Historical Grassland Turboveg Database Project:

2067 Relevés recorded by Dr Austin O' Sullivan 1962 – 1982

Final report

(Including User Guide and CD of Database)

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1. Introduction

1.1 Irelands grasslands in context

The more common grassland types occupy about 70% of the Irish landscape (O'Sullivan, 1982), but information on these vegetation types is rare. Generally, Irish grasslands are distinguished based on the intensity of their management (improved or semi-natural grasslands), and the drainage conditions and acidity of the soil (dry or wet, calcareous or acidic grassland types) (Fossitt, 2000). However, little is known about their floristic composition and the changes in floristic composition over time. The current knowledge on grassland vegetation is mostly based on a survey of Irish grasslands by Dr. Austin O'Sullivan completed in the 1960's and 1970's (O'Sullivan, 1982). In this survey O'Sullivan identified Irish grassland types in accordance with the classification of continental European grasslands based on the principles of the School of Phytosociology. O'Sullivan distinguished five main grassland types introducing agricultural criteria as well as floristic criteria into grassland classification (O'Sullivan, 1982). In 1978, O'Sullivan made an attempt at mapping Ireland's vegetation types including the five grassland types distinguished in his later publication as well as two types of peatland vegetation (Figures 1 and 2). This map was completed using 1960's soils maps (National Soil Survey, Teagasc, Johnstown Castle) and a subsample of the dataset on the composition of Irish grasslands. Phytosociological classification of vegetation is based on the full floristic composition of the vegetation as determined by assessing the abundance and spatial structure of the plant species in a given area. The actual area of the survey (or relevé) is determined according to strict criteria, which include how representative the sample area is for the wider vegetation (*i.e.* how many of the species found in the wider area are also present in the survey area).

Irish grasslands have traditionally only been important economically for production agriculture, occupying 5.6 million ha or 93% of the agricultural land (Jeffrey *et al.*, 1995). Recent requirements under the Convention of Biological Diversity and the EU

Habitats Directive, however, have renewed interest in assessing the floristic composition and diversity of Irish vegetation types. The dataset collected by O'Sullivan provides data on the state and species composition of Irish grasslands before Ireland joined the EU and the onset of increased agricultural intensification. There is a great need for baseline data and long-term monitoring to highlight the temporal changes resulting from our management practices (Willis *et al*., 2005).

Certain Irish grassland types also are of great national importance for their amenity value and as holders of our natural heritage (*e.g.* Fermanagh meadows, Shannon callows, calcareous grasslands associated with eskers, Burren grasslands, and coastal and wetland grasslands) (Jeffrey *et al*., 1995). The area occupied by these grasslands is small today compared with the past. Change and intensification of land-use is continuing to be responsible for their decline as often their location has not been identified and they are not protected by environmental legislation. The survey of Irish grasslands by O'Sullivan provides a valuable historical baseline representing many of Ireland's grassland types.

The use of historical biological data is becoming more and more widespread as the value of long-term studies is being recognised in biological and environmental sciences.

However, over time, information loss from biological datasets can be considerable and the quality and detail of metadata associated with historical datasets will determine to what extent historical datasets can be interpreted (Michener *et al*., 1997). Since O'Sullivan's data have both an immediate use as a source of information on the floral composition of Irish grasslands and a future use in terms of providing a baseline for future studies of grasslands, it was particularly important that the full extent of information about this valuable dataset was preserved and made accessible to a wide range of potential and current users.

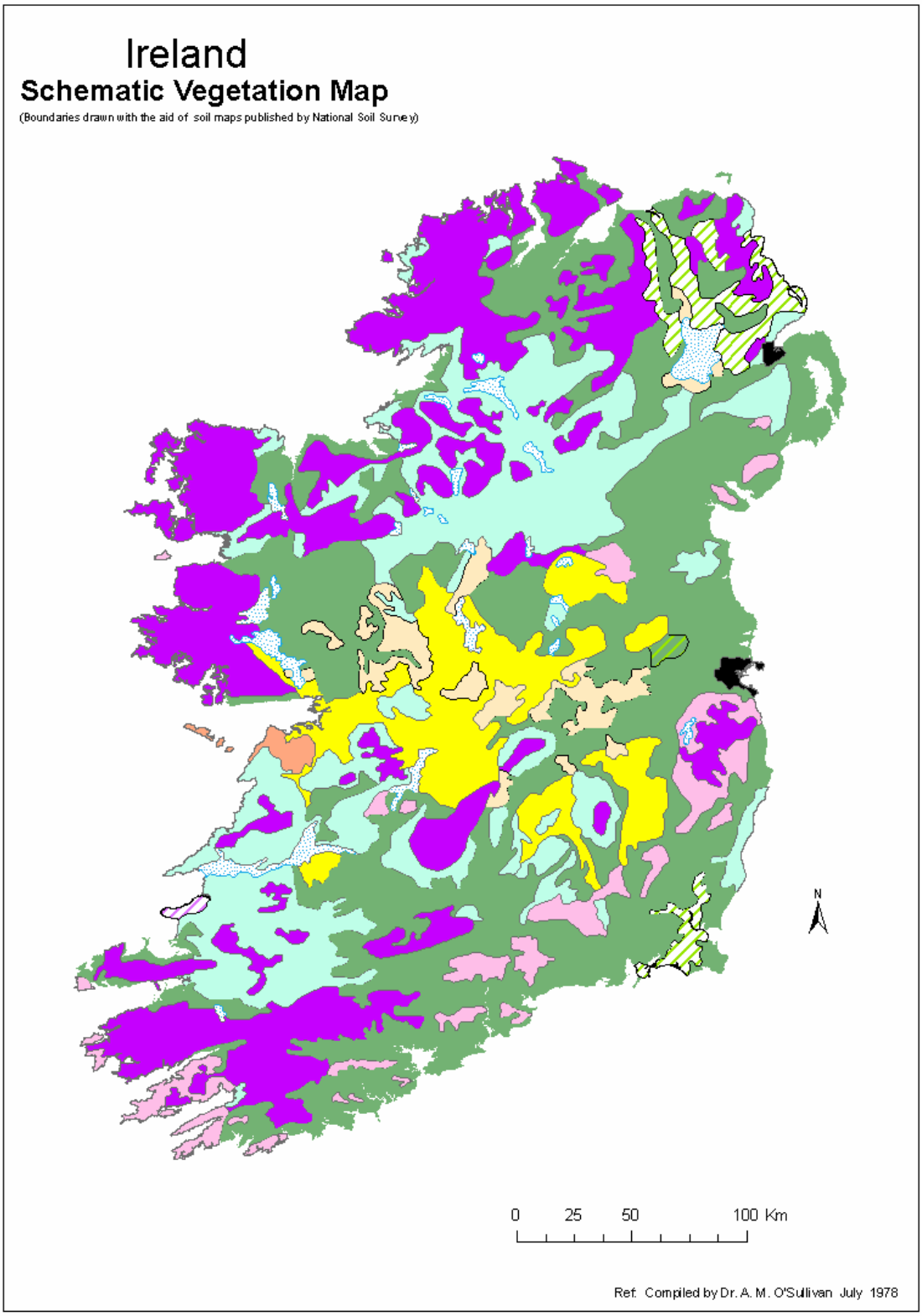
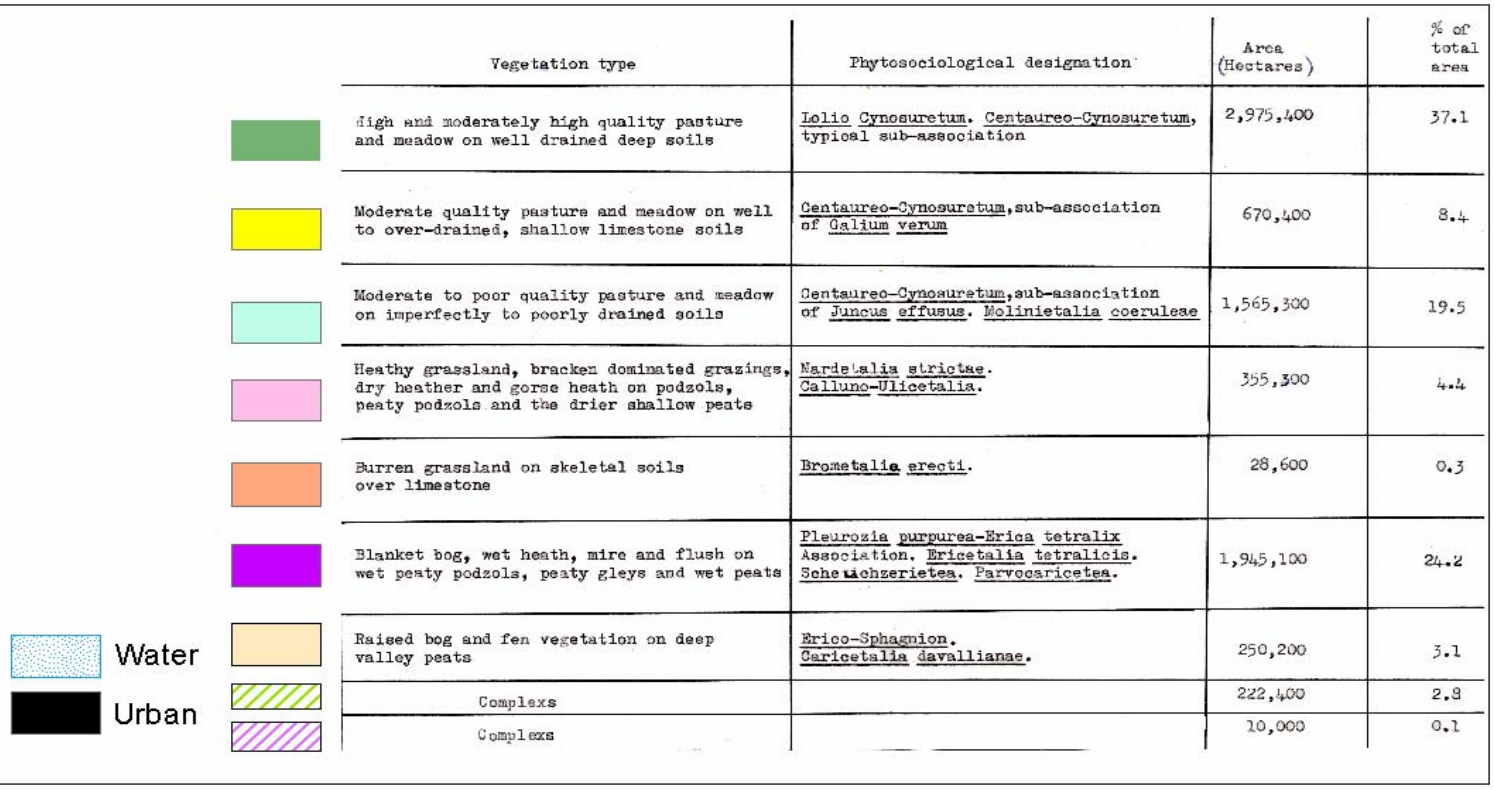


