171* (I-ledw.)

10 *Festuca Drina* L. (sheep's fescue).

11 *Festuca ruhra* L. (red fescue, creeping fescue).

12 *Galium saxa/ile* L (heath bedstraw).

1311o/ens lanalus L (Yorkshire fog).

14 *Ho/cus mollis* L. (creeping soft-grass).

1 *Luzula campestris* L. (field woodrush).

16 *Luzula sp.* A species of *Luz.u/a* identified to its genus but species unidentified.

17Pdosella officinarinn, L. (mouse-ear hawkweed).

18 *Pau pratensis* L. (smooth meadow-grass).

19 *Potentilla credo'* L. (common tormentil).

20 *Pieridium aquilimun* L (bracken).

21 Rhyhdiadelphus squarrosus· (Fledw.) Warnst. *Ulylocomium squarrawun (Fledw).*

27) *R11171eX ace lava* L. (common sorrel).

23 Rumex acelawlla I,. (sheep's sorrel).

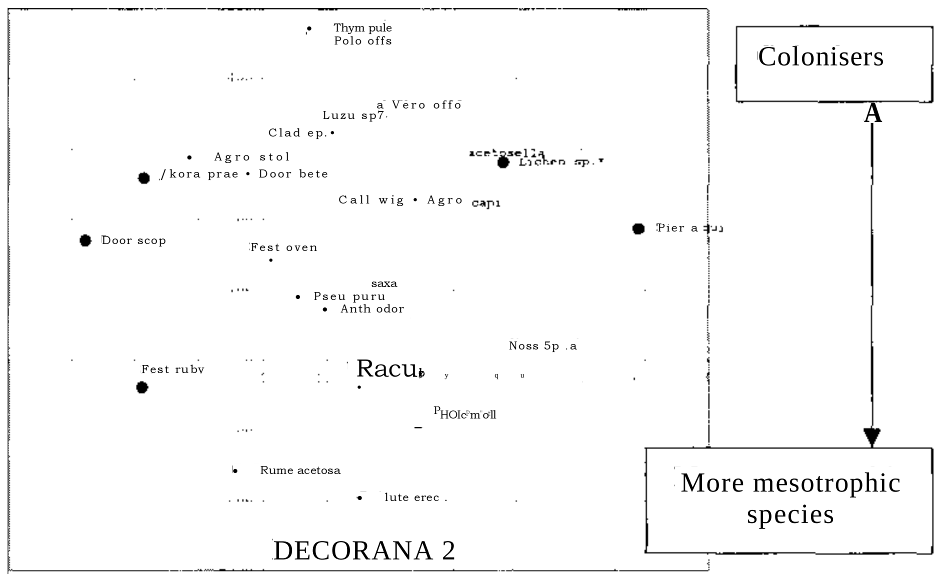
74 *Scleropodium purem* iledw. (formally *Pseudoscleropodium purem* I Iedw).

25 Alums' pulgoides· L. (large thyme).

261'cronica *offinaii.s*· L. (heath speedwell).

- **4.1.** <u>Results of DECORANA (detrended correspondence analysis).</u>

The ordination of species from the test data usin(2, DECORANA has been displayed on a two dimensional Figure 4, and by using knowledge on the individual species an attempt has been made to interpret the acting environmental gradients along the axis of the graph (Gauch, 1982; Gauch, Whittaker & Singer. 1981; DEFRA. 1999). Figure 5 (page 26). displaying DECORANA ordination of species from the test data, displays an obvious environmental gradient along axis 1 with colonising species which exploit severely disturbed and productive habitats with the highest scores along axis 1. through heath and grassland species to the more mesotrophic, fast-growing species of better soils with the lowest scores. For example, the more ruderal opportunistic and rapidly growing colonising species with the highest scores along axis 1. such as *R11111CX acausella* and *Aira praecox* (both stress-tolerant ruderals) are restricted to infertile sites of more rocky. sandy and disturbed acid soils (Grime *et at* 1988; DEFRA, 1999; Grime. 2001). Species such as *Deschampsia.fiexuosa* and *Galium saxalile* which are both common in acid heathland and grassland on relatively undisturbed and more or less infertile sites, have mid ranging scores along axis 1 (Hill *et al.*, 1999: Grime *et al.*, 1988). The more competitive species of lower disturbance such as *Licula campc.s.tris* and *R11117eX aCTIOSa,* occur on comparatively more fertile sites (although on rather infertile sites). of higher productivity and which are quite undisturbed have the lowest scores along axis 1 (Grime et *al.* 1988; Grime. 2001). Ordination of species along axis 2 of the graph is less obvious and differences between species along axis 2 have not been identified. Soil depth, aspect and slope, recorded in NVC survey sheets on site for each of the samples was also investigated, with aims of identifying any environmental variables acting along DECORANA axis 2. Due to the very similar soil depth. aspect and slope recorded throughout the site. nothing was shown by this along axis 2



Species

Figure 5, DECORANA ordination of species, showing environmental gradient acting alorw, axis I .
* species not fully identified in the field, ordination derived from the input of named similar species.

From the same data set. DECORANA produced a second graph displaying the ordination of samples 1-30 alongside the ordination of species from Figure 5 (see Figure 6. page 27), the samples displayed in this way appear as one cluster concentrated centrally in regards to the ordination of species on the graph. proving difficult in its environmental interpretation. A third graph was created from the data displaying the ordination of samples alone (Figure 7. page 26), thus increasing the scale of the graph allowing the cluster to he interpreted with the aid of a second analytical program lbr classification (Gauch. 1982).

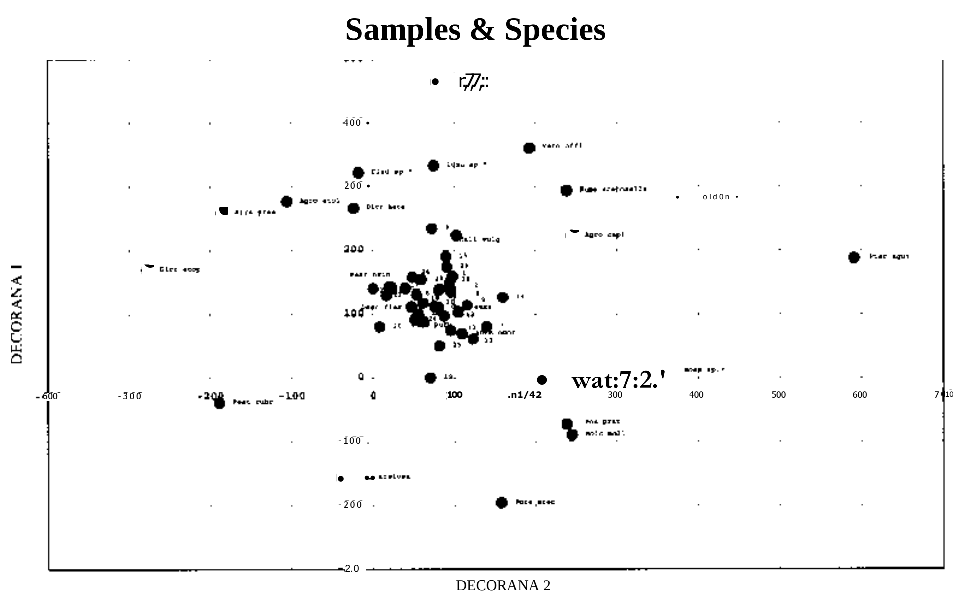
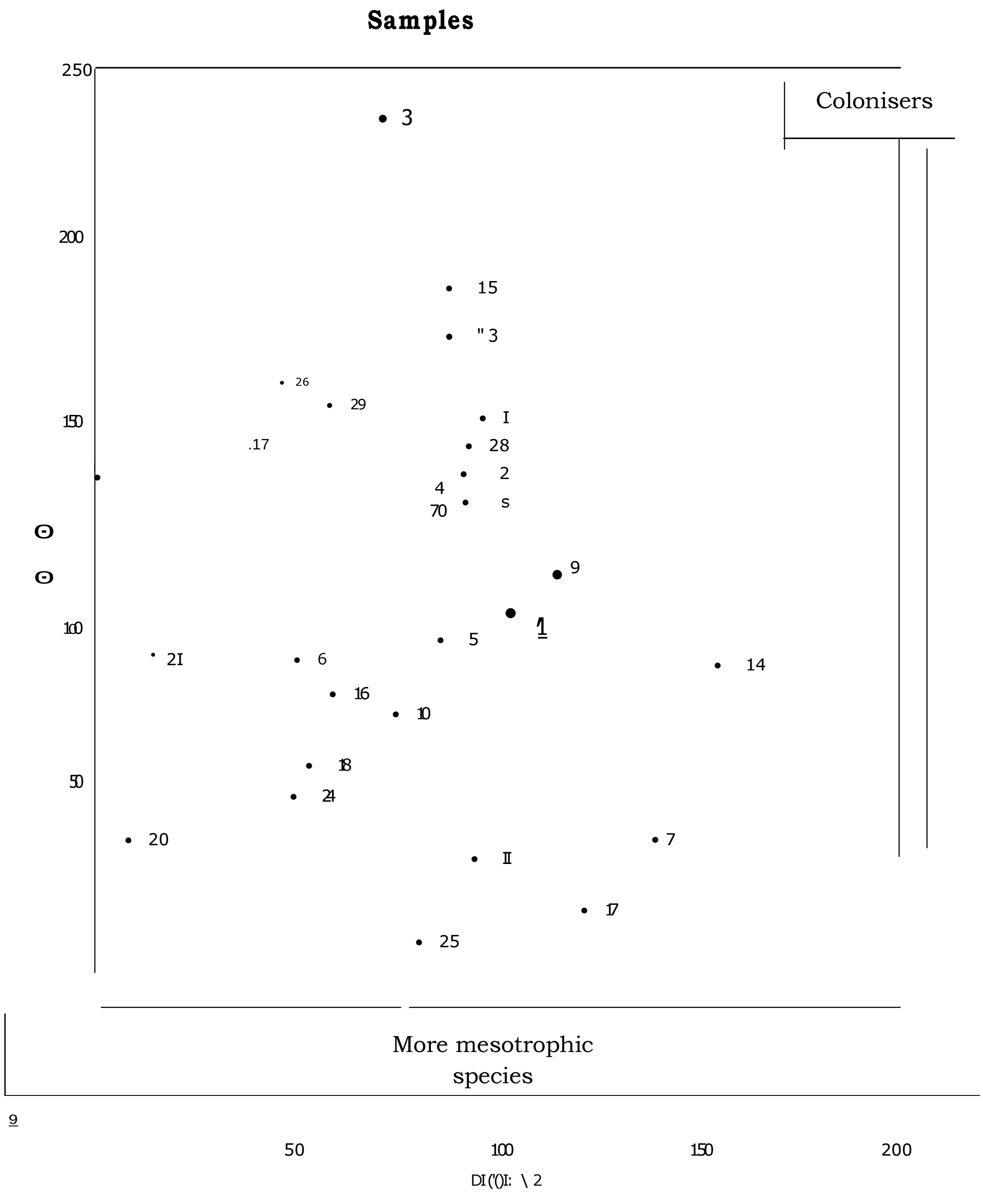