Figure 1: Distribution of main vegetation types in Ireland (O'Sullivan, 1982).

Schematic Vegetation Map Legend



Vegetation type	Phytosociological designation	Area (Hectares)	% of total area
High and moderately high quality pasture and meadow on well drained deep soils	Lolio Cynosuretum. Centaureo-Cynosuretum, typical sub-association	2,975,400	37.1
Moderate quality pasture and meadow on well to over-drained, shallow limestone soils	Centaureo-Cynosuretum, sub-association of Galium verum	670,400	8.4
Moderate to poor quality pasture and meadow on imperfectly to poorly drained soils	Centaureo-Cynosuretum, sub-association of Juncus effusus. Molinietalia coeruleae	1,565,300	19.5
Heathy grassland, bracken dominated grazings, dry heather and gorse heath on podzols, peaty podzols and the drier shallow peats	Nardetalia strictae. Calluno-Ulicetalia.	355,300	4.4
Burren grassland on skeletal soils over limestone	Brometalia erecti.	28,600	0.3
Blanket bog, wet heath, mire and flush on wet peaty podzols, peaty gleys and wet peats	Pleurozia purpurea-Erica tetralix Association. Ericetalia tetralicis. Scheuchzerietea. Parvocaricetea.	1,945,100	24.2
Raised bog and fen vegetation on deep valley peats	Erico-Sphagnion. Caricetalia davallianae.	250,200	3.1
Complexs		222,400	2.8
Complexs		10,000	0.1

Water

Urban

Figure 2: Legend describing the phytosociological designation of Ireland's vegetation types illustrated in Figure 1.

1.2 Relevé information

The O'Sullivan grassland dataset was only available in their original hard copy form at the Teagasc Environmental Research Centre, Johnstown Castle, Wexford. The survey consists of approximately 2,900 relevés from grassland sites around Ireland, many of which included information on landscape context, management, and soils as recorded on standardised sample cards. At all sites, the relevé (Figures 3 and 4) contains at least a list of the species present, their abundance and the sample area. Many of the relevés also contain information about the site, associated ecology (*e.g.* slope, aspect, altitude, rainfall, landscape and habitat features, total cover of vegetation, grass cover, moss cover, hedge species and information on phenology), and management. Information on the soil chemical, biological and physical characteristics (*e.g.* soil phosphorus, potassium, lime requirement, magnesium, pH, organic carbon, manganese, aluminium, soil texture, stoniness, drainage, poaching, permeability, presence of earthworms, groundwater level, organic matter content, depth of solum, main rooting zone, soil parent material, geological bedrock, and a description of the soil profile including information on the horizonation, depth of horizons, colours, and texture, structure, consistency, mottling, stoniness, rooting, etc., at each horizon) was also collected on many sites.

The current project (Phase 2) builds on an initial project (Phase 1) funded by the Heritage Council, which collated, organised and examined the raw data; describing the associated metadata, and assessed various database systems available (Bourke and Hochstrasser, 2006). Database software (Turboveg Website; Hennekens and Schaminee, 2001), specifically designed to store phytosociological vegetation data and used by the European Vegetation Survey, was chosen and modified to provide a safe home to this large and detailed dataset.

The overall aim of the current project was to input 2067 grassland relevés into the modified Turboveg database, thereby ensuring that this valuable biological dataset was brought into the public domain ensuring full access to all potential users in an up-to-date data management system. It is hoped that a final project (Phase 3) will see a further 800 recently sourced O' Sullivan relevés inputted into Turboveg by the end of 2007.

Figure 3: Front page of the sample card used to record a survey of a grassland site (relevé), giving details of the site location, local landscape and habitat features, site management, hedge species present and species in flower as well as the grassland species cover abundance present.

Figure 4: Back page of the sample card used to record a survey of a grassland site (relevé), giving details of the soil chemical, biological and physical characteristics, along with any additional information on species present at the site.

2. Objectives

The specific objectives of this project proposal were to:

- Input the historical grassland dataset (2067 relevés), as collected by O'Sullivan and currently held by Teagasc Environmental Research Centre, Johnstown Castle, Wexford, into Turboveg.

- Complete a final report on the project and provide a description of the metadata including the materials and methods used in the collection of the data, and explanations of the data together with definitions and personal comments made by O'Sullivan during the period of the project, along with relevant maps, field cards and associated literature.

3. Description of the work

3.1 Project tasks

The most important and time consuming task was the inputting of the O'Sullivan grassland dataset into vegetation database Turboveg. Database management (updating the database structure, *etc*) and ensuring the quality of the data entered into the database was retained formed on-going tasks during the project. Quality checking was carried out using a variety of methods, including using in-built functions in Turboveg, by plotting exported data looking for outliers, by re-entering of the relevés, and by simply re-checking the entire relevé as entered. Describing the data (metadata) being entered into the database was also constantly up-dated as necessary during the project.

Project meetings between the researchers and the technical officer were held on a monthly basis, reviewing project progress and planning the remaining project time accordingly, ensuring the project met its objectives. A meeting was held with the staff from the National Parks and Wildlife Service in February 2007 in Johnstown Castle to

review the progress of the project. There was also on-going telephone and email communications with the staff of the National Parks and Wildlife Service.

The final task was to ensure that all available grassland data held by Teagasc had been entered into the Turboveg database and was accompanied by the relevant metadata documents and a final report.