Figure 6, DECORANA ordination of samples and species.

N.B. Two more species of plant were recorded in the test data. one a species of lichen and the other an acrocarpous species of moss. both of which were unidentified.


Samples
250
200
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Colonisers
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Figure 7. 1)[(ORANA ordination of samples. showing environmental gradients acting along axis I

- 4.2. Results of TWINSPAN (two-way indicator species analysis).

Six groups of samples were identified in the data matrix produced by the two-way indicator species analysis (see Table 3. page 30). these groups of samples were then combined with the graph produced by the DECORANA analysis. Combination of ordination and classification techniques applied to the same set of data is especially useful and it is highly desirable to have some overall view of the structure of the data before making a classification, this is done by makino, a preliminary ordination and using it as the basis of classification (Hill *el al.*. 1975: Gauch, 1982). These two approaches combine the power of classification with the effectiveness of ordination in revealing relationships: DECORANA ordination positions are helpful for understanding the divisions imposed by the TWINSPAN classification. Classification derived from ordination is fully compatible and complements the continuous description of the data structure provided by the ordination (Noy-Meir. 1973), and is known as a hybrid ordination-classification technique. and classification groups can be drawn by hand on the ordination graph produced by detrended correspondence analysis (see figure 8, page 31 IGauch, 1982]).

N.B. Two more species of plant were recorded in the test data. one a species of lichen and the other an acrocarpous species of moss. both of which were unidentified.

Table 3. TWINSPAN results displayed as a data matrix. highlighted are seven groups.

Rel.	Species True		Samples,	relative numbers.	
			21222'2 23	122F22 11 1111	
			607129614880	3537 945590871234	
27			Lichen sp. ---	1 L--------------1	0000
1	Agro		stol - 1 ----------	---------------------------	
3	Aira		prae --------3	1-------------------------	00010
13	Luzu	spp.		-------------- 2	00010
14	Pilo	offi		---------------fl	00010
20	Vero	offi		-------------- 11	00010
28	Thym		pule --------	1 -------------------	00010
23	Moss	spp.	-1 -------------	1 ------------	00011
26	Clad	spp.	--111-2 -----	2232 ------------ 1	00011
19	Rume		aceto - 2 22 1	2 ----- 2	001
22	Dicr	hete		21233332222233223	001
5	Call	vulg	--4--43212332-	4--3-3 ---- 1-2-3	01
7	Fest	ovin		33121323321332-222-22122222 1-	01
8	Fest	rubr	-3222-1 ------	r 2321---2 ----	100
24	Pseu	puru		22313211431311122233134213333	100
6	Desc	flex		4333333443344123343334433433344	1010
2	Agro		capi -	1221112/121-2-21122-213	1011
4	Anth	odor		-21-2212222i-33233123322 1322-	1011
9	Cali	saxa		1222222232322312233233333324342	1011
21	Camp	intr	1 ---------- 1	-----1-------------------- 2	1011
12	Luzu		camp ---		1100
16	Pote		erec ----11-1	-------12 2 11--22	1100
10	Holc	lava	1 --------3--1 -------		1101
15	Poa		1 11-----	------------ 311--	1101
25	Rhyt	squa	prat ------ 1-k	2-2----2--21	1101
11	Hole		moll ----------------	--------	111
17	Pter		aqui ----------------	---------1	111
18	Rome		acet -------------	1 1221 --------	111

b0000000000000000L11111111111
p00000111111111111'000000000001
t0111100000000111110001111111 11
0111111, 000001111

000001 01111

:V.13. entries in the table are

pse dospecies levels and not quantitative or DOMIN values. Species I8 Rume acet *Rume' acciosa*

3.

4.

2 1.

(all samples)

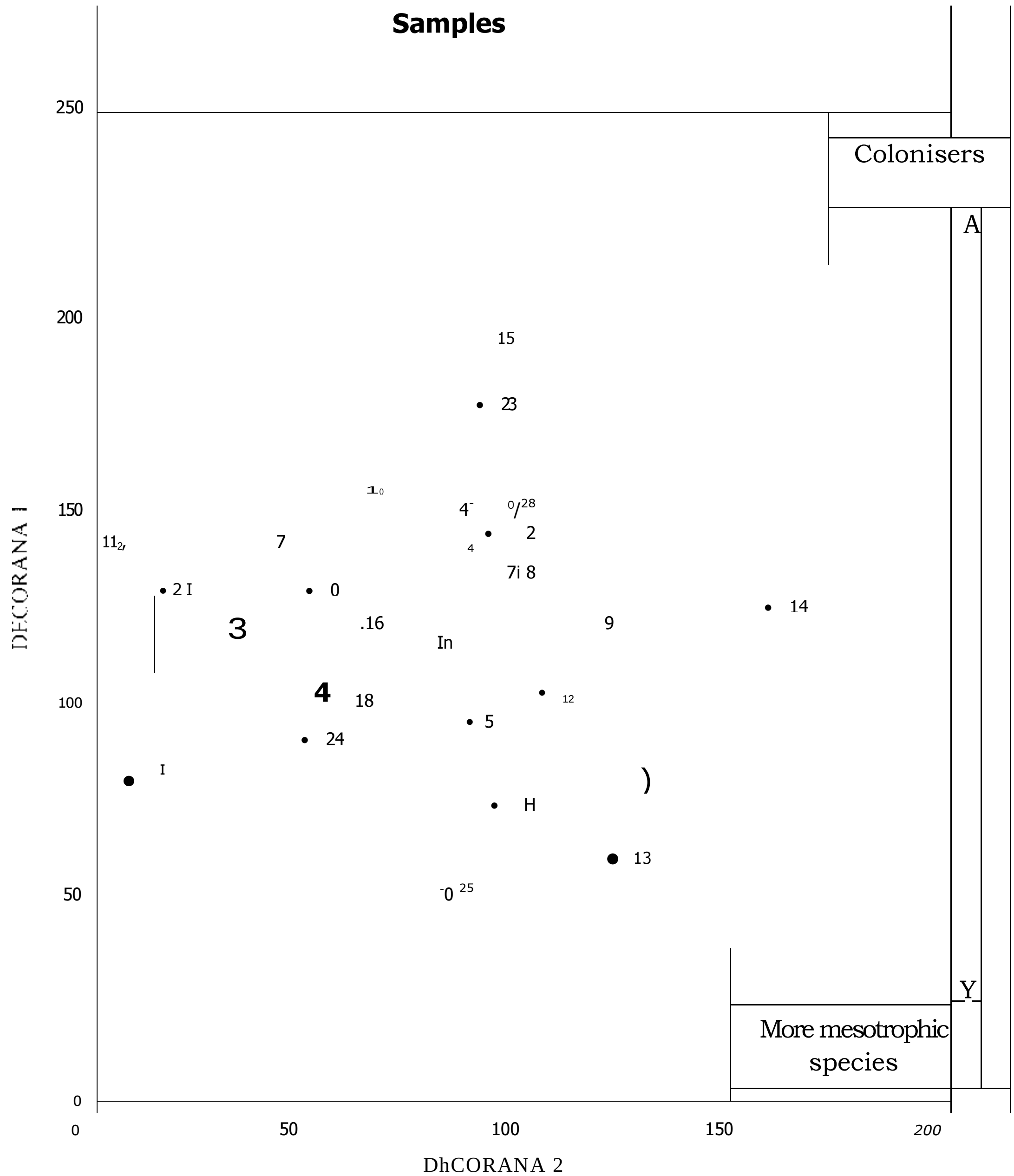


Figure 8. DECORANA ordination of samples. showing hand-drawn IWINSTAN groups and acting environmental gradients along axis 1.

N.B. Two more species of plant were recorded in the test data. one a species of lichen and the other an acrocarpous species of moss. both of which were unidentified.

• 4.3. MATCH results.

In total seven groups of vegetation data were interpreted with MATCII (Malloch, 1990). Collected data from each group was mathematically compared with the diagnostic data held in the MATC1I program. Groups 1 to 6 contained vegetation data from the 6 groups of samples separated by TWINSPAN, and group 7 contained vegetation data from all 30 samples (see section 3.3.2.). For each group, coefficients of similarity were calculated. and a list of the top ten most similar diagnoses to the collected data was displayed. Values of coefficient were displayed alongside the diagnoses, together with details of the major departures of the collected data from the diagnoses. Coefficient values of similarity were low for many of the groups diagnoses, and the top 3 or 4 diagnoses for many of the groups had very small differences in coefficient values. Those diagnoses with the highest values were used to draw up a short list of possible communities. which were then considered in detail using keys and descriptions given in Rodwell (1992).

Group 1. containing 13 samples of the first TWINSPAN division, was matched to 3 different communities. highest ranked was the NVC U20a *Pleridium aquilinum-Gcdium .vaxatile* grassland community; A *tilhoxanthum odoralum* subcommunity (from hereon abbreviated by the NVC numerical format U20a). followed by the U4a *Fesiteca ovina-Agroslis capillaries-Galium saxaille* grassland community; typical subcommunity (from hereon abbreviated by the NVC numerical format U4a). and the U20 *Picridium aquilinum-Galium savalile* grassland community (from hereon abbreviated by the NVC numerical format U20). Group 2. containing 17 samples of the first TWINSPAN division was most closely ranked to the NVC U 1 e *Fesluca ovina-Agrosas capillaries-R11111CX* acetosella grassland community: *Cia/iuni savaii/c-Poterailla crecia* subcommunity (from hereon abbreviated by the NVC numerical format t `la Ibllowed closely by the t 120b *PR:1·0111m aquilinum-Galium su.valilc* urassland community, *"accininin invriilhis-nicrunwn Avopariltin subcommunity (from* hereon abbreviated by the NVC numerical format t 20h). and the 1120 community. Group 3. containing 6 samples of the second staue of TWINSPAN divisions was most closely ranked to the

NVC U20b subcommunity followed by the U4a subcommunity and the U20 community. Group 4 containing 7 samples of the third stage of TWINSPAN divisions and is most closely matched to the NVC Ule, U20a subcommunities and the U20 community respectively. Group 5. containing 4 samples of the third stage of TWINSPAN divisions was most closely matched to the NVC Ule subcommunity, followed by the U20 community and the U20b subcommunity. Group 6 containing 9 samples of the third stage of TWINSPAN divisions and was equally most closely matched to the NVC U20a subcommunity and the U20 community followed closely by the U4a subcommunity. 4 different NVC communities with very little difference between them in coefficient values, were matched to group 7 (all 30 samples containing 28 species). The U20 grassland community was most closely matched and with equal rankings of the U20a and U20b subcommunities, and with a coefficient value of merely 0.1 less the Ule subcommunity.

None of the groups examined were finally assigned to the U20 grassland community or any of the U20 subcommunities drawn up in the short-list of possible communities for each of the 7 groups (see Table 4. page 35). NVC U20 communities persists in a number of situations, particularly on base-poor soils and are abundant on upland fringes in the north and west on hill sides and valleys in areas of high rainfall. Although the grassland surveyed could fit to this distinction. U20 grasslands are best suited to colluvial soils from downwash from the slopes above, and normally on deeper. moist soils (important for the development of rhizomes and healthy growth of *P. aquilinuni)* of formally forested land (Rodwell. 1992). The area surveyed, predominantly along a hill slope. is of shallow soils and has a long history of grazing. The major discrepancy that truly separates the surveyed area from a U20 community (including the I. subcommunities), is the absence of *aglilli1111171* from the stand. *P. aquilimun* is the sole dominance in l 120 grasslands. with a minimum of 25% cover of the area. and some fronds reaching in excess of 2m.

Groups 1. 3 and 6 were assigned to the U4a grassland following consideration of the proposed short list of communities using the MATCH printout and the use of keys and descriptions in Rodwell (1992). However, the assigned U4a grassland is not a perfect match. Numerous departures in the species composition given in the MATCH printout have been displayed against the assignment of the groups to the 114a community. The keys and descriptions in Rodwell (1992) do suggest. following careful consideration. that the groups are most like U4a grasslands. sharing affinities with U20 grasslands. Groups 2. 4 and 5 were assigned to the Ule grassland, and again, not a perfect match with numerous departures against the community assignment. The assigned Ule community does have the strongest likeness to groups 2, 4 and 5. also with the highest coefficient values of similarity. but also shares affinities with U20 grasslands. Group 7, containing collected data from all 30 samples has also been assigned to a Ule grassland community. Again, not a perfect match, following consideration of the species composition and character of the site, it was decided the closest match was the Ule community. which also shares affinities with U20 grasslands. extending to a U4 community in more plush localities of the surveyed area.

N.B. Two more species of plant were recorded in the test data. one a species of lichen and the other an acrocarpous species of moss. both of which were unidentified.

Table 4, most closely matched NVC communities using MATCH (Malloch, 1990) to TWINSPAN groups, with final NVC assignment using keys and descriptions in Rodwell (1992) and comments.

TWINSPAN group	Samples	MATCH top ranked NVC groups with coefficient scores of similarity	NVC group assignment using keys and description in Rodwell (1992) and MATC11 handout	Comments
1	5. 7, 9, 10. 11, 12. 13, 14, 16. 19, 74, 75	u70a (58.3) U4a(57.6) U20 (56.7)	A U4a *Fe.sluca ovina-:It I.OSILS ccipillaris-Galium' saxatile* grassland community, typical subcommunity.	A U4a grassland with some affinities with U20 grasslands.
2	1, 2, 3, 4, 5. 6, 8. 15, 17, 20, 21, 22, 23, 26, 27. 28. 29, 30	Ul e (53.6) u70b (52.3) U20 (52.2)	A Ule *Fesluca °villa-Agrostis capillaris-Rumex acelosella* urassland; *Galium saxalile-Polenlilla erecla* subcommunity.	A Ul e grassland with some affinities with U20 grasslands.
3	6. 17, 20, 71. 77. 79	U20b (45.1) U4a (44.6) U20 (43.4)	A U4a *Fesluca ovina-Agrosii.s capillaris-Galium saxalile* grassland community. typical subcommunity.	A difficult group to classify, with low coefficient scores and discrepancies against described communities, most probably a 1J4 grasslands.
4	1. 2. 4, 8. 26. 28. 30	Ll 1 e (55.1) 1120a (54.1) 1120 (53.0)	A *Ule Festuca ovifla-Agrostis capillaris-Rumex accioselhl* grassland; *Galluni scut/We-Potent/Hu crecia* subcommunity.	A Ule grassland with some affinities with 1120 uasslands.
	. l'S, -)3. 27	111c (49.3) 1120 (46.3) 1120b (45.5)	A tile *Fesiuca orina-Agrastis. capillaris-Rumex acciosc/ht* urassland; *(ia/irrin ,s'axafile-Polemilla erect('* subcommunity.	A IIe grassland with some affinities with 1120 tuasslands.

6	*5*, 7, 9, 10, 11, 12, 13, 18, 25	U20a (57.9) U20 (57.9) U4a (57.6)	A U4a *Fesluca ovina-Agrostis capillaris-Galium* s - *Ile* grassland community, typical subcommunity.	A U4a grassland with affinities I U20 grasslands.
7	All samples	U20 (56.4) U20a (55.0) U20b (55.0) Ule (54.9)	A *U l e Fesluca ovina-Agrosiis capillaris'-Runiex acciosella* grassland; *Gaiiitin savahle-Polenlilla credo* subcommunity.	A Ule grassland sharing affinities with a U20 community and extending in more mesotrophic parts to a U4a subcommunity, with numerous discrepancies against the plant assemblages 01e, s of all the matched communities. the overall character of the site most like the U 1 e community.

N.B. Two more species of plant were recorded in the test data. one a species of lichen and the other an acrocarpous species of moss. both of which were unidentified.