3.2 Time

The project was carried out between October 2006 and September 2007. The time allocated in October 2006 was used to advertise, interview and recruit a suitable candidate for the technical officer position. It had been foreseen that a technical officer would be required to work on the project for a seven month period based on the time it takes to enter a single relevé into the database, calculated at between 20 and 45 minutes, depending on the amount of information contained in the relevé. Time for quality control had also been factored into this time period. However, the time for quality checking the inputted relevés was underestimated and the project was granted an extension until September 2007 to allow the completion of the quality checking and the final report to be submitted.

3.3 Location

The dataset and database were located at Teagasc, Johnstown Castle. The main data inputting was carried out at Teagasc Johnstown Castle by Stephen Nolan with help from Tamara Hochstrasser, David Bourke and Rogier Schulte.

4. Project outputs

Outlined below is a list of the outputs from the project include:

- A database of 2067 grassland relevés collected by Dr. Austin O'Sullivan between 1965 and 1982 inputted into the vegetation database Turboveg (v2.44). This dataset has been fully quality checked and is provided in two databases (NPWS Baseline and NPWS Resurvey) on CD and attached inside the back cover of this report.
- A Users' Guide (Grassland dataset in Turboveg), including a full description of metadata associated with the grassland dataset (See Appendices 1 and 2).
- A Final Report outlining a description of the undertaken work, and a list of the project outputs and recommendations.
- Popup lists developed during the project in conjunction with Dr. Stephan Hennekens (Alterra, Wageningen) specific to the O'Sullvan grassland dataset.
- Species lists specific to the O'Sullivan grassland dataset (*i.e.* a modified version of the "Brittain" species list associated with Turboveg 2.44).
- An MS Excel file containing the list of species found in the dataset and a description of the modifications made to the Turboveg species list where discrepancies occurred between it and the O'Sullivan list.
- Maps and literature associated with the O'Sullivan grassland dataset.
- Recommendations arising from the project, relating to future inputting of biological data into Turboveg, future needs of the O'Sullivan grassland dataset and associated resources, and future research projects.
- Presentation of the dataset at the 'High Value Grassland' conference at Keele University, Staffordshire, UK, April 2007.

The National Parks and Wildlife Service intend on making this grassland database and report available to the National Biodiversity Records Centre who will be responsible for making the O'Sullivan grassland dataset and report available to the public.

The current location of the original hard copies of the grassland relevés and the associated resources (maps and literature) is at Teagasc Environmental Research Centre, Johnstown Castle, Wexford. To obtain access to these items please contact Dr. Rogier Schulte of Teagasc or Dr. Austin O'Sullivan. These items are very sensitive to handling and movement due to their age, and will not be allowed to be moved from their current location.

5. Recommendations

- A further 800 relevés have been recovered by Dr. Austin O'Sullivan since the current project began. It is recommended that these relevés be inputted into Turboveg as soon as possible.
- The information inputted into Turboveg was found on the original relevé cards as filled out by Austin O'Sullivan during his survey of Ireland's grasslands between 1965 and 1982. Associated with these relevés were 1/2 inch Ordinance Survey maps on which the locations of the surveyed relevés were marked. Photographs of many of these sites were also taken during the survey. It is recommended that the original relevé cards, the 1/2 inch maps and the colour slides (stored at Teagasc, Johnstown Castle) be preserved electronically by scanning and that they are held with the O'Sullivan grassland dataset now stored in Turboveg.

Use of the grassland dataset for future research

- The O'Sullivan grassland dataset has the potential to contribute towards a full classification of Irelands grassland plant communities.
- As the O'Sullivan grassland dataset was collected during the 1960's and 1970's it has the potential to provide a valuable baseline for assessing the effects of agricultural intensification on the vegetation. The lack of baseline data in monitoring programmes has been highlighted in European agri-environmental schemes and in particular REPS in Ireland as a difficulty in assessing the environmental effectiveness of the schemes.

- The future of Ireland's grassland habitats will require the development of tools to allow appropriate management and monitoring of these habitats. There is much scope for remote sensing combined with GIS to provide such tools, allowing the on-going monitoring and mapping of grassland plant communities and their assessment in the face of changing national and international policy and local management prescriptions. The O'Sullivan grassland dataset will provide an important baseline for such monitoring.
- The O'Sullivan dataset will also be important towards the development of appropriate management prescriptions to help manage, restore and safeguard the diversity of Ireland's grasslands.

6. References

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Michener, W.K., Brunt, J.W., Helly, J.J., Kirchner, T.B., Stafford S.G. (1997). Nongeospatial metadata for the ecological sciences. Ecological Applications, 7: 330-342

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Turboveg Website: http://www.synbiosys.alterra.nl/turboveg/

Willis, K.J., Gillson, L., Brncic, T.M., and Figueroa-Rangel, B.L. (2005). Providing baselines for biodiversity measurement. Trends in Ecology and Evolution, 20: 107-108.

Appendix 1: Irish grasslands database in Turboveg: Users' Guide

1. How to install the programme and the set it up for the database?

1. If you have Turboveg (Version 2.44) installed on your computer proceed immediately to step 2. Otherwise begin with copying the file tvsetupCD from the CD with the database onto your desktop and double click it to install Turboveg. We recommend you accept defaults during the installation process. This will install Turboveg in c:\turbowin.

2. In order to use the Irish Grassland Database you need to copy the specific categorical data about the environment where relevés were taken into the programme directory of Turboveg. They are stored in the directory called 'new popup' on your Irish Grassland Database CD. Copy all files from this directory into your c:\turbowin\popup directory (you only need to worry about overwriting files in this directory if you have made modifications to the original pop-up lists of Turboveg for another database). These data will show up in the relevés themselves as well as in the so-called pop-up lists in the programme menu, when new relevés are entered. If you fail to copy these pop-up lists the categorical data will show up as numbers instead of categories (*e.g.* you will see 02 instead of 'slight' in the 'poaching' category).

3. Now you still need to copy the data from your CD into the directory c:\turbowin\data. Simply copy and paste 'Grassland' folder from your CD into the c:\turbowin\data folder.

2. Starting Turboveg and opening the databases

To start Turboveg simply click on Tvwin. (In the older version (2.0) you will be asked for user name (default: 'manager') and password (default: 'zostera')).

To open a database click on Database -> Open…. To open the overall grassland survey (including baseline data for experiments) select the "baseline" database in the Grassland directory. Also included in the Grassland Directory will be relevés associated with sites in the baseline database that were resurveyed by O'Sullivan which can be found in the "resurvey" file.

In order to see all the header and species data displayed properly in your grassland database, you need to make the changes to the header data and species data described under section 4.2 of this appendix.

3. About the data

3.1 Remarks

The remarks are stored in a separate MSWord file as well as in the Turboveg database.

(1) Address: the address gives the approximate location of the field that was sampled. Usually a distance (in miles – read from the car mileage meter) from a certain village/ town is given**.** The exact location of the field is marked on 0.5" Ordinance Survey maps stored at Johnstown castle. Usually O'Sullivan would stay overnight in a town and survey about 8-10 fields a day. These relevés would have consecutive serial numbers on the map, such that the route of the day can be reconstructed. This will give the direction in which O'Sullivan was driving when approaching the field's location. **The field will always be on the left hand side of the road.** The selection of the fields was random in that the distance O'Sullivan would drive was decided on in the town before setting out. Since O'Sullivan was surveying along the main road, the survey maybe slightly biased towards grassland types on better soils and with better agricultural management (this would apply more so in the E of Ireland).

(2) Landscape and habitat features of stand: At the end of this section often a description of the field can be found.

(3) Management: overall management, grazing intensity and plant growth is mentioned.

(4) Soil profile description: if a soil pit has been dug, the description of the horizonation, soil colour and sometimes texture is given here. For a period of two years the soil descriptions were done by an experienced soil scientist from the soil survey (Paddy Barry – later Dr. Paddy Barry of UCD Faculty of Agriculture).

(5) Description of field boundary as well as miscellaneous other remarks.

3.2 Turboveg header data

3.2.1 Sampled by

The principal author of the data was entered as noted on the relevé cards. Austin O'Sullivan would have often been present when James White was sampling. Sometimes a second name is mentioned on the relevé card. D. McG. stands for David McGrath a student, who worked alongside O'Sullivan for a summer, and P. B. stands for Paddy Barry, the soil scientist working with O'Sullivan.