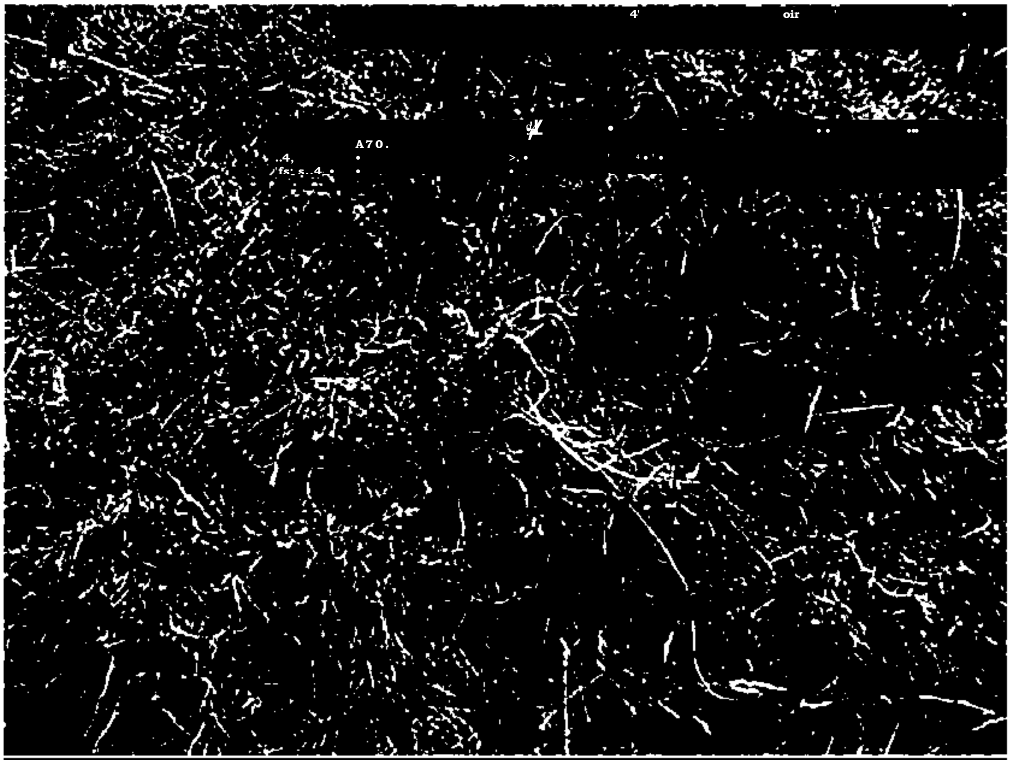
I

III

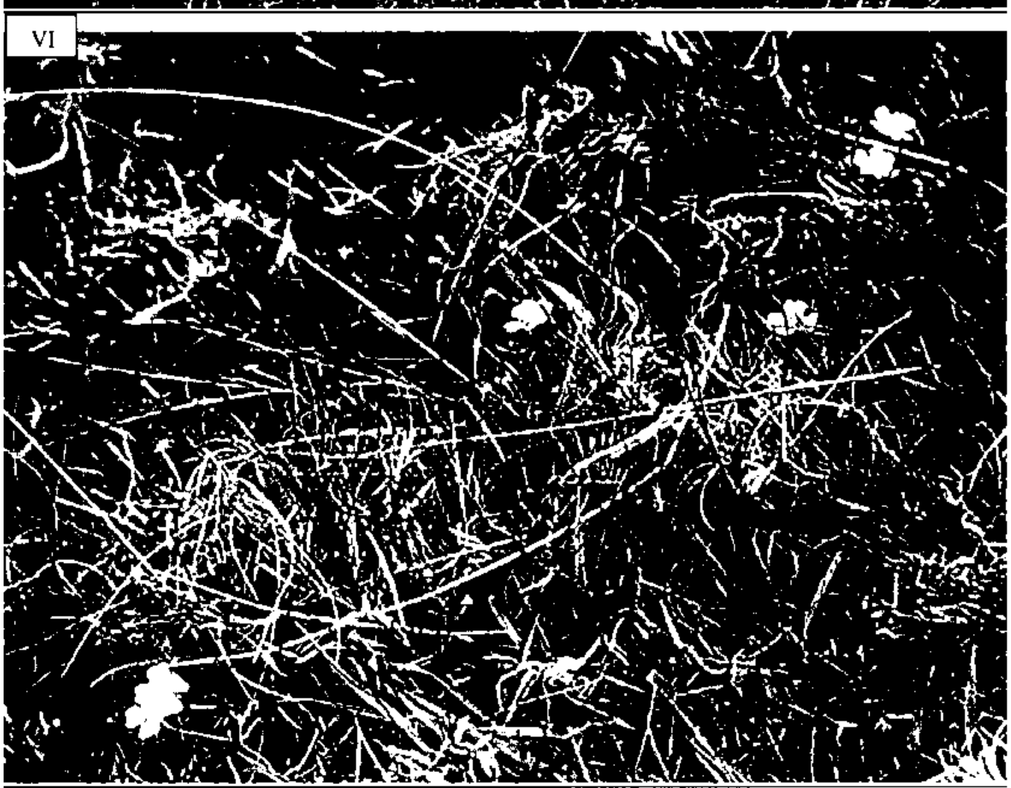
IV

N.B. Two more species of plant were recorded in the test data. one a species of lichen and the other an acrocarpous species of moss. both of which were unidentified.

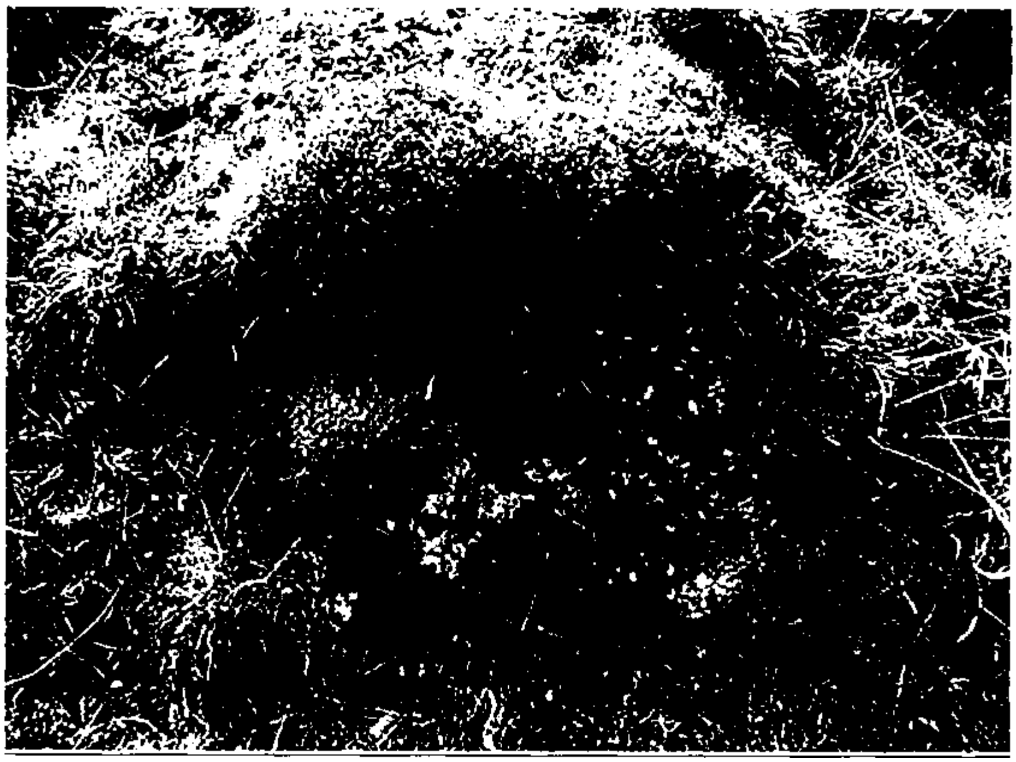
V



VI



VII



Plates Ito VII, showing differences in vegetation structure and character throughout the surveyed area containing *Calluna vulgaris* in British Camp (August, 2003). I, Area with many anthills (facing North). II, close-cropped sward on summit of Millennium Hill (facing South-East). III, *Calluna vulgaris* in quadrat. (facing South-East). IV, *Calluna vulgaris* in quadrat. V, Areas of dense carpets of moss species. VI, Tormentil *(Potentilla erecta)* within sward. VII, Species of grass, moss and lichen growing with *Calluna vulgaris* on an anthill.

• 5. Discussion.

It must be reminded that the aims of the report presented are to arrive at any conclusions regarding the occurrence of (*vulgaris,* whether its occurrence in the British Camp area of the Malvern I !ills is natural and has not been introduced or sown and is an integral part of the semi-natural composition of the community. In order to arrive at any conclusions regarding this. the land cover type was identified using knowledge of the prescribed communities described by Rodwell (1992). This included a knowledge of the individual identified species. species composition and community structure using the ordination and classification methods applied, providing ecological interpretations with the use of additional information not used in the analytical programs. The main discrepancies highlighted by the MATCI I analysis was strongly considered with reference to the prescribed communities and subcommunities as described by Rodwell (1992) with use of site and sample descriptions in completed NVC survey sheets.

Reasons for dividing the 30 samples taken from the site into several different groups using TWINSPAN, were to identify environmental gradients which provide a basis for plant coexistence (Pickett & Bazzaz, 1978) and any differences in the community structure throughout the site, aided with the ordination of samples and species through the DECORANA analysis. Different samples from the same homogeneous community are rarely identical, variation in species composition between samples is partly variation in environmental factors and also due to interesting noise. The causes of noise are complex and differences in species composition and abundance between samples can be partly explained by very local differences in environmental factors, the chance establishment and distribution of individuals, local disturbances. local variations in biotic pressures. *c.g.* animal activity including scraping and grazing. burning, mowing dc.. errors or variations in the recordings of abundance (Gauch. 1982: Kent & Coker, 1992).

The difficulty in interpreting the DECORANA ordination of samples is due to the small number of very similar species recorded from a very homogeneous stand of vegetation, and the small number of samples taken composing of similar aggregations of a small number of similar species. This is highlighted in figure 6 (page 27), showing one centrally ordinated cluster of samples in relation to the ordination of species. To add to this, of the 28 species recorded in the 30 quadrats, 10 species did not occur in any more than 2 of the 30 quadrats. thus were "outliers- *i.e.* chance occurrences. holding no real significance in the test data, (Gauch, 1982). The similarity of recorded species and samples may he partly explained by similar acting environmental variables on a very homogeneous stand of vegetation. However it is evident there are differences throughout the site, in character, vegetation structure (displayed in plates I to VII, pages 37 to 40) and species composition. Ordination of species in figure 4. with the use of knowledge on the individual plants, highlights environmental gradients along axis 1, which influence the ordination of colonising species to the more mesotrophic species. as discussed in section 4.1.

All the NVC communities (including subcommunities) most closely matched to the 7 groups using the MATCH analysis. namely the U 1 e, U4a, U20a and U20b subcommunities and U20 community should contain the ambiguous *Calluna vulgari.s.* (Rodwell, 1992), suggesting its presence in the acid grasslands of the British Camp area of the Malvern I lills as an integral part of the community structure. This evidence alone is not strong enough to answer the question posed. When one looks at the community structure of each of the TWINSPAN groups and the occurrence of individuals and their abundance and frequency of occurrence throughout the groups and compares them with the prescribed NVC communities, it becomes apparent that any conclusions to he drawn arc far more questionable and complex. Many examples of discrepancies in the matched data. *e.g.* species present which should not he. species which should he present and discrepancies in the quantitative values of species recorded are highlighted MATC11. As discussed in earlier sections (see section 3.3.3.). the top ranked NVC' community may not he the "correct answer-, the presence or absence of one or two anomalous or key species. may lead to a best Overall fit being. the second or third ranked

N.B. Two more species of plant were recorded in the test data. one a species of lichen and the other an acrocarpous species of moss. both of which were unidentified.

community (and/or subcommunity) On the list, requiring some degree of ecological interpretation (Goldberg, 2003).

Two different communities have been assigned to the 7 groups of collected data. groups 1. 3 and 6 assigned to the U4a grassland, and groups 2. 4, 5 and 7 to the Ule grassland. Groups 1 and 6 are very similar in species composition, with nothing obvious shown to explain the TWINSPAN separation. Group 3 differs somewhat in species composition to the more similar groups 1 and 6. *Dicrauella heteromalla* occurs at low percentages of cover (low pseudospecies values) in merely 38.5% of samples in group 1 and 33.3% of samples in group 6, whereas in group 3, *D. heieromalla* occurs in 100% of samples at high percentages of cover. Added to this, are the occurrences of *Agrostis ccTillaris* in 69.2% of samples in group 1 and 77.8% of samples in group 6. with no occurrences in group 3. also with 92.3% of samples in group 1 containing *Amhexanthum ()domai)* and in 100% of samples in group 6, with it occurring in merely 33.3% of samples in group 3. explaining the division imposed by TWINSPAN. Groups 2. 4 and 5, assigned to the

grassland. are very similar in species composition, with the biggest differences between groups 4 and 5. The species of lichen identified to its genus *Ciadonia* App. occurs in only 14.3% of samples in group 4, 47% of samples in group 2 and 100% of samples in group 5. *Rumex aceiosella* occurs in 47% of samples in group 2, 57.1% of samples in group 4 and 100% of samples in group 5. *Calluna vulgaris* occurs in 100% of samples in group 4, 58.8% of samples in group 2 and 25% of samples in group 5, explaining the divisions imposed by TWINSPAN. The fact that *C. vulgaris* occurs in 100% of samples in group 4 and merely 25% of samples in uroup 5, may be enough to explain the separation imposed by TWINSPAN, however, both groups 4 and 5 have been assigned to the Ii 1 e grassland. The difference between the percentage cover of (*rie/guris* may be sufficient to initiate a TWINSPAN division. but has not been sufficient enough to separate the groups from their assignment to the I.J1c grassland. possibly suggesting an insignificance of('. *rulgaris* in this type of' grassland.

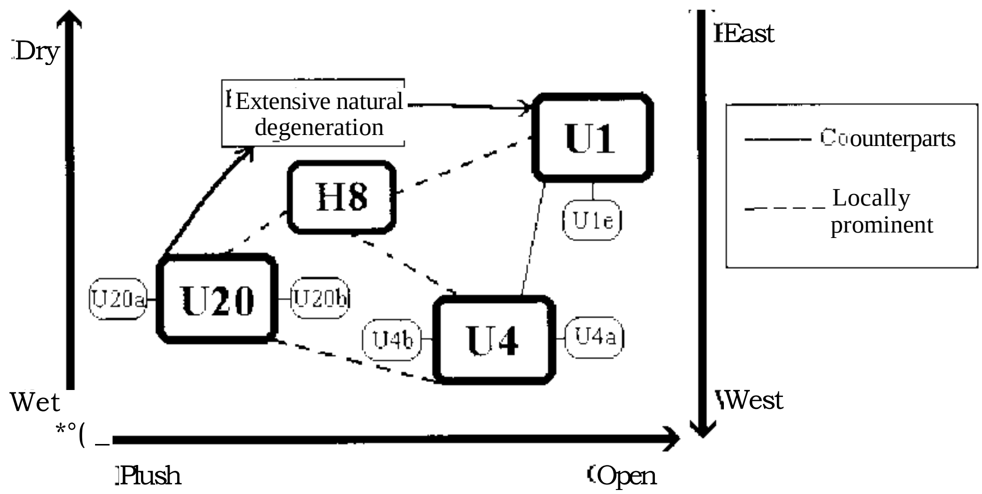
The character of the site is most unlike that of the prescribed U20 community, a close-cropped sward exists, with herbivory grazing maintaining the site as a plagioclimatic community as described fbr U 1 and U4 communities. Most like the Ul community is the long history of grazing management which the site is associated with, and the influence of the extensive warrens in the area, maintaining the close-cropped sward with a short herb height. stalling succession at very early stages (Cates R. Orians 1975), and an area open semi-natural scenery frequented by visitors with influence of their attendant trampling (Rodwell, 1992). U4 communities tending to be more plush, and as with the U20 community. are found on sites of formally forested land. Soil depth is shallow (5-10cm) in the area surveyed, most unlike the deeper soils of a U20 community, also the site has little downwash of alluvial materials which is said to be important in U4 communities. The altitude range of the site (245-315m) agrees with that described for U20 and U4 communities. but although the suggested altitude range of Ul communities is slightly lower than that recorded on site. Rodwell (1992) mentions the Malvern Hills range in his description of the Ul community in regards to the Pre-Cambrian parent materials on which the community persists.

From the description and species composition of the U20 communities given by MATCI I and Rodwell (1992), primarily from the absence of *P. aquilinum* it is reasonable to suggest the entire surveyed area is not of this land cover type. The Ule community seems to have the most likeness to that of the surveyed area, whereas the MATCH analysis has highlighted major discrepancies in the species composition of the site and for each of the prescribed Ule TW1NSPAN groups. for example the absence of *Ccrasliwitlanianuni* and the presence of *Scleropodium purem* in the stand. Added to this. the 111e community was not significantly matched to three of the TW1NSPAN uroups. Particular care was take in the identification of grasses so to reduce any recording, bias. proving very difficult to be certain of the diagnosis of'cropped vegetation in such a close-grazed sward. Rodwell (1992). also mentions similar problems encountered in surveys of grazed grasslands. in particular the awkward separation of *Ec,sm•a mina* from *ruhra.* Rich & Woodruff (1992 in Cherrill ci *al.. I* 1995) 1bund that scarce species tended to be less completely recorded than common species. but

N.B. Two more species of plant were recorded in the test data. one a species of lichen and the other an acrocarpous species of moss. both of which were unidentified.

should not be missed in the 2x2 quadrat samples. It is, however, unlikely that any recording bias in the collection of data would greatly distort the findings of the MATC11 analysis. it is the key species and their abundance and frequency which determine the coefficient values of NVC communities to the test data, and it seems each of the prescribed communities to each of the TWINSPAN groups have similar corresponding occurrences as well as discrepancies against any of the prescribed communities.

The close association of the prescribed communities between one another, and the results of the MATCH analysis may suggest the surveyed area to he a possible intermediate between the communities described by Rodwell (1992) or additional subcommunities. Figure 9 (page 46) partly illustrates how the prescribed communities arc closely associated. each locally prominent among the NVC H8 *('alluvia vulgari.s-Ulex gallii* heathland community. Rodwell (1992) also mentions the particular association of the U20 community with the U4 community, advancing and retreating in an overall state of balance. Natural degeneration of a U20 community leads to a *Ul* community. and the Ul and U4 communities are the counterparts of the dry east to the wetter west. Soil moisture playing the key role, U4 shifting to Ul as water becomes less available. with the wetter Ule subcommunity extending to parts of the oceanic west (Rodwell, 1992).



td. B. There are broad divisions in the aHes of the prra 1- paw_ uccaisional overlaps.

Figure 9, displaying associations of prescribed communities.