3.2.2 A, Serial No. (Ser. No) and Cont

A serial number was given to each relevé by O'Sullivan. This number is included in the three card system that was used for coding information on field cards onto 80 column IBM punched cards (1-73). The first two cards contained botanical information only with the third card containing soil chemical and physical information. Supplementary information was contained on rest of the card. Numbers 74-80 were used to help identify the card using a UCD computerised system. G = grassland, A was O'Sullivan's code in UCD etc. **This serial number will act as a link (*i.e.* key field) between the relevés as entered into Turboveg and the original relevé cards.**

3.2.3 Relevé area, slope, aspect and altitude

As described on the relevés card by O'Sullivan. In the case of experimental sites all plots were assumed to be the same size (usually 16m x 6m, *i.e.* 96 m^2). Some relevés were very large, *i.e.* 10 m x 10 m (100 m^2) or 20 m x 20 m (*i.e.* 400 m^2).

3.2.4 Vegetation cover scale

Vegetation cover scale used for all relevés of Austin O'Sullivan and James White is: 01: Braun-Blanquet (old) (Table 1). If the abundance of a given plant species was in parentheses (*e.g.* (+)), it was entered as r into Turboveg. **Therefore the value r has to be re-interpreted for this dataset as meaning present in field, but NOT in relevé.** On occasion a ° is noted besides a cover value (*e.g. Veronica chamaedrys* 1°). This means that the species is growing badly, *i.e.* it is sickly looking and does not seem to be in its optimal habitat (*e.g.* a nettle growing in a manure patch). This annotation was not entered into Turboveg in the current database.

Table 1: Braun-Blanquet scale used to describe cover-abundance of grassland species (Braun-Blanquet, 1928, 1964).

Cover value	Description	Percentage cover (%)
r	Present in field, but NOT in relevé	0%
+	sparsely or very sparsely present, cover very small	<1%
1	plentiful but of small cover value	1-5%
2	any number of individuals covering 6-25% of the area	6-25%
3	any number of individuals covering 26-50% of the area	26-50%
4	any number of individuals covering 51-75% of the area	51-75%
5	any number of individuals covering 76-100% of the area	76-100%

3.2.5 Plant cover within relevé

The cover was taken from the relevé cards. The total cover of the vegetation was often < 100. This was because the cover of grazed grassland often drops below 100, because of hoof prints, manure patches and other soil surface disturbance. Herb cover (also called Layer 1 on some cards) and moss cover (also called Layer 2 on some cards) can overlap such that their sum could on occasion exceed 100 per cent. This could arise where there was a well-developed moss layer beneath a herb/grass layer. It could also arise where certain species like creeping thistle (*Cirsium arvense*) and bracken (*Pteridium aquilinum*) created a canopy over the pre-existing herb and/or moss layer.

Sometimes the sum of the cover of the herb layer and the moss layer add up to less than the number entered for total cover, in which case the values for the herb layer and moss layer should be trusted and the total cover should be replaced by the sum of the cover of the layers. In different vegetation types such as Heathland or Woodland more vegetation layers are described. The moss layer would sometime be < 1% cover. This was entered as 1%, since Turboveg does not allow for cover to be entered as a fraction of a percent.

3.2.6 Vegetation formation, association and subassociation

These were entered according to O'Sullivan's analyses. Austin O'Sullivan completed many phytosociological tables refining his classification over the years. The relevés that represented a particular grassland type well were stamped with the appropriate association and subassociation name.

3.2.7 Land use

Land use was coded by conversion of the qualitative description on the relevé card into 5 categories as shown in Table 2. Broadly speaking grassland is utilized either for grazing farm-animals or for cutting as a stage in converting the crop into either hay or silage. The number of annual cuts may vary from one to three during the growing season. On dairy farms, especially, a grass field may in the same year be alternately used for grazing and for cutting. Land use (pasture or meadow) was described as encountered at the time of the relevé. Most Irish grassland is managed as permanent (old) pasture grazed by either cows, cattle or sheep. Permanent meadows are mainly confined to the gley soils of the western counties of Clare, Limerick, and Kerry and the Shannon floodplain south of Athlone.

Grassland reseeded with bred varieties of grass and clover and less than five years sown is called ley grassland. It may be utilized for grazing or for cutting to convert the hay or silage as with permanent grassland. It was determined if the grass had been reseeded by digging up a piece of sod and determining if it was falling apart. If it did, the field was

considered reseeded. Further evidence for reseeding was the composition of the vegetation: a reseeded field would have a predominance of *Lolium* spp. as well as the occurrence of weedy forb species (*e.g. Stellaria media, Papaver rhoeas,* and *Senecio vulgaris*). Reseeded fields also tended to have an uneven soil surface. The full description can be found in the remarks section.

Table 2: **Land use categories used in Turboveg**

Code	*Category name*	*Description*
01	Ley and permanent pasture	Sward less than 5 years old or in tillage rotation
02	Ley and permanent meadow	Young sward (less than 5 years old) and closed for cutting.
03	Old pasture	Sward over 5 years old and mainly grazed
04	Old meadow	Sward over 5 years old and mainly cut.
05	Rough pasture	Badly managed or poor pasture with *e.g.* rock outcrops and/or invading scrub

3.2.8 Grass growth

Grass growth was determined by O'Sullivan in the field and written down as a verbal comment (Table 3). The estimation of grass growth involved a quantitative assessment of sward appearance in relation to the time of year. Sward height and sward luxuriance, especially the proportion of leaf to stem, was used to arrive at a conclusion. The baseline for the judgement on a particular field was also influenced by visiting fields with similar ecological and management regimes in the days prior to sampling. Minor indicators for the length of time since the last grazing would have included the age of the dung-pats among others.

Table 3: Grass growth categories as used in Turboveg

Code	*Category name*	*Other descriptions on relevé cards*	*Description*
01	Poor	Poorish Poorish to moderate Very poor	Grass growing badly. Sward poor in grass (<20 % cover) and rich in herbs
02	Moderate	Moderate to poor Moderate to good Moderately good	Grasses AND herbs conspicuous, about 60% grass and 40% herbs.
03	Good	Good to moderate Fairly good	Good grass growth.
04	Excellent	Very good Lush	Vigorous grass growth (over 80 % grass cover)

3.2.9 Field size

The field size was mostly estimated in acres. Where this was not the case, the size categories created in Turboveg were discussed with O'Sullivan and correspond to what he would call 'small, medium and larger' (Table 4). Additionally, non-numbered categories were created for relevés where a non-quantitative description of field size was available. **When analyzing the data these will have to be merged with the quantitative categories.**

Table 4: Field size categories as used in Turboveg.

Code	*Category*	*Quantitative description of size (for last three categories)*
01	< 2 acres	
02	3-6 acres	
03	7-10 acres	
04	11-14 acres	
05	15-19 acres	
06	> 20 acres	
07	small	0-2 acres
08	medium	3-5 acres
09	large	6-20 acres and more

3.2.10 Grazing animal type

Austin O'Sullivan would often mention what grazing animals were observed on the field where he did the relevé. Often also the breed of the grazing animal is mentioned (cf. remarks section). The description was matched as closely as possible to the categories described in Table 5, with sometimes one or two extra animals left out (*e.g.* chicken, donkeys, etc**.). For relevés that do not contain information in this category the information may possibly be supplemented with information from the general landscape description (cf. remarks).** Botanically, the most important distinction between grazing animal types lies between cattle and sheep.

Table 5: Grazing animal categories as used in Turboveg

Code	Category	Other descriptions on relevé cards
01	Cows or heifers	Herd of Friesian
02	Cattle (non-milking)	Bullocks, Calves over 3 months old, mature cattle
03	Cows and calves	Cows and cattle
04	Sheep	
05	Sheep and cattle	
06	Sheep and horses	
07	Horses	Racehorses
08	Goats	
09	Cattle and horses	

3.2.11 Grazing intensity

The grazing intensity was described qualitatively by O'Sullivan and translated into a category system (Table 6). The grazing intensity was determined by looking at the amount of dung pads and dead plant material. If the fertilization regime was known, grazing intensity also took into account amount of regrowth.