The area surveyed was a Ul extendino, to a U4 grassland community in wetter areas, sharing affinities with a U20 community. TW1NSPAN groups I, 00 and 101, closer to the U4 community in wetter localities, and groups 1, 3 and 6 closer to the Ul community in the dryer parts. Another possible explanation is additional subcommunities to the U4 or UI communities. Extensive further sampling in the UK since the NVC in the early 1990's has revealed considerable variation within vegetation types which are described in *Brilish Plan! Communitics* (Rodwell. 1991a, 1991b. 1992, 1994) and is not adequately covered by the range of existing subcommunities, ibr example. it has been suggested that the U5 *Na•du.s-Gct/item* and U6 *Juncus-Ecsmca* grassland communities have transitions to heaths and tall-herb communities which are not covered in the NVC. (Rodwell el *al.*. 2000). Strachan & Jackson (2003 in Goldberg 120031) suggest there is a need to set up a system for describing and validatimg new types of communities to represent the variations they find. as the NVC does not cover the entire range of variation in the composition of the British flora. intracommunity variability needs to he critically evaluated (Cherrill ci *al.*. 1995: lilackstock ei *al.*. *1999).* Furthermore. the emphasis of the NV(' on semi-natural vegetation also means the

N.B. Two more species of plant were recorded in the test data. one a species of lichen and the other an acrocarpous species of moss. both of which were unidentified.

representation of species is underestimated in the present model (Cherrill *al.*. 1995). New systems are being developed to circumvent such problems in the gaps in current knowledge of the distribution of land cover types and plant communities. Alma (2002). also suggests apparent intermediates between one or more groups described by Rodwell (1991. 1992) on studies on the plant communities of the North

I lill of the Malvern range. due to the imperfect match of surveyed heath and grassland communities. with particular reference to the prescribed 118e subcommunity with the absence of *C. vulgarly* from the stand, commenting on the uniqueness of the Malvern plant communities due to the geographical isolation of the hills to other elevated. acid soils and other similar vegetation types. The following communities were found by Alma Jones (1992):

- lilt) *Fesluca ovina-Agraslis eapillaris-Rumex acetosella* grassland, typical subcommunity.
- U2a *Deschampsia flexuasa* grassland. *Fesluca ovina-Agrestis capillaris* subcommunity.
- 1.120a *Pieridium aquilinum-Galium saxalile* community, *4nihoxanihuin odorat um* subcommunity.
- I. *Pleridium* *un-Galium sax-wile* community. *l'accinium* 1111'1'7111 Ls *Dicranum scoparium* subcommunity.
- 1 18e *('alluna vulgarly-ble.v* heath. I *accinium myrtillus subcommunity.*

Davis (1 994) is also said to have come to the same conclusions regarding the incomplete coverage of the N VC on such unique plant communities. in studies and her anal\ sis of veixtation in the South I tills of' the Malvern range (which includes the British ('amp area). identilvinti the Ibllowing communities:

- *Ulh Festuca ovina-Agrarlis capillaris-Rumex aceiosella* grassland. typical subcommunity.

- ti 1 e *Festuca ovina-Agroslis capillaris-Rnmex acelosella* grassland. *Gahm)] erecla* subcommunity.

- U2a *Deschampsia flex-Hasa* grassland, *Fesiuca ovina-Agroslis capillaris* subcommunity.

- U4a *Fesnrca ovina-Agrosli.s ccqfillaris-Galium .saxatile* grassland, typical subcommunity.

Due to the findings of the study, including conclusions made on the incomplete NVC coverage of vegetation types. and the systematic and analytical approach taken, requirino, an interpretation of on-site observations, the question posed regarding the origin of C. *vulgaris* on the Malvern Hills cannot be answered. Although nothing can be proved by this study, it does however suggest and possibly help confirm ideas. identifying areas of concern and help identify priorities for further research, thus helping the area to be managed in a more informed way. *C. vulgaris,* as suggested in earlier sections, is not out of character in such acid grasslands which persist throughout the Malvern range, although not integral in any of the matched communities, its presents possibly due to its close association with the NVC 1-18 *Callum' rulcrris Clexgailii* heath, where *C. vulgaris* attains constancy (the heathland community also identified by Alma 8. Jones (1992) in the North I Iills, without the occurrence of ('. *vulgari.s*• *Rodwell.* 1992 I).

The isolation of C. *vulgari.s* in the British Camp area of the Malvern I lilts invites the questions posed. It is reasonable to suut2,est the origin of('. *vulgaris* in the British Camp area of the Malvern I fills is the result of an introduction of the plant to the area. humans have been suLTested as a major dispersal vector of plants (Dunmail c Thompson. 1997). and as possibly an inyasible community. C. *vulgar-is* has been able to become

N.B. Two more species of plant were recorded in the test data. one a species of lichen and the other an acrocarpous species of moss. both of which were unidentified.

established, has persisted and may continue to expand in the area (Burke & Grime, 1996). The nutrient poor conditions and factors such as grazing and exposure which halt succession and occur in the area, are favorable to *C. vulgaris* (Britton. Marrs, Carey & Pakeman, 2000; Chapman. 1967: lason & Hester, 1993; Marrs *et al.*. 1998: Genny, Alexander & Hartley. 2002). Results from experiments by Carvers & Harper (1967). supports the picture of grassland communities found by Tamm (1956 in Carvers & 1-carper.11967]) in which vegetative recruitment from seed is extremely rare. Exhibited by the many grassland species which appear to not grow well from seed. but from rhizomes or stolons, those which do start from seed, do so in local disturbances. where the surface is broken by trampling. molehills, rabbit scratchings and anthills exposing bare soil and provide entry points for seedling recruits in communities which appear overall undisturbed (Rackham. 1986; Fenner, 1978; Grime, 2001).

Areas of bare ground is beneficial to the germination and establishment of C. *vidgari.s*·. providing there is a sufficient soil seed bank or seed rain from the surrounding area. and it is well known that *C. vulgaris* requires light for germination and is adversely affected by shading. The maintenance of a short sward through grazing, and the attendant trampling provides hare ground for the germination of seed occur (Britton, Marrs. Carey & Pakeman, 2000; Owen & Marrs. 2000). A possible boundary to the invasion of *C. vulgaris* on the hills to the north of British Camp is the A449 restricting the movement of sheep between the hills. Similar conditions and communities have been found occurring along the Malvern range in various studies, and assuming its occurrence in British Camp established over hundreds of years. one may expect C. *vulgaris* to he found throughout the hills. One may therefore he inclined to suggest a much more recent introduction of the plant to the area. and through the grazing management applied has been able to become established. has persisted and has expanded only in the British Camp area.

knglish Natures description of the acid grassland with heather given in their mana:!ement statement is that it is extensively over-uazed and the *C. ru/gariN* is in a dew'aded condition (Alma. 2002). with management proposals for the area to:

"Encourage regeneration by temporary enclosure of.vheep from small blocks to allow more vigorous growth of established shrubs, and establishment of new growth from seedlings.

In highlighting this. future management of the area is aimed at conserving and encouraging the growth of *C. vulgaris,* regardless of any suggestions of its origin. As suggested in earlier sections. the *C. vulgaris* has persisted in the area due to the levels of grazing pressures it has received. Future research could include fencing off small blocks. Grasslands can he altered by small changes of management. and it is well known that the relative growth of grass and C. *vulgaris* differ between sites. *i.e.* in the absence of grazing, *vulgaris* may replace grass and in other sites, vice-versa (Rackham, 1986; Birch *et al..* 2000). Excessive grazing, in particular if applied at the wrong time of year, can lead to suppression of *C. vulgaris* and an increase in grasses, the inherently slow growth rate of *C. vulgaris* restricts its capacity for rapid growth beyond the reach of herbivores and for the replacement of tissues removed by them (Britton. Marrs, Carey & Pakeman, 2000; lason & Hester, 1993). *C. vulgaris* is very susceptible and strongly influenced by grazing, especially during the early stages of growth and may need protecting (Owen & Marrs, 2000), high densities generally cause death. thus fragmentation and convergence to grass. Although sheep prefer grass. with C. *vulgaris* phenolics implicated in reducing its digestibility. and they generally only eat a small proportion of its annual production, C. *vulgaris* utilisation is often heaviest during winter when other forage is scarce (Miller, 1979; Palmer & I fester. 2000; Hester, Gordon, Baillie & Tappin. 1999; lason & I !ester. 1993). It was also found by I fester, Gordon. 13aillie & Tappin. (1999) that sheep deposited 73% of their faecal depositions within the grass patches (linked to spending most of their time ruminating within the grass patches). leading to increased rates of soil-nutrient cycling within the soils under grass. accelerating suLLLssion towards more mesophytic soil conditions and vegetation assemblages. It is well established that vegetation composition can change dramaticall\ as a result of changes in soil nutrients. and could reduce the likelihood of('. *•ulgari.s.* recolonisation even if grazing ceased (I Lester. Miles & (iimingham. 1991). The

N.B. Two more species of plant were recorded in the test data. one a species of lichen and the other an acrocarpous species of moss. both of which were unidentified.

replacement of C. *vulgaris* by grasses is unclear, it has been attributed to over-grazing as well as under-grazing, but probably needs to he maintained at a particular degree of grazing, cutting or burning before it becomes to old and leggy to rejuvenate (Rackham, 1986).

With the area meticulously and accurately mapped using the GPS and GIS systems available, future research, could include the identification of neighbouring plant communities according to the NVC, with an emphasis on the rates and patterns of mosaics and boundaries of bracken. grasslands. scrub and woodlands on the hills, with contemplation of possibly identifying communities not adequately covered by the NVC, in respect to strengthening the suggestions made on the uniqueness of the plant communities of the Malvern Hills (Alma, 2002; Alma & Jones, 1992; Davis, 1994 lin Alma, 20021). The spatial distribution of different plant communities has a strong influence on the foraging behaviour of free ranging herbivores, a subject poorly understood, leading to poorly developed management strategies. The effects of grazing animals can have paramount importance in determining the speed or direction of plant changes in plant communities, illustrated in figure 10 (page, 52), highlighting the effects of different grazing intensities on the NVC UI *lestuca-Rumex* grassland community (I !ester, Miles & Gimingham. 1991; Rodwell, 1992). With such research on the effects of grazing intensities on the unique plant communities which exist in the Malvern Hills. a more informed approach to the management of the hills may he achieved.

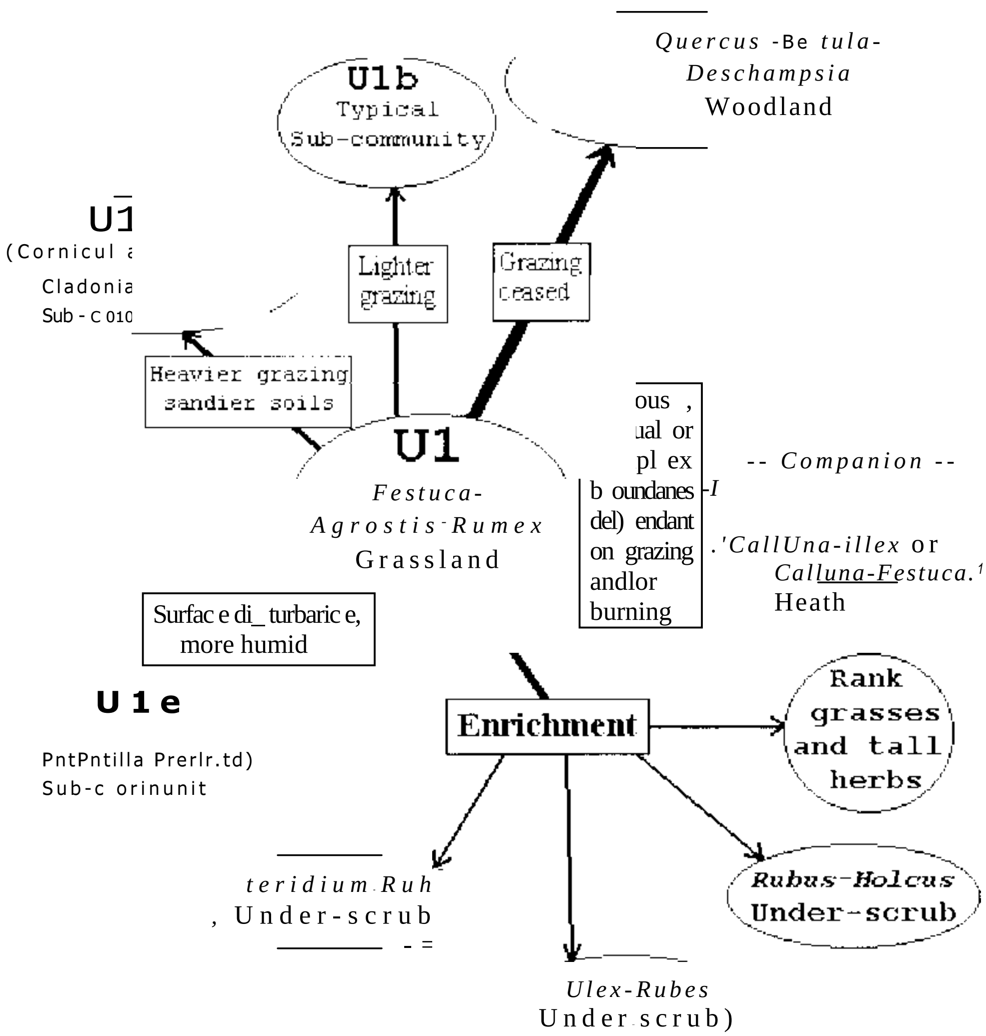


Figure 10. I lects of grazing pressures and enrichment on an NVC U I community.

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- 7. Appendix 1 .

Copies of completed National Vegetation Classification site survey sheets.

Nyc record sheet 2/76

Location (jko,t ((•)	Grid reference So 760 395	Region d,(Cx./N„d1)	Author

Site and vegetation description

C7/ ¡Ck Ot—c Gt C

ı o c -1_ c,' L

t 6 m below])

efı) r / Bramble

← rose 10 m away

J Very dry, muck

Date 770	Sample no. (S„
Altitude Og m	Slope C) 0
Aspect , o	Soil depth (0 Co
~~Stand area~~ C\	Sample area x Z n

Layers : mean height
5C m m m r

Layers: cover
80 % % %

Geology

list

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• N 1A

rt'■

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• i

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)CC 1)

Soil profile

I lardi C. W. G. (1970). A *Guide to the Geology of the .1Ialvern Hills and Adjacent .1reas.*
Publication details not given.

NYC record sheet 2/76

Location
441, /

reference
SO 760397

Region
1 ; 1

Author
P B

Site and vegetation description

Gley

soil on

Hill.

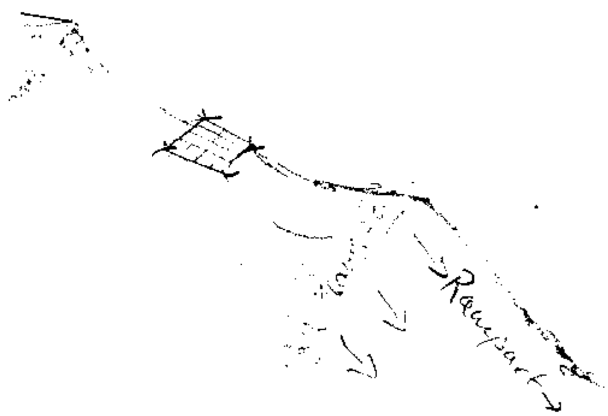
close to top of

slope, low rabbit

Calcareous

;err'

(J-



Date /
/

Sample no.
~~1eq~~

Altitude
CD 0 m

Slope / Y°

Aspect
0

Soil depth

Stand area

Sample area
x 2 n

Layers: cover

Geology

Species list

A. ... (6)

... (6)

D. flexuosa (6)

G. saxatile (5)

4

F. rubra

(5)

Soil profile

Rose. F. (1981). *The frild 1ower* Kcy Penguin Books.

NYC record sheet 2/76

Location	Grid rererenc.e	Region	Author
British camp Malvern Hills	760390	West Midlands	PB

Site and vegetation description

grassy acid grassland with Vaccinium ... below, encroaching bracken to either side (5 m)

Date //• (7°	Sample no. 15
Altitude 7 m	Slope 30°
Aspect 155 o	Soil depth 5- 6 cm
Stand area x m	Sample area 7 m x ? m
Layers: mean height Cm	
Layers: cover % % % %	
Geology	

Species list

C. vulgaris 8
D. flexuosa 6
Luzula sp. 3
P. ... 2
... 3
...
... 3

Soil profile

- 8. Appendix 2.

GIS printouts.

Rose. F. (1981). *The frild 1ower* Kcy Penguin Books.

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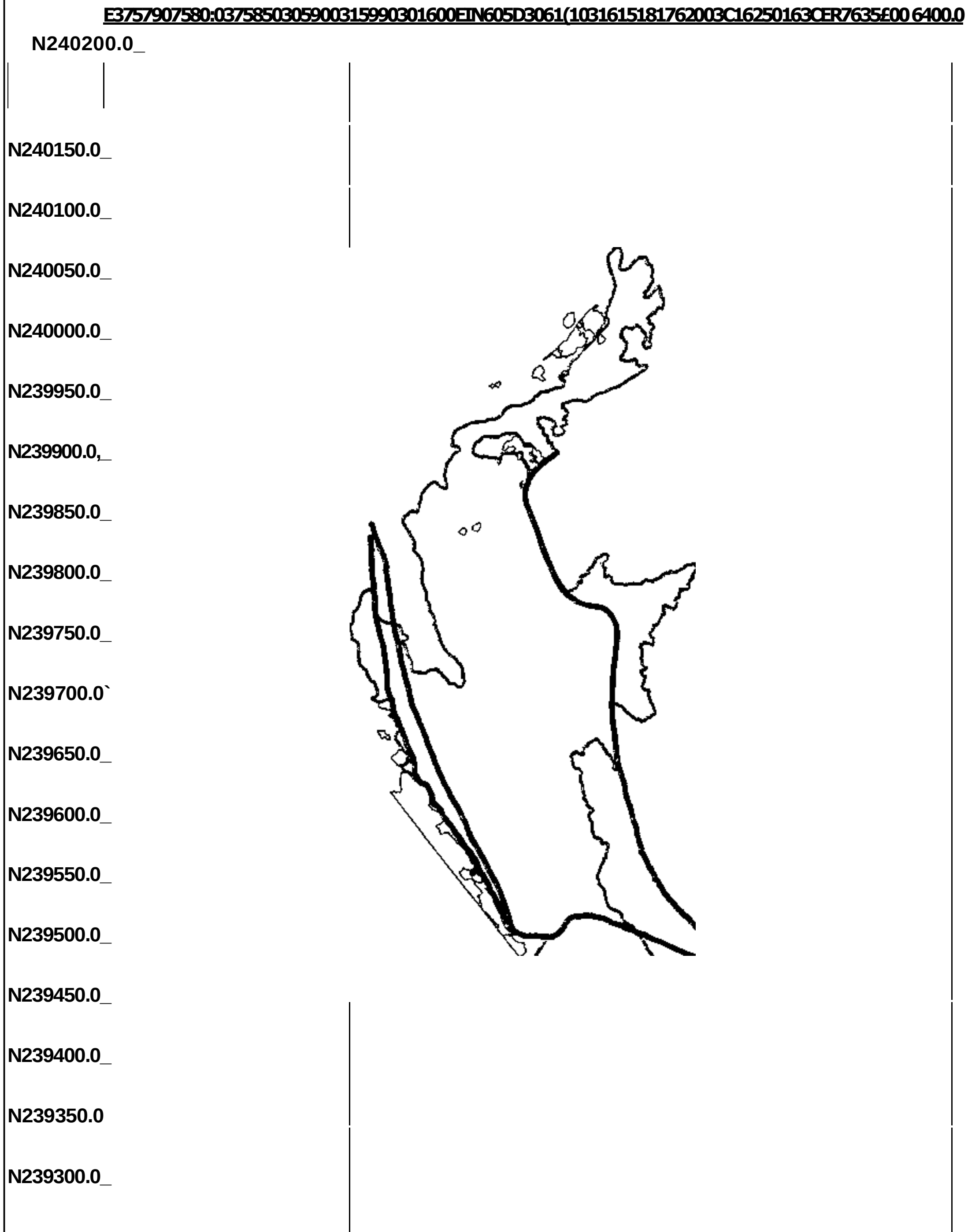