Table 6: Grazing intensity categories as used in Turboveg

Code	*Category name*	*Other descriptions on relevé cards*	*Description*
01	Light	Extensively	Grazing sparse and patchy
02	Moderate		Some grazing obvious all over the field
03	Heavy	Overgrazed Very heavily	Most of the sward grazed down

3.2.12 Field boundaries

Woody hedge species were coded in the species list (cf. below) and their relative abundance is written down in the remarks section of the database. Apart from the woody species note was also taken of the presence and absence of *Digitalis purpurea* and *Pteridium aquilinum* as they are indicators of acidic conditions, and of *Anthriscus sylvestris* as it indicates high fertility and high pH conditions. The information on hedge species from this survey was also used by O'Sullivan to create a map with the aid of the General Soil Map (An Foras Taluntais (1969)) entitled "Composition of Field Boundaries

1974". In Turboveg the physical boundary around the field (apart from the hedge) is included.

3.2.13 Parent Material (Geology)

The parent material categories were entered into Turboveg as noted on the relevé cards by O'Sullivan. Austin O'Sullivan determined these by examination of the rock fragments in the subsoil (*e.g.* by using acid). (Austin O'Sullivan had studied geology at UCD and had worked alongside experienced soil surveyors (*e.g.* Dr. Paddy Barry of UCD) at various times). Glaciers would mix rock material in varying proportions, move it around and then deposit it in a way that was often unconnected with the underlying rock. For about eight Irish counties soil surveys have been completed by staff of the former An Foras Taluntais (later Teagasc). The only practising glaciologist in Ireland, Francis Synge of the Geological Survey, had an input to several of the County Soil Surveys and also prepared a special map of the glacial drift deposits (Counties Carlow, Limerick for example).

3.2.14 Soil type

The soil at each relevé site where a soil pit had been dug was summarised as belonging to one of the following Great Soil Groups (see Gardiner and Ryan (1964): Soils of Co. Wexford. An Foras Taluntais): Brown Earth, Brown Podzolic, Podzols, Grey-Brown Podzolic, Gley, Regosols, Lithosols, Peat. In Turboveg, the categories were taken from the soils map of Ireland (General Soil Map, An Foras Taluntais (1969)) and entered as described by O'Sullivan. There were also a few transitional types – these can be seen in the remarks section, or the categories 'intermediate' were chosen, such as in the case of Acid Brown Earth (entered as 'Intermediate Brown Earth/ Brown podzolic').

In counties where a soil survey was completed (*e.g.* Meath, Carlow, Limerick, Clare, and Donegal), O'Sullivan described the vegetation on a number of typical soil profile sites. In these locations the particular Soil Surveyor had already examined the soil in detail and classified it to Soil Series level. This designation is recorded on the relevé card where it was known. A summary of the vegetation description can also be found in the soil survey of the particular county.

3.2.15 Soil characteristics

Soil characteristics were coded as on the relevé cards. Methods for soil analysis are described in the Appendix. 'Living organisms' were coded the same as 'Earthworms'. With this category the user should keep in mind that earthworm activity is weather (soil moisture) dependent and as such the data may not be very reliable. Lime requirement was sometimes entered as XL on the relevés cards: this means that there was excess lime

present (Appendix 2). In the database this can be seen in the 'Remarks' section and lime requirement was entered as '0'.

3.2.16 Depth of solum

Definition: upper layers (*i.e.* a combination of A and B horizons) of a soil profile in which biological activity occurs. This can also be interpreted as the maximum rooting depth. At the bottom of the solum often the density of the soil increases and it becomes stony.

3.2.17 Colour slide

Slides are in 2 formats, 35 mm film in cardboard mounts, 127 mm (Super Slides, not available now) film in glass mounts. Taken with twin lense reflex camera, can be projected with standard 35 mm projector.

3.3 Species list

3.3.1 Herb and moss layer

Austin O'Sullivan would have used Webb's flora of that time (3rd Revised Edition published 1959) to identify and name the species he encountered (Webb, 1959). We used an existing (relatively old) species list called 'Brittain' which was the standard species list for this part of the world in Turboveg v2.44. This had the advantage that most of the species names used by O'Sullivan were in this list. A few species names had to be updated to correspond to the species list available. The species name used in Turboveg v2.44 can be seen in Table 7. **When looking at this table the reader should bear in mind that the subspecies was NOT determined by O'Sullivan, such that the subspecies selected for this database have to be verified before further use.**

Table 7: Species names differing between relevés and Turboveg database

Name used in relevés	Name used in Turboveg
Acrocladium cuspidatum	*Calliergon cuspidatum*
Agropyron junceum	*Elymus farctus borealii-atlanticus*
Agropyron repens	*Elymus repens*
Agrostis tenuis	*Agrostis capillaris*
Atricum undulatum	*Atrichum undulatum*
Bartsia odontites	*Odontites verna*
Brassica arvensis	*Sinapis arvensis*
Bromus mollis	*Bromus hordeaceus hordeaceus*
Carex fusca	*Carex nigra*
Carex leporina	*Carex ovalis*
Catapodium marinum	*Desmazeria marina*
Centaurium minus	*Centaurium littorale*
Cerastium caespitosum	*Cerastium fontanum triviale*
Cerastium vulgatum	*Cerastium fontanum triviale*
Chrysanthemum leucanthemum	*Leucanthemum vulgare*
Cirsium anglicum	*Cirsium dissectum*
Cirsium lanceolatum	*Cirsium vulgare*
Cladonia sylvatica	*Cladonia arbuscula*
Conopodium	*Conopodium majus*
Crepis taraxacifolia	*Crepis vesicaria*
Dactylorchis fuchsii	*Dactylorhiza fuchsii*
Filipendula hexapetala	*Filipendula vulgaris*
Helictotrichon pubescens	
Avena pubescens	*Avenula pubescens*
Juncus glaucus	*Juncus inflexus*
Koeleria gracilis	*Koeleria macrantha*
Lycopsis arvensis	*Anchusa arvensis*
Matricaria matricarioides	*Chamomilla suaveolens*
Mnium undulatum	*Plagiomnium undulatum*
Myosotis palustris	*Myosotis scorpioides*
Nardus	*Nardus stricta*
Neotinea intacta	*Neotinea masculata*
Odontites rubra	*Odontites verna*
Ophrys muscifera	*Ophrys insectifera*
Poterium sanguisorba	*Sanguisorba minor*
Riccardia pinguis	*Aneura pinguis*
Rosa spinosissima	*Rosa pimpinellifolia*
Sarothamnus species	*Cytisus species*
Sesleria caerulea	*Sesleria albicans*
Sieglingia decumbens	*Danthonia decumbens*
Spergularia salina	*Spergularia marina*
Taraxacum officinale	*Taraxacum species*
Thymus drucei	*Thymus praecox arcticus*
Trichophurum caespitosum	*Scirpus caespitosus*
Trisetum	*Trisetum flavescens*
Veronica serpyllifolia	*Veronica serpyllifolia serpyllifolia*
Vicia angustifolia	*Vicia sativa*
Viola stagnina	*Viola persicifolia*

3.3.2 Hedge species

Hedge species were noted by their genus name (unless the full species name was on the relevé card). Certain genera of species in the Irish flora have only one common representative, and it is therefore obvious, which species was observed by O'Sullivan. Austin O'Sullivan agrees that these were the species observed. The name entered can therefore be translated into the names below if the user wishes so.

Table 8: Hedge species

Genus noted on relevé cards	Full species name
Aesculus species	*Aesculus hippocastanum*
Anthriscus species	*Anthriscus sylvestris*
Castanea species	*Castanea sativa*
Chamaecyparis species	*Chamaecyparis lawsoniana*
Clematis species	*Clematis vitalba*
Corylus species	*Corylus avellana*
Crataegus species	*Crataegus monogyna*
Cytisus species	*Cytisus scoparius*
Digitalis species	*Digitalis purpurea*
Euonymus species	*Euonymus europaeus*
Fagus species	*Fagus sylvatica*
Hedera species	*Hedera helix*
Ilex species	*Ilex aquifolium*
Juniperus species	*Juniperus communis*
Lonicera species	*Lonicera periclymenum*
Pteridium species	*Pteridium aquilinum*
Rhamnus species	*Rhamnus cathartica*
Rhododendron species	*Rhododendron ponticum*
Sambucus species	*Sambucus nigra*
Symphoricarpos species	*Symphoricarpus albus*
Taxus species	*Taxus baccata*

All species mentioned in the 'Hedge spp.' box were entered as 'hedge species', even if they were NOT in the hedge. Sometimes herbaceous species were included as well.