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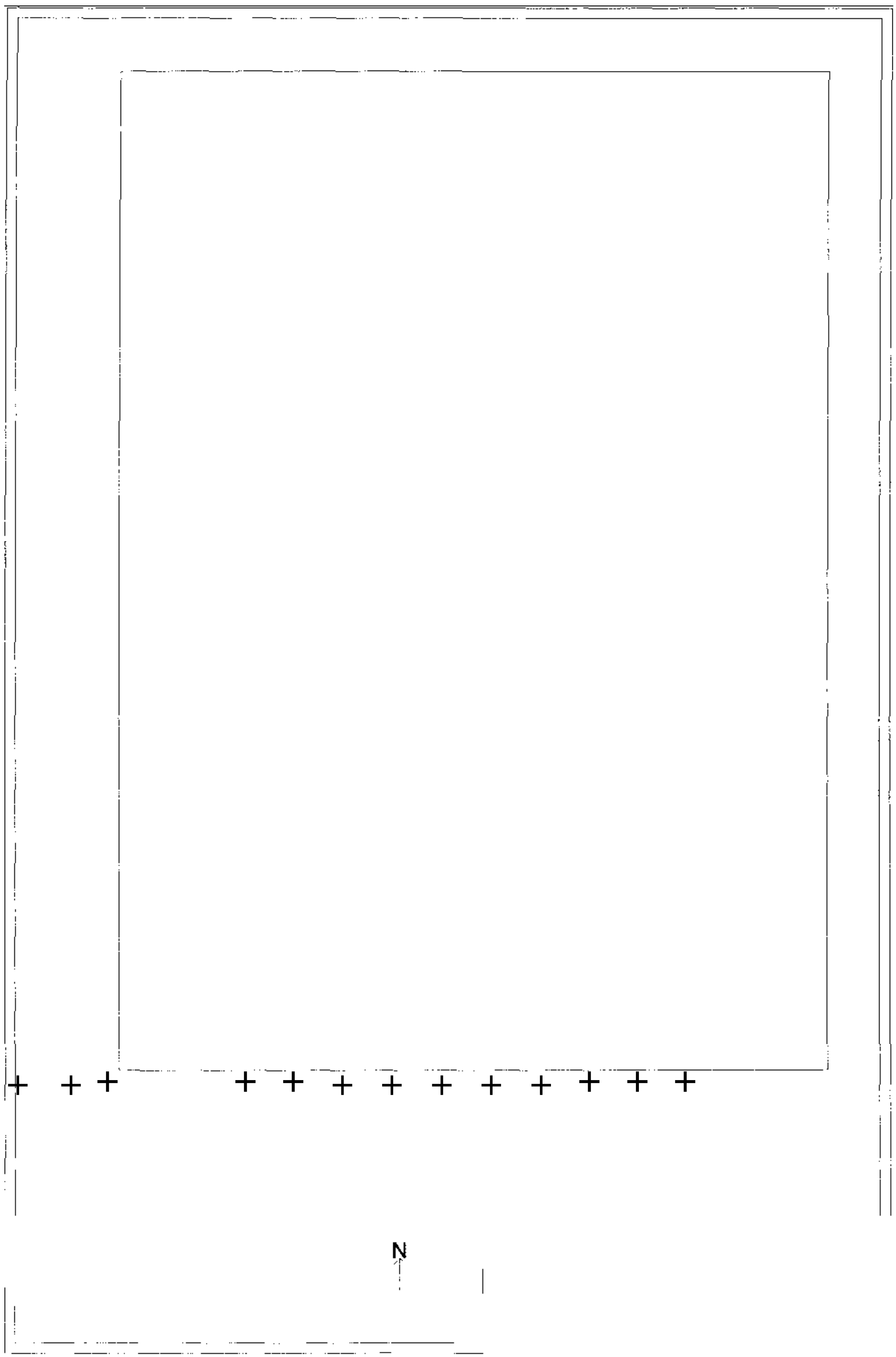

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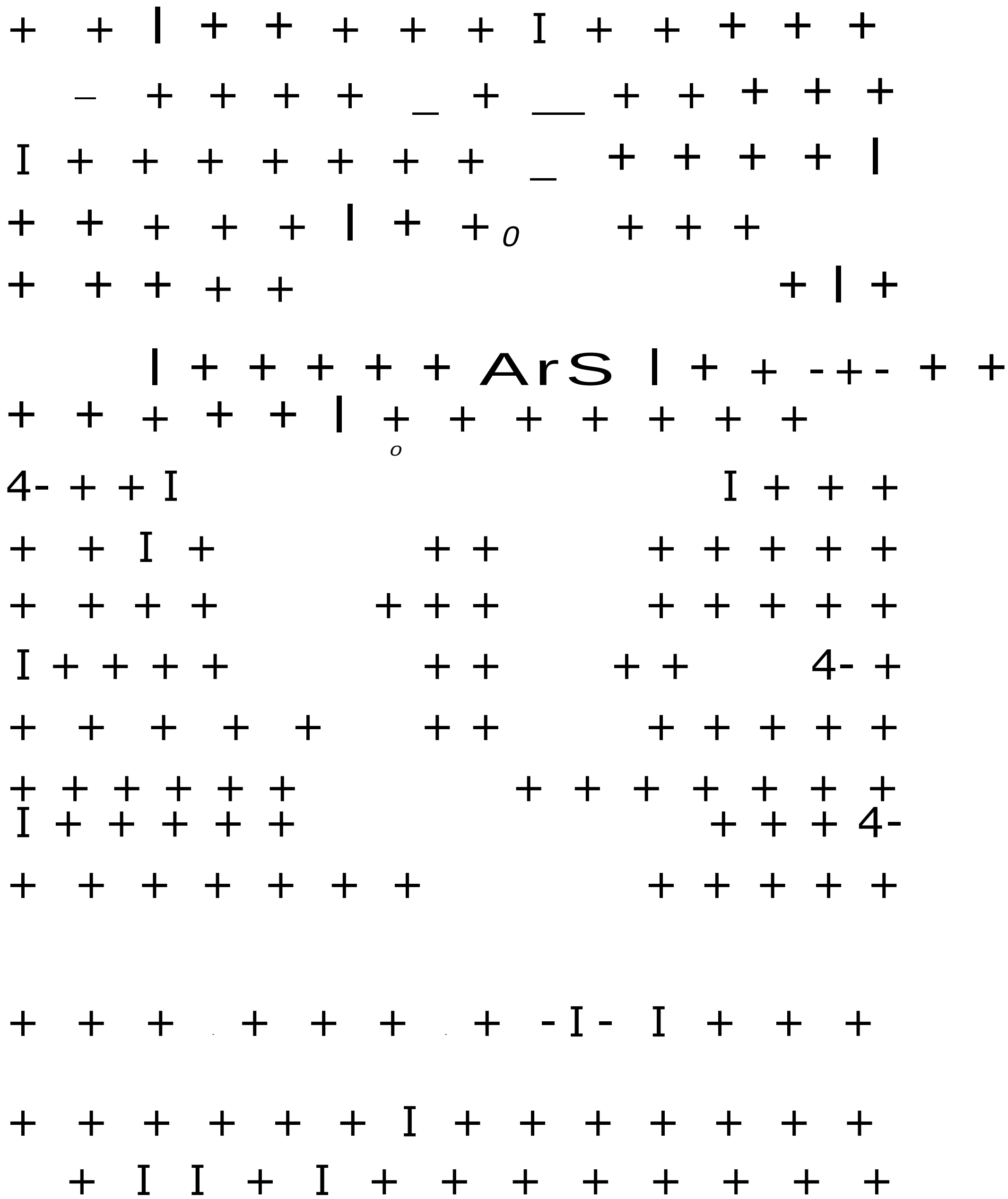

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