3.3.3 Phenology

All species noted as flowering were entered in the 'phenology' section, irrespective of the intensity of flowering (aspect, few flowers). If a genus name was mentioned as flowering, all species in the respective genus were noted as flowering.

4. Entering data

4.1 Creating a new database

If you would like to create a new grassland database, following the template used for this project, you simply choose *Database -> New…* . You will be asked what name you want to give to the database and the location where it should be stored. You can have folders within your turbowin/data folder. All grasslands data should be entered in the folder named 'Grassland'. Further you need to specify the species list that you want to use (for the project outlined here the species list called 'Brittain' was used) and you will have to enter a 'range for system numbers'. The minimum for this range cannot be less than 1 and the maximum can be as high as you want. Turboveg is automatically assigning a unique number to each relevé you are entering in the database and the numbers are chosen consecutively from the range that you specify here. So the minimum number that you are entering here should correspond to the number you would like to assign to the first releve entered, and the maximum number to (number of first relevé + number of relevés entered). This range can be changed later on by going *to Database -> Modify attributes*, so it is not essential that the numbers are covering the whole range of relevés that you would like to enter. Click on *Create* to make a new database.

It must also be noted that with each new Turboveg database, each relevé entered will be labelled with a relevé number, beginning with number one, unless specifically instructed to begin with a higher number. In the current project, the serial number was used as the key field, linking the relevés entered into the Turboveg databases (baseline and resurvey) to the original relevé cards.

4.2 Preparing the species list and header data structure

Once the new database is created you need to make the following changes to the database in order to enter all data contained in the grassland dataset. Go to *Database -> Modify structure*. This will open a dialogue box with two tabs: *Header file* and *Species file*. On the *Header file* tab add the fields contained in Table 9 by using CAPS lock and underscore for blank spaces. Each time you entered a field, click Add and at the end click on Rebuild. Do the same with the *species file* tab by adding the additional fields described in Table 10.

4.3 Entering data

Once you have set up your database you can start entering the data by clicking on Edit -> Add relevé. The first thing you see is a form containing the header data. For the data that are linked to pop-up lists, you can click on the question mark to the left in order to find the category that corresponds to the data you are entering. For more information about

what the categories mean refer to section III of this guide. A few of the categories have two names, depending on when the data were collected. Use them in the following way:

- ‘Living organisms’ is equivalent to ‘earthworms’
- Geologic bedrock: choose the category with the number that you find on your relevé card
- Abbreviations used for rocks: sst. = Schist, lst. = Limestone, O. R. S.: Old Red Sandstone.

Finally, type all the text from the relevé using the provided template in MS Word and copy and paste the remarks into remarks section in the header data.

Once you finished entering the header data, click on Save and this will automatically bring up the species list. Choose the species from the species list by starting to type the first three letters of the genus and the first letter of the specific epithet. If you mistype the name you can use backspace to delete what you wrote. Once the correct species name is highlighted, enter a cover value and a layer in which the species occurred. Most of the species in the grassland database are in the herb layer, except for bryophytes (mosses). Once the cover and the layer are entered, click on Add and the species will be added to your relevé data. Continue this process until all species are added.

4.4 Hedge species

Turboveg does not allow you to enter 0 for a cover value of a selected species. Thus enter a + for the cover value and then enter also a + into the box HEDGE_SPP. Make sure you enter the layer as a ‘low shrub layer – s2’. The latter will allow you to filter the hedge species out from the relevé when exporting the data from the database (Section 5).

5. Exporting data

In order to export data from your Turboveg database you need to first highlight all the relevés that you want to export (Menu item: Select). Make sure you have not previously selected relevés in another database that you would NOT like to export (ALL highlighted relevés will be exported even if they are not in the current database). Then from the Export menu select the format that you would like to export in. If you would like to export to Excel (spreadsheet) you cannot export more than 253 relevés at one time, because of worksheet size limitations in Excel**. If you are only interested in the actual composition of the relevé make sure to exclude the shrub layer – s2 from your exported data.**

Table 9: Description of structural modifications that need to be made to standard Turboveg header file to accommodate O'Sullivan's grassland dataset. (N = number and C = Code).

Field name	Description	Data type	Data width	Decimals	Description
SOIL_N	Soil Nitrogen	N	5	1	Plant available soil nutrient content (mg/l^{-1}).
SOIL_P	Soil Phosphorus	N	5	1	Plant available soil nutrient content (mg/l^{-1}).
SOIL_K	Soil Potassium	N	5	1	Plant available soil nutrient content (mg/l^{-1}).
SOIL_LR	Soil Lime requirement	N	5	1	Agronomic advice to improve soil production quality/ condition.
SOIL_MG	Soil Magnesium	N	5	1	Plant available soil nutrient content (mg/l^{-1}).
SOIL_PH	Soil pH	N	5	1	Measure of soil acidity or alkalinity.
SOIL_C	Soil Carbon	N	5	1	Soil organic carbon (%)
SOIL_MN	Soil Manganese	N	5	1	Plant available soil nutrient content (mg/l^{-1}).
SOIL_AL	Soil Aluminium	N	5	1	Plant available soil nutrient content (mg/l^{-1}).
SERIAL_NO	Serial no.	C	6	0	Relevé identification system used by A. O'Sullivan
SLIDE_NO	Colour slide no.	N	5	0	Number of the photograph (slide) associated with the surveyed site.
VEG_FORM	Vegetation formation	C	20	0	Vegetation formation (*e.g.* Lowland grassland, Upland grassland, Heathy grassland, Heathland, Shrub, Forest (planted), Woodland, Sanddunes, Marsh, Fen, Raised bog, Blanket bog etc.).

Table 10: Description of structural modifications that need to be made to standard Turboveg species file to accommodate O'Sullivan's grassland dataset. (N = number and C = Code).

Field name		Data type	Data width	Decimals	Description
HEDGE_SPP	Hedge spp.	C	2	0	List of species identified in the hedgerow surrounding the surveyed site.
PHENOLOGY	Phenology	C	2	0	List of species in flower at the time of the survey.

Appendix 2: Field and laboratory methods for determining soil properties (chemical, biological and physical).

1. Soil sampling, preparation and storage

At each quadrat (relevé site) twenty soil cores to a depth of 10 cm were collected in a zig-zag pattern **within** the quadrat. Manure patches (faeces and urine) were avoided in the process. The combined sample was packed in a waxed cardboard box (cake box) and labelled to coincide with the relevé number. A funnel sampler (1 cm diameter) was developed for the grassland survey and subsequently adopted for all soil sampling in Teagasc (Figure 5). The samples were sent by mail back to the lab, such that could be stored properly as soon as possible after collection. Dried soils (oven dried at 40^{o}C or air dried in a laboratory) were stored in cardboard boxes at room temperature prior to chemical analysis. All soils were sieved to < 2 mm before analysis.

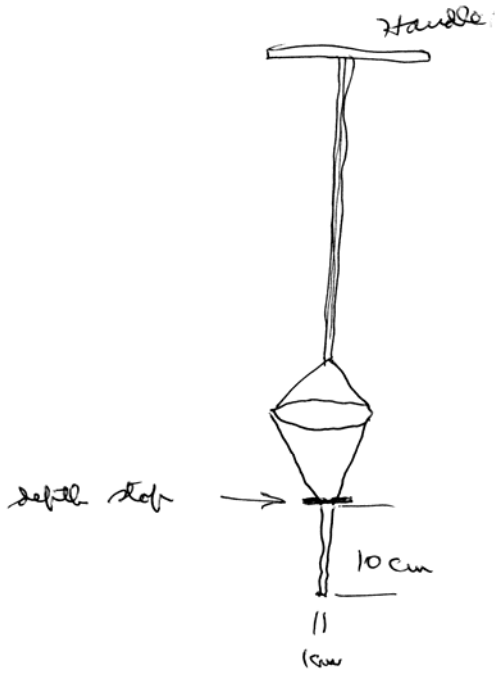

Figure 5: Teagasc bucket soil sampler.

2. pH Estimation

This procedure estimates the acidity of a soil and is an index of the lime requirement.

Soil acidity influences a number of important aspects of soil fertility including phosphorus availability, Mn and Al toxicity and organic matter decomposition as well as trace elements supply.

The hydrogen-ion concentration expressed as a power of 10 is known as the pH. By definition the pH is equal to the negative log of the hydrogen-ion concentration or

$$pH = -\log (H^+) = \log 1/H^+$$

And similarly, the pOH scale is often used to express the hydroxyl-ion concentration. pOH is defined as the negative logarithm of the hydroxyl concentration: that is,

$$pOH = \log 1/OH- = -\log (OH^-)$$

The sum of the pH and pOH is 14 because they originated from the hydrogen and hydroxyl-ion concentration (expressed in moles per litre).

Thus if H^+ ion concentration = 1×10^{-10} mol/l then the pH becomes

$$pH = \log \frac{1}{1 \times 10^{10}}$$

$$= \log 1 \times 10^{10} = \log 1 + \log 10^{10}$$

$$pH = 0 + 10 = 10$$

Method

Mix a 10ml volume of dried sieved soil (scoop measure) with 20ml of H_20 in a beaker. Stir with a glass rod and allow to stand for about 10 min. Measure the pH of the suspension to the first decimal place using a digital pH meter with glass and calomel electrodes. It is advisable to use a use a calomel electrode with sleeve type connection as the wick type can easily clog with soil particles. Stir each suspension vigorously just before measuring the pH.

3. Extraction of P, K, Mg, Ca

Soil analyses are used to predict the amount of lime and fertilisers necessary to obtain a specific crop yield from a particular soil. The majority of soils contain plant nutrients in excess of plant requirements but in a form which the plant cannot use so estimation of total nutrients is valueless.

An extracting solution is therefore designed to take from the soil an amount of nutrient proportional to that which the plant can use in any one growing season.

Morgan's extracting solution is used at Johnstown Castle.

Method:
Mix an 8ml volume of soil with 40ml of Morgan's Extracting solution pH 4.8 in a 100ml round bottomed shaking flask. Shake for 30 minutes on Brunswick Gyratory shaker, until equilibrium has been reached. Filter the suspension through No 2 Whatman filter papers into 40 ml beakers. Check that the filtrate is clear and refilter if necessary. Analyse for P, K, Mg and Ca on the clear extract. The pH of the extracting solution should be at 4.8 as differences in pH can mean difference in extracting power and higher pH values could interfere with the phosphorus determination

Filter papers should be removed from beakers as soon as possible as they increase evaporation and concentration of the solution. Do not place extracts on or near a heater. Re-filter any cloudy or soil-contaminated extracts.

Reagents

40% NaOH:- Dissolve 4 kg NaOH, Analar grade, in H_20 and dilute to 10 litres.
Morgan's extracting solution: - Add 1,400ml of 40% NaOH to about 15 litres of cool purified H_20 and shake well to mix. To this solution add 1,440ml of glacial acetic acid and dilute with H_20 to 20 litres. Adjust solution pH to 4.8.

Reference: - Rapid micro chemical soil tests, Peech, M. and English, L. (1944) Soil Science, 57: 167

Phosphorus

Phosphorus is one of the major plant nutrients and its level in soil needs to be strictly monitored because of plant nutrition and environmental impact aspects. Of the total phosphorus in the soil less than1% is available to plants and Morgan's solution is designed to dissolve an amount of phosphorus proportional to this available fraction.

Phosphorus exists in the soil in many farms, both as organic and inorganic compounds, and it is also added to the soil in manures and fertilisers in a variety of materials.

Phosphorus in soil extracts is analysed colorimetrically using the chemical reaction between P and ammonium molybdate. A characteristic blue colour (the "molybdenum blue reaction") is produced when either molybdate or its heteropoly complexes are partially reduced. The usual reducing materials used are stannous chloride, ascorbic acid or hydroquinone and sodium sulphite. Some of the molybdenum ions are reduced from 6+ to a valence, probably 3+ and or 5+, involving unpaired electrons from which the development of a colour (blue) would be expected. Phosphorus is measured on a Camspec 230 UV spectrophotometer at 675mu.

The formation of phosphorus molybdenum blue is sensitive to solution pH. If this is too acid no colour is developed; if too alkaline a blue compound, molybdenum blue, usually a precipitate, is formed which is independent of phosphorus content *(see Soil Chemical*

Analysis by M.L. Jackson, 1958 Edition, published by Prentice-Hall, Inc., Englewood Cliffs, N.J.,U.S.A.).

Phosphorus (non automated method)

Add 1ml of Morgan's soil extract to 9ml of phosphorus reagent and mix well. Stand for 20 minutes, then compare with standards using camspec spectrophotometer using 675µm wavelength. Read directly in concentration.
Dilutions; For soil extracts with P values higher than top of graph dilute as required with Morgan's extracting solution and proceed as above.

Standards 0 - 5 - 10 - 15 mgP/l in Morgan's Extraction Solution

Standards treated in similar fashion to exts.
1ml of standard mixed with 9ml of P reagent.
Results for P are expressed as mg P/l soil i.e. mg P/l in soil extract x 5 - 25 - 50 - 75 mg P/l soil.

Reference to P method: A modified single solution method for the determination of phosphate in natural waters. Murphy, J. and Reily, J.P. Analytica Chimica Acta 27 : 31-36, 1962.

Potassium

This is also a major plant nutrient and deficiencies are common, and again Morgan's is designed to extract only that fraction of the element that is available to the plant. The reaction is similar to that for calcium.

$$K\ Clay + Na^{+} = Na\ Clay + K^{+}$$

The reaction is reversible and reaches equilibrium. Potassium is widely distributed in soil minerals such as potash feldspar, mica and glauconite from which it is slowly converted into soluble forms by weathering processes. Heavy soils contain larger amounts of potassium than light soils. Very small amounts of potassium are present in the soil solution at any given time, but exchangeable potassium when present in good supply, appears to be readily available to plants.

Potassium (Non Automated)
To 0.5ml of Morgan's Extraction Solution add 9.5ml of water and mix well. Read against standards.
Dilutions: For soil extracts with K values higher than top of graph dilute soil extract with Morgan's extracting solution and proceed as above.

0 - 1 - 2 - 5 mg K/l in 5% Morgan's Extraction Solution

Potassium is determined flamephotometrically at 768nu on a Sherwood single channel low temperature flame photometer.

Lime Requirement

Lime has a number of beneficial effects on soil:

1. Lime improves soil fertility
2. It removes acidity
3. Crops and grass respond better to manuring
4. Some retentive soils drain better and are easier to till after liming.

The most important action of lime is to correct soil acidity. Land becomes acid when its supply of lime runs low. Light, free-draining soils lose lime more quickly than heavy retentive soils. For this reason, light land needs extra attention, especially where the soil is not derived from limestone. Peat soils are generally short of lime. Very wet heavy soils may or may not need lime.

When the lime content is low the soil water, being acid, dissolves more of the aluminium and manganese in the clay. Soil water containing a lot of manganese and aluminium is poisonous to many plants particularly beet, barley and clover.

The lime requirement quoted in tons per hectare is the amount of lime necessary to maintain the soil at its optimum pH for the crop in question over a 5-year period. The soil will reach its peak pH about three years after liming.

Peat soils with peat depth greater than 15cm do not require a pH as high but are usually limed to a pH of about 5.3 to 5.4. Consequently for such peat soils subtract 15 tons from the standard lime requirement quoted as t/ha.

Soil Lime Requirement Analysis
Using a scoop measure mix a 10ml volume of soil with 20ml of SMP buffer solution (SMP from Shoemaker, McLean and Pratt) in 100ml round bottomed shaking flasks. Shake for 30 minutes on a Brunswick gyratory shaker. Filter through a no 2 Whatman filter paper.

The pH Meter is calibrated using pH buffer solutions pH 4 and pH 7.

Reagents

SMP Buffer Solution
Dissolve the following compounds in about 24 litres of distilled water: -

45 grams	p - Nitrophenol
62.5 ml	Triethanolamine (Analar grade)
75 grams	Potassium chromate (K_2CrO_4)
50 grams	Calcium Acetate (dried)
1,485 grams	Calcium Chloride (hydrated)

Adjust the pH to 7.5 with HCL or NaOH, and dilute with distilled water to 25 litres.

Note:- P-Nitrophenol should be handled with care and weighing and dissolving should be carried out in a fume cupboard using rubber gloves. Some heat is required to dissolve p-nitrophenol. All splashes of SMP buffer solution should be washed off immediately.

Checking buffer capacity: Take 20ml of buffer solution (pH 7.5) and titrate to pH 5.0 using N/IO HCL and a pH meter. The titration figure should be 7.0ml of the N/IO HCL. As a routine procedure it is sufficient to take 20ml of the buffer solution and add 7.0ml of the N/IO HCL and then check the pH. The pH of the solution should always be 5.0.

N/IO HCL: Weigh 18.033 grams of constant boiling point HCL and dilute with distilled water to 1 litre.

Method

Using a scoop measure, place 10ml of dried sieved soil into a beaker and from a syringe or automatic pipette add 20ml of the buffer solution. Stir the mixture with a glass rod and then allow to stand for at least 15 minutes. Read the suspension pH using a glass electrode stirring each sample again before immersing the electrodes.

For lime requirement of the soil use the following table relating soil/buffer pH to tons of lime (also t/ha) required per acre.

Soil/Buffer	Lime req		Soil/Buffer	Lime req		Soil/Buffer	Lime req	
pH	t/ac	t/ha	pH	t/ac	t/ha	pH	t/ac	t/ha
6.9	0	0	6.1	4.0	10.0	5.3	8.0	20.00
6.8	0.5	1.25	6.0	4.5	11.25	5.2	8.5	21.25
6.7	1.0	2.50	5.9	5.0	12.50	5.1	9.0	22.50
6.6	1.5	3.75	5.8	5.5	13.75	5.0	9.5	23.75
6.5	2.0	5.0	5.7	6.0	15.00	4.9	10.0	25.00
6.4	2.5	6.25	5.6	6.5	16.25	4.8	10.5	26.25
6.3	3.0	7.50	5.5	7.0	17.50			
6.2	3.5	8.75	5.4	7.5	18.75			

Note: - Soil/buffer pH readings of 7.0 and 7.1 are recorded as XL and soil/buffer pH readings of 7.2 and higher are recorded as XX. The XL is a symbol for excess lime and XX a symbol for very high lime content. The symbols are used as a warning of possible trace elements problems.

Comment: - It is difficult to wash the SMP buffer solution from the electrodes, particularly the calomel electrode, where it is likely to lodge under the glass sleeve. Electrodes must be washed carefully between samples and before and after reading the pH buffer solutions.

The method for measuring lime requirement is based on the treatment of the soil sample with a pH buffer solution as described by Shoemaker, McLean and Pratt of Columbus in 1960.

Reference: Buffer method for estimating lime and sulphur applications for pH control of soils. P.F. Pratt and F.L. Blair, Soil Science 93: 1963, page 329.
Buffer methods for determining lime requirements of soils with appreciable amounts of extractable aluminium. H.E. Shoemaker, E.O. McLean and P.F. Pratt. Soil Sci. Soc. Amer. Proc. 25: 274 - 277, 1961.

Extraction of P, K, Mg for Automated System

Soil analyses are used to predict the amount of fertilisers necessary to obtain a specific crop yield from a particular soil. The majority of soils contain plant nutrients in excess of plant requirements but in a form that the plant cannot use so estimation of total nutrients is valueless.

An extracting solution is therefore designed to take from the soil an amount of nutrient proportional to that which the plant can use in any one growing season.

Morgan's extracting solution is used at Johnstown Castle.

Extraction and Filtration P, K, Mg in Soil Analyses
(Automated System)

Method:
Mix a volume of soil 3ml with 15ml of Morgan's Extracting solution in a round-bottomed shaking flask. Shake for 30 minutes on a Brunswick gyratory shaker until equilibrium has been reached and then filter the suspension through No. 2 Whatman filter papers into an Istamec Kasette Track of Disposable test tubes. The Kasette Track of extracts are then placed on the automated Istamec Transporters for analysis

Analysis
"Soil extract dilution", "P reagent addition" and Analytical Instruments parameters are all pre set into automated analysis system computer. The P reagent addition (Ratio 1:9) is also the necessary dilution ratio for P, K, and Mg Analysis. As sample extracts and standards are similarly diluted it is unnecessary to include this dilution in results calculation
Working Standards

(1)	(2)	(3)	(4)	(5)
Blank	0.5 mg P/l	2.0 mg P/l	4.0 mg P/l	6.0 mg P/l
Morgan's	5.0 mg K/l	10.0 mg K/l	15.0 mg K/l	30.0 K/l
Extracting Solution	10.0 mg Mg/l	20.0 mg Mg/l	50 mg Mg/l	100.0 mg Mg/l

Results are reported in mg/l in soil. The 1:5 ratio in soil extraction factor is pre-programmed for calculating results.

Analysis
A warm up period of 20 minutes is necessary after power and gas has been switched on to automated soil analysis system. The system is initialised by clicking Rubert icon on computer monitor.

The first stage of analysis involves the sampling of a fixed aliquot of blank and standards and the addition of a fixed aliquot of P reagent/sample dilutant.
This involves:
1. Robotic sampler
2. Compudil pump
3. P reagent/sample dilutant reservoir
4. Additional Istamec Track of sample vials and Transporter

The system then reads standards for P, K, and Mg and draws graphs.
Analysis will only proceed if all standard parameters are correct. Standards are checked at the intervals, for samples 25, 50 and 75 as analysis proceeds.

Control samples are checked during analysis of every 10 samples.

4. Organic carbon

Organic matter in the soil is made up of plant and decomposed plant residues and microbiological artefacts. It is a most important factor in soil fertility and some of the useful properties which are attributed to it are, formation of crumb structure is soil, high base exchange capacity, nutrient storage and water holding capacity. Organic matter accumulates under grassland but breaks down under tillage. An estimate of the organic matter of the soil is obtained by determining the organic carbon and multiplying this result by a factor. The factor varies with the material under test and can be up to 2 but the most common factor is 1.732. Consequently, organic carbon x 1.732 = organic matter.

Method

Weigh out 0.5g of dry, finely ground soil into a 350ml conical flask and add 20ml of N potassium dichromate solution. Mix and add 20ml conc. H_2SO_4 (in the case of standards avoid charring), swirl gently and allow to stand for 30 minutes. This operation is best carried out in a fume cupboard. Filter the suspension through 12.6cm glass fibre filter papers into 50ml beakers. If glass fibre papers are not available centrifuge a measured volume of the solution for 15 minutes at 2000rpm.

Pour the clear supernatant solution or filtrate into 2cm optical cells and compare with standards using an EEL absorptiometer, filter 607, or any suitable spectrophotometer. Calibrate the instrument at zero using a reagent blank.

For samples high in carbon it will be necessary to weigh out a smaller sample and multiply the result by the appropriate factor. Results are quoted as percent carbon in dry soil on a weight basis.

Reagents

N. Potassium dichromate

Dissolve 49.04g of Analar grade potassium dichromate K2CR2O7 in 1 litre of distilled water.

Concentrated H2SO4

Standard carbon solution

2.5% glucose solution – wt/vol.

Working standards

The above figures for carbon in the soil would be correct if all the carbon in the soil reacted with the dichromate and the carbon was oxidised to the same extent as glucose. In practice a correction must be applied. This correction has been calculated by comparison with the gravimetric method of Shaw, K.J. Soil Science, Vol. 10, pp. 316-326, 1959. Carbon measured gravimetrically is taken as the standard method and gives an accurate measurement of carbon in soils.

The correct formula is: -

Carbon (gravimetric) = -0.1 + 1.16 CWB

CWB = Carbon by the Wakley Black method which is the method described above.
Therefore, carbon in soils = -0.2 + 1.16 apparent carbon in soil.
A standard graph is drawn between galvanometer readings and percent carbon in standards. For percent carbon in soil each reading from the graph must be corrected using the above formula